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ASSESSING THE HEALTH OF THE CHETTABA FOREST (ALGERIA)

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ABSTRACT

The establishment and interpretation of diameter and height structures are essential for forest management decisions. This study aims to describe the diameter structure and spatial distribution of *Pinus halpensis* populations in the Chettaba state forest (Constantine, Algeria). The knowledge of these parameters is an essential step for their sustainable management. The diameter at 1.30 m from the ground and the total height of *P. halpensis* individuals were measured on 6 plots along an altitudinal gradient. The height structure shows that trees in the height classes between 5 and 10m have a very high density, indicating low natural regeneration. The total structure indicates that smaller trees are more abundant than larger trees (17.5<d≤27.5cm). These results contribute to the improvement of knowledge on current condition indicators of natural *Pinus halpensis* stands that can be used as a basis in the management of Chettaba forest.

Keywords: *Pinus halpensis, floristic diversity, spatial distribution, regeneration*

INTRODUCTION

The concern for the conservation of biodiversity, taking into account the needs and aspirations of local populations, has become real since the Earth Summit in 1992. This has led to an urgent need to understand the direct and indirect effects of human activities on biodiversity, which are the subject of numerous scientific debates. Despite this collective awareness, the erosion of biodiversity continues [1]. [2] and is a threat to humanity. The overall Algerian biodiversity counts about 16000 species of which only 1% of this total is used in the economy. The richness of the national biodiversity is a reflection of the ecosystem diversity. The mountainous massifs of Algeria conceal an important biological diversity.

In order to better understand the degradation of ecosystems, which is both natural and anthropogenic, the study of vegetation seems very appropriate. Indeed, the flora and vegetation of a region are the result of a long process of natural selection under the action of climate, edaphic and topographical conditions, without forgetting anthropic activities [3], [4], [5].

A precise knowledge of the existing forest resources, as well as their evolution should focus on the floristic composition, on the structure and on the regeneration of valuable species, hence the need to carry out a forest inventory which is the subject of this work.

The objective of this work is to obtain information on the characteristics of woody resources (height, diameter, basal area...) and the quantitative relationships between them. This will help to take care of this forest formation considering all the ecosystems that are connected to it and studying different alternatives of development and conservation of all the forest species that are in the Chettaba forest, which would contribute to the protection of the latter.

MATERIAL AND METHODS

The situation of the forest of Chettaba

The state forest of Chettaba belongs to the watershed Kebir Rhumel, it is located southwest of Constantine, south of Ibn Ziad, north of Ain Smara and east of Oued Athmania. The study area is located on the topographic map of Constantine Scale 1/200.000 sheet N 17 and more or less located between the coordinates 36°18', 36°21' north latitude and 6°26', 6°30' east longitude (Figure 1).

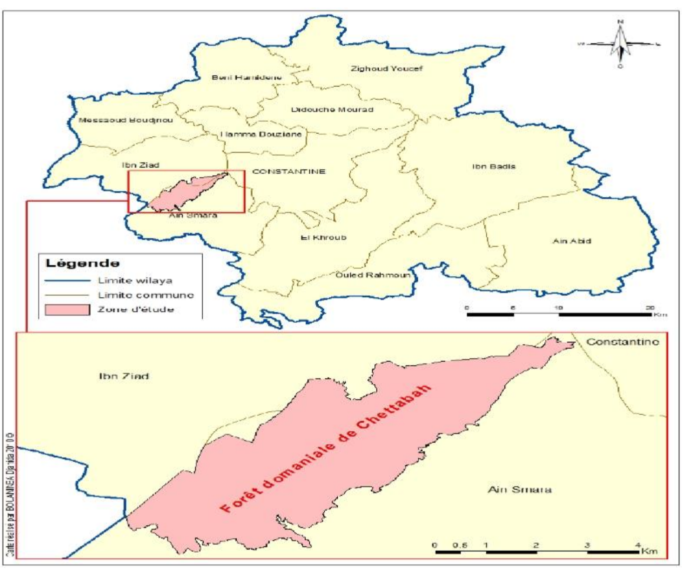

Fig. 1. *The geographical location of the Chettaba forest.*

Dendrometric parameters

In order to characterize the diametrical distribution of Aleppo pine stands present in this forest and the vertical structure, 6 sampling plots were randomly established. These plots were rectangular, with an area of 400 m^2 (20 m x 20 m) within which all individuals were counted. For each of these trees, the circumference at 1.30 m (C) and the total height (H) were measured.

The data obtained were entered into the Excel spreadsheet, which allowed us to determine the ecological characteristics and the structure of the natural population of *Pinus halepensis*.

The formulas of the parameters studied at the level of each plot are shown in Table 1 and which are:

- The density (A) or number of individuals per hectare.

- Basal area (G in m^2/ha) is the sum of the cross-sectional area at 130 cm above the ground of all *P. halepensis* individuals.

A multitude of indices are developed and those used in this paper are the Shannon, Pielou and Simpson indices [6].

Table 1. *Measures of diversity.*

Index	Measuring diversity
Specific richness: $RS = \sum_{i=1}^{K} Si \; RS = \sum_{i=1}^{K} Si$	Horizontal
Shannon Index: $H = \sum_{i=1}^{K} Pi \; x \; lnPi \; H = \sum_{i=1}^{K} Pi \; x \; lnPi$	Horizontal
Simpson's Index: $D = 1 - \sum_{i}^{s} Pi^2 D = 1 - \sum_{i}^{s} Pi^2$	Horizontal
Hill Index: $Hill = (1/D)/e^H$	Horizontal
Pielou Index: $E = \frac{H}{lnS} E = \frac{H}{lnS}$	Spatial Distribution

RESULTS AND DISCUSSION

The average density of woody plants in Chettaba forest is 492±368 individuals/ha with an average basal area of 30.18±5.04m^2/ha and an average volume of 75.68±5.04m3/ha (Table 2). For all plots, the average diameter ranged from 25.65 to 34.12 cm; these stands show more developed characteristics at the perch stage (low and high). The maximum diameter observed was 48.47 cm.

Table 2. Characteristics of the plots studied.

Plots	N/ha	D (cm)	G (m^2/ha	H (m)
P1	250	30.61	18.92	9.03
P2	600	25.65	32.50	9.29
P3	645	26.42	35.50	10.02
P4	350	28.18	23.03	8.35
P5	467	34.12	35.50	11.45
P6	645	27.89	35.65	10.42

The distribution of individuals by diameter class was fitted to a polynomial function (Figure 2). This figure shows a high proportion of individuals with dbh between 17.5 and 27.5 cm. This actually reflects the heterogeneity of dry forests with respect to woody diameters. However, it was observed that there are dry forests with many small-diameter individuals and dry forests with very few small-diameter individuals. The vertical distribution is given by the distribution of the number of stems in all plots per hectare for each height class, and provides information on the vertical stratification of the stand [7]. A large proportion of trees are between 10 and 15 m tall (low perch); this class has a large number of individuals (Figure 3).

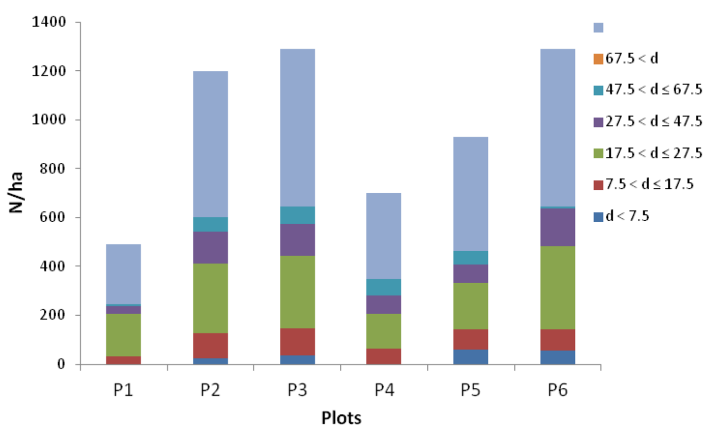

Fig. 2. *Distribution of the number of stems according to the diameter classes.*

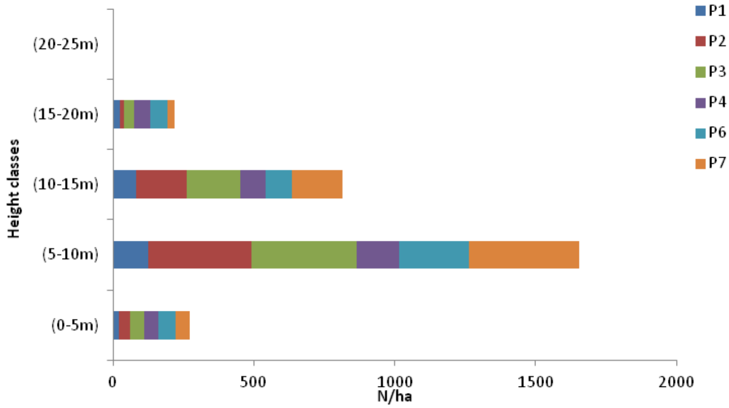

Fig. 3. *Distribution of the number of stems per hectare by height classes.*

The values of the Shannon and Simpson indices are not very significant and indicate a low floristic diversity (Table 3). The Shannon index is often accompanied by Pielou's equitability index. The equitability index measures the distribution of individuals within species, independently of species richness. Its value varies from 0 (dominance of one of the species) to 1 (equidistribution of individuals within the species). These two indices remain dependent on the size of the samples and on the type of habitat. It is therefore difficult to use them as a descriptor of the state of an environment unless threshold values for each type of habitat and for a given sampled area are determined beforehand, as proposed by [8]. The Hill Index ranges from 0.84 to 0.99. The closer the Hill Index approaches 1, the lower the diversity. In order to facilitate interpretation, it is then possible to use the 1-Hill index, where maximum diversity will be represented by the value 1, and minimum diversity by the value 0. The Hill index seems to be the most relevant insofar as it integrates the other two indices and thus allows comparisons of different stands. However, it may be useful to use all three indices together in order to extract a maximum of information and to better understand the community structure.

Table 3. *Diversity indices.*

Plots	RS	D	H	E
P1	1.09	1.29	0.84	0.40
P2	0.36	0.59	0.88	0.67
P3	0.67	0.50	0.99	0.50
P4	1.09	1.41	0.84	0.30
P5	0.33	0.58	0.88	0.72
P6	0.44	0.61	0.86	0.61

CONCLUSION

The structural study and the floristic composition of the forest allowed to know the diversity of the plant groups of this ecosystem. The forest of Chettaba functions today as an isolated ecosystem undergoing pressures at its periphery and justifies the need to conserve this ecosystem. The evaluation of the specific diversity by the index of Shannon index and equitability shows a certain relationship with the disturbance of the environment. In spite of a relatively average density of woody plants, the woody flora of the forest massif presents species with a strong socioeconomic use that is a priority for revalorization. These assets militate in favor of strengthening the strategies of development and sustainable management of the forest massif.

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ASSESSMENT AND DIAGNOSIS OF POTENTIAL BIODIVERSITY IN THE CHETTABA FOREST (ALGERIA)

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ABSTRACT

In view of the challenges facing forest management today (global warming, increased demand for wood energy), taking account of biodiversity in forests is an immediate necessity. The aim of this work is to estimate the biodiversity of the Chettaba forest by studying these structural elements which provide indirect information on the state of biological diversity and aims to provide the first elements of an answer for the construction of a potential biodiversity index (PBI). This diagnostic tool is based on the scoring of a set of ten factors, seven of which are dependent on recent forest management and three independent of it. A score from 0 to 5 is assigned to each factor. The results show that the potential forest biodiversity is average in the Chettaba massif. The average or rather low values of the criteria in the investigated forest often depend on climate, soil and human actions.

Keywords: *Chettaba, PBI, structure, forest management*

INTRODUCTION

The forest is a complex ecosystem whose biological diversity has long been recognised and has been at the heart of discussions on forest management since the Helsinki conference in 1993, following the Earth Summit in Rio de Janeiro in 1992, which established the concept of biodiversity. It is important to take into account forest biodiversity as many species are forest-dependent [1]. Methods for assessing biodiversity and sustainable forest management have developed considerably over the last two decades, at various scales, from stand to national forest heritage. The potential population biodiversity index is an indirect and composite indicator of ordinary biodiversity based on the structure of the population. The study of these structuring elements thus provides indirect information on the state of biological diversity [2]. The PBI is a simple and quick assessment method, for forest owners and managers, which avoids the difficulties of a taxonomic approach. This indicator evaluates the potential biodiversity of a population corresponding to its carrying capacity, in relation to its current characteristics, and without prejudicing the actual biodiversity. The forest wealth of the Constantine region is made up of a heritage that consists of 5173 hectares of Aleppo pine, 2258 hectares of holm oak, 1249 hectares of eucalyptus, 1226 hectares of pinion pine, 785 hectares of cypress and 427 hectares of other trees of different species. Our study focuses on the state forest of Chettaba, located in the southwest of Constantine, which covers an area of 2398 hectares. The potential biodiversity of the Chettaba forest is poorly known, no study has been done to determine its potential biodiversity despite the fact that it is the most important ecosystem in the Constantine region. The objective is to easily and quickly estimate the potential biodiversity of a forest structure by studying these structural elements, which can then provide indirect information on the state of biological diversity. The PBI is sufficient to be used in the diagnostic framework of forest managers, parcel description operations preceding the drafting of management documents, as well as during visits prior to the marking of the cuts. The PBI also makes it possible to compare the biodiversity of several stands or to monitor their evolution [3].

MATERIAL AND METHODS

Presentation of the study area

The forest of Chettabah is located southwest of Constantine (Algeria). The estimated terrain elevation above sea level is 865 meters. The study area is located on the map topographic Constantine Scale 1/200 000 sheet N° 17 and located between the coordinates 36°19'4" north latitude and 6°28'36" East longitude.

Stand Potential Biodiversity Index (PBI)

The Stand Potential Biodiversity Index (PBI) consists of assessing a set of ten factors among those usually recognized as the most favourable to the internal diversity of forest stands [4]. We considered stand-specific composition and structure, the supply of tree-related "micro-habitats", the presence of forest-associated habitats, the maturity of current stands, and the continuity of the wooded condition. Open wet and rocky environments are taken into account for the originality of their specific composition and for the functional role they play for forest stands [5].

Each factor is assigned a score, regarding a scale of threshold values. The sum of the scores then makes it possible to assess overall diversity with a theoretical maximum level of biodiversity [6].

Seven factors are directly dependent on stand and management: Aboriginal species (A), vertical structure of vegetation (B), standing deadwood (C), deadwood on the ground (D), very large live wood (E), live trees bearing microhabitats (F), open environments (g) and three others are more context-related: temporal continuity of the wooded state (H), aquatic environments (I), rocky environments (J). A score of 0, 2 or 5 is given to each of the factors according to a scale of threshold values. The PBI was designed to be used at the forest stand scale, which corresponds to the most common operational level. The minimum area that can be scored is set at 0.25 ha, with the maximum limit being reached when the stand changes significantly. The results are synthesized in the form of a "radar" graph in a spreadsheet that facilitates both the comparison of stands, their monitoring over time, and the diagnosis of factors that should be improved.

RESULTS AND DISCUSSION

The Potential Biodiversity Index is a practical tool for estimating the biodiversity of forest communities. It is based on the scoring of a set of ten factors, carried out during a rapid diagnosis [3]. Our results indicate that the Chettaba forest stand has PBI values in the order of 49% and 27% (Tables 1, 2). The potential biodiversity related to management is average and the contributions of contextual factors are low due to the absence of dead trees, aquatic environments and the lack of rocky environments.

In order to improve the potential biodiversity of the stand, an effort could be made to maintain living trees that contain microhabitats. The diversity of species should be maintained. Maintenance of the rocky environment present will also be necessary to preserve the contributions it confers for biodiversity.

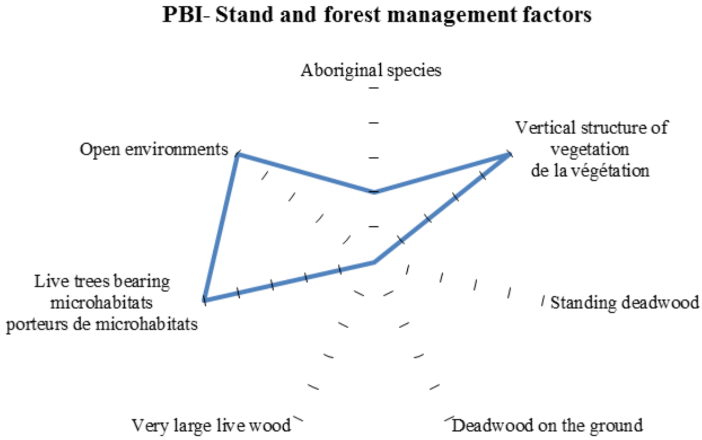
Table 1. *Scoring of PBI factors.*

PBI : Stand and forest management factors							**PBI : Contextual factor**		
Vegetation		**Tree-related microhabitats**				**Associated habitats**	**Ecosystem continuity**	**Associated habitats**	
A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Species richness	Vertical structure	Standing dead wood	Dead wood on the ground	Very large woods	Microhabitat trees	Open areas	Older of woodland condition	Aquatic areas	Rocky area
2	**5**	**0**	**0**	**0**	**5**	**5**	**2**	**0**	**2**

Table 2. *PBI rating.*

PBI value	**Absolute**	**Relative (% of maximum score)**	**Class**
Stand and forest management factors	17	49%	Average
Contextuel factor	4	27%	Low
Total	21	42%	Average

According to the graphs in Figure 1, a score of 2 is assigned to three genera (pine and evergreen oak). Concerning the vertical structure of the vegetation, the number 5 means that there are 4 strata in this forest (herbaceous, semi-woody, low foliage <5 m, intermediate 5-15 m). Standing deadwood, groundwood and very large wood are absent (0). Microhabitats exist on the majority of trees (lichens), open environments (edge and gap type) are maximised for the whole stand for which the score is 5. A score of 2 for the temporal continuity of the woodland state and the existence of a single rocky environment with the absence of aquatic environments (score = 0).



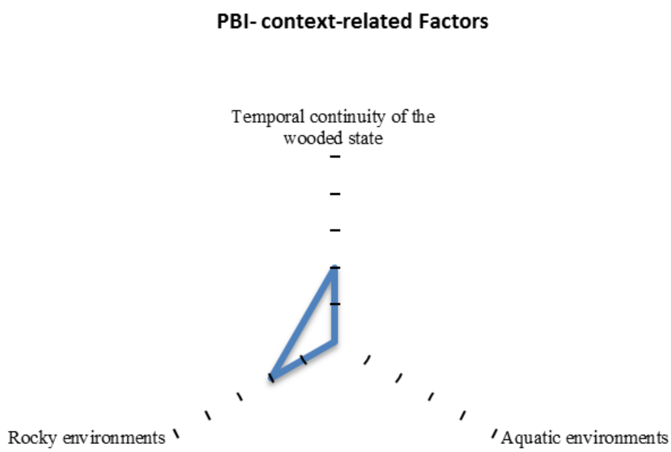


Fig. 1. *Graphical representation.*

CONCLUSION

The Chettaba forest is a very rich forest area in terms of biological diversity, with an ecotourism vocation. The Potential Biodiversity Index is a criterion for sustainable management. Estimating the potential biodiversity of a forest stand by studying these structural elements can therefore provide indirect information on the state of biological diversity. The total potential biodiversity of the forest is medium. The management-related potential biodiversity values are medium and the contributions of context-related factors are low. Biodiversity carrying capacity is average to low and needs to be improved. To maintain biodiversity at its current level for favourable factors (leave a fraction of the stand to complete its sylvigenetic cycle and preserve secondary species to stratify the stand).

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CHARACTERISATION AND ASSESSMENT OF THE DECLINE OF THE OULED BECHIH FOREST (ALGERIA)

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ABSTRACT

The establishment of the state of the massif by a diagnosis on different forest plots is part of a project of monitoring and silvicultural management. The purpose of this study is to assess the health status of the Ouled Bechih forest. The methodology used was the visual assessment of the tree crown of the dominant species (i.e. *Quercus suber* and *Quercus canariensis*) according to the protocols DEPEFEU, DEPERIS and ICP Forests. These protocols were selected for adoption based on field observations and their applicability in record time. The results obtained indicate that the health status of the trees within the studied plots is declining. The DEPEFEU value index shows an average of 1.75 for *Quercus suber* and 2.6 for *Quercus canariensis* while the DEPERIS has an average level of 2.36 *Q. suber* in and 3.37 in *Q. canariensis*. ICP Forests has also contributed to providing clearer information on the consequences of this health situation by deducting an average visibility rate of 1.20 and 2.63; social status of 1.17 and 3.11 and competition of 1.11 and 2.49 for *Q. suber* and *Q. canariensis* respectively. In general, the health status of the tree crown is average and almost adapted to the environmental conditions. In contrast, the carrying capacity of biodiversity is low and needs to be improved.

Keywords: *Q. suber, Q. canariensis, DEPEFEU, DEPERIS, ICP*

INTRODUCTION

The importance of forests no longer needs to be demonstrated from an economic, ecological, aesthetic or cultural point of view, but great attention must be paid to preserving them. In the alarming context of climate change and drastic erosion of biodiversity, the need to sustain the ecosystem services offered by forest ecosystems is indispensable. It is therefore important to monitor forest areas in order to assess their state of health and try to identify the precise causes of any decline.

At present, many natural Mediterranean forests and reforestation areas are out of balance. Many outbreaks of dieback have been reported in recent years. Among the main forest species affected by the phenomenon are the Atlas cedar in Morocco and Algeria [1], several pine species in Morocco and France, some oak species (especially cork oak) in France, Spain, Portugal, Morocco and Algeria [2], beech and fir in France.

The estimation of these symptoms is standardized by using the DEPEFEU protocol, developed by the Forest Health Department [3]. This protocol allows the assessment of the condition of deciduous tree crowns on several criteria. The main ones are crown transparency, mortality of perennial organs (branches) and leaf mass distribution [4]. The primary objective is to estimate the health status of the Ouled Bechih forest through the health assessment of a set of plots considered as representative of the forest's condition.

MATERIALS AND METHODS

Presentation of the study area

Forest of Ouled Bechih is located north of Souk Ahras (Algeria). The study area is located between the coordinates 36°21'26" north latitude and 7°50'08" East longitude. It covers an area of 6582 ha, mainly composed of *Quercus suber* and *Quercus canariensis*. This region is characterised by a sub-humid climate. The average annual temperature is 16°C and the average annual rainfall is 625 mm, with an atmospheric humidity of 68%. The altitude of the Ouled Bechih forest varies from 790 m to 1050 m, with slopes of over 15%.

Assessment of the health of forest plots

The assessment of the crown condition by specific protocols makes it possible to characterize the stages of decline of each individual observed [5]. In order to characterize the health status of Ouled Bechih stands, the DEPEFEU, DEPERIS and ICP forests protocols were used to assess the condition of *Q. suber and Q. canariensis* crown trees. As the season does not allow the use of all the criteria proposed by Nageleisen [6], the criteria represented in Table 1 were used.

The hardwood dieback protocol (DEPEFEU) is used to assess the dieback of hardwood forests based on a multi-criteria description of the crown. It is based on the observation from the soil of symptoms giving information on the crown health status. Three symptomatological criteria can be distinguished: crown transparency, mortality of perennial organs (branches, twigs) and leaf mass distribution. Each of these symptom categories is divided into sub-categories (Table 1), symptomatological criteria to be observed in the upper crown of trees (adult trees of the dominant stage) in order to make a dieback rating.

Table 1. *Notations used for the DEPEFEU method [6].*

Note	Frequency	Number	Number	Indicative (%)
0	Absence or trace	None to very low	0 to a few rare	0-5
1	Low	Low	A few to a small number	6-25
2	Somewhat strong	Moderate	Somewhat numerous	26-50
3	Strong	Important	Many	51-75
4	Very strong	Very important	Very numero	76-95
5	Total	The entire rated party concerned	Total	96-100

To conclude, the sustainability of a forest ecosystem is closely linked to its health. The diagnosis of the health status of *Q. suber* and *Q. canariensis* stands in the Ouled Bechih forest is based on field observation of individuals of each species and on three methods: DEPEFEU, DEPERIS and ICP Forests. The interest of this study is the characterization of the forest stands of this forest. However, the comparison remains difficult because the dominant species on the plots studied is not the same.

This method allows the assessment of forest dieback based on a multi-criteria description of the tree crown [7]. The results show that the majority of cork oak trees are classified in class 2 with a percentage of 49.12%. A significant proportion of trees are in class 3 (29.82%) and the percentage of trees in class 1 is the lowest (21.05%). Trees in classes 0 and 4 are non-existent; this is explained by the absence of dead crowns and trees with no symptoms. The health status of this species is therefore good as the presence of dying trees is quite low.

In the plots, it can be seen that the majority of the trees of the *Quercus canariensis* are classified in category 2 with a percentage of 70% where the symptoms are totally absent (Table 2); whereas the crowns of the trees in plot 3 are dying and show 30%. The health status of this species is therefore good. The health status of this species is therefore good.

Table 2. *Number of trees in DEPEFEU classes for both species.*

Plots	Species	Fully visible	Partially visible	Against the light	Not visible
P1	*Quercus suber*	17	11	18	0
P2		17	22	59	0
P3		58	32	0	0
P4		8	36	24	0
P1	*Quercus canariensis*	0	0	0	0
P2		0	0	20	66
P3		0	0	20	22
P4		0	0	60	12

According to the above results, the overall tree crown condition is good for the *Q. suber* and *Q. canariensis* in the Ouled Bechih forest. Visibility refers to the possibility to observe the crown optimally, i.e. in a side view at an angle of about 45° [8]. Figure 1 shows that 21.05% of the trees have a fully visible crown. The crowns are partially visible for 49.12% of the oaks. The remaining part of the oaks has backlit crowns (29.82%). The closer a tree is to its neighbours, the lower the visibility. In dense stands, it becomes very difficult to see the upper part of the crown. Therefore the trees in the plots are in a form of thinning.

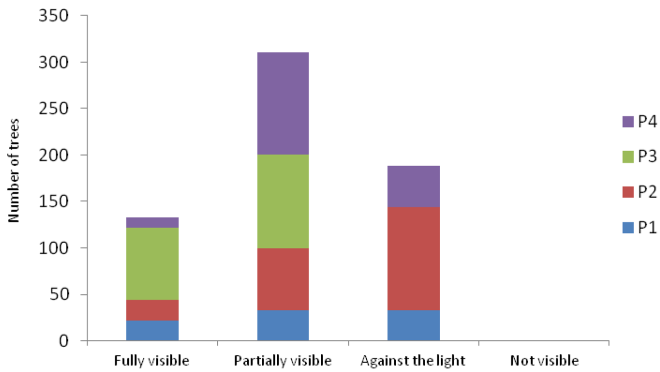

Fig. 1. *Distribution of trees by visibility level.*

The situation of trees in relation to the neighbouring. This information is used to interpret the condition of the crown and its sensitivity to stress [9]; [10]. Figure 2 shows that the majority of the trees are under-dominant or dominant with 31.58% and 29.82% of the trees observed respectively. About 29.82% of the oaks are subdominant and 8.77% are codominant. According to [11]; [12], dominant trees are supposed to be more sensitive to stresses than codominant trees, which are better inserted in the canopy mass. From the results obtained in our experiment, we can say that most of the trees are less sensitive.

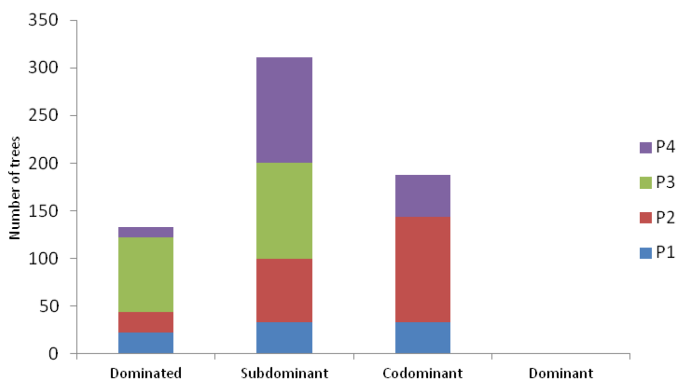

Fig. 2. *Distribution of trees by social status.*

Competition is defined as the space available for crown development [9], [13]. The majority of oaks have two or three sides of their crown in contact with other crowns, respectively 37.77% of the trees (Figure 3), and the crowns that are more competitive (four sides) represent 10.53% of the cases.

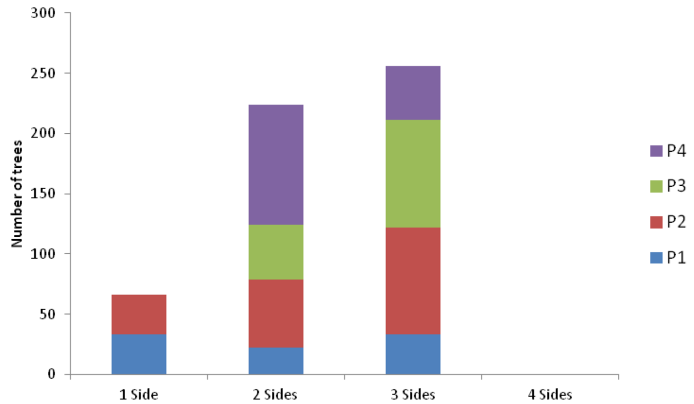

Fig. 3. *Distribution of sampled trees according to shade levels.*

The discoloration is defined as any alteration in the normal colour of the foliage of the species observed, either in hue or in the distribution of that colour. Trees with normal discolouration make up 33.33% of the observed trees, 49.12% have a light discolouration, 12.28% are trees with Moderate discolouration and 5.26% of the trees are subject to strong discolouration (Figure 4).

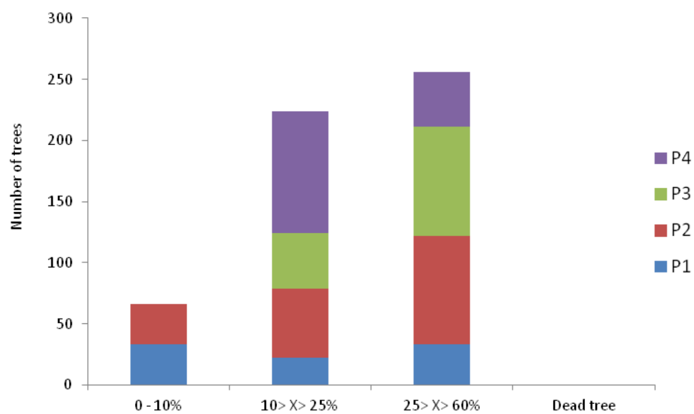

Fig. 4. *Distribution of sampled trees according to the level of discoloration.*

CONCLUSION

The results obtained from the different indicators and criteria used to determine the health status of the Ouled Bechih forest indicate the possibility of a health crisis in the study plots, which worsens over time. This health plan calls for further analysis of the contribution of the various potential decline factors - be they soil, global changes, silvicultural treatments and/or logging. And to take the necessary management measures. It would be interesting to develop more comprehensive method of characterising the health of hardwoods and trees in general, taking into account, for example, the condition of the crown and trunk, productivity, local causes of dieback through physical and chemical soil analyses and together with analysis of starch reserves and the impact of game, will be considered.

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CONTRIBUTION TO THE APPLICATION OF ARCHI METHOD FOR HOLM OAK IN THE CHETTABA FOREST (ALGERIA)

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ABSTRACT

The concepts of plant architecture are powerful tools for understanding plant development over time and the growth strategies of species in their environment. The architecture of plants depends on the nature and arrangement of each element and is, at a given time, the expression of a balance between endogenous processes of growth and the constraints exerted by the environment. Our work is a contribution to the health monitoring of our forest Chettaba (Algeria) which is currently done at the scale of the tree, within plots of small area (4 plots), by an original method of visual diagnosis of oaks is used (ARCHI method). To assign an Archi type to a tree, a diagnosis of the development and physiological state is made. The diagnostic results show that the holm oak in the studied plots is currently in a healthy state despite the presence of trees with degraded crowns with impoverished branching, abnormal mortality and without any viable restoration process such as substitutes, which cannot be chosen as a future tree. The holm oak of Chettaba forest is classified as a viable ecosystem, with a good probability of remaining alive.

Keywords: *holm oak, ARCHI, health monitoring, viability*

INTRODUCTION

The genus (*Quercus spp.*) is one of the most species-rich forest genera. It includes several hundred woody species of temperate and Mediterranean zones, America, Europe and also Asia, among which are some species of high economic importance [1]. In Algeria, the oaks represent a forest capital where they cover nearly 40% of the Algerian forest [2]. These oaks play an undeniable role on the ecological, economic and social. The holm oak is one of the main forest species of the Mediterranean basin. It is also one of the basic species in the National Reforestation Plan (NRP) in Algeria. The holm oak is threatened by multiple factors [3], such as the extension of agriculture, infrastructure (settlements and roads), overgrazing, fires and neglect for lack of interest [4].

Faced with these threats that risk the health and quality of forest stands of holm oak of the forest of Chettaba; the method of diagnosis ARCHI allows to appreciate the dynamics of reaction of holm oaks after a stress (leaf deficit, abnormal coloration, mortality ...), and to take traces that allow to know the state, the future of this forest by the marks and the processes of restoration (development of gourmands ...) [5]. ARCHI is the method that relies on a reading of the architecture of trees [6]. The study of the architecture of a plant organism is based on a morphological analysis of the entire aerial part [7]. Its principle consists in describing in situ all the main structural forms that the plant follows during its development, in order to deduce by comparison the dynamics of growth linking them over time. This method is widely used for trees because of their slow building process [8]. The main objective of monitoring the health status is, on the one hand, to assess the current state of health of the Chettaba forest and, on the other hand, to initiate to form a database to analyze its evolution since 2021 and to identify possible trends.

MATERIAL AND METHODS

Presentation of the study area

Forest of Chettabah is located southwest of Constantine (Algeria). The estimate terrain elevation above sea level is 865 meters. The study area is located on the map topographic Constantine Scale 1/200 000 sheet N° 17 and located between the coordinates 36°19'4" north latitude and 6°28'36" East longitude. The forest of Chettabah spreads over an area of 2398 ha and 94a, and is perfectly limited and divided into six districts. Extreme altitudes of the forest is about 1104 m (maximum altitude) and 652 m (minimum altitude), corresponding to each of them respectively following map coordinates: (x = 839, y = 344), (x '= 839.9, y' = 340.3). Its bioclimatic is semi-arid to sub-humid. The average annual rainfall is estimated between 670 and 800 mm and the mean annual temperature of the region is 18°C, with an average of the warmest month above 35°C and the coldest month varies between 1.25 and 3.05°C. A large plant grouping as the forest of Chettabah can be studied in its entirety, especially when it concerns hundreds of acres to be treated in the detail.

The ARCHI method:

A method for diagnosing tree decline and resilience, based on architectural analysis of aerial parts [6]. The principle is to carry out two series of observations: the first concerns the symptoms of crown degradation (leaf deficit, abnormal coloration, mortality...); the second concerns the processes of crown restoration (development of suckers, covering of wounds, resumption of growth...) [9]. Six architectural types can be distinguished

- Healthy tree (ARCHI H): tree whose architecture is in conformity with its development stage.
- Stressed tree (ARCHI S): tree whose architecture deviates from the reference sequence (uncertain future).
- Resilient tree (ARCHI R): tree showing a dynamic return to normal.

- Tree in crown descent (ARCHI CD): tree building a new crown under the original one.
- Tree in irreversible decline (ARCHI I): tree blocked in a situation of non-return to the reference sequence.
- Dead tree (ARCHI D): tree with dead cambium at 1.3 m above the crown [10].

RESULTS AND DISCUSSION

The results obtained from the 4 holm oak plots are shown in Table 1. In the ARCHI S type, the highest value is recorded in plot 3 with a percentage of 31.42%. The maximum value of ARCHI R type is obtained in plot 1 with a percentage of 45.83%; while the minimum is obtained for plot 3 (4.16%). For the healthy ARCHI type, the highest values are found in plots 3 and 4. The smallest values are noted for the ARCHI I and ARCHI Dead types, ranging from 0 to 4 trees per plot.

Table 1. *The different states of Aleppo pine according to the ARCHI type.*

Plot	ARCHI H	ARCHI R	ARCHI S	ARCHI I	ARCHI CD	ARCHI D
P1	6	11	10	2	0	0
P2	3	4	10	3	0	1
P3	8	1	11	3	0	0
P4	8	8	4	4	0	2

Among the 99 holm oak trees in Chettaba forest (Fig. 1), the largest number of trees is ARCHI S type (35.35%); second are the two ARCHI H and ARCHI R types with percentages of 25.25 and 24.24%. The ARCHI I and ARCHI D types have only 12.12 and 3.03% respectively. The ARCHI CD type is totally absent.

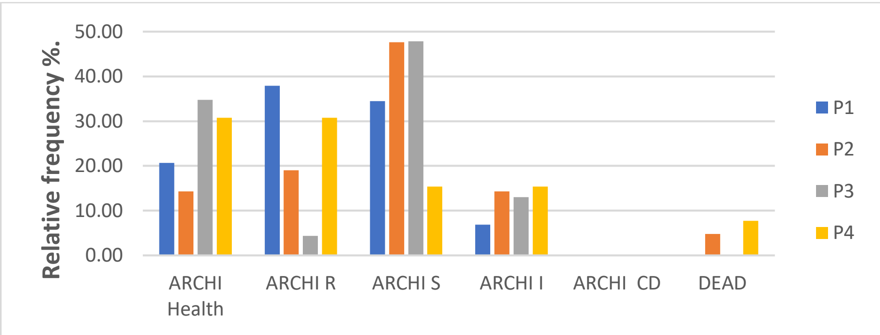

Fig. 1. *Distribution of holm oak trees by different ARCHI types.*

Our results indicate that the majority of holm oak trees in Chettaba forest are ARCHI H and ARCHI R type (50%). The healthy ARCHI type characterized by trees showing no significant symptoms of crown degradation and whose architecture is consistent with its stage of development [11]. Stressed trees show 35%; when a healthy tree undergoes stress, it expresses symptoms at the level of different organs (leaves, roots, bark...), but also at the level of its overall architecture. One should not confuse the symptoms linked to decline (branching impoverishment, mortality...) and those resulting from the tree's defense mechanisms (covering of wounds, appearance of suckers). The first ones reflect physiological degradations; the second ones reveal repair mechanisms. Depending on the nature of the stress and the initial health status of the tree, the tree may move towards different pathways [12; 13]. The pathways of resilience, i.e. the return to a healthy state after a phase of physiological and morphological recovery. This resilience can lead to the restoration of the crown or to the establishment of a second crown and the gradual disappearance of the crown branches (top-down phenomenon), but the trees are not immune to a second stress. The dead-end paths, either because the tree is blocked in a situation of slowed and irreversible growth, or because the general weakening precipitates the organism towards an ineluctable death [8]. Thus, a resilient, or even healthy, tree may become stressed, if the climatic conditions of the next few years are unfavourable. An irreversible tree will remain alive if, on the other hand, climatic conditions remain very favourable and no biotic problems occur [14].

The ARCHI I type presents by a low value 12% and the absence of the ARCHI CD. The plots are in good health and viable despite their exposure to pressures and threats. The prediction of health is impossible without knowing the evolution of many other factors of the forest environment, mainly climate and the presence of pathogens.

The Archi method offers the forester the possibility of placing his stand, already identified as dying, in the dynamics of dieback: is it an irreversible dieback (leading to death within a variable time interval), under stress, or in the process of resilience [15].

CONCLUSION

The forester is interested in the individual "tree" for the diagnosis. During this decisive operation, the questions he asks are no longer quantitative, but qualitative. The hammerer wants to know if the tree he is observing is in good health or if it has a good probability of remaining alive at least until the next cut or thinning. This is the focus of the Archi method. The diagnostic results show that the holm oak of the Chettaba forest is in a good state of health despite the negligible presence of dead trees, the absence of descending trees and the presence with a low value of irreversible dieback trees. It is not of course the Archi method that will decide the future of the tree, but the forester will have additional information, which he will integrate in his analysis of the economic and silvicultural aspects.

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CONTRIBUTION TO THE SILVICULTURAL STUDY OF CUPRESSUS SEMPERVIRENS

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ABSTRACT

In order to promote the timber industry of *Cupressus sempervirens* in Algeria and to be able to give a proposal of silvicultural conduct, we undertook research on the species and a silvicultural analysis of some stands of the forest of El Hamimet (East Algeria). The results of the bibliographic research reveal that the wood of *Cupressus sempervirens* is of superior quality, having all the criteria such as aesthetic aspect, hardness, structural stability and durability that a multitude of uses requires. The results of the silvicultural analysis of the studied stands show that the forest of El Hamimet is a very favourable station for *Cupressus sempervirens.*

Keywords: *Cupressus sempervirens, timber, El Hamimet forest*

INTRODUCTION

In Algeria, forests and scrubland cover 4.1 million hectares, i.e. an afforestation rate of 16.4% for the north and only 1.7% if the arid Saharan regions are also taken into account. These afforestation rates are obviously very insufficient to ensure physical and biological balance. The *Aleppo pine* occupies an area of more than one million ha followed by the cork oak and holm oak [1]. Among the secondary endemic species, *cupressaceae*, especially the Thuja (*Tetraclinis articulata*) and junipers (*Juniperus phoenica, Juniperus thurifera, Juniperus oxycedrus*) which constitute the majority of forest and pre-forest formations in dry mountainous areas [2], [3]. These formations are of great importance on the ecological plans, through their role of protection against the processes of desertification and erosion, very dynamic in these regions [4].

In Algeria, the *Cupressus genus* is found in small formations, as isolated trees or used as windbreaks or ornamental trees or alignments. The endemic or naturalized species of this genus are: the Tassili cypress (*Cupressus dupreziana*), the Atlas cypress (*Cupressus atlantica*), the evergreen cypress (*Cupressus sempervirens*) and the Arizona cypress (*Cupressus arizonica*) which is an introduced species and not much used.

All along the Mediterranean Sea rim, green cypress (*Cupressus sempervirens*) is used mainly as a windbreak in areas at risk of high winds [5]. During the colonial period, in the plain of Mitidja and Mohammedia where it was planted vast fields of citrus, this species massively in order to border and delimit these fields serving as shelters and create a microclimate favourable to the culture of citrus. This species with thick cover, cones consisting of overlapping scales woody or fleshy at maturity could be used in the Mediterranean area at low altitude for several purposes namely, the exploitation of the technology of its wood, the fight against erosion, for various types of reforestation and because of its lower susceptibility to fire. The main objective is to promote the timber and service wood sector of *Cupressus sempervirens* and to propose a silvicultural management.

MATERIAL AND METHODS

Presentation of the study area

The El Hamimet area is located in the wilaya of Oum El Boughi, between 35° 58' 26" N and 7° 11' 11.7" E. It extends over the territories of the communes of Ksar Sbihi, Ain Diss, Ain Babouche, Oum El Boughi, Berriche and Zorg. It covers an area estimated at 78 000 ha. The reforestation area El-Hamimet extends over an area estimated at 1460ha.

Delimitation of plots

It is not possible to cover the entire area of the forest of El Hamimet, it is therefore necessary to proceed to a sampling of existing environments and choose a representative site. We made the choice of eight plots of Aleppo pine in relation to the floristic composition and altitude.

The plots chosen for the study have rectangular shapes; each plot has an equivalent area of 900m2 (30m x 30m), within each plot all individuals are inventoried foot by foot. The geographical coordinates of each plot were taken with a GPS to facilitate their location at the time of data collection (Fig. 1).

Fig.1. *Boundaries of the study plots.*

DATA COLLECTION

Data collection takes place at two levels: Observations that provide qualitative data can be complete (considering all individuals) or partial (focusing on a few individuals); Counting and measuring quantitative data requires well-defined physical devices. Within each plot, the traditional diameter at 1.30 m from the ground (BHD: breast height) was for all species including BHD ≥ 2cm. The total height was measured using Bloom Lies on individuals of characteristic and valuable forest species by diameter class and plot [6].

RESULTS AND DISCUSSION

Recall that the horizontal structure of a species combines the distribution of stems and the distribution of basal area by diameter class. Since density, basal area and stand development are strongly linked, the study of one cannot be done without the introduction of another [7]. This study will be done by taking into account at least two of these factors. Table 1 summarizes the main stand characteristics of regenerating Cupressus sempervirens in each plot, concerning trees with measurable basal area. With an average diameter between 9 and 11.94 cm, these stands are in the sapling stage. The total density of cypress trees with a diameter at breast height greater than 5 cm varies from 67 to 378 individuals per hectare. The youngest of all is the one in plot 7 with an average DBH of 9.03 cm. This stand contains a large number of young trees.

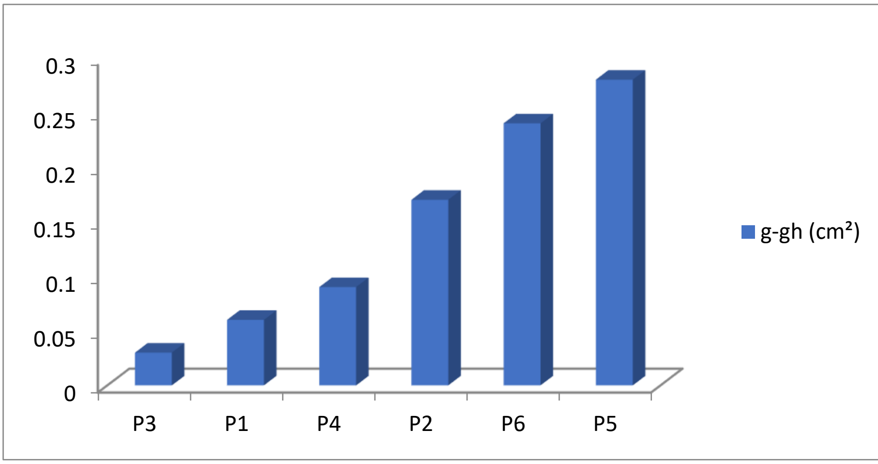
Table 1. *Quantitative characteristics of the stands*

Plot	D	H	H/D	g (m^2)	gh	g-gh	N/ha	G
P1	10.51	6.2	61.47	0.0079	0.01	0.06	78	0.616
P2	9.69	4.46	47.17	0.0081	0.01	0.17	233	1.887
P3	11.94	5.81	52.22	0.012	0.01	0.03	22	0.264
P4	11.25	5.95	58.11	0.014	0.01	0.09	67	0.938
P5	11.88	5.55	41.83	0.0014	0.01	0.28	222	3.108
P6	9.03	3.63	42.04	0.0071	0.01	0.24	378	2.684

The results of Figure 2 allow us to deduce that for a naturally regenerating stand without any intervention, up to 10 cm of average stand diameter, it is mainly the development state of the stand that determines its total basal area. However, from the high perch state (average diameter greater than 10 cm), the total basal area depends on both the total density and the distribution of stems across the diameter classes.

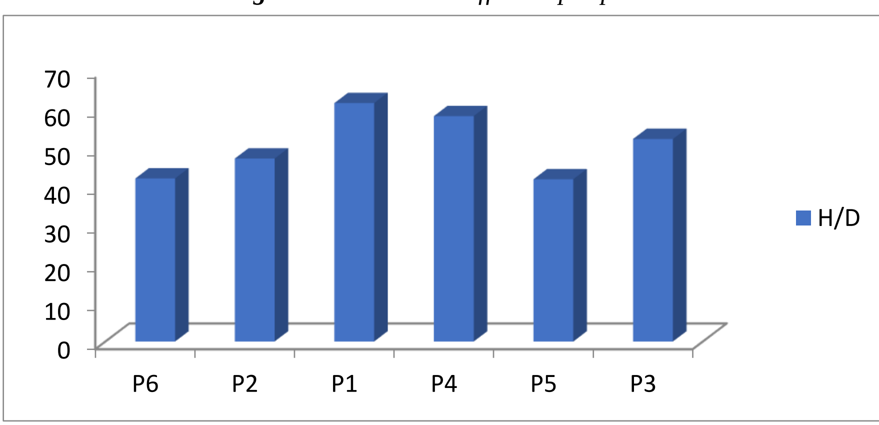
The value of (g - gh) of Cupressus sempervirens varies from 3 cm^2 for plot 3 to 28 cm^2 for plot 5. Stands with an average diameter between 9.03 cm (plot 6) and 11.94 cm (plot 3) all have a positive (g - gh). This means that in these stands the trees are on average larger than the average tree [8]. These developmental states then correspond to a stage where the trees reinforce their stability by growing in the width direction. The variation of (g - gh) is irregular between 9.03 cm and 11.94 cm. The total density and the average diameter of the stand no longer explain the parameter (g - gh). We can say that the other development factors such as spacing, texture and canopy influence a lot the productivity of the stand towards the average diameter of 11 cm.

Fig. 2. *Difference between average basal area and average tree basal area.*



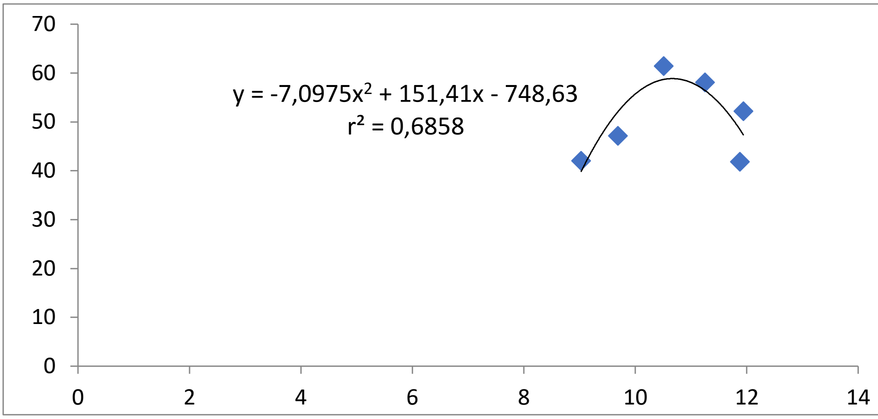
The first three plots (6, 2 and 1), with an average diameter between 9.03 cm and 10.51 cm, have average slenderness coefficients between 42.04 and 61.47%. Between plots 4, 5 and 3, which have respectively 11.25 cm, 11.88 cm and 11.94 cm of average diameter, the variation of H /D is irregular (Fig. 3). This finding allows us to assume that the slenderness coefficient is a function of the average diameter and therefore of the age of the stand [9], [10].

Fig. 3. *Slenderness coefficient per plot.*



According to this figure, the slenderness coefficient is a negative function of the mean diameter. The coefficient of determination $r^2 = 0.6858$ of the trend line means that only 32% of the observed values are not explained by the trend line. This 32% surely corresponds to the almost constant portion of the curve in the interval from 10.51 cm to 11.25 cm. Thus, there is a relationship between the mean diameter and the mean height of the natural regeneration stand **(Fig. 4).**

Fig. 4. *Slenderness coefficient as a function of average stand diameter.*



CONCLUSION

Through this research, we have been able to highlight the opportunities that *Cupressus sempervirens* can bring in the timber and service wood sector of Algeria. The use of the species in reforestation for the purpose of timber production will not only be a way to valorize the various qualities of its wood, but also a way to diversify the products on the timber market and a way to protect the barren soils of some arid areas. This research has also allowed us to understand some of the behaviors of the species and therefore to recommend silvicultural care and treatments to improve the future production of *Cupressus sempervirens* stands.

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DYNAMIC COEFFICIENT FOR 50 YEARS OF AREA BY CATEGORIES OF THE LAND CADASTER OF THE VOLGA MUNICIPALITY OF THE REPUBLIC OF MARIY EL

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ABSTRACT

In territorial planning and forecasting in the conditions of Russia, it is necessary to take into account the coefficients of dynamism of the area of all lands and by categories of the cadastre. On the example of the Volzhsky district of the Republic of Mari El, it can be seen that agricultural lands have contradictory three fluctuations, which decrease in amplitude until 2070. The largest number of fluctuations over 50 years occurred for two categories of lands: 3 - industrial lands (9 wavelets), 7 - stock (8 fluctuations). The maxima in modulus of the dynamism coefficient are as follows: Category 1 - 0.0799 in 1992; 2 - 0.0177 in 1976; 3 - 0.2384 in 1998; 4 - 0.0018 in 2000; 5 - 0.2714 in 1992; 6 - 0.0160 in 1999; 7 - 6.4204 in 2020; all lands of the Volzhsky region of the RME - 0.0135 in 1977. The most dynamic are stock lands. For agricultural land since 1970, there has been a constant half-life of 5.09737 years. In Russia, the Soviet system of land use in agriculture was preserved, and it was aimed at increasing dynamism. In this case, the first and third fluctuations are directed against (negative sign) the growth of the dynamism coefficient. Not enough attention is paid to the dynamics of agricultural land. The third wave will slow down: 1970 with a period of 4.7 years, in 2020 - 4.3 years, and according to the forecast by 2070 - 3.9 years. Such an increase in vibration frequency is already dangerous. Wavelets # 1 and # 4 of stock lands dynamism become especially dangerous, as they strongly influence the future. Stock wavelets # 3, # 5-7 are a thing of the past. And the rest of the wavelets will continue after 2020. Therefore, stock lands require special attention

Keywords: *municipality, land, categories, area, dynamic factor, patterns*

INTRODUCTION

To understand the new parameter we are introducing - the dynamism coefficient - to describe the oscillatory behavior of land surveyors of the Russian Federation for 50 years from 1970 to 2020, and only at the level of a separate municipality, it is necessary to consider seven categories of the land cadastre in dynamics. These seven categories were accepted as the dominant land classification, although we did not find any indication as to why agricultural land (ACL) was accepted as the first category. In another classification, the sum of five types of agricultural land does not coincide with the area value of the first category of the land registry.

For a deeper understanding, within the framework of climatic geomorphology, you need to rely on the first part of the definition: “The Earth is the most important part of the natural environment, characterized by space, relief, climate, soil cover, vegetation, bowels, waters, ...” [1]. This enumeration of the objects of the natural and natural-anthropogenic environment surrounding a person makes it possible to introduce into the science of land use achievements from related sciences - geomorphology, climate, soil and vegetation, biology and zoology, river systems, open pit mines and much more.

But while in Russia anthropocentrism still prevails, when the entire land surface is declared an unconditional property of man: “Land resources on the territory of Russia are classified according to their suitability for various types of land use as follows: - by land categories; - by type of land; - in terms of quality and ecological status; - by administrative-territorial affiliation; - by forms of ownership ”[2]. There are no categories and types of land use, except for specially protected areas, necessary for the preservation of the descendants of the primitive natural environment.

From [3] it can be seen that Rosstat does not publish summary data for all municipalities of the country at all, although it is customary to consider them as elementary units of administrative-territorial affiliation. The tables contain federal districts [4] and subjects of the federation. With climate change, the challenges of protecting the natural environment are becoming more acute.

The environment is already being affected by significant changes in climate regimes around the world, leading to more complex and therefore more expensive biomass and bioenergy supply chains. The presented approaches should be taken into account in future research and practice to ensure sustainable forest management [5].

The purpose of the article is to identify the patterns of the dynamic factor in the distribution of lands by cadastre categories for 1970-2020 in the Volzhsky region of the Republic of Mari El (RME).

MATERIALS AND METHODS

From the annual reports on the structure of the land fund, data on the area of the territory of the region were written out according to seven categories of the cadastre (Table 1).

Table 1. *Dynamics of lands in the Volzhsky district, ha*

Year	Time, τ year	Land area by category							Total
		1	2	3	4	5	6	7	
1970	0	48597	2930	1121	-	38929	-	2694	94271
1971	1	50014	2930	1234	-	38893	-	2694	94271
…	…	…	…	…	…	…	…	…	…
1992	22	44569	-	1200	17469	19563	2498	18	91895
…	…	…	…	…	…	…	…	…	…
2018	48	41539	3404	1108	17502	24903	2578	352	91386
2019	49	41537	3404	1110	17502	24903	2578	352	91386
2020	50	41537	3404	1110	17502	24903	2578	352	91386

1– for agricultural purposes; 2 - settlements; 3 - industry ...;
4 - especially protected. territories ...; 5 - forest fund; 6 - water fund; 7 - reserve fund.
Since 1992, land registry categories 4 and 5 have been allocated.

Oscillatory adaptation in nature requires data with a series of at least 50 years to reveal the behavior of different decision-makers. The nature of behavior is determined by the dynamism coefficient K_D according to the formula

$$K_D = (S_F - S_T)/S_T , \qquad (1)$$

where S_F is the actual value of the total area and land by category (Table 1), ha; S_T – the calculated value of the area, hectares. The higher the value K_D, the more dynamic the distribution of land in the category over the years.

Models of dynamics for 50 years of values of the land area of each category were identified using a two-term formula of a clearly nonlinear trend

$$y = aexp(-bx^c) + dx^e \exp(-fx^g) \qquad (2)$$

where y – is a dependent indicator, x – is an influencing variable, a-g are model parameters (2) identified in the CurveExpert-1.40 software environment.

LAND DYNAMICS BY TREND

Table 2 and Figure 1 show the results of identifying the model (2) of a two-component trend to describe the dynamics of the area (Table 1) of lands.

Table 2. *Parameters (2) of the dynamics of the area by land categories of the Volzhsky district*

Category code	Trend $y = aexp(-bx^c) + dx^e \exp(-fx^g)$							Coef. correl. r
	Exponential law			Biotechnical law [4]				
	a	b	c	d	e	f	g	
All	3611.2284	0.10999	1	91345.928	0	0	0	0.9177
1	48588.7025	-0.031182	0.43270	-180.04340	1.15341	0	0	0.9203
2	2915.4126	0.0016487	1.73803	11.29123	1.50401	6.30277e-5	2.23242	0.9918
3	1331.1763	0.0041297	1	0.00067889	6.04352	0.0011693	2.78852	0.9354
4	17431.393	-7.54436e-5	1	4.53873e-46	41.55598	0.95853	1.04313	0.8956
5	40349.602	0.0071075	1	-2.20553e-10	13.17073	0.43332	1	0.9635
6	2582.2862	0	0	-227.2107	0	0.00034368	2.51678	0.8770
7	2676.7168	2.26292e-5	3.09067	-8.98135e-44	48.15864	1.95127	0.99707	0.9793

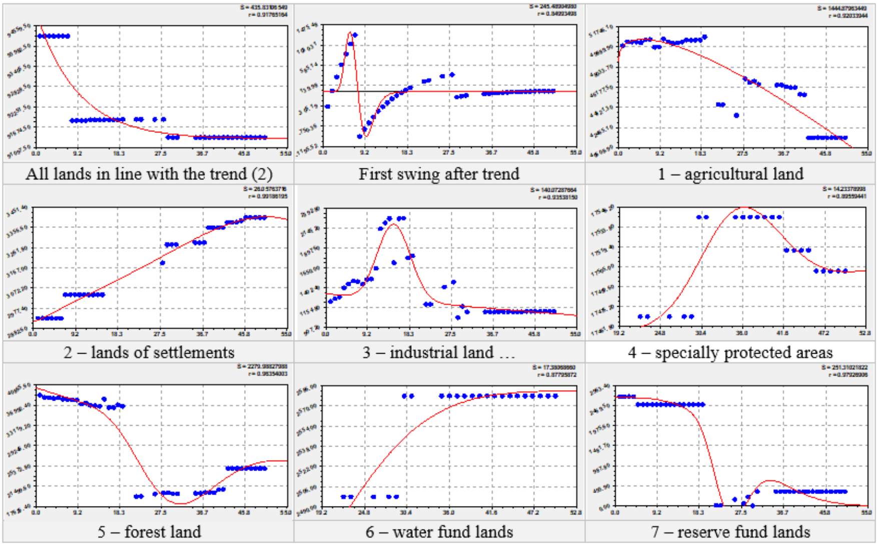


Fig. 1. *Graphs of the dynamics of the land fund of the Volzhsky region from 1970 to 2020.*

(in the upper right corner: S - standard deviation; r - correlation coefficient)

All lands of seven categories according to Table 2 change in dynamics according to Weibull's law until reaching the minimum area value of 91,346 hectares. For 50 years, the decline has occurred according to Laplace's law (in mathematics), Mandelbrot (in physics), Zipf-Perl (in biology) and Pareto (in econometrics). The dynamism is proved by the fact that, in addition to the trend, six more oscillations were obtained, and for agricultural lands there were 16 such wavelet signals. The dynamism coefficient makes it possible to abandon the identification of asymmetric wavelets and calculate it according to the trend using formula (1).

According to the first component of the trend, the lands of settlements are decreasing according to the modified Mandelbrot's law, this is opposed by the biotechnical desire of people to expand their habitat. This category of land according to the schedule (Fig. 1) will decrease.

DYNAMISM FACTOR FOR 50 YEARS

The results of calculations by formula (1) are given in table 3.

Table 3. *Coefficient of dynamism of land distribution in the Volzhsky region*

Year	Time, τ year	Area dynamic factor by category							Total
		1	2	3	4	5	6	7	
1970	0	0.0002	0.0050	-0.1579	-	-0.0352	-	0.0065	-0.0072
1971	1	0.0013	0.0028	-0.0692	-	-0.0292	-	0.0065	-0.0033
…	…	…	…	…	…	…	…	…	…
1992	22	-0.0779	-	-0.1119	0.0004	-0.2714	0.0063	-0.9945	0.0025
…	…	…	…	…	…	…	…	…	…
2018	48	-0.0035	0.0001	0.0148	0.0000	-0.0364	-0.0014	3.6004	0.0002
2019	49	0.0035	-0.0005	0.0209	0.0000	-0.0446	-0.0015	4.8130	0.0003
2020	50	0.0107	-0.0008	0.0251	0.0000	-0.0508	-0.0015	6.4204	0.0003

The maxima in modulus of the dynamism coefficient are observed: 1 category - 0.0799 in 1992; 2 - 0.0177 in 1976; 3 - 0.2384 in 1998; 4 - 0.0018 in 2000; 5 - 0.2714 in 1992; 6 - 0.0160 in 1999; 7 - 6.4204 in 2020; all lands of the Volga Municipal Formation RME - 0.0135 in 1977. The most dynamic are lands of the reserve fund (category 7).

The dynamism coefficient has a wave nature and therefore asymmetric oscillations (wavelet signals) are written by the wave formula [4] of the form

$$y_i = A_i \cos(\pi x / p_i - a_{8i}),\quad A_i = a_{1i} x^{a_{2i}} \exp(-a_{3i} x^{a_{4i}}),\quad p_i = a_{5i} + a_{6i} x^{a_{7i}}, \quad (3)$$

where y – is the indicator (dependent factor), i – is the number of the component of the model (3), m – is the number of members in the model (3), x – is the explanatory variable (influencing factor), $a_{1 \ldots} a_8$ – are the parameters of the model (3), which take numerical values in the course of structural-parametric identification in the CurveExpert-1.40 software environment, A_i – the amplitude (half) of the wavelet (axis y), p_i – the half-period of the oscillation (axis x).

CHANGE IN TIME COEFFICIENT OF DYNAMISM

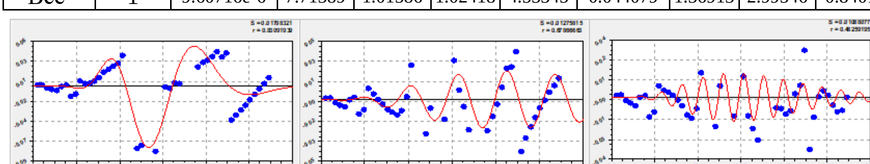
After structural-parametric identification of formula (3), oscillations were identified, the parameters of which are given in Table 4.

The largest quantities of components were obtained for industrial lands (nine) and stock reserve lands (eight). Let us briefly consider the half-periods a_{5i} of oscillations in 1970 (Fig. 2).

For agricultural land since 1970, there has been a constant half-period of 5.09737 years, that is, the period of fluctuation is equal to two Soviet five-year plans. It turns out that the Soviet system of land use in agriculture has been completely preserved in Russia and it is aimed at increasing dynamism (positive sign).

Table 4. *Parameters (4) of the dynamics of the coefficient of dynamism (1) of the area of the Volzhsky district*

Category code	N i	Asymmetric wavelet $y_i = a_{1i}x^{a_{2i}}\exp(-a_{3i}x^{a_{4i}})\cos(\pi x/(a_{5i}+a_{6i}x^{a_{7i}})-a_{8i})$								Coef. correl. r
		Amplitude (half) oscillation				Wobble half period			Shift	
		a_{1i}	a_{2i}	a_{3i}	a_{4i}	a_{5i}	a_{6i}	a_{7i}	a_{8i}	
1	1	-4.44792e-10	8.39551	0.30343	1.01850	5.74377	0.075444	0.99345	3.84830	0.8809
	2	2.21350e-6	3.45101	0.077315	1.03386	5.09737	0	0	-1.11047	0.6787
	3	-3.15947e-7	4.66245	0.13862	1.05898	2.34334	0.0033574	1.09519	-1.57130	0.4826
2	1	0.0047864	0.73883	0.074069	1.00547	5.06078	0.0077458	0.93143	-0.67991	0.7449
3	1	-0.077831	1.35333	0.32117	1	9.64892	-0.55580	0.93081	-0.22971	0.4387
	2	1.11955e-16	13.23651	0.055541	1.54867	6.26564	0.0028069	1.80573	-2.59274	0.5364
	3	-2.73867e-7	7.48942	0.73882	0.84240	2.40005	-0.012834	1.18355	3.52907	0.7707
	4	-0.15765	0	0.95559	1	2.73256	0	0	0	0.6067
	5	4.46313e-13	10.62192	0.29327	1.06420	1.90841	-0.0041105	1.12346	-0.00267	0.4535
	6	-0.0050175	1.73751	0.67086	0.53369	1.56008	0.011292	1.38125	-1.41253	0.6604
	7	7.38770e-11	13.63608	1.09142	1.00978	1.19578	-0.00015858	1.95519	-0.17763	0.7068
	8	-1.21636e-10	7.67374	0.061574	1.39302	22.03094	0.0017644	1.22767	4.08453	0.5962
	9	1.87305e-8	6.27891	0.13903	1.18899	4.12497	0.0038884	1.86632	1.46845	0.5904
4	1	0.00018657	2.01828	0.20066	0.98864	5.27218	0.0011785	1.11309	-0.13546	0.4992
5	1	9.82985e-12	10.54189	0.23936	1.16226	4.42575	0.010090	1.44952	4.20309	0.8851
6	1	-0.00090592	2.30471	0.17738	1.01263	6.66338	0.00021626	2.08641	5.86615	0.6684
7	1	-2.52567e-8	2.97311	0	0	1.19473	0.70353	0.90971	-3.55120	0.9984
	2	5.18042e-5	3.47174	0.24644	0.63749	4.36298	0.022918	1.37327	2.58463	
	3	1.37030e-10	10.45961	0.82865	0.84579	0.94766	0.046449	1.01542	-2.07511	0.7482
	4	1.07840e-9	1.90544	-0.23937	1	4.27723	0	0	0	0.7065
	5	-0.00050453	6.06047	1.01210	0.98865	8.62759	-0.32370	1.00157	-3.27053	0.3758
	6	2.08113e-12	11.80506	0.54771	1.00515	2.27040	-0.012772	0.80501	-3.01453	0.5489
	7	1.74345e-24	22.58916	0.72998	1.03644	1.26530	0.00073494	0.50329	-3.93304	0.6864
	8	0.00044464	1.69814	0.015866	1.33491	13.69788	-0.15737	1.01679	-0.016866	0.7233
Все	1	9.60716e-6	7.71389	1.01586	1.02418	4.53345	0.044079	1.36913	2.99546	0.8401



First wavelet signal | Second hesitation | Third hesitation

Fig. 2. *Dynamics of the distribution of the dynamic factor of agricultural land*

In this case, the first and third fluctuations are directed against (negative sign) the growth of the dynamism coefficient, but they calm down with an increase in the fluctuation period from 2 × 5.74377 ≈ 11.5 years. In 1970, the first cycle of dynamism was equal to the average cycle of solar activity, in 2020 it was 19 years, and by 2070, according to the formula from Table 4 (if the land policy does not change), it will already be slightly more than 26 years. Such is the relaxation in the dynamics of agricultural land.

The third wave will slow down the growth of dynamism: 1970 with a period of $2 \times 2.34334 \approx$ 4.7 years, in 2020 - 4.3 years, and according to the forecast by 2070 - 3.9 years. Such an increase (Fig. 2) will already be dangerous.

However, all three oscillations decrease in amplitude. Apparently, the country has simply calmed down and is no longer paying attention to the ecological distribution of land.

THE DYNAMISM OF INDUSTRIAL LANDS

The largest number of wavelets was received by the category of lands for industry, transport, ... (Fig. 3). According to the maximum correlation coefficient of 0.2384 in 1998, the third category in terms of dynamism takes the third place after reserve lands and forest resources.

Of the nine wavelets, the fourth received a constant period of $2 \times 2.73256 \approx$ 5.5 years, which is closer to the Soviet five-year plan or half of the solar activity cycle. The remaining periods for 1970 according to the hazard reduction rating: No. 7 - 2.4 years with a decrease; No. 5 - cycle 3.8 years with a decline; No. 3 - 4.8 years with a decrease in the period; No. 1 - 19.3 years with a reduction; No. 3 - 4.8 years with an increase in the period; No. 9 - 8.2 years up; No. 8 - 44.1 years with an increase.

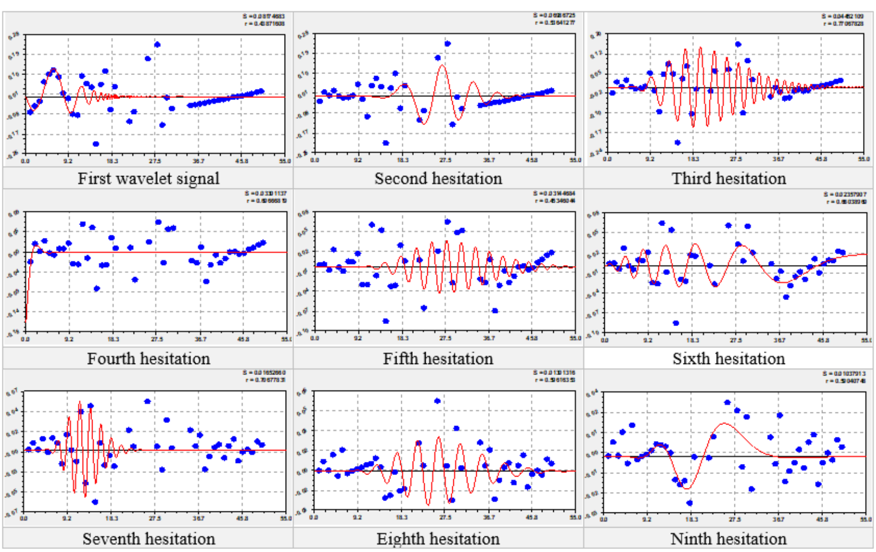


Fig. 3. *Dynamics of industrial and transport lands of the Volzhsky region from 1970 to 2020*

The fourth fluctuation is transitional from retrospective to 1970. At the same time, the amplitude of all fluctuations in the future decreases, that is, industrial lands calm down. All asymmetric wavelets are finite-dimensional, and they appear only until 2020.

THE DYNAMISM OF THE LANDS OF THE RESERVE FUND

The category of the reserve stock (Fig. 4) refers, in our opinion, to the waste of land management that is undefined for its purpose.

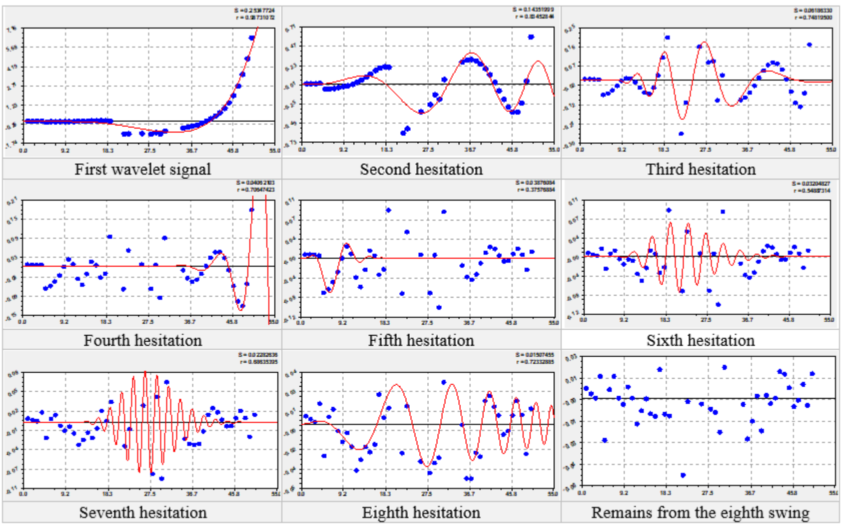


***Fig. 4.** Dynamics of reserve lands of the Volga region of the RME from 1970 to 2020*

Wavelets # 1 and # 4 are becoming especially dangerous, as they strongly influence the future.

The amplitude of wavelet # 1 changes according to a power function, and that of wavelet # 4 according to the law of double growth (anomalous biotechnical law). Wavelets # 3, # 5-7 are finite-dimensional, as their influence is in the past. And the rest of the wavelets, although they are finite-dimensional, will continue after 2020. Therefore, reserve fund lands require special attention. It is known that in the best farms of municipalities the reserve lands are equal to zero.

THE DYNAMISM OF OTHER LAND CATEGORIES

Graphs for one waveform per category are shown in Figure 5.

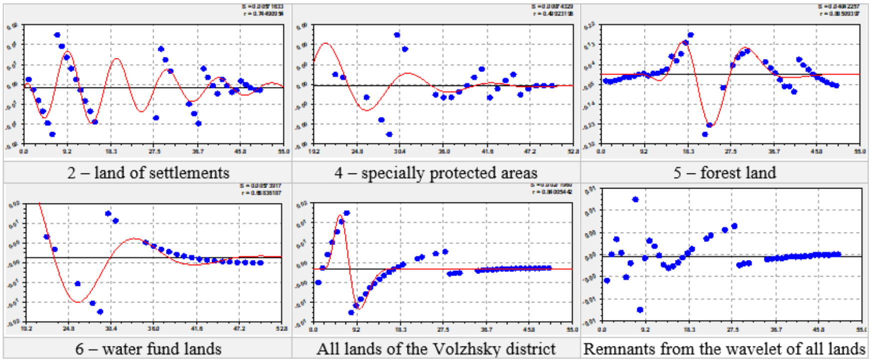


***Fig. 5.** Dynamics of other land categories in the Volga region of the RME from 1970 to 2020*

All categories in Figure 5 have received fluctuations over 50 years, which most often appear due to the unconscious behavior of people in land use and land management. The periods of fluctuations grow with time and in 1970 they were equal: category 2 10.1 years, that is, settlements in Soviet times had a 10-year development cycle; specially protected areas - 10.6 years; forest land - 8.8 years; water fund lands - 13.4 years; all lands of the Volzhsky region - 9.1 years. Basically, in our country, the cycles of the past five-year plans clearly prevailed in land management and in the dynamism of the categories of the land fund.

CONCLUSION

In territorial planning and forecasting in the conditions of the Russian Federation, it is necessary to take into account the coefficients of dynamism of the area of all lands and by categories for all municipalities of the country, and not less than 50 years since 1970.

On the example of the Volga region of the Republic of Mari El, it can be seen that agricultural lands have contradictory three fluctuations, which decrease in amplitude until 2070. The largest number of fluctuations in 50 years occurred for two categories of lands: category 3 (industrial lands), nine wavelets, category 7 (lands of reserve stock) eight fluctuations.

The maxima in modulus of the dynamism coefficient are observed: 1 category - 0.0799 in 1992; 2 - 0.0177 in 1976; 3 - 0.2384 in 1998; 4 - 0.0018 in 2000; 5 - 0.2714 in 1992; 6 - 0.0160 in 1999; 7 - 6.4204 in 2020; all lands of the Volga region of the RME - 0.0135 in 1977. The most dynamic are lands of the reserve stock (category 7).

For agricultural land since 1970, there has been a constant half of the period of 5.1 years. It turns out that the Soviet system of land use in agriculture has been completely preserved in Russia and it is aimed at increasing dynamism. The first and third fluctuations are directed against the growth of the dynamism coefficient. For the third wave, the half-period will decrease (the oscillation frequency will increase): 1970 with a period of 4.7 years, in 2020 - 4.3 years, and according to the forecast by 2070 - 3.9 years.

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DYNAMICS OVER 50 YEARS OF AREA OF LANDS BY CATEGORIES OF THE INVENTORY OF THE VOLGA MUNICIPALITY OF THE REPUBLIC OF MARIY EL

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ABSTRACT

The waves of dynamics for 1970-2020 are revealed. by categories of land cadastre in the Volzhsky region of the RME. The first two terms out of eight forms Weibull's law, showing a decrease of 3292 hectares in the area according to Mandelbrot's law. Since 1970, the decline has been 3.60%. For 50 years, there have been two leaps in the reduction of the total area. After the first jump, 20 years have passed from 1978 to 1998, and after the second jump - 21 years from 1999 to 2020. For agricultural lands, the trend shows a steady decrease in area. This trend is noticeable for the country's municipalities. The first component of exponential growth reflects the desire to expand the habitat. And the second term, according to the law of the power function, gives the counteraction of nature to people. This fact shows that there is no ecological balance between agriculture and nature. In territorial planning and forecasting in the conditions of the Russian Federation, arrays of tabular data are urgently needed for all municipalities of the country since 1970. Agricultural lands have especially strong dynamics in 18 components in the form of fluctuations. In Finland, an ecological balance has long been formed, even at the farm level. In Russia, in the legalized minimum territorial unit (municipality) in the total area, strong fluctuations have occurred. A sharp surge in the land fund of the Volzhsky region occurred during the socio-economic crisis from 992 to 2005. This proves the lack of awareness of decision-makers in land policy. Next, you need a conscious behavior in the distribution of the land fund of municipalities of the Russian Federation by categories and types of land.

Keywords: *municipality, land, categories, area, dynamics over 50 years, patterns*

INTRODUCTION

"The earth is the most important part of the natural environment, characterized by space, relief, climate, soil cover, vegetation, bowels, waters, ..." [1]. In this part of the definition, the primacy of nature over man is fixed. And the second part "... which is the main means of production in agriculture and forestry, as well as the spatial basis for the location of Enterprises and organizations of all sectors of the national economy" already allows us to strongly doubt the primacy of nature.

For the municipalities of the Russian Federation, there is no data even for the categories of the land cadastre, although the level of municipalities is considered an elementary territorial unit of the country [2]. Due to the lack of official tabular data, it is necessary, for example, for the Volga municipal formation of one of the subjects of the federation - the Republic of Mari El, to use archival data to compile a tabular model for 50 years from 1970 to 2020. Such dynamics allow us to consider the behavior of land surveyors during the times in the USSR, during the transition period and in the post-Soviet period.

In article 1.9 of the law [2], there is "a differentiation of state ownership of land to the property of the Russian Federation, the property of the constituent entities of the Russian Federation and the property of municipalities, according to which the legal basis and the procedure for such a distinction are established by federal laws." Lands are lands that are systematically used or suitable for use for specific economic purposes and differ in their natural and historical characteristics [1], [2].

However, in the official data [3] there are land areas of the Russian Federation, federal districts [4] and subjects of the federation. But there is no data on municipalities. As a result, it is difficult to compare the territories of districts from different subjects of the federation. There are also no data tables in dynamics, for example, since 1970, even for the whole country.

All this hinders the study of lands, for example, in climatic geomorphology.

Outside of Russia, intensive research is being carried out on lands as part of the natural environment. For this, the consolidation of information from different sciences is carried out.

For example, geomorphic classification is a categorization and description of nature, origin and development of landforms. The fundamental basis of this classification is that a geomorphic unit can be classified collectively on the basis of its origin and development (process), from its general structure and shape (relief), from size and characteristics (morphometry), as well as the presence and overlay states (geomorphological generation). The first type of geomorphic process is considered the emergence and evolution of river networks [5].

The purpose of the study is to identify the patterns of dynamics of 1970-2019 land distribution by cadastre categories using the example of the Volga municipal formation from the Republic of Mari El (RME).

MATERIALS AND METHODS

From the annual reports on the structure of the land fund, data were written out on the area of the territory, as well as on seven categories of the cadastre (Table 1).

Table 1. *Dynamics of lands in the Volzhsky district, ha*

Year	Time, τ year	Land area by category							Total
		1	2	3	4	5	6	7	
1970	0	48597	2930	1121	-	38929	-	2694	94271
1971	1	50014	2930	1234	-	38893	-	2694	94271
…	…	…	…	…	…	…	…	…	…
1992	22	44569	-	1200	17469	19563	2498	18	91895
…	…	…	…	…	…	…	…	…	…
2018	48	41539	3404	1108	17502	24903	2578	352	91386
2019	49	41537	3404	1110	17502	24903	2578	352	91386
2020	50	41537	3404	1110	17502	24903	2578	352	91386

1– for agricultural purposes; 2 - settlements; 3 - industry ...;
4 - especially protected. territories ...; 5 - forest fund; 6 - water fund; 7 - reserve fund.
Since 1992, land registry categories 4 and 5 have been allocated.

We adhere to the concept of vibrational adaptation in nature and society. To detect fluctuations, land dynamics data of at least 50 years of series are needed to reveal the behavior of decision-makers.

On many examples of modeling, it was found that oscillations (asymmetric wavelet signals) are written by the wave formula [4] of the form

$$y = \sum_{i=1}^{m} y_i \;\; y_i = A_i \cos(\pi x / p_i - a_{8i}) \,,\;\; A_i = a_{1i} x^{a_{2i}} \exp(-a_{3i} x^{a_{4i}}) \,,\; p_i = a_{5i} + a_{6i} x^{a_{7i}} \quad (1)$$

where y – is the indicator (dependent factor), i – is the number of the component of the model (1), m – is the number of members in the model (1), x – is the explanatory variable (influencing factor), $a_1 ... a_8$ – are the parameters of the model (1), which take numerical values in the course of structural-parametric identification in the CurveExpert-1.40 software environment, A_i – the amplitude (half) of the wavelet (axis y), P_i – the half-period of the oscillation (axis x).

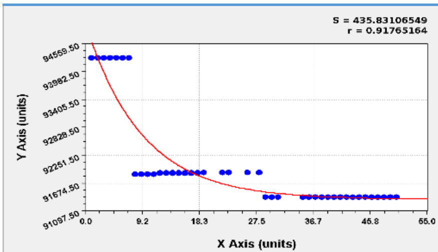
DYNAMICS OF ALL LANDS

After structural-parametric identification (1), the components were obtained, the parameters of which are given in Table 2 (Fig. 1 and Fig. 2).

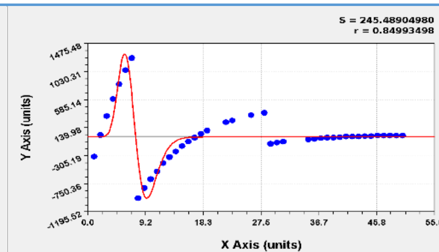
Table 2. *Parameters (1) of the dynamics of the Volzhsky district area for 1970-2020*

Number i	Asymmetric wavelet $y_i = a_{1i} x^{a_{2i}} \exp(-a_{3i} x^{a_{4i}}) \cos(\pi x / (a_{5i} + a_{6i} x^{a_{7i}}) - a_{8i})$								Coef. correl. r
	Amplitude (half) oscillation				Wobble half period			Shift	
	a_{1i}	a_{2i}	a_{3i}	a_{4i}	a_{5i}	a_{6i}	a_{7i}	a_{8i}	
1	91315.506	0	0	0	0	0	0	0	0,9812
2	3291.8604	0	0.091494	1	0	0	0	0	
3	-0.052884	11.09664	1.60631	0.97955	6.82907	0.00039541	3.35307	-1.39915	
4	19.68937	5.90198	1.09985	1	0.010183	0.051563	0.83742	2.94403	0.8068
5	-0.00025907	6.58958	0.29896	1	-0.041829	1.09124	0.48228	5.60842	0.6858
6	-358.09544	0	0.434823	1	1.59887	-0.036815	1	0.51327	0.6506
7	-30.46909	0.40398	0.00018312	2.38707	3.20749	0.0021286	1.62585	0.75863	0.6513
8	1.15333e-121	122.6843	3.88055	1.04132	2.57343	0	0	-4.45910	0.7655

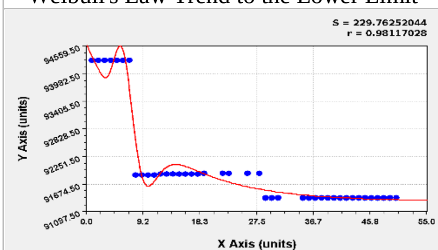
Two terms form Weibull's law, showing the limit and decrease by 3292 hectares of area according to Laplace's law (in mathematics), Mandelbrot (in physics), Zipf-Perl (in biology) and Pareto (in econometrics). Since 1970, the decline has amounted to 100 3291.86 / 91315.5 = 3.60%.



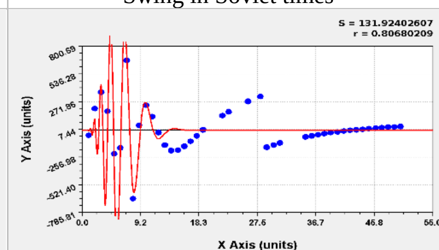
Weibull's Law Trend to the Lower Limit



Swing in Soviet times



Three components together

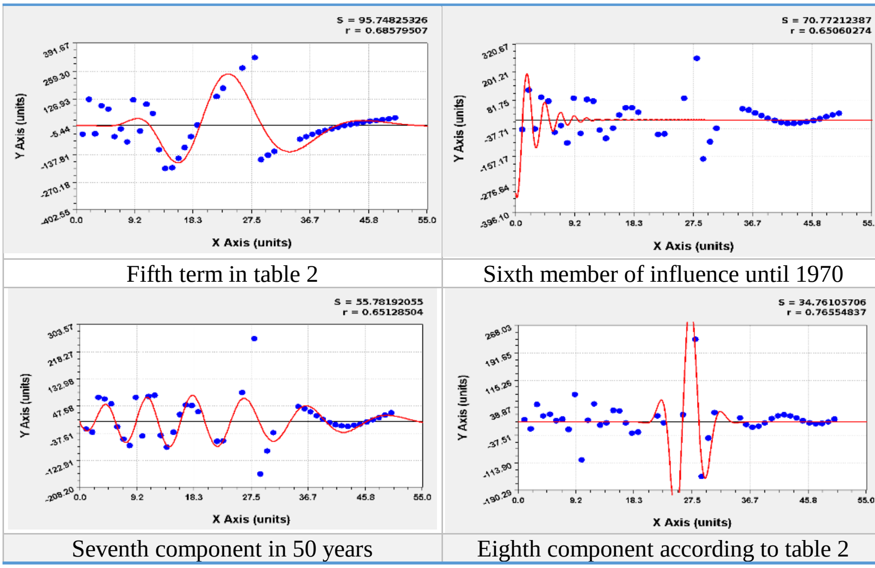


Wavelet signal of Soviet times

Fig. 1. *Dynamics of the distribution of all lands in the Volzhsky district of the Republic of Mari El*

(in the upper right corner: *S* - standard deviation; *r* - correlation coefficient)

For 50 years, there have been two leaps in the reduction of the total area. Each jump shows the work on the land inventory. After the first jump, 20 years passed from 1978 to 1998, and after the second jump - 21 years from 1999 to 2020.



Fifth term in table 2 | Sixth member of influence until 1970

Seventh component in 50 years | Eighth component according to table 2

Fig. 2. *Additional graphs of the dynamics of the land fund of the Volzhsky region*

Even in the legalized minimal territorial unit (Volzhsky municipality), strong fluctuations occurred in the total area. The fifth and seventh wavelets show that the dynamics of the land area was not influenced by socio-economic changes (from 1970 to 1991 Soviet times, from 1992 to 1998 the transition period, and from 1999 to 2020 post-Soviet times). The basic principles of land use have remained unchanged

However, a sharp surge occurred during the socio-economic crisis in the period 1992-2005. Apparently, such a perturbation in the land fund was historically the last. Next, we need a conscious behavior in the distribution of the land fund of all municipalities of the Russian Federation in seven categories and 13 types of land. The residuals after the eighth term give the modeling error (Fig. 3).

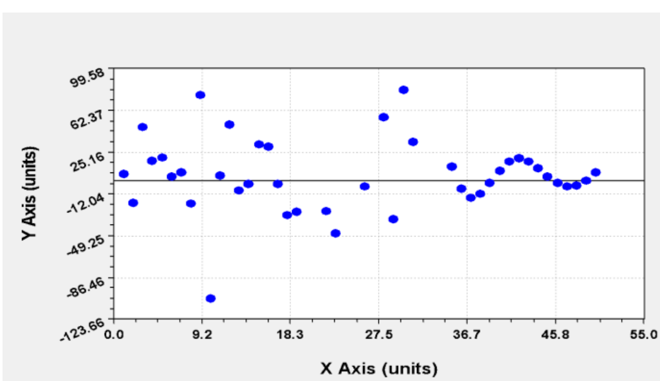


Fig. 3. *Remains after the eighth component*

The relative modeling error Δ is calculated by the formula

$$\Delta = 100\varepsilon_8 / y_f, \qquad (2)$$

where ε_8 – is the absolute error (residuals) after the eighth component (they show that other, but smaller, wavelets are also possible), y_f – are the actual values of the area of the district's land fund. The maximum error is -0.11% for 1980.

A small error in the decomposition of the dynamics of the land fund of the municipality into quanta of behavior shows that oscillatory adaptation is inherent not only for the total area, but also for the dynamics over 50 years of the area for certain categories of the land cadastre.

DYNAMICS OF THE AREA OF AGRICULTURAL LAND

The first category turned out to have the largest number of 18 components (Fig. 4, Table 3).

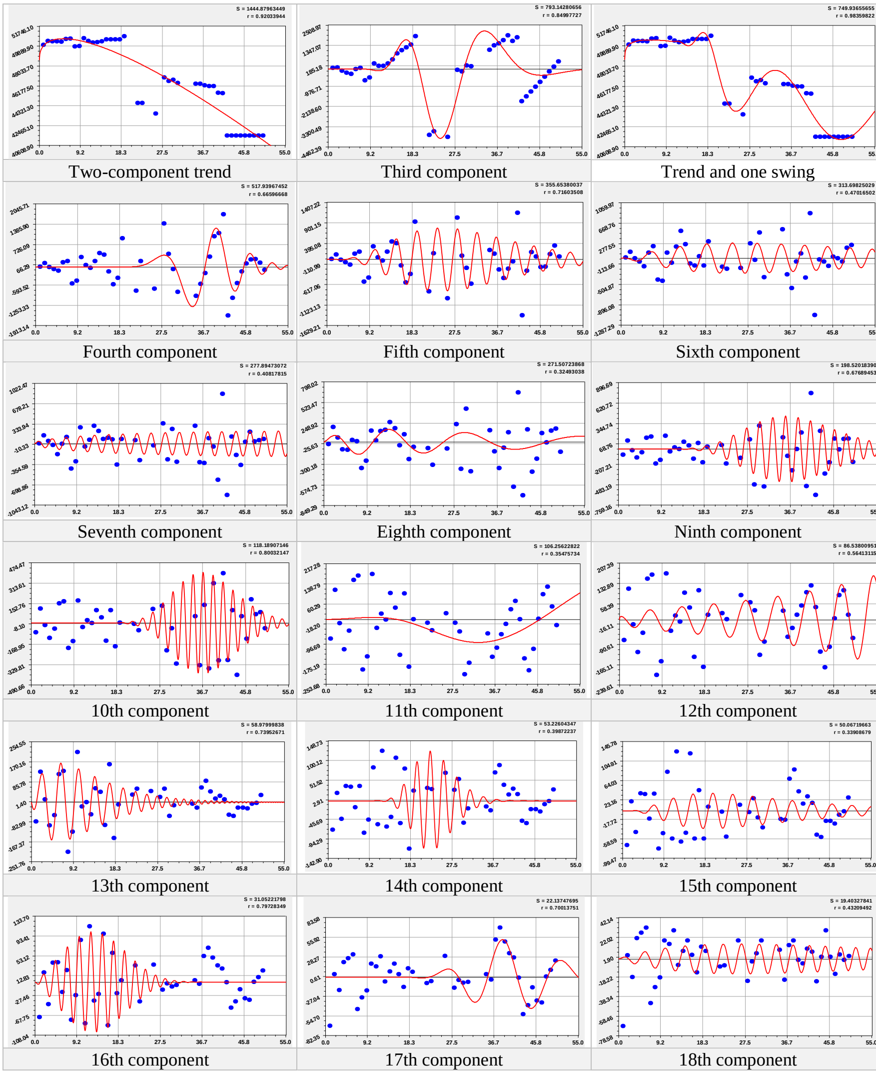


Fig. 4. *Dynamics of agricultural land in the Volzhsky region*

Table 3. *Parameters (1) of the dynamics of the area of agricultural land*

Number i	Asymmetric wavelet $y_i = a_{1i}x^{a_{2i}}\exp(-a_{3i}x^{a_{4i}})\cos(\pi x/(a_{5i}+a_{6i}x^{a_{7i}})-a_{8i})$								Coef. correl. r
	Amplitude (half) oscillation				Wobble half period			Shift	
	a_{1i}	a_{2i}	a_{3i}	a_{4i}	a_{5i}	a_{6i}	a_{7i}	a_{8i}	
1	48605.154	0	-0.068670	0.49573	0	0	0	0	0.9836
2	-2057.1628	0.58454	0	0	0	0	0	0	
3	1.07320e7	35.75245	51.92701	0.26637	0.48543	0.014150	1.32616	4.70353	
4	-1.05652e-32	29.69545	0.42318	1.14424	28.50149	-1.12339	0.75158	-4.10578	0.6660
5	0.12378	3.96909	0.16114	1	2.68892	-0.069322	0.51090	0.48493	0.7160
6	13.30661	1.37972	0.054277	1	13.28174	-8.87503	0.042751	-0.76643	0.4702
7	-45.92247	0.47778	0.0066244	1	1.54110	0	0	-1.64850	0.4082
8	-2.89811e6	3.02723	11.04307	0.17983	5.52788	0.020222	1.26775	3.92816	0.3249
9	5.06179e-14	14.37291	0.43211	0.98595	1.55625	-0.00047032	1.46711	0.75304	0.6769
10	-1.26778e-31	29.70062	0.81135	1.00085	1.11429	-0.00020152	1.28213	-4.55356	0.8003
11	-0.36756	1.22677	-0.033215	1	19.69619	0.00029996	2.60563	-2.31461	0.3548
12	20.09584	0.30405	-0.00083484	1.73894	3.41353	0	0	-0.30562	0.5641
13	-81.94109	0.89394	0.14977	1	2.23998	-0.010230	1.24441	-0.016226	0.7395
14	-2.48651e-21	57.70709	31.14591	0.45245	1.47803	0	0	0.92905	0.3987
15	-54912.385	8.64364	15.10267	0.26284	2.19944	0	0	-6.00482	0.3391
16	-7.91802	1.16215	0.00027135	2.86581	1.32601	-0.00012881	1.99985	1.15404	0.7973
17	9.33025e-23	19.91563	0.35329	1.07698	5.80799	0.010796	0.93198	0.84538	0.7001
18	-1.70827	0.96517	0.036703	1	2.35418	-0.0079353	1	-1.73565	0.4321

The two-term trend shows a steady decline in the area of agricultural land over the years. This trend is noticeable for all municipalities in the country. The first term is a modified Mandelbrot's law of exponential growth, and it reflects the desire to own an increasingly larger area. But the second term of the trend is negative for a person and, according to the equation of the power function, characterizes the opposition of the natural environment to the desire of people to expand their habitat.

DYNAMICS OF LANDS OF OTHER CATEGORIES

The rest of the dynamics models for 50 years have been identified according to the trend

$$y = aexp(-bx^c) + dx^e\exp(-fx^g), \qquad (2)$$

where y – is an indicator, x – is a variable, a-g – are parameters (2) detected in CurveExpert-1.40.

The stock lands received one asymmetric wavelet signal. Table 4 and Figure 5 show the results of model identification (2). Note that the trend is formed from the oscillation (1) under the condition of multiple excesses of the oscillation period over the measurement period.

Table 4. *Parameters (2) of area dynamics for other land categories*

Category code	Trend $y = aexp(-bx^c) + dx^e \exp(-fx^g)$							Coef. correl. r
	Exponential law			Biotechnical law [4]				
	a	b	c	d	e	f	g	
2	2915.4126	0.0016487	1.73803	11.29123	1.50401	6.30277e-5	2.23242	0.9918
3	1331.1763	0.0041297	1	0.00067889	6.04352	0.0011693	2.78852	0.9354
4	17431.393	-7.54436e-5	1	4.53873e-46	41.55598	0.95853	1.04313	0.8956
5	40349.602	0.0071075	1	-2.20553e-10	13.17073	0.43332	1	0.9635
6	2582.2862	0	0	-227.2107	0	0.00034368	2.51678	0.8770
7	2676.7168	2.26292e-5	3.09067	-8.98135e-44	48.15864	1.95127	0.99707	0.9793

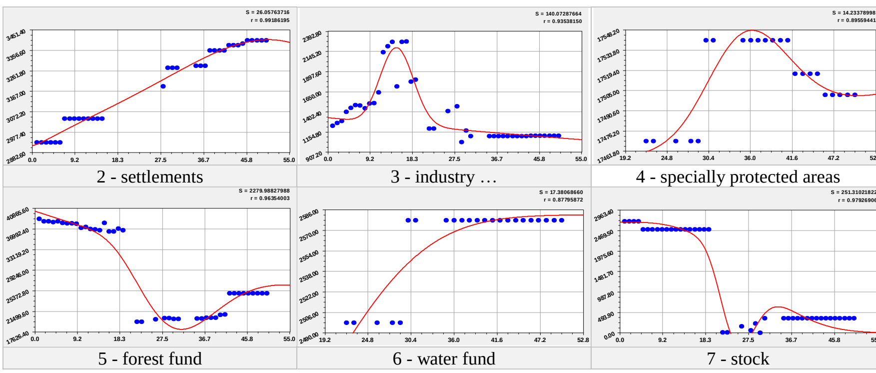


Fig. 5. *Graphs of the dynamics of the categories of the land fund of the Volzhsky region from 1970 to 2020*

The first term of formula (2) is physically natural, and the second term shows the stressful arousal of decision-makers. For example, the lands of settlements according to the first component of the trend are decreasing according to the modified Mandelbrot law, and this is opposed by the unlimited desire of people to expand the territory of their settlements. Over time, this category of land, according to the graph in Figure 5, will even decrease.

In the third category, in 1978-1991, an industrial boom was outlined and additional land areas for industrial construction were allocated more than twice in relation to 1991. The general trend according to Mandelbrot's law is decreasing. Only this fact indicates that they do as they want with the land fund. The area of specially protected areas has been sharply decreasing since 2010. According to Weibull's law, the area of the water fund has slightly increased, but since 2000 it has not changed at all.

The area of the forest fund naturally decreases according to Mandelbrot's law, but a sharp decline (due to the negative sign there was a strong crisis) occurred in three years from 1989 to 1992. (from 36756 to 19563 hectares, that is, a 1.9-fold decrease). This fact means that the forest management system did not function in any way in the Volzhsky region. A slight increase in the forest area in 2012 occurred due to the transfer of the fallow overgrown with trees to the forest fund. As a result, the 50-year dynamics of the land was unconscious and not economic.

CONCLUSION

In territorial planning and forecasting in the conditions of the Russian Federation, there is an urgent need for arrays of official tabular data for all municipalities of the country, and for at least 50 years since 1970.

On the example of the Volga region of the Republic of Mari El, it can be seen that the land reforms carried out in our country have even aggravated the confusion in the understanding of environmental principles in the distribution of the land fund by categories of the land cadastre. Agricultural lands have particularly strong dynamics in 18 components in the form of a multitude of fluctuations. A strong struggle of opinions and official decisions are visible here.

There is no ecological balance between agriculture and the natural environment, as is achieved in Finland even at the farm level. In Russia, even in the legalized minimum territorial unit (Volzhsky municipality), strong fluctuations occurred in the total area. The basic principles of land use remained archaic.

A sharp surge in the eighth component of the general equation occurred in the entire land fund of the Volzhsky region during the socio-economic crisis in Russia from 1992 to 1998 and continued in the municipality until 2005. This proves the lack of awareness of the land policy. Next, we need a conscious behavior in the distribution of the land fund of all municipalities of the Russian Federation in seven categories and 13 types of land.

ACKNOWLEDGEMENTS

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ECOLOGICAL EDUCATION - ELEMENTS OF THE NATIONAL STRATEGY FOR THE SUSTAINABLE DEVELOPMENT OF ROMANIA 2030

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ABSTRACT

In the article, based on our own studies and research, we present and critically analyze the content and provisions of the national strategy for the sustainable development of Romania 2030. Thus, starting from the prescriptions of the European Union in the field, adopted on June 20, 2017, "A sustainable future for Europe: the EU's response to the 2030 Agenda for Sustainable Development", the national framework for supporting the 2030 Agenda and implementing the set of 17 Sustainable Development Goals (SDGs). The three pillars of the national strategy for the sustainable development of Romania 2030 are analyzed: the economic, social and environmental pillars. Also presented and critically analyzed are the three chapters of the national strategy for sustainable development of Romania 2030: Chapter I Introduction (presents a recent chronology of the evolution of the concept of sustainable development from an international perspective); chapter II - Objectives for Sustainable Development (presents the current stage of development of Romania, as a result of the implementation of the National Strategy for Sustainable Development of Romania) and Chapter III - Implementation and Monitoring (presents the decisions to be taken to ensure the operational framework for the implementation and monitoring of the achievement of the concrete objectives and targets of the Strategy). We also analyze in the article the specificity and adaptation of Romania to the requirements of the European Union within the national strategy for sustainable development.

Keywords: *Sustainable Development, Ecological Education, National Strategy*

INTRODUCTION

Romania, as a member of the United Nations (UN) and the European Union (EU), has expressed its support for the 17 Sustainable Development Goals (SDGs) of the 2030 Agenda, adopted by UN General Assembly Resolution A / RES / 70/1, at the UN Summit on Sustainable Development in September 2015.

EU Council conclusions adopted on 20 June 2017, "A sustainable future for Europe: the EU's response to the 2030 Agenda for Sustainable Development" is the policy paper adopted by EU member states on implementing the 2030 Agenda for Sustainable Development.

Through this strategy, Romania establishes its national framework for supporting the 2030 Agenda and implementing the set of 17 SDGs. The strategy supports Romania's development on three main pillars, namely economic, social and environmental. The strategy is citizen-oriented and focuses on innovation, optimism, resilience and confidence that the state serves the needs of every citizen, in a fair, efficient and clean, balanced and integrated environment. The documentation and substantiation of the strategy were based on reports received from ministries and other central institutions, developed for this purpose, synthesis materials developed under the auspices of the Romanian Academy and other scientific and academic forums, accessible data of European institutions and the UN, suggestions and the recommendations recorded following public consultations with the business community, academia, national research and development institutes, NGOs and representatives of civil society, as well as the contributions of individual experts.

DESCRIPTION AND ANALYSIS OF THE NATIONAL STRATEGY FOR THE SUSTAINABLE DEVELOPMENT OF ROMANIA 2030

The strategy is structured in three chapters:

Chapter I Introduction presents a recent chronology of the evolution of the concept of sustainable development from the international, European and national perspective, as well as the way in which it has gradually materialized both in the UN and EU programmatic documents and in Romania's public policies.

Chapter II Objectives for Sustainable Development present the current stage of development of Romania, as a result of the implementation of the National Strategy for Sustainable Development of Romania. Horizons 2013-2020-2030, approved by the Government in November 2008. The shortcomings identified are identified and specific areas are identified where further efforts and resources are needed to achieve the convergence objectives and bring the EU average closer to the main indicators of sustainable development.

Chapter II presents the national targets for each of the 17 SDGs, namely Horizon 2020 for the envisaged measures and 2030 Targets for the rational phasing of efforts to achieve this goal.

Chapter III Implementation and Monitoring presents the decisions to be taken to ensure the operational framework for the implementation and monitoring of the achievement of the concrete objectives and targets of the Strategy. The aim is to ensure the coherence of government actions and increase the active involvement of all relevant factors of society and citizens' actions, with the motivation to ensure the harmonious combination of the three dimensions of sustainable development for transformation into a sustainable society.

THE SPECIFICITY AND ADAPTATION OF ROMANIA TO THE REQUIREMENTS OF THE EUROPEAN UNION IN THE FRAMEWORK OF THE NATIONAL STRATEGY FOR SUSTAINABLE DEVELOPMENT

Romania needs a change in the current paradigm of development to meet the challenges of the 21st century. We are living in a period marked by the process of globalization, accentuation of inequalities and aggravation of environmental problems. Sustainable development is the solution. The national strategy addresses these challenges, proposing the transition to sustainable development based on the principles and in the spirit of the 2030 Agenda for Sustainable Development, as a member of a prosperous and invigorated European Union.

Sustainable Development represents, in the Romanian context, the desire to achieve a balance, a synthesis between the aspirations of the free-born citizen, the society on which it depends and through which it is defined and the context that allows self-realization. This balance starts from man, the central actor who seeks an individual balance and favourable conditions to achieve.

Favourable conditions are influenced by the society that needs to support and motivate it and by the environment through which it finds itself and can find its balance. The role of the state in the context of sustainable development is to help achieve this balance, not only for today's citizens, but also for future generations.

The previous strategy supported the recovery from the economic and financial crisis felt after 2008. A new approach is now needed in the 2020s, taking into account the economic, social and environmental realities of the global, European and national horizons. Overtime, to meet "the needs of the current generation without compromising the chances of future generations to meet their own needs"[1].

If in the last ten years Romania's targets were set in relation to the evolution of the world economy and in line with EU policies, now both Romania and the EU must redesign their medium and long term priorities to achieve the 2030 Agenda for Sustainable Development, adopted at the United Nations Summit in September 2015 [2]. This is a sure way to achieve a better future for future generations.

Romania, along with 192 other states, has undertaken to establish the national framework to support the 2030 Agenda for Sustainable Development, which includes a set of 17 Sustainable Development Goals and the Addis Ababa Agenda for Action. The global action plan, which Romania chooses to support in the coming years, addresses poverty alleviation, combating inequalities, social injustice and protecting the planet by 2030.

It is an action plan for people, planet and prosperity, which aims to strengthen a climate of security and freedom, in which "no one will be left behind" [3].

ANALYSIS OF THE 2030 AGENDA FOR SUSTAINABLE DEVELOPMENT IN THE CONTEXT OF ROMANIA

The 2030 Agenda for Sustainable Development has resulted from a long international process of analysis, which recognizes that global problems can only be solved through global solutions. Changing perceptions and awareness of the unprecedented evolution of society, rising birth rates on a global scale, accelerating economies of developing countries and social disparities have highlighted the limits of planetary growth. Rising prices for certain resources have highlighted the fact that the Earth can deplete its renewable and non-renewable physical resources, leading to a catastrophic imbalance. [4].

The foundations of progress in the field of environmental protection, linked to development, were first introduced on the international agenda at the Stockholm Conference (1972). The result was the creation of the UN Environment Program by adopting a Declaration on Environmental Protection in order to "protect and improve the human environment for present and future generations.".

This conference gave legitimacy to the concept of sustainable development with the three pillars: economic, social and environmental [5].

The three pillars under which the 2030 Agenda for Sustainable Development is structured have been defined in the Brundtland Report (1987) [6], [7]. The most important pillar is **SOCIAL EQUITY** – whereby developing nations must be able to meet their basic employment needs.

The Millennium Summit in 2000 ratified the Millennium Declaration, the first international framework document to combat poverty, hunger, disease and inequality worldwide. In order to achieve the aspirations of the Millennium Declaration, 8 specific development objectives have been defined, known as the Millennium Development Goals, 21 targets and 60 indicators, with a deadline of 2015 [8], [9], [10].

The 2030 Agenda calls for action from all countries, poor, rich and middle-income.

Recognizes that ending poverty must be accompanied by a plan that contributes to economic growth and addresses a range of social needs, including education, health, social protection and employment, while addressing the issues of combating climate change and protecting the environment. It also covers issues such as inequality, infrastructure, energy, consumption, biodiversity, oceans and industrialization.

The agenda promotes the involvement of all stakeholders, by democratizing the process decision-making on sustainable development. The responsibility and role of generations is emphasized for the creation of sustainable development The European Context of Sustainable Development.

Within the EU, since 2006 [11], the concept of sustainable development has been integrated into the Enlarged Europe Strategy, in a unified and coherent strategic vision, with the general objective of continuously improving the quality of life for present and future generations, for the creation of sustainable communities capable of managing and using resources efficiently and harnessing the potential for ecological and social innovation in the economy, in order to ensure prosperity, environmental protection and social cohesion.

In 2010, as a follow-up to the EU's sustainable development, the Europe 2020 Strategy for Promoting Smart Growth (based on: education, research, innovation), sustainable (based on reducing carbon emissions, energy efficiency, renewable resources) was adopted, and inclusive (creating new jobs, reducing poverty, etc.).

Together with the member states and respecting the principle of subsidiarity, the EU is committed to becoming a leader in the implementation of the 2030 Agenda and, implicitly, of the 17 Sustainable Development Goals.

The UN Conference on Sustainable Development Rio + 20, in 2012, drafted the document The Future We Want, which made progress towards the achievement of the Millennium Development Goals and made the transition to setting Sustainable Development Goals for the post-2015 Agenda.

This document is further recognition of the importance of the three dimensions of sustainable development - social, economic and environmental10.

The 2030 Agenda for Sustainable Development - Transforming our world, adopted on 25 September 2015 by the heads of state and government of 193 countries at the UN General Assembly, is a fundamentally modified version of the conceptual framework of sustainable development, structured on a package of 17 sustainable development goals, supported by 169 underlying targets.

The 2030 Agenda calls for action from all countries, poor, rich and middle-income.

Recognizes that ending poverty must be accompanied by a plan that contributes to economic growth and addresses a range of social needs, including education, health, social protection, and employment while addressing the issues of combating climate change and protecting the environment.

It also covers issues such as inequality, infrastructure, energy, consumption, biodiversity, oceans and industrialization.

The agenda promotes the involvement of all stakeholders, by democratizing the decision-making process on sustainable development. The responsibility and role of young generations in creating sustainable development are emphasized.

Starting from the idea that the benefits of economic development must outweigh the costs, including those related to environmental conservation and improvement, Romania's first Sustainable Development Strategy of 1999 aimed at progressively improving and maintaining the welfare of the population in line with the requirements of rational use. natural resources and ecosystem conservation.

Accession to the European Union in 2007 adjusted national priorities through the National Strategy for Sustainable Development. Horizons 2013-2020-2030 (SNDD), approved by the Romanian Government on November 12, 2008, aiming to reduce the socio-economic gap compared to that of the Member States of the European Union.

For sustainable development to succeed in Romania and, therefore, the 2030 Agenda, together with the commitments of the European Union, this strategy is built around the citizen and the needs of future generations.

The strategy starts from the premise that sustainable development presents a framework of thinking that, once mastered by the citizen, will help create more equitable society, defined by balance and solidarity and able to cope with the changes brought by current global, regional problems. and national, including population decline. The care of the state towards the citizen and the respect of the citizen towards the institutions, towards his neighbour, moral values and cultural and ethnic diversity will lead to a sustainable society.

The European Commission presented on 22 November 2016 the Communication "Next Steps for a Sustainable European Future". The document presents the European Union's response to the 2030 Agenda and confirms the integration of sustainable development objectives into European policy and current European Commission priorities, assessing the situation and identifying the most relevant sustainability concerns.

Through this communication, the European Union is committed to sustainable development by "ensuring a dignified life for all while respecting the limits of the planet, bringing together prosperity and economic efficiency, peaceful societies, social inclusion and environmental responsibility".

The EU's response to the 2030 Agenda is to integrate the 17 SDGs into the Union's public policies, in order to support the global effort to build a sustainable future in collaboration with its partners. The 17 SDGs are already pursued by many of the policies of the European Union, and Romania, as a member of this community, aims through this strategy to integrate the objectives of the 2030 Agenda for Sustainable Development.

Romania's Perspective on Sustainable Development Starting from the idea that the benefits of economic development must outweigh the costs, including those related to environmental conservation and improvement, Romania's first Sustainable Development Strategy in 1999 aimed at progressively improving and maintaining the well-being of the population. correlation with the requirements of rational use of natural resources and conservation of ecosystems.

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For sustainable development to succeed in Romania and, therefore, the 2030 Agenda, together with the commitments of the European Union, this strategy is built around the citizen and the needs of future generations.

Through this communication, the European Union is committed to sustainable development by "ensuring a dignified life for all while respecting the limits of the planet, bringing together prosperity.

CONCLUSION

The concept of sustainable development, which involves ensuring the development of welfare for the present generation without negatively affecting the development and safety of future generations, is a concept with poor application in Romania (massive deforestation, irrational exploitation of nature reserves, etc.). In this context, ecological strategies designed to ensure sustainable development are of particular importance.

The national strategy for the sustainable development of Romania until 2030 contains several provisions for fulfilling this concept. Thus, an important place is occupied by the 17 Sustainable Development Goals (SDGs) of the 2030 Agenda, adopted by the Resolution of the UN General Assembly A / RES, in 2015.

The 2030 Agenda for Sustainable Development is a global action plan, which Romania chooses to support in the coming years. This plan addresses poverty alleviation, combating inequality, social injustice and protecting the planet by 2030.

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ELEMENTS OF THE EDUCATIONAL SYSTEM IN THE ECOLOGICAL FIELD PRINCIPLES OF ENVIRONMENTAL LEGISLATION

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ABSTRACT

This article has as a starting point the definition of the concept of ecological principles. Then, after classification of the principles of ecology (domestic principles and international principles), we present and critically analyze and compare the main principles in the field of ecology. Among the ecological principles on the domestic chain, we present and analyze 11 principles, namely: pollution must be combated at the source; the interests of environmental protection must be taken into account in all design or execution decisions; any exploitation or use of natural resources must be avoided if it is accompanied by damage; it is necessary to raise the level of scientific and technological knowledge, inter alia by supporting scientific research; the costs of preventing and combating pollution to be borne by the polluter; the activity of one state not to harm the environment of another state; during the elaboration of the community policy in the field of environmental protection to take into account the interests of the developing states; community environmental protection policy must be developed in the long term and protection must be comprehensive and international, which is achieved, inter alia, through cooperation within international bodies; the cause of environmental protection is everyone's responsibility and for this reason education is irreplaceable; depending on the source of pollution, the most appropriate level of action must be established taking into account the nature of the pollution, the necessary measures, the characteristics of the protected territory. This principle is defined as a "subsidiary principle"; it is necessary to harmonize and coordinate national policy in the field of environmental protection in accordance with the long-term commonly accepted directives. We also present and analyze the principle according to which environmental protection must be an essential element of the economic and social policy of the state. Finally, another ecological principle, the principle of prevention of ecological risks and damage.

Keywords: *Ecological Principles, Educational System, Ecological Risk Prevention*

INTRODUCTION

The principles of environmental legislation represent a kind of ABC of ecology. Their knowledge is necessary (but, unfortunately, not sufficient) for the scientific application of effective procedures for environmental protection.

The importance of these principles by the environmental legislation is also reflected by the provisions coming from the European Union (EU). It is the duty of each EU Member State to adapt these provisions to national specificities and needs.

European environmental policy is based on the principles of precaution, prevention, correction of pollution at source and "the polluter pays". Multiannual environmental action programs set the framework for future action in all areas of environmental policy. They are integrated into horizontal strategies and are taken into account in international environmental negotiations. Last but not least, implementation is key [1].

Article 11 and Articles 191-193 of the Treaty on the Functioning of the European Union (TFEU). The EU has the power to act in all areas of environmental policy, such as air and water pollution, waste management and climate change. The scope of its competence is limited by the principle of subsidiarity and the requirement of unanimity in the Council on matters such as taxation, land use planning, land use, quantitative management of water resources, choice of energy sources and the structure of energy supply. [2], [3].

PRINCIPLES OF ENVIRONMENTAL LEGISLATION

The principles of environmental law are those essential rules, of maximum applicability, which underlie the branch of law.

There are two categories of principles of environmental legislation:

A. Internal principles

B. International principles.

Principles of internal environmental legislation

Modern regulation of environmental protection is no stranger to the **theoretical substantiation of principles.** The fundamental principles of environmental law are influenced by **tradition and innovation** and determine the content of all norms of environmental law. Moreover, these specific principles give to the obligatory social norms regarding the protection, improvement and development of the environment that unity, that general logical affinity and common to all norms of environmental law, which guides the content of these norms and delimits them from other branches of law [4], [5].

Any general principle of law is the **result of a social experience** and at the same time a reflection of some objective requirements of the evolution of the society, of the social coexistence, of ensuring that necessary balance between the rights of some and the obligations of others.

As a result of a process of **abstraction and crystallization**, these principles express **the essence of environmental protection policy.**

The importance of general principles is also highlighted when we consider a large number of normative acts, the current chaotic stage of regulatory activity and the need to quickly find answers to environmental degradation problems [6], [7].

The principles of law direct the activity of legal regulation, both within the special law on environmental protection and in the context of other regulations.

Legislation can only be consistent when it follows pre-determined directions and strictly follows some well-defined principles.

In most cases, the fundamental legal principles are not only theoretical speculations, made at the level of scientific research, but result from the analysis of current trends applicable to the rule of law. The inclusion of fundamental principles in the rules of law takes place when those rules of law are important in principle.

These fundamental principles also facilitate the concrete application of the rule of law and help to discern the will of the legislator, as they constitute the "spirit of the law", the social support of law, ie their connection with social values. That is why, in certain cases, the principles of law take the place of the norm of regulation.

In a civil or commercial case, if the law is silent, the judge resolves the case based on the general principles of law. Or such a solution, in the case of environmental law, in full affirmation and crystallization, has very special importance.

Thus, they are recognized as principles of environmental law: the public interest character of environmental protection, conservation, prevention, caution in decision making and "the polluter pays". These principles are expressly enshrined in law or may result from dispersed provisions, thus being the product of orders of national law.

In the following, we will highlight only two aspects of the complex process of identifying the basic principles: the first refers to the ***European Community's policy and regulations in the field of environmental law***, and the second refers to ***the model environmental law project. developed by the Council of Europe in 1994.***

Principles of international environmental legislation

At the level of Community policy, environmental protection was institutionalized in 1973, by announcing the first Action Program of the European Community, considered the skeleton of Community policy in the field of environmental protection. The first rules of principle were formulated in this program, which were subsequently legally enshrined through successive amendments to the Treaties: the Single European Act (1986), the Maastricht Treaty (1992), the Amsterdam Treaty (1997).

Action programs are political statements of intent that include all those measures that are planned to be implemented in a given period, as well as a definition of their context. The programs also have the role of establishing the necessary measures for change and announcing their introduction.

The importance of the first Action Program, carried out in 1974-1976, is due, first of all, to the ***11 fundamental*** principles announced, which constitute, even today, the basis of all the other action programs as well as other regulations. These principles are:

1. Pollution must be combated at source.
2. The interests of environmental protection must be taken into account in all design or enforcement decisions.
3. Any exploitation or use of natural resources must be avoided if this is accompanied by damage.
4. It is necessary to raise the level of scientific and technological knowledge, inter alia by supporting scientific research.
5. The costs of preventing and combating pollution shall be borne by the polluter.
6. The activity of one state should not harm the environment of another state.
7. The interests of developing countries shall also be taken into account in the development of Community policy in the field of environmental protection.
8. Community policy on environmental protection must be developed in the long term and protection must be comprehensive and international, which is achieved, inter alia, through cooperation within international bodies.
9. The cause of environmental protection is everyone's responsibility and for this reason education is irreplaceable.
10. Depending on the source of pollution, the most appropriate level of action must be established taking into account the nature of the pollution, the necessary measures, the characteristics of the protected territory. This principle is defined as a "subsidiary principle".
11. It is necessary to harmonize and coordinate national policy in the field of environmental protection in accordance with the long-term commonly accepted directives.

These basic principles or component parts of the Action Program can be found in other important documents of the European Community or the European Union.

PRINCIPLES FOR THE DEVELOPMENT OF ENVIRONMENTAL LAW

Another example, also European, is the elaboration, in 1994, by a team of experts of the Council of Europe of a model law on environmental protection to support the legislative activity of the states of Central and Eastern Europe. The model not only contains and explains these principles, but also emphasizes that they are important auxiliary tools for the development of environmental law.

The principles set out in this model are:

1. The precautionary principle;
2. The principle of the alternative, according to which polluting activities must be replaced with less polluting activities (element of novelty);
3. Preservation of biodiversity;
4. Prohibition of the destruction of natural energy resources;
5. The "polluter pays" principle;
6. The principle of civil society participation and the right to information;
7. The principle of cooperation.

Internationally, the first significant documents were:

- Stockholm Declaration (1972)
- World Nature Charter (1982)
- The Rio Declaration (1992), which in fact enshrined the principles set out in the first documents.

These were later supplemented by a series of international treaties which, taking over the principles enunciated by various international conferences, gave them binding legal status.

For the most part, the principles of environmental law can be deduced by interpreting legal regulations, but they can also be formulated directly in the rules of this branch of law.

Romanian environmental law has been used both ways. Thus, art. 3 fin the former law of environmental protection, no. 137/1995, were listed the principles and strategic elements underlying ensuring sustainable development.

The same solution was adopted by the new framework regulation, Government Emergency Ordinance no. 195/2005. The principles and strategic elements underlying it are listed in art. 3, as follows:

a) the principle of integrating the environmental policy in the other sectoral policies;

b) the precautionary principle in making the decision;

c) the principle of preventive action;

d) the principle of withholding pollutants at source;

e) the "polluter pays" principle;

f) the principle of conservation of biodiversity and ecosystems specific to the natural biogeographical framework;

g) sustainable use of natural resources;

h) informing and participating the public in decision-making, as well as access to justice in environmental matters;

i) development of international collaboration for environmental protection.

In art. 4 of the O.G. provides the ways to implement the principles and strategic objectives, as follows:

a) integrated pollution prevention and control by using the best available techniques for activities with significant impact on the environment;

b) adoption of development programs, in compliance with the requirements of environmental policy;

c) correlation of land use planning and urban planning with the environmental one;

d) conducting the environmental assessment before approving plans and programs that may have a significant effect on the environment;

e) environmental impact assessment in the initial phase of projects with significant environmental impact;

f) introduction and use of incentive or coercive economic levers and instruments;

g) solving, on competence levels, the environmental problems, depending on their magnitude;

h) the promotion of normative acts harmonized with the European and international regulations in the field;

i) establishing and monitoring the implementation of compliance programs;

j) creation of the national system for integrated monitoring of environmental quality;

k) recognition of products with low impact on the environment, by granting the ecological label;

l) maintaining and improving the quality of the environment;

m) rehabilitation of areas affected by pollution;

n) encouraging the implementation of environmental management and audit systems;

o) promoting fundamental and applied research in the field of environmental protection;

p) educating and raising public awareness, as well as its participation in the process of elaboration and application of environmental decisions;

q) development of the national network of protected areas for maintaining the favourable conservation status of natural habitats, species of flora and fauna as an integral part of the European ecological network - Natura 2000;

r) application of systems to ensure the traceability and labeling of genetically modified organisms;

s) the priority removal of pollutants that directly and seriously endanger human health.

CONCLUSION

The scientific application of the principles of environmental legislation presupposes first of all their knowledge. From this point of view, the educational process specific to the ecological field has special importance. Education for respect and protection of nature must be based, among others, on the saying "Let nature heal itself". That means if you can help nature with something, do it, if not… better let it heal on its own.

The two main categories of principles of environmental legislation (domestic principles and international principles) each have their importance. In this context, it is very important that the principles at international level be adapted to the national specifics of each country.

One of the most important principles of environmental legislation is "The polluter pays". This implies, even punitively, that pollution be combated right from the source.

Another important objective of the principles of environmental legislation must be the elaboration of environmental strategies for as long as possible. These strategies must also take into account the condition and methods of implementing the concept of sustainable development.

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ENVIRONMENTAL ISSUES OF SURFICIAL URANIUM DEPOSITS: OUM DHEROUA CASE STUDY (ISLAMIC REPUBLIC MAURITANIA)

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ABSTRACT

Uranium deposits and resources are considered as an important raw material base for the implementation of scenarios for the green and clean energy transition. Traditionally discussed risks of potential environmental impacts of Uranium projects development could be subdivided by deposit type. Surficial type mineralization connected to the calcretes in shallow paleovalleys or playas has many specific features which might be analysed separately. Case study of Oum Dheroua Uranium project in the Islamic Republic of Mauritania shows an unexpected lower estimation of environmental risks comparatively to conventional Uranium projects despite to open-pit mining technology. The reasons for such estimation, connected to geographic location, the inclusion of Uranium minerals in natural ecosystems and low scale of deposits (both in grade and size sense). Potential by-products (Vanadium and Strontium) are not part of environmental factors assessment.

Keywords: *Uranium, calcretes, environment, Mauritania*

INTRODUCTION

Nuclear power is often excluded from the clean energy conversation, despite being the second largest source of low-carbon electricity in the world after hydropower. U.S Office of Nuclear Energy answers the question why we can consider nuclear energy sustainable and clean [1], [2]. It is a source with no harmful by-products like fossil fuel energy production. This is especially true about air and land pollution. The need for land resources is much less than any other source of clean air. The next reason why - nuclear energy produces minimal waste [2]. Today 34% of the total clean electricity in the world is produced from nuclear energy [1].

In the report of the World Bank Minerals for Climate Action, uranium is not included in the list of minerals for the green energy transition, but nuclear energy is included in the list of technologies that this transition is associated with. One of the models in this report – the International Energy Agency (IEA) model assume increased contribution from hydropower and nuclear power as sources that do not pollute the environment [3].

Given the above, uranium deposits and resources are considered as an important raw material base for the implementation of scenarios for the green and clean energy transition.

Energy transition to the low-carbon economy demands a deeper focus not only on "green" technologies (solar, wind, geothermal, etc.) but alternative like nuclear. There are some negative reasons commonly disputed with nuclear:

1. This energy source is not renewable (similar to fossils);
2. High risk related to the safety of nuclear reactor with catastrophic damages while accidents (Chornobyl, Fukushima, etc.)
3. Risk of groundwater contamination due to mining, including underground leaching method;
4. Risk of air and groundwater contamination during the ore processing;
5. Risk of radioactivity impact during the transportation and finally
6. Risk of soil and groundwater contamination during the storage of buried nuclear fuel.

Another reason impacted to spreading of nuclear power is a significant inhomogeneity of World commodity distribution [4]. The major producers like Kazakhstan, Australia and Canada have concentrated a significant part of World production [5]. The common feature of these countries is a low density of population and large country area. On other hand, Uranium has various genetic types of deposits with very different peculiarities of deposits position, ore mining and processing technology, including grades, Uranium minerals variety, and mining methods (underground mining of leaching, open pits). The only one surficial type connected with calcretes allowing the open pit method due to shallow position (1-20 meters). There are some very specific characteristics of such deposits [6]:

1. Near-surface origin of mineralization connected with mixing of Uranium-rich and Vanadium-rich groundwater in arid conditions;
2. Structural position connected to the parts of comparatively young paleovalleys or lakes playas;
3. Usually they still occur in deserts due to arid origin;
4. Very poor grades (0.01-0.1% of U_3O_8) and small tonnage but economically significant due to low CAPEX and OPEX.

The most known deposit of this type is Yeelirrie (Western Australia) with the worldwide highest grades of about 1600 ppm. The story of this deposit is quite bright due to environmental issues, which were approved and then appealed long time during the rehabilitation of the project [7].

Oum Dheroua project was discovered in 2013 by Karfagane Ltd. with the collaboration of Taras Shevchenko National University of Kyiv, Ukraine. The project site is located in the north-western part of Reguibat Precambrian shield (Figure 1).

Prospecting and exploration work in the licensed area began in 2013. The first stage of research was completed in 2015 and made it possible to draw a conclusion about the general prospects of the site for uranium mineralization. Based on the results of geological, geophysical and geochemical studies, promising structures were identified, the genetic types of a possible deposit were determined, and the area of the license area was reduced from 500 km^2 to 300 km^2. Two types of mineralization are identified, which are found on the site. The main one is the surface type, associated with calcretes in the rivers paleochannels and/or the lake's shores. The second type is associated with pegmatite veins in granitoids. It is very likely that the origin of the first type is closely related to the redeposition of uranium from bedrock.

Primary Uranium sources are connected to granite-hosted pegmatite veins situated to the northeast from the deposit (Figure 2). Vanadium source is identified in banded-iron formation of Lebthenia iron ore project westward. Vanadium could be considered as a by-product due to the mineralization of tyuamunite or carnotite. Vanadium grade was estimated by ICP method in 2015 for trench data (60 samples). The highest grade is up to 0.2% that is much lower than economically valuable Vanadium deposits (1.0-1.5%).

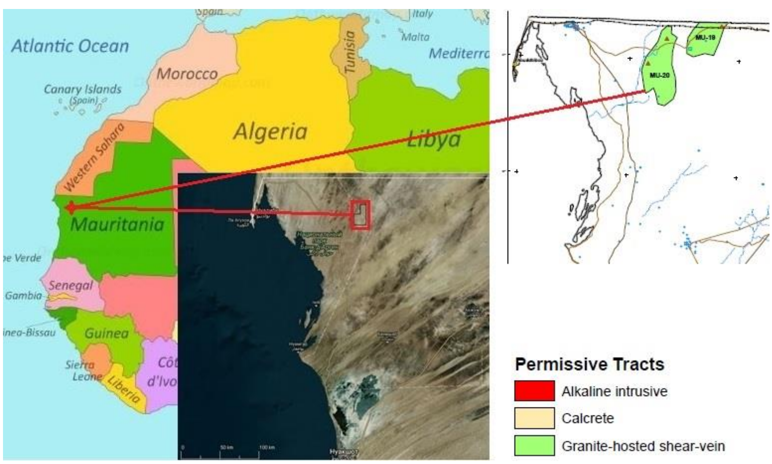

Fig. 1. *Location of the study area and Uranium permissive tracts (modified after [8])*

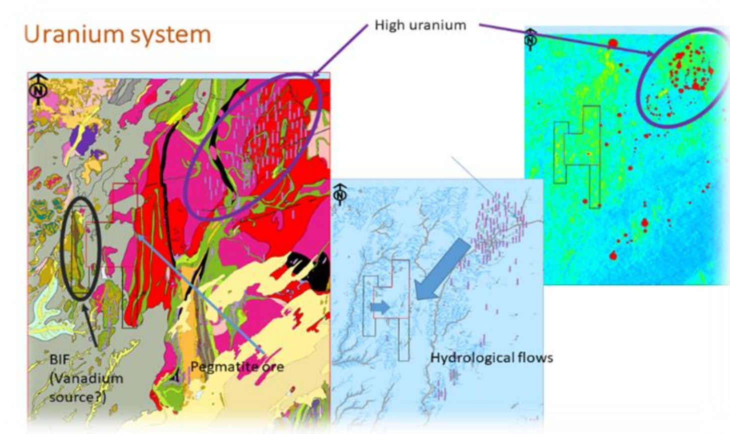

Fig. 2. *Conceptual model of Uranium system in Oum Dheroua site (modified after [8], [9])*

More specific is high-grade Strontium mineralization reported previously [10]. A large number of Sr anomalous values (over 8000 ppm, 0.8%) are noted with modes of 1% and 1.5%. The highest grade reaches almost 8%. The relationship between Uranium and Strontium are not clear yet, but there is the second potential by-product of deposit.

These results allowed the second stage (2016-2019) to conduct a targeted study of promising structures. Three priority areas have been identified, with an area of 3 km2, 0.9 km^2 and 1.7 km^2, where calcrete type mineralization has been identified, exploration work is being carried out to delineate them and then calculate the reserves. In addition, other promising zones have been discovered with potential mineralization.

Available resource estimation with pessimistic grade of 105 U_3O_8 representing a very small development area of measured and indicated resources (Figure 3). Due to proposed mining plan different targets could be developed separately as individual pits. The decision for each target is applied independently. Detailed resources list by targets (Table 1) shows sizes of targets, which relatively defines a potential industrial impact for the environment.

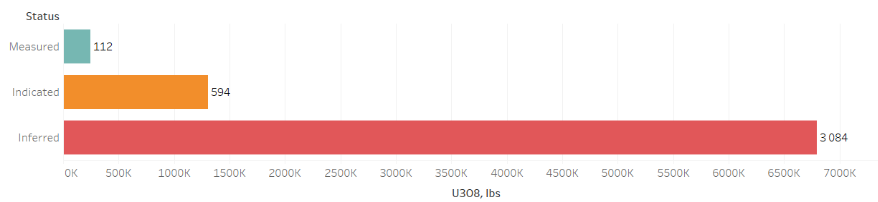

Fig. 3. *Resource summary of Oum Dheroua project (labels near bars is U_3O_8 content in tons)*

Table 1. *Resource list for targets of Oum Dheroua project*

Target Name	**Resources status**	**Confidence**	**Area, km2**	**U_3O_8 Content, klbs**
ABH	Measured	High	0.026	93.8
ABH_West	Measured	High	0.013	44.6
B_TR2	Measured	High	0.030	108.2
A_SouthTR3	Indicated	Average	0.203	723.5
A_NorthTR1	Indicated	Average	0.073	260.3
A_NorthStream	Indicated	Low2High	0.090	320.7
A_EastFlank	Inferred	Low	0.321	1 144.4
A_EAnom	Inferred	VeryLow	0.074	263.5
A_NEastTR1	Inferred	Low2Average	0.072	255.1
B_NWAnom	Inferred	Low	0.014	52.1
C	Inferred	Low2Average	1.424	5 076.0
Total			**2.340**	**8 342.3**

Special research for all aspects of potential environmental impact will be provided before any activity related to the mining or processing operations. No permanent settlements or nomadic groups in radius of 30 km from planned mining sites are located. Impact on other industrial facilities (Tasiast gold mine, Lebthenia iron ore deposit) will be evaluated. Archaeology, cultural heritage, terrestrial fauna, flora and biodiversity, aquatic ecology, hydrogeology and air condition issues will be estimated. Effects of artisan gold miners will be included withthe correction to the current situation periodically. The development of Oum Dheroua project allowing to create some workplaces for local people living in the Chami region as well as some artisan gold miners could find here a permanent job.

The most important environmental factors of potential mining are the following (Table 2). We ranked different types as a relative environmental factors of potential impact. This analysis is not connected to the potential by-products (Vanadium and Strontium).

__Table 2.__ Environmental factors impact summary.

Environmental factors group	Impact	Impact type	Impact rate	Rank (0-10)	Impact suppression procedures
Flora and vegetation	Clearing of flora	Direct	very low due to desert conditions	1	Possible rehabitlitation of rare-happened trees or seeding new ones
	Clearing of vegetation	Direct	absent	0	
Terrestrial fauna	Clearing of fauna	Direct	very low due to desert conditions	1	There are huge areas nearby with the similar condition for living for most of species
Subterrestreal fauna	Clearing of fauna	Direct	medium while mining especially during startup stage	4	Management of preparatory works with activity which cause the fauna migration (noise, vibration)
Fauna	Conservation of threatening species	Direct	need to be estimated locally on site	n/a	Demand special longterm research
Hydrogeology	Abstraction of groundwater level	Indirect	absent due to absence of permanent groundwater	0	
	Reinjection of groundwater	Indirect	very low due to absence of leaching plant	1	Control of water management for camp and ore primary processing procedures
	Alteration of groundwater	Direct	absent due absence of permanent groundwater	0	
	Uptake of radionuklides	Direct	low due to the low grades and resistance of vegetation living with	2	

			near-surface deposit		
Hydrology	Alteration of surface water flows	Direct	low-to-medium due to shallow pits and quick backfilling	3	Full and rapid recultivation of mined areas by waste backfilling and natural sand dust filling
Air conditions	Dust impact	Direct	medium due to significant wind and treatment of radionuclides in the dust.	5	Constriction of closed buildings, waste dumps, management of spatial location of facilities
Land management	Construction of facilities and roads	Direct	Low-to-medium due to small capacity of project productivity	3	Spatial analysis of facilities location while planning

CONCLUSION

The environmental issues of any Uranium project demand careful investigations of potential impacts. The surficial type deposits have a specific position in this question due to shallow near-surface ore bodies and thus, demands just only open-pit mining technology. But many peculiarities of such deposits show lower risks compared to more rich, conventional Uranium deposits (sandstone-hosted, unconformity or metasomatic types). As shown in our analysis on the example of the Oum Dheroua project, most of the factors are low level due to specific geographic position, low-grade ores and comparatively simple processing.

The most risked environmental factors are the dust impact on air condition dangerous for people, flora and fauna in the local area and mechanical destroying of near-surface potential habitable layer (0-10 meters). The first factor must be controlled by specific engineering decisions such as wind-protective dumps, covers of trucks, etc. The second factor should be estimated by continuous observation of fauna and biodiversity.

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FIRST RECORDS OF AZALEA SAWFLY *NEMATUS LIPOVSKY* SMITH, 1974 (HYMENOPTERA: TENTHREDINIDAE) IN LATVIA

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ABSTRACT

Invasive non-native insect species are well-known threat to both local and introduced plant species in Europe. With increasing global trade and effects of climate change it is expected these alien species will continue to expand their distribution areas. One such non-native species is azalea sawfly *Nematus lipovskyi* Smith, 1974 (Hymenoptera: Tenthredinidae) that feeds on deciduous *Rhododendron* spp. This species is known to occur in the USA and was found in the Czech Republic for the first time in Europe in 2010. We report the first findings of this species in Latvia that were made based of field observations in the period of 2018-2020. The current known status of the species in Latvia is presented. Our observations of damage caused by sawfly larvae are summarized. Host plants used by sawfly larvae are listed – we note *Rhododendron albrechtii* as a host plant of this species for the first time. The possible pathways of its introduction and the overall importance of our findings in context with other non-native species expansions are briefly discussed.

Keywords: *invasive species, Nematus lipovskyi, Europe, Latvia, Rhododendron*

INTRODUCTION

The rhododendrons (*Rhododendron* L.) are widely used introduced ornamental plants in Latvia. This popularity is enhanced by the Botanical Garden and Rhododendron Breeding and Experimental Nursery "Babīte" of the University of Latvia where breeding work is performed and the largest collection of rhododendrons in Baltic states is located [1]. Although introduction history of genus *Rhododendron* is already two centuries-long in Latvia no serious pest problems had been detected until the end of 20th century [I. Apine pers. comm.].

In Latvia, the first observed non-native insect species that caused quite serious damage for evergreen rhododendrons was rhododendron whitefly *Massilieurodes chittendeni* (Laing, 1928), (Hemiptera: Aleyrodidae) that has been known to horticulturists since the end of 20th century [I. Apine pers. comm.] but first official published data came only in 2013 [2]. Since then few more alien insect species have been found on introduced *Rhododendron* spp. One of better known species is the rhododendron leafhopper (*Graphocephala fennahi* Young, 1977, Hemiptera: Cicadellidae) that has been present in Europe since 1935 and since then has become rather widespread in European countries, including Latvia [3]. Another example is the mirid bug *Tupiocoris rhododendri* (Dolling, 1972) (Hemiptera: Miridae) which also has recently been found in Latvia [U.Piterāns pers.comm.]. Although such alien species often are not highly invasive and of high economic importance in Europe, some of them can still have a negative impact on the local level [4].

This paper deals with the first observations of new alien insect species *Nematus lipovsky* Smith, 1974 in Latvia. *Nematus lipovsky* is a member of the Tenthredinidae (Hymenoptera) family that was first described only in the second half of 20th century from specimens collected in the eastern part of North America [5]. Nowadays species has spread also to the western part of North America [6], [7]. In 2010, for the first time this non-native species for Europe was recorded in Charles University Botanical Garden located in Prague, the Czech Republic (Fig. 1) where it has spread in many places since [8]. No records are known from other countries.

Host plants of *N. lipovskyi* are typical deciduous species of rhododendrons representing different regions of origin, for example, *R. luteum* (native to Europe), *R. molle* (native to China and Japan), as well as *R. calendulaceum* and *R. occidentale* (native to North America). However, in the Czech Republic the larvae were found also on *R. poukhanense* × *R. mucronatum* hybrid 'Ledikanense' that belongs to a group of semi-evergreen azaleas native to Asia [6], [7], [8]. The insect species is univoltine. Adults fly on average from the end of April until the middle of May, depending on the season. Larvae feed on leaves, consuming the whole leaf except central vein, and sometimes also flowers. They can be found on the host plant from the middle of May until the end of June. [8] The aim of present study was to describe the distribution area and host plants of *Nematus lipovsky* in Latvia.

Fig. 1. *Current known distribution of Nematus lipovskyi in Europe [8], [pers.obs.]*

MATERIALS AND METHODS

Observations of sawfly larvae were made in 2018-2020 during field surveys of *Rhododendron* spp. in the University of Latvia (UL) Botanical Garden (56°56'56"N, 24°03'21"E) and Rhododendron Breeding and Experimental Nursery "Babīte" (56°57'47"N, 23°56'55"E). Both locations are about 7 km apart. Adult insects were searched during the period of May 1st and 21st 2020 using visual surveys and sweeping *Rhododendron* spp. bushes with an entomological net.

RESULTS AND DISCUSSION

First notes of the possible occurrence of *N. lipovskyi* were made during June 2018, when extensive damage caused by larvae of then-unknown insects, were found on leaves of several deciduous *Rhododendron* spp. in the territory of UL Botanical Garden. The presence of these larvae in UL Botanical Garden continued also in subsequent years (2019 and 2020). One year later, in 2019 similar damages were observed in the second area – UL Rhododendron Breeding and Experimental Nursery "Babīte". The presence of larvae continued in this second locality also in 2020. The initial identification of these larvae belonging to *N. lipovskyi* was made during 2019 but breeding and rearing attempts that could confirm the identification were unsuccessful. Only during the spring of 2020 first adult insects were successfully obtained that confirmed the identification.

Collected materials: 4 ♀, 21.05.2021, UL Botanical Garden, caught on *R. luteum* with entomological net, leg. U. Piterāns. Specimens are deposited in the collection of the Latvian National Museum of Natural History (Fig. 2).

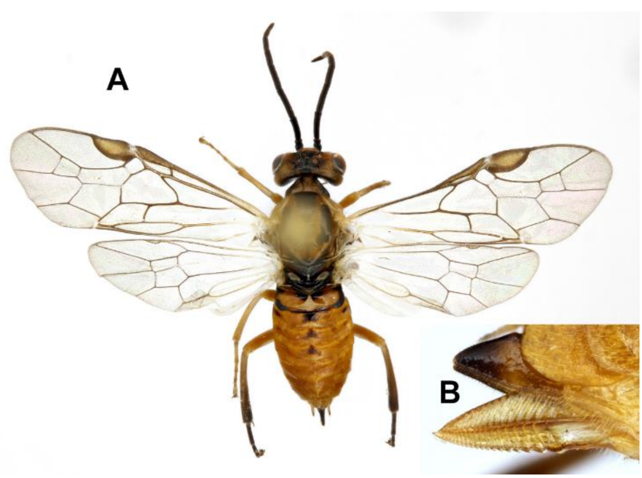

Fig. 2. *Collected specimen of Nematus lipovskyi. Female, dorsal view (A), details of the female abdomen: ovipositor and ovipositor sheath, lateral view (B).*

Feeding of *N. lipovskyi* larvae has been observed on such species in Latvia: *Rhododendron calendulaceum, R. luteum, R. occidentale,* and *R. albrechtii*. The *R. albrechtii* has never been previously mentioned as host plant for azalea sawfly (Table 1). Additionally, feeding of larvae was observed on numerous rhododendron hybrids that belong to different groups: Knap Hill-Exbury, Kosterianum, Mixtum, Occidentalis and Rustica. That confirms that *N. lipovskyi* can use as a host plant not only rhododendrons belonging to subgenus Hymenanthes and section Pentanthera, which are typical deciduous azalea species and their hybrids, but also plants of other subgenus – Azaleastrum.

Table 1. *Taxonomic list of host plants of Nematus lipovskyi [6], [8], [pers obs.]. Rhododendron systematics follow [9].*

Taxonomic affiliation of host plant			**Countries where host plant has been noted**
Subgenus	**Section**	**Species, hybrids**	
Hymenanthes	Pentanthera	*R. calendulaceum* (Michx.) Torr.	USA, Latvia
		R. luteum Sweet	Czech Republic, Latvia
		R. molle (Blume) G. Don	USA, Czech Republic
		R. occidentale (Torr. & A. Gray)	USA, Latvia
		R. viscosum (L.) Torr.	USA
		Hybrids	USA, Czech Republic, Latvia
Azaleastrum	Sciadorhodion	*R. albrechtii* Maxim.	Latvia
	Tsutsusi	*R. poukhanense* hybr. 'Ledikanense'	Czech Republic

Larvae were mostly feeding on leaves but less often also on flowers. Our observed damage on inhabited azalea shrubs during the feeding period of larvae (end of May – June) sometimes was quite extensive – close to 100% defoliation (Fig. 3). The intensity of defoliation did differ rather significantly with some plants, depending on genotype. We suggest that the physiological status of plants can affect their defense level against this pest as well. For example, from three genetically identical *R. calendulaceum* (propagated by cuttings) growing close together, the sawfly larvae severely damaged only one plant that was more weakened than others (replanted year ago – with a weaker root system). Since the larvae feed relatively early in the season, the plants manage to regrow leaves and form flower buds later in the season. However, severe defoliation lead to delay of shoot development, which in turn caused the reduced length of shoot and reduced number of flower buds.

Fig. 3. *Defoliation caused by Nematus lipovskyi larvae (top), and larvae, lateral view (bottom). Photos are taken in Botanical Garden UL, 06.06.2019.*

This study is only one example that characterizes the expansion of the distribution area of invasive species. This is an ongoing problem worldwide and regular reports on this issue are an increasingly common phenomenon, showing that limiting the expansion of alien species on a larger scale (e.g. on a European level) is still a big challenge [4], [10]. In both European countries, the Czech Republic and Latvia, *N. lipovskyi* for the first time was detected in the botanical gardens. It clearly demonstrates the important role of the botanical gardens in ensuring biosecurity that has been emphasized during the last decades. Continuous monitoring of diverse collections of native and introduced plants located in these gardens gives the opportunity for early detection of both alien pests and pathogens [11].

Although the introduction of non-native organisms is apparently helped by extensive trade and travel, however impact of climate change has been also mentioned in this regard [4], [12]. Changes in climate can be especially important factor in our region as there is evidence that even distribution areas of many native European species have expanded their northwards during 21st century. For example, at least 30 new true bug Heteroptera species have been recorded in last 20 years in Latvia that can be classified as expansion species [U. Piterāns pers. comm.]. Thus it can be expected that also non-native alien species could follow similar trend and continue their expansion northwards even without human aid. Recent observations of invasive western conifer seed bug *Leptoglossus occidentalis* Heidemann, 1910 (Hemiptera: Coreidae) in Baltic states and northern Europe is a good example to that [13], [14]. Regarding rhododendrons, there are several other alien insect species as *Stephanitis rhododendri* (Kolenati, 1857), *S. pyrioides* (Scott, 1874) (both Hemiptera: Tingidae) and *Caloptilia azalaella* (Brants, 1913) (Lepidoptera: Gracillaridae) which are present elsewhere in Europe but have not yet been found in Latvia [4]. Careful monitoring of plants must be carried out to control the spread of non-native species.

CONCLUSION

Latvia is only second country in Europe where *N. lipovskyi,* a potentially invasive species, has been observed in Europe (Figure 1) though we expect that the species could be present also elsewhere, for example, in Germany and Poland, where several large rhododendron collections are located and there is ongoing and active rhododendron plant trade. The exact pathway of species introduction in Latvia is not known but we suspect that plant trade of imported plants is a most likely scenario as such plants are widely available in the local plant trade. So far there are no observations of extensive damage of sawfly larvae in private gardens and the two current known localities (UL Botanical Garden, Rhododendron Breeding and Experimental Nursery “Babīte”) in Latvia remain the only ones where presence of azalea sawfly has been noted in our country. Monitoring of other suitable sites is needed in future to determine exact spread of *N. lipovskyi* in Latvia.

Our observations show that *N. lipovskyi* can use rather wide range of host plants that are native to different parts of the world (North America, Europe and Asia) – including many of artificially created azalea varieties that are not found in the wild. Several of known host plants are used commonly as an ornamental plants in gardens, city green spaces etc. We conclude that host plant availability most likely is not a limiting factor in further spread of this species.

Long term effect of repeated sawfly larvae attacks on health of *Rhododendron* spp. bushes should be monitored but our preliminary observations show that strong and healthy plants survive the defoliation caused by larvae relatively better.

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FLORISTIC DIVERSITY AND STRUCTURAL CHARACTERIZATION OF THE FOREST OF CHETTABA (ALGERIA)

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ABSTRACT

The structure of various stands, defined as the diversity of trees in the stands, can be an indication of overall biodiversity and habitat suitability, be useful in predicting stand growth and provide stand details for forest inventories.

In an effort to find sustainable resource management strategies, a study was conducted on the structural and ecological characteristics of stands in Chettaba forest (Algeria). In this study, six diversity indices were used to characterize the horizontal and spatial distribution of individuals in multi-species stands, using four plots, located in the Chettaba forest (East-North Algeria). The results obtained allowed us to note that P2 and P3 present similar average densities (600 feet/ha), the plots P1 and P4 present low average densities (250 feet/ha and 350 feet/ha). The average DBH values vary from 25.65 cm for the P2 stand to 30.61 cm for the P1 stand. The average basal area varied between 33.73 m²/ha (P3) and 18.92 m²/ha (P1). The Shannon and Weaver index reached its maximum in plot 4 with 8 species. The study allowed us to evaluate the floristic diversity of the forest. Moreover, it indicated the need for its integral protection for its dynamics towards a dense forest vegetation.

Keywords: *Chettaba, floristic diversity, spatial distribution, horizontal distribution*

INTRODUCTION

The forest is a complex ecosystem and remains a universal common good [1], [2]. It provides vital goods and services that contribute to human well-being [3]. Pressures on forest lands and unsustainable exploitation of forest resources cause negative impacts on forest genetic resources. It is therefore important to find mechanisms for sustainable management of forest ecosystems [4]. It is therefore important to find mechanisms for sustainable management of forest ecosystems. Sustainable forest management requires a better understanding of the ecological and physiognomic aspects of the vegetation [5]. The reconstitution of forest cover is one of the many challenges facing sustainable natural resource management policies.

The plant formations of the forest of Chettaba are poorly known, no study has been made to know its floristic richness although it presents the most important ecosystem of the region of Constantine. One meets at the level of this massif a formation of matorral type resulting from the degradation of the forest under the combined action of various factors in particular the repeated fires and the not controlled grazing.

To better understand the degradation of ecosystems, which is of natural and anthropic orders, the study of vegetation seems very appropriate. Indeed, the flora and vegetation of a region are the result of a long process of natural selection under the action of climate, edaphic and topographic conditions, without forgetting anthropic activities [6], [7], [8].

A precise knowledge of the existing forest resources, as well as their evolution should focus on the floristic composition, structure and regeneration of valuable species, hence the need to conduct a forest inventory, which is the subject of this work.

The objective of this work is to obtain information on the characteristics of woody resources (height, diameter, basal area, volume,...) and on the quantitative relationships between them. This will help to take care of this forest formation considering all the ecosystems that are connected to it and studying various alternatives of development and conservation of all the forest species that are in the Chettaba forest, which would contribute to the protection of the latter.

MATERIAL AND METHODS

Situation of the forest of Chettaba

The state forest of Chettaba belongs to the watershed Kebir Rhumel, it is located south-west of Constantine, south of Ibn Ziad, north of Ain Smara and east of Oued Athmania. The study area is located on the topographic map of Constantine Scale 1/200.000 sheet N° 17 and more or less located between the coordinates 36 ° 18', 36 ° 21' north latitude and 6 ° 26', 6 ° 30' east longitude (Figure 1).

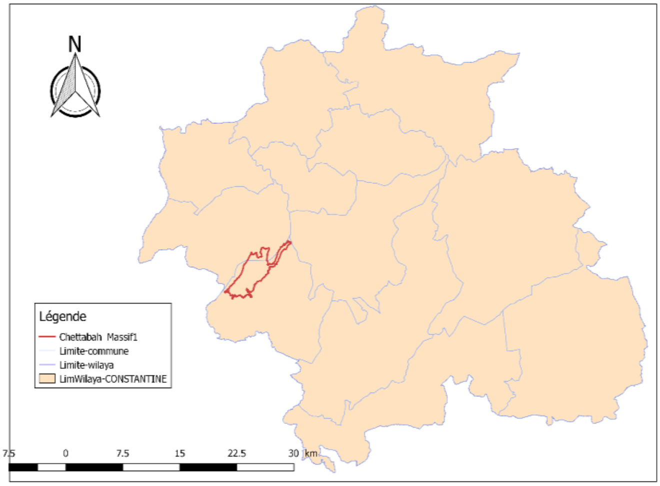

Fig. 1. Geographical location of the Chettaba forest.

Method of study

The dendrometric characterization was done by means of a forest inventory. Within the Chettaba forest, 4 plots were installed. Within each of the plots all individuals of the species were inventoried. For each individual, the average diameter and total height were measured.

The following formulas were used to calculate the dendrometric parameters.

- Stand density (N) is the number of stems per hectare.
- The basal area of the stand is the sum of the basal areas of all trees and shrubs. It was obtained by the formula:

$$G = \Sigma\pi \, D2/4, \text{ with:}$$

G = basal area expressed in m2/ha.

D = diameter at breast height of trees.

- Floristic diversity covers floristic richness and equitability, which is the way individuals of the species encountered are distributed.
- Shannon's index (H), Simpson's diversity index (D) and Piélou's equitability index (E) expressed by the following equations [9]:

$$H = -\Sigma(Ni/N)\log2(Ni/N).$$

$$D = 1-\Sigma(Ni/N)2.$$

$$E = H/\log2(S) \text{ with:}$$

ni = the number of individuals of a species i.

N = the total number of individuals of all species.

S = the total number of species.

RESULTS AND DISCUSSION

The management objective of modern forestry is to reconstruct the structure of artificial forests by simulating the structure of forests. For this purpose, the first question is how to express the characteristics of forest structure. But it seems impossible to describe the structure of forests well by using only one parameter because of their complexity. Therefore, a system used to assess different aspects of spatial stand structure was created by combining four indices: species richness, Simpson's index, Shannon and Weaver's index, relative density, relative basal area, diameter differentiation index and Pielou's segregation index in this study. A number of studies have indicated that they are available and can effectively interpret the spatial characteristics of different forest types.

The basal area, density, Shannon's diversity index, Simpson's index and Pielou's index of the different woody groups are shown in Tables 1 and 2. The results obtained show that two of the four stands analyzed (P2, P3) had similar basal areas (32.50-33.73 m2/ha, N = 600/ha). The stands in the forest (plot 4) had a greater extent of DBH, but the height extent was in plot 1. The lowest average DBH of all live trees was in plot 2 (d1.3 = 25.65 cm) and the highest in plot 1 (d1.3 = 30.61 cm). The highest average height was obtained in plot 3 (10.02 m) and the lowest in plots 1 and 2. Density is the stand variable most closely associated with stability, although its effect depends on other factors such as the type of abiotic factor or wind exposure. In general, the higher the density, the greater the snow damage, as it is easier for snow layers to pile up on the crowns (Table 1).

Table 1. *Characteristics of the plots studied.*

Plots	N/ha	D (cm)	G (m^2/ha	H (m)
P1	250	30.61	18.92	9.03
P2	600	25.65	32.50	9.29
P3	600	26.42	33.73	10.02
P4	350	28.18	23.03	8.35

The proportion of species implies the importance value per species, which may result in the need to manage a large number of values in very diverse stands. Therefore, when mixtures include more than two or three species, indices that summarize species composition are often preferred. In forest stands (Table 2), species richness (SR) ranges from 4 in plot 3 to 8 in P4, the latter being, by definition, richer. The Shannon-Weaver index (H) increased with increasing species number and uniformity of individuals per species. In the tree plots (1, 2 and 3) with 6 and 4 species respectively, the index is 0.53. Simpson's index ranged from 0.83 in plot 3 to 0.92 in plot 4. Pielou's segregation index (E) shows that Aleppo pine has a tendency to independent distribution in 4 plots.

Table 2. *Diversity indices.*

Parcelles	SR	H	D	E
P1	6	0.53	0.89	0.20
P2	6	0.53	0.87	0.21
P3	4	0.43	0.83	0.26
P4	8	0.51	0.92	0.17

CONCLUSION

The state forest of Chettaba presents the most important ecosystem of the region of Constantine with a surface of 2400 ha.

The spatial structure of an ecosystem, that is to say the way in which the individuals which compose it are organized in space, often plays an essential role in its functioning. This spatial structure of an ecosystem contributes to improve the knowledge of the natural resources present in the Chettaba forest and serves as a data base for forest management. For all the results concerning the dendrometric parameters, plots 3 and 4 are the most abundant and dominant; it can be deduced that some plots are well adapted to the climatic and soil conditions of the environment. Each of the three stand structure indices used quantifies spatial relationships in a specific way. Floristic diversity is low within the forest, which therefore tends to be very homogeneous.

The floristic composition and structure of the site indicate the need for its integral protection for its dynamics towards a climatic vegetation. Consequently, any development aiming at wood production will be detrimental to it. The objective of possible developments on the site should be to safeguard biodiversity by protecting and restoring the natural vegetation. However, this can only be achieved if the riparian populations are associated for a participatory management.

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FLORISTIC DIVERSITY OF THE OULED BECHIH FOREST (ALGERIA)

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ABSTRACT

The objective of this study is to inventory the flora of the Ouled Bechih forest (Algeria) with a quantitative and qualitative analysis through significant parameters. This study allowed the identification of 27 species belonging to 26 genera and 17 families. The results show an important diversity of the regional flora which is essentially dominated by the Asteraceae, Fabaceae, Fagaceae and Rosaceae. Hemicryptophytes and geophytes dominate the biological spectrum of the flora of this forest, which is morphologically characterised by the dominance of perennial herbs. The analysis of the chorological types shows the predominance of the Mediterranean element.

Keywords: *Ouled Bechih forest, inventory, floristic diversity*

INTRODUCTION

Mediterranean plant biodiversity is the product of a complex and eventful palaeogeography, but also of a traditional and harmonious use of the environment by man [1]. The flora of the Mediterranean basin is of great interest, given its great richness linked to the heterogeneity of historical, palaeogeographical, palaeoclimatic, ecological and geological factors that characterize it, as well as to the age-old impact of anthropic pressure [2]. Belonging to the Mediterranean forests, the Algerian forest, with its biological diversity, is an essential element of the ecological, climatic and socio-economic balance of different regions of the country. Its current situation is one of the most critical in the Mediterranean region [3]. Indeed, the persistence of destructive factors such as fires, overgrazing and land clearing only accentuates the process of degradation of the existing forest system and the loss of its biological diversity [4].

The present study focuses on the open forest of Ouled Bechih, located in eastern Algeria. This forest is used for cork production and is characterized by a very high biodiversity. The objective of this study is to inventory the flora of this forest with a quantitative and qualitative analysis through significant parameters: global composition (number of taxa), biodiversity indices, morphological types, biological types and chorological type in order to evaluate the importance of the floristic diversity of this region.

MATERIAL AND METHODS

Presentation of the study area

Forest of Ouled Bechih is located north of Souk Ahras (Algeria). The study area is located between the coordinates 36°21'26" north latitude and 7°50'08" East longitude (Fig. 1). It covers an area of 6582 ha, mainly composed of *Quercus suber* and *Quercus canariensis*. This region is characterized by a sub-humid climate. The average annual temperature is 16°C and the average annual rainfall is 625 mm, with an atmospheric humidity of 68%. The altitude of the Ouled Bechih forest varies from 790 m to 1050 m, with slopes of over 15%.

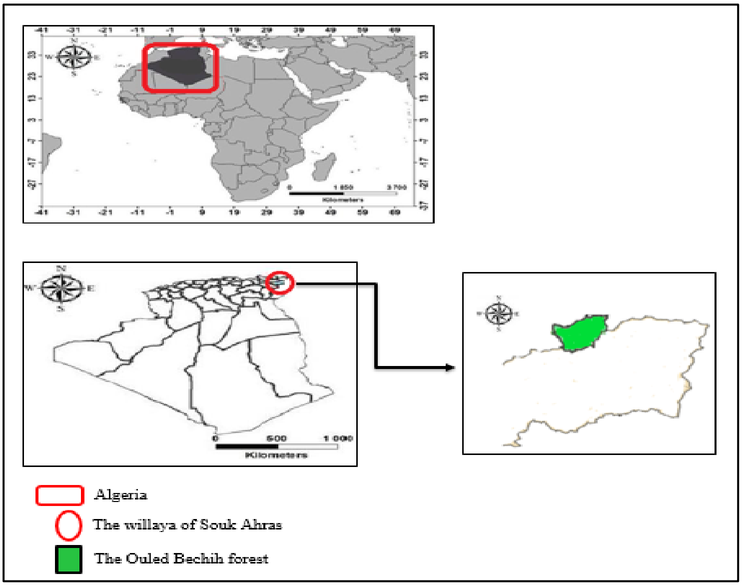

Fig.1. *Study area.*

Choice of study stations

4 randomly selected rectangular plots with an equivalent surface area of 900m2 (30m x 30m) within each plot all individuals are surveyed foot by foot. Floristic inventory The species encountered in the study plots were inventoried, identified with a PlantNet smartphone application, and then classified according to family, genus, biological, morphological and chorological type.

RESULTS AND DISCUSSION

The floristic inventory of the different plots of the Ouled Bechih forest revealed 27 taxa belonging to 26 genera and 17 families (Table 1). The most common families are: Asteraceae, Fabaceae, Fagaceae and Rosaceae (Fig. 2). These families represent 50% of all species encountered [5]. The species inventoried represent the floristic procession of *Quercus suber* and *Quercus canariensis* such as: *Hypochaeris glabara*, *Bellis prennis*, *Lotus corniculatus*, *Ranunculus muricatu*, *Charybdis maritima*...

Table 1. *Floristic diversity of the Ouled Bechih forest.*

Family	Species	Biological type	Morphological type	Chorological type
Fagaceae	*Quercus suber*	Phanerophytes	Woody	Western Mediterranean
	Quercus canariencic	Phanerophytes	Woody	Western Mediterranean
Asteraceae	*Hypochaeris glabara*	Therophytes	Perennial herb	European
	Hyoseris radiata	Hemicryptopytes	Perennial herb	European-Mediterranean
	Bellis prennis	Hemicryptopytes	Perennial herb	Eurasia - European
	Artemisia arborescens	Chamephytes	Perennial herb	Western Mediterranean
	Carduus nutans	Hemicryptophytes	Annual herb	Eurasian
	Echinopss phaerocephalus	Hemicryptophytes	Perennial herb	Mediterranean
	Galactites tomentosus	Hemicryptophytes	Annual herb	Mediterranean
Fabaceae	*Lotus corniculatus*	Hemicryptophytes	Perennial herb	Southern Orophyte
	Calicotume spinosa	Phanerophytes	Woody	Western Mediterranean
	Cytisus villosus	Chamephytes	Woody	Mediterranean
Ranunculaceae	*Ranunculus muricatus*	Therophytes	Annual herb	Mediterranean
Iridaceae	*Romulea bulbocodium*	Geophytes	Perennial herb	Mediterranean
Asparagaceae	*Charybdis maritima*	Geophytes	Perennial herb	Mediterranean
Rosaceae	*Rubus ulmifolius*	Hemicryptopytes	Woody	European
	Carataegus monogyna	Phanerophytes	Woody	Eurasian
Xanthrrhoea-ceae	*Asphodelus ramosus*	Geophytes	Perennial herb	Mediterranean-Atlantic
Oleaceae	*Phillyrea media*	Phanerophytes	Woody	European
Ericaceae	*Erica arborea*	Phanerophytes	Woody	Cosmopolitan
Liliaceae	*Gagea pratensis*	Geophytes	Perennial herb	European
Caryophylla-ceae	*Stellaria media*	Hemicryptopytes	Annual herb	Cosmopolitan
Araceae	*Arum italicum*	Geophytes	Perennial herb	Mediterranean-Atlantic
Dennstaedtia	*Pteridium aquilinum*	Geophytes	Annual herb	Cosmopolitan
Primulaceae	*Cyclamen hederifolium*	Geophytes	Perennial herb	Southern European
Lamiaceae	*Rosmarinus officinaliss*	Chamephytes	Perennial herb	Mediterranean
Thymelaeaceae	*Daphne gnidium*	Phanerophytes	Woody	Mediterranean

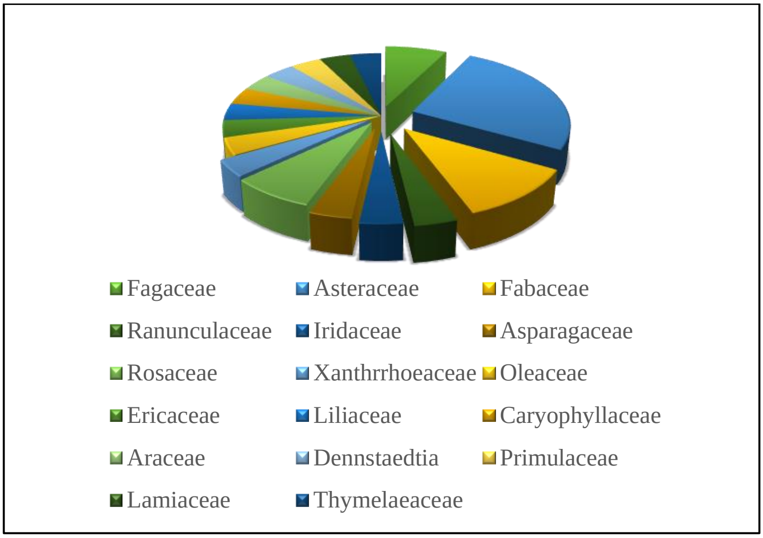

Fig. 2. *Systematic and floristic composition of the vegetation.*

The biological spectrum according to [6] is the percentage of different biological types. The dominance of a biological type is noted, which allows the plant formation to be named. The latter is therefore the physiognomic expression, which reflects the environmental conditions. The overall biological spectrum of the vegetation is of the type HE> PH > GE > CH > TH with the dominance of hemicrytophytes (Fig. 3).

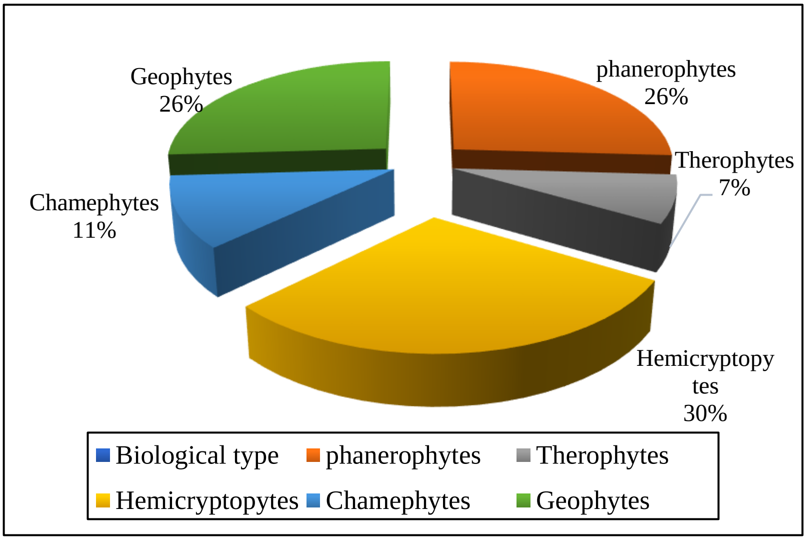

Fig. 3. *Biological type of vegetation in the Ouled Bechih forest.*

The morphological type leads to the natural shape of the plant, the precise aspect of the shape obtained and depending on the variations of the environment. Morphologically, forest vegetation is characterized by heterogeneity between woody (33%), herbaceous and between perennials (48%) and annuals (19%) (Fig. 4).

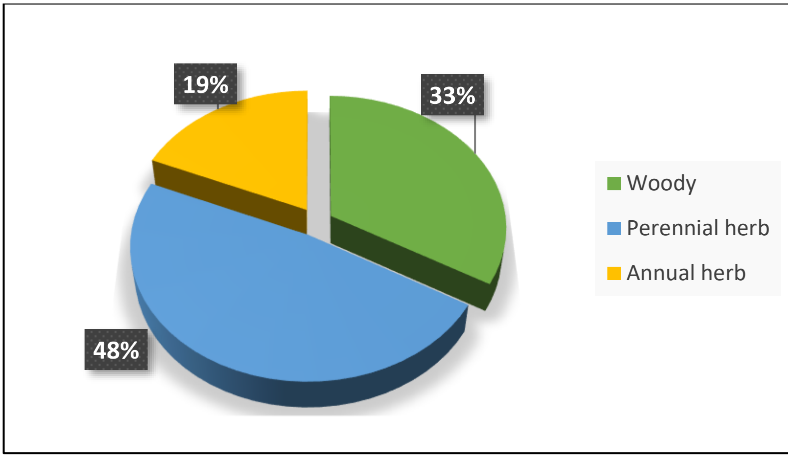

Fig. 4. *Morphological type of vegetation in the Ouled Bechih forest.*

Geobotany is the study of the distribution of plants around the world. It is defined as the study and understanding of the distribution of living organisms in the light of present and past factors and processes [7]. Phytogeographic studies also constitute a true model for interpreting regression phenomena (Fig. 5) [8]. For Quezel [9], a phytogeographical study is an essential basis for any attempt to conserve biodiversity.

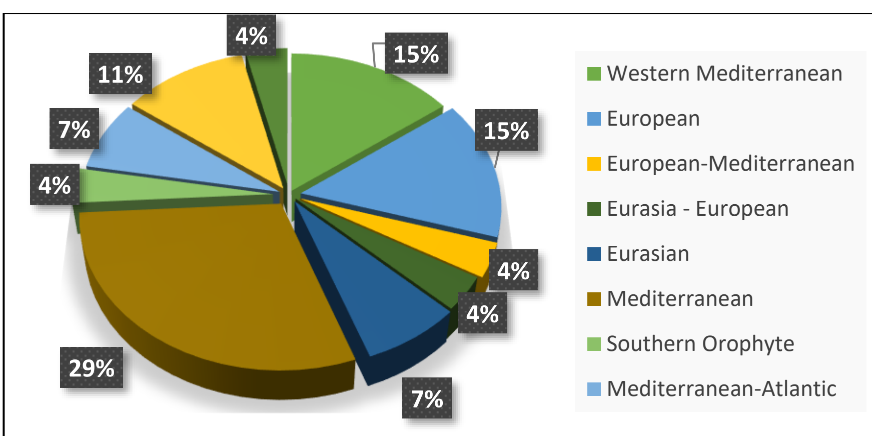

Fig. 5. *Chorological type of the vegetation of the Ouled Bechih forest.*

CONCLUSION

The analysis of the cork oak stands allowed a better knowledge of their floristic values based on three types of spectra (morphological, biological and biogeographical). The biogeographical distribution shows that the Mediterranean element dominates the forest. The latter follows a pattern: Th > HE > CH > GE > PH. Therophytes have the highest rate, which means that the forest is very open and degrading. This study was carried out in the forest of Ouled Bechih (Algeria). The results of the floristic diversity show the existence of 27 species which are distributed in 26 genera and 17 families, of which the most important are: Asteraceae, Fabaceae. The biological type of the plant formation of this forest shows a dominance of hemicryptophytes. The floristic diversity of this forest is dominated by woody plants on the one hand, and by Mediterranean species on the other.

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IMPACT OF MONTANE ENVIRONMENTAL LOADS ON THE ENVIRONMENTAL QUALITY OF THE SLOVAK REPUBLIC

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ABSTRACT

Environmental burdens are currently a significant determinant ofenvironmental quality. The occurrence of montane environmental burdens affects the environmental quality at the local, regional and supraregional levels, mostly to a negative extent. Environmental pollution, due to montane environmental burdens is accompanied by a reduction in environmental quality in all spheres of anthropogenic existence. It is for this reason that the presented article studies the occurrence of montane environmental burdens and their impact on environmental quality in individual regions of the Slovak Republic. In the analyses Analytic Hierarchy Process a multi-criteria decision-making method based on values of the weights in terms of the principles of the Saaty matrix – a quantification of synergistic interactions of indicators. The study concentrates on selected comparative years 2008, 2012, 2017 and 2021 and includes a matrix of their elimination. The results present a categorization of montane environmental loads in the Slovak Republic into categories of the environmental load (from very low to very high) on the environmental quality. In the summary matrix of a comprehensive assessment of montane environmental loads, negative indicators (55.65%) prevails over positive ones (44.35%) with a total scoring ratio of 0.80, i.e. III. category, the average impact on environmental quality.

Keywords: *montane environmental load, environmental quality, matrix, categorization*

INTRODUCTION

Environmental burdens can be understood, also in accordance with Act No. 409/2011 Coll., as any anthropogenic creation that caused an environmental burden, except in cases where the state undertook to rehabilitate the environmental burden based on a contract or on the basis of a decision of the Government of the Slovak Republic or the environmental burden arose as a result of waste landfill which has complied with the valid permit. However, it should be noted that the obligation of the originator of the environmental burden is, in accordance with the valid legislation of the Slovak Republic, to ensure the elaboration and implementation of the work plan for the removal of the environmental burden. If this does not happen and the environmental burden represents an immediate threat to the health of the population, the relevant ministry will spend the funds for remediation from public sources and subsequently the originator is obliged to pay the funds to the ministry within one year at the latest.

CHARACTERISTICS OF MONTANE ENVIRONMENTAL LOADS

An environmental burden is, in accordance with Act No. 569/2007 Coll. on geological works (Geological Act), "pollution of an area caused by human activity which poses a serious risk to human health or the rock environment, groundwater and soil with the exception of environmental damage". The following two terms are further defined in this Act:

- probable environmental burden – a potentially contaminated site considered to be a burden only on the basis of indications, i.e. the state of the territory where the presence of an environmental burden is reasonably presumed is taken into account,
- environmental burden – a burden confirmed by a survey.

Environmental burdens are currently registered in the so-called Register of Environmental Burdens, which consists of the following four sections [1]:

Section A – so-called probable environmental burdens with direct or indirect indications of contamination at the site, including:

- the presence of sources of contamination,
- records of state administration or self-government bodies on pollution of environmental components or on inappropriate handling of pollutants,
- older archival information on pollution,
- data from selected environmental databases, manifestations of landscape damage – e.g. dead organisms.

Section B – confirmed environmental burdens, which are confirmed by indicative geological survey,

Section C – sites where remediation or reclamation took place, depending on the degree of risk,

Section D – environmental burdens removed from the register.

From the results of the mapping of environmental burdens in the Slovak Republic, there are currently 2054 localities with environmental burdens, with about 15.14% (311) confirmed by survey works, 45.13% (927) probable environmental burdens and 39.73% (816) reclaimed or rehabilitated sites (Table 1).

Sites in which the source of contamination has been eliminated is considered reclaimed, and sites in which new structures and functions of the territory have been created through an appropriate concept of restoration and creation of a new landscape to create an environmentally balanced and aesthetically impressive landscape and environment are considered reclaimed sites.

Table 1. *A comparison of registered environmental burdens in 2008, 2012, 2017 and 2021 in the Slovak Republic (prepared according to [1]).*

Year / Section	2008	2012	2017	2021	index of change 2021/ 2008	index of change 2021/ 2012	index of change 2021/ 2017
A	878	953	882	927	1.06	0.97	1.05
B	257	294	311	311	1.21	1.06	1.00
C	684	713	804	816	1.19	1.14	1.01

Of the total number of environmental burdens, the use of the raw material base consisted of 100 montane environmental burdens, including the processing of minerals and metals, of which 44.0% are probable, 24.0% confirmed and 32.0% reclaimed. The highest number of montane environmental burdens was recorded in the Banská Bystrica Region, where 35.0% (35) of registered environmental burdens (8 confirmed, 18 probable and 9 reclaimed) was allocated and the lowest number was recorded in the Trenčín and Nitra regions, where it was both 2% (2) environmental burdens, while in the Nitra region there were only probable and in the Trenčín region 1 probable and 1 reclaimed montane environmental burden (Figure 1). A 59% share of environmental loads from the exploitation of raw material deposits consisted of loads from raw material mining and 41.1% share from its processing or storage, most of which were environmental burdens from ore mining (36.0%) and the least from ore mining (4.0%) (Figure 2).

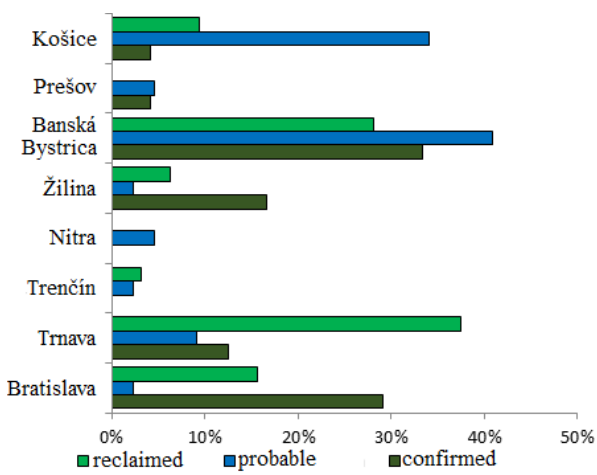

Fig. 1. *Montane environmental burdens in the regions of the Slovak Republic.*

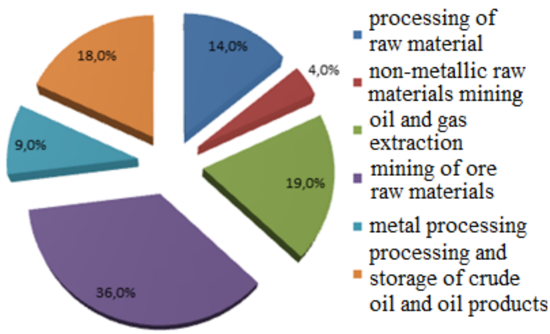

Fig. 2. *Registered montane environmental burden in the Slovak Republic.*

For the needs of environmental risks elimination of the use of the raw material base, Act No. 24/2006 Coll. on Environmental Impact Assessment (EIA) as amended, the aim of which is to explicitly identify measures leading to the preservation or improving environmental quality. The purpose of the mentioned law, which is considered an international instrument of environmental policy, is [2]:

- to ensure the required level of environmental protection in a timely and effective manner and contribute to the promotion of sustainable development,
- to identify, describe and balance the direct and mediated effects of the extraction and processing of minerals on the environment,
- to justify and at the same time compare the advantages and disadvantages of a specific method of mining and its further processing to explicitly define measures leading to the reduction or elimination of environmental quality, or prevention of environmental damage,
- to obtain an expert opinion based on which a decision on the permit (or refusal) of mining or processing of extracted mineral raw material according to special regulations.

ASSESSMENT OF THE IMPACT OF MONTANE ENVIRONMENTAL LOADS ON THE ENVIRONMENTAL QUALITY OF THE SLOVAK REPUBLIC

The comprehensive methodology for the assessment of montane environmental burdens was based on the quantification of synergistic interactions of environmental and socio-economic indicators of the occurrence of montane environmental burdens, which we divided according to their impact into two groups of indicators affecting positive and negative environmental quality in the Slovak Republic.

Analytic Hierarchy Process (AHP) is a multi-criteria decision-making method, developed by mathematician Thomas L. Saaty. It is a tool that can be applied in various areas of planning and management [3]. It was applied in evaluations of urban landscape management problems [4], [5], [6], [7]. AHP uses a pairwise comparison method for generation of criteria weightings (ratio scales), instead of a simple listing and ranking of the importance levels [8].

From the previous experience and the results of the analyzes, 14 positive and 14 negative indicators of the exploitation of raw material deposits were identified. They are characterized by reversible and irreversible impacts on the environment, in terms of promoting sustainable development. A quantification of synergistic interactions of indicators by numerical expressing of their prioritization through their weights – α_i was realized. The numerical value of the weights α_i for all indicators, accepting the generally valid condition $\sum\alpha_i = 1$, was determined. The values of the weights in terms of the principles of the Saaty matrix, whose dimensions m x n, where $m = 1 \dots i$ and $n = 1 \dots j$, were given by the number of rows and columns, while observing the condition m = n, were quantified. This symmetrical shape of the matrix also corresponds to the fact that the method is based on an interactive comparison of all defined indicators of the same order with the evaluation in Table 2 [9].

Table 2. *Evaluation of negative and positive indicators in the Saaty matrix.*

Determinant Value	Description of Comparative Determinants
1	Determinants *i* and *j* are equivalent
3	The determinant *i* is slightly preferred over the determinant *j*
5	The determinant *i* is strongly preferred over the determinant *j*
7	The determinant *i* is very strongly preferred overthe determinant *j*
9	The determinant *i* is absolutely preferred over the determinant *j*

Subsequently, the value of 1 was plotted on the diagonal of the matrix, as the principle of comparison of the same indicators, i.e. their equivalence was accepted, and pairwise comparisons of individual indicators were identified. If the indicator listed in the row is preferred over the indicator listed in the column, a reciprocal value was assigned. After evaluating the individual indicators in this way, partial products of the lines were created according to the relation:

$$S_i = \prod_{j=1}^{f} \quad S_{ij},\ \mathrm{j} = 1, 2, 3, \dots f, \tag{1}$$

f – number of factors,

S_{ij} – individual factors.

Further the value of R_i for each criterion, i.e. row of created matrix was quantified according to formula:

$$R_i = (S_i)^{\frac{1}{f}} \tag{2}$$

Based on calculations, the sum of R_i was calculated, based on which the final value of individual weights α_i were quantified reflecting the mutual interactions of the compared indicators of the use of the raw material base and their prioritization in the process of supporting sustainable development.

Table 3. *Negative indicators of the impact of environmental burdens.*

Indicator / Interaction	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	S_i	R_i	α_i
I1	1	3	5	3	3	3	3	3	3	5	54.675	2.98	0.24
I2	1/3	1	1	1/3	1	1/3	1/3	1	1	1/3	0.004	0.58	0.05
I3	1	1	1	1	3	1	3	3	3	1	81	1.55	0.12
I4	1/3	3	1	1	1	1/3	1/3	1/3	1	1	0.037	0.72	0.06
I5	1/3	1	3	1	1	1/3	1	1	1/3	1/3	0.037	0.72	0.06
I6	1/3	3	1	3	3	1	3	3	1	1	81	1.55	0.12
I7	1/3	3	3	3	1	1/3	1	1	1	1	3	1.12	0.09
I8	1/3	1	3	3	1	1/3	1	1	1	1	1	1.00	0.08
I9	1/3	1	1	1	3	3	1	1	1	1	3	1.12	0.09
I10	1/5	3	1	1	3	3	1	1	1	1	5.4	1.18	0.09
SUM												**12.51**	**1.00**

NOTE: S_i, R_i, α_i were defined in Eq. (1) and (2).

In terms of the above methodological procedure, the weights – α_i to negative indicators were explicitly quantified (Table 3), including [9], [10]:

- I1 – impact on the public health,
- I2 – impact on the environment,
- I3 – impact on the air,
- I4 – impact on hydrogeological conditions,
- I5 – impact on biotic components of the environment,
- I6 – impact on protected areas in accordance with applicable legislation,
- I7 – impact on the territorial system of ecological stability,
- I8 – impact on the landscape–aesthetic character of the environment,
- I9 – impact on urban complex,
- I10 – production of mining waste, which is classified in accordance with applicable legislation as hazardous waste.

Using an analogous procedure, the weights – α_i to positive indicators (Table 4) were explicitly quantified, while the possibilities resulting from the revitalization of montane environmental loads were included as follows [9], [10]:

- I1 – existing transport infrastructure,
- I2 – existing technical infrastructure,
- I3 – existing production facilities,
- I4 – existing administrative buildings,
- I5 – support for regional development,
- I6 – impact on the living standards of the population,
- I7 – increasing environmental quality,
- I8 – improving the aesthetic character of the landscape,
- I9 – positive effect on environmental health.

Table 4. *Positive indicators of the impact of environmental burdens.*

Indicator / Interaction	I1	I2	I3	I4	I5	I6	I7	I8	I9	S_i	R_i	α_i
I1	1	1	1/3	5	1/3	1/3	1	1/5	1/5	0.0074	0.58	0.06
I2	1	1	1/5	1/3	1/3	1/5	1/3	1	1	0.0015	0.49	0.05
I3	3	5	1	1/3	1/5	1/3	1/3	7	5	3.8889	1.16	0.12
I4	1/5	3	3	1	1/3	1/3	1/3	1/5	1	0.0133	0.62	0.06
I5	3	3	5	3	1	1	1/3	1/5	1	9	1.28	0.13
I6	3	5	3	3	1	1	3	1/3	1/3	45	1.53	0.15
I7	1	3	3	3	3	1/3	1	1/3	1	9	1.28	0.13
I8	5	1	1/7	5	5	3	3	1	5	803.5714	2.10	0.21
I9	5	1	1/5	1	1	3	1	1/5	1	0.6	0.94	0.09
SUM											**9.97**	**1.00**

NOTE: S_i, R_i, α_i were defined in Eq. (1) and (2).

Constructing the summary matrix of a comprehensive assessment of montane environmental loads on the environmental quality of the Slovak Republic (Table 5), negative indicators (55.65%) showed a slight superiority over positive ones (44.35%) with a total scoring ratio of 0.80 based on which the category of impact on the quality of the environment could also be predicted. It was identified as III. category, i.e. average impact on environmental quality, as the scoring ratio reached 0.80.

Table 5. *The impact of montane environmental loads on the environmental quality of the Slovak Republic.*

Indicator / Interaction	Deter-minant	Partial score	Score	Scoring rate
impact on the public health	-	13.24	55.65	**0.80**
impact on the environment	-	2.57		
impact on the air	-	6.90		
impact on hydrogeological conditions	-	3.20		
impact on biotic components of the environment	-	3.20		
impact on protected areas in accordance with applicable legislation	-	6.90		
impact on the territorial system of ecological stability	-	4.96		
impact on the landscape-aesthetic character of the environment	-	4.45		
impact on urban complex	-	4.96		
production of mining waste, which is classified in accordance with applicable legislation as hazardous waste	-	5.26		
existing transport infrastructure	+	2.58	44.35	
existing technical infrastructure	+	2.16		
existing production facilities	+	5.17		
existing administrative buildings	+	2.75		
support for regional development	+	5.68		
impact on the living standards of the population	+	6.79		
increasing environmental quality	+	5.68		
improving the aesthetic character of the landscape	+	9.35		
positive effect on environmental health	+	4.20		

Table 6. *Categorization of the impact of environmental burdens on environmental quality.*

Category of impact of montane environmental loads		Degree of impact
I. category	Very low impact	**Above 1.80**
II. category	Low impact	**1.79 – 1.30**
III. category	Average impact	**1.99 – 0.80**
IV. category	High impact	**0.79 – 0.30**
V. category	Very high impact	**0.29 and less**

CONCLUSION

The exploitation of mineral deposits forms the basic platform for the functioning of all national economic sectors of the Slovak Republic, which is determined by the development and dependence of the primary, secondary and tertiary spheres of individual sectoral economies of the Slovak Republic. The actual exploitation of mineral deposits is accompanied by the emergence of montane environmental burdens, which negatively affect the environmental quality, environmental health and regional development in the Slovak Republic with other negative manifestations in the socio-economic sphere. In the analyses Analytic Hierarchy Process a multi-criteria decision-making method based on values of the weights in terms of the principles of the Saaty matrix – a quantification of synergistic interactions of indicators. The study concentrates on selected comparative years 2008, 2012, 2017 and 2021 and includes a matrix of their elimination. The results of quantitative analyzes of the occurrence of montane environmental burdens pointed to their fluctuating development trend with the highest occurrence in the Banská Bystrica region and the lowest in the Trenčín and Nitra regions.

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MATERIAL CHARACTERISTICS AND RECYCLING OF INDIUM-CONTAINING WASTES

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ABSTRACT

The aim of article is to present the types of indium wastes, including WEEE and by-products resulting from manufacturing. The authors decided to collect information about the chemical composition of wastes containing indium in one place. Methods and processes of recycling indium from WEEE and by-products are also presented.

Keywords: *WEEE, indium wastes, recycling indium*

INTRODUCTION

Indium-containing materials are of various kinds: from minerals and concentrates, metallurgical by-products, to municipal wastes and end-of-life products. Waste of electric and electronic equipment (WEEE) mainly differs in chemical composition and origin. Their indium contents can be as high as 1 wt. %, although often the content is much lower. They can be an alternative source of this critical element next to the primary raw materials. Recycling indium turns out to be very difficult and defined – according to the chemical composition of the initial material.

Due to technological progress, indium occurs more and more often in electrical and electronic equipment, generally in the form of indium-tin oxide. Recycling indium rate is below 1 %, and the main limitation is the high dissipation rate [1].

This article presents the types of indium-containing wastes, their origin and some examples of recycling.

TYPES AND ORIGINS OF INDIUM-CONTAINING WASTES

ITO and etching solution. Pure indium-tin oxide (ITO) is a compound consisting indium and tin oxides in a mass ratio of 9:1; the impurity contents are below 20 ppm [2]. ITO is often admixed to improve functional properties to form a multicomponent mixture comprising also zinc, cadmium, gallium or aluminum. ITO is an optoelectronic material, characterized by transparency in visible light, electrical conductivity and reflects thermal radiation. It is widely used in many optoelectronic devices where transparent conductive layers are required, such as liquid crystal displays (LCD), touch panels, thin film transistors, transparent electrodes, plasma displays, solar cells, multifunctional glasses, anti-frost systems, gas sensors, heat shields and many others. The main manufacturing method of ITO layers with a thickness 1000-3000 angstroms [3] is physical vapor deposition process by using magnetron sputtering under the influence of direct current on a substrate (glass, ceramics), followed by oxygen plasma oxidation or annealing in an oxygen-free atmosphere [3]. Only 15-33 % of ITO is deposited and the rest 67-85 % is lost as waste that needs to be recycled [2] [4]. Finally, in order to even out the ITO layer, it is etched in a chloride medium [3].

The pattern of ITO layer is usually formed by a photolithography process using acid etching [5]. During etching, tin and indium undergo partial dissolution to form complexes, respectively $[In(H_2O)_6]^{3+}$ and $[SnCl_6]^{2-}$. The etching solution can be used over several etching cycles until in the solution is too high concentrations of impurities [3]. In order to utilization of the spent solution (after ITO etching), it can be neutralized, resulting in the precipitation of the so-called utilization cake in which the indium content may be about 2 % [6].

LCD and photovoltaic cells scraps. An important source of secondary indium is scrap of liquid crystal displays in which the indium is present in the form of ITO on the surface of two glass supports with liquid crystal between them. LCD scrap contains many metals, a small part of which is indium [7] [8]. The situation is similar in the case of photovoltaic cells, especially thin-layer CIS (copper-indium-selenide) solar cells and their modifications: CIGS (copper-indium-gallium-selenide) and CIBS (copper-indium-selenide-boron). Their life span is 25-35 years and the indium content is no more than 2900 ppm [1] [9].

LED. Light-emitting diode (LED) consists of gallium nitride (GaN) diodes which gives high-efficiency white light. LEDs are composed of various semiconductor materials and their key part is a chip which closely adjacent to the metal frame. Chip contains rare and precious metals such as gallium, germanium, arsenic, selenium, indium, gold [10] [11], in the forms for example gallium arsenide (GaAs), gallium nitride (GaN), gallium nitride and indium (InGaN), gallium aluminum arsenide (GaAlAs), zinc selenide (ZnSe), InGaP-Al and germanium [10] [11]. LED lighting has partially replaced traditional light bulb and other types of lighting. Currently, LEDs are starting to be in post-consumer scrap stream [1].

MATERIAL CHARACTERISTICS OF INDIUM WASTES

Tab. 1 shows the chemical compositions of WEEE containing indium. The percentage concentration values of individual elements come from many publications (references in Tab. 1). The materials were divided according to waste types as well as origin and genesis. In WEEE, most indium is in ITO scrap, more than 70 % wt. Apart from relative high concentration of indium in utilization cake, noteworthy there are high concentrations of molybdenum and aluminum. There is also a lot of indium in LCD scrap, about 12 % wt. In photovoltaic cells and LEDs are scarce in indium, and only recycling of indium with other accompanying metals (for example gold and gallium) allows for cost-effective investment.

RECYCLING INDIUM FROM WASTES

ITO [2], spent ITO etching solution [3] [4] [6] [8], as well as LCD scrap [7] [8] [13], photovoltaic cells scrap [9], and ITO-containing scrap in general, are important sources of secondary indium and other accompanying and valuable elements. Out many of them, a select few are presented below.

ITO and etching solution. In research [2] it was taken into account high tin content in wasted ITO, which should be separated from indium. Recycling tests were carried out in the following order: 1. Leaching, 2. Precipitation of tin sulfide, 3. Indium cementation.

Due to the intensive HCl evaporation and comparable leaching yields with lower H_2SO_4 concentration (compared to the HCl concentration, i.e. 0.75 vs 1.5 M), H_2SO_4 was selected for further tests. The optimal parameters of leaching are as follows: H_2SO_4 concentration – 100 g/l; l/s – 10 ml/g; temperature – 90^0C; duration of leaching – 2 h. With these parameters, In was leached in 99 %, and Sn only in 8 %.

Tab. 1. *Chemical composition of indium-containing wastes (references inside)*

type	source/references			chemical composition											
				Ga	In	Au	Si	Al	Cu	Mo	Sn	Cr	Fe	Zn	Ni
ITO	ITO scrap		[2]	wt. %											
				-	71.21	-	-	-	≤0.01	-	7.65	-	-	-	-
	etching	spent sol	[3] [8]	kg/m³											
				-	~2.1927	-	-	~1.178	~3.249	~0.545	~0.045	-	-	-	-
		Utili-za-tion	[6]	ppm											
				-	22169	-	340.6	38644.6	1041.1	31418.7	1965.5	9305.7	1421.2	255.5	64.4
LCD scrap			[7]	wt. %											
				-	12.0 (In_2O_3)	-	0.8 (SiO[2])	75.6 (Al_2O_3)	0.2 (CuO)	-	1.6 (SnO_2)	1.0 (Cr_2O_3)	4.5 (Fe_2O_3)	0.8	0.4 (NiO)
photovoltaic cells	CIS		[12]	wt. %											
				-	0.04 ($CuInS_2$)	-	96.9 (glass)	-	-	0.025	-	-	-	0.035 (ZnO)	0.0003
LED	chips		[10]	ppm											
				5377.0	551.0	1521.8	-	-	-	-	-	-	-	-	-
	waste			~36.20	~1.56	~16.66	5.31	2.27	-	-	-	-	-	-	-

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Tin precipitation was carried out from post-leaching solution by using H_2S. The precipitation reaction is very fast - less than 10 minutes. Due to a certain SnS solubility, totally tin precipitation cannot be obtained. Further selection of parameters was aimed at minimizing the loss of co-precipitated indium. The effect of the initial acidity shows that the tin precipitation yield is proportional to the indium loss. Tin precipitation yield and indium losses increase as temperature decreases. The optimal conditions for tin removal are as follows: 1 M initial acidity and temperature 50^0C. Tin precipitation yield was almost 100 % and the indium loss was only 0.47 %. The precipitate consists of tin oxide and sulfide as well as traces of indium in the form of oxide and sulfide.

From the purified solution, indium was precipitated by cementation with zinc under the conditions: 65^0C, pH = 1-1.5, 40 h. During cementation, the solution was neutralized with Na_2CO_3 to pH = 1.2. The cementation yield was 99.9 %.

The cemented indium was pressed into pellets, covered with NaOH in the amount of 50 % by weight of indium and melted at 300^0C for 3 hours. Finally, indium with a purity of 99.92 % was obtained.

Study [3] was concerned the recycling indium from spent etching solution. Proposed method was aimed at recycling not only indium, but also Mo, Sn and Al. Firstly, Mo and Sn are removed from spent solution by solvent extraction with Cyanex 272, then proper indium extraction is performed on the purified solution with DP-8R. The remaining components of solution, such as Cu or Al, are recovered by cementation or neutralization after indium extraction.

Indium solvent extraction from Mo-Sn-free solution, with an aqueous to organic phase ratio <10:1, was performed at a controlled pH = 0.7. The optimal concentration of DP-8R is 0.5 M, which allows the extraction of most indium. Then, re-extraction with 4 M HCl was carried out for 4-5 minutes at a 10:1 ratio of organic to aqueous phase. After re-extraction, the indium was concentrated 28-fold. Finally, indium is recovered strictly by a hydrometallurgical route until the indium sponge is obtained.

Other study [6] concerned the recycling indium from utilization cake. Due to the chemical composition of utilization cake, which contain some admixtures, laboratory tests on the recycling indium was carried out in the following order: 1. Alkaline leaching, 2. Acid leaching, 3. Indium solvent extraction, 4. Indium electrolysis.

In the alkaline leaching of utilization cake, impurities such as Mo, Al, Cr and Mg are removed. Among the various reagents, NaOH is selected as the one which can remove the above-mentioned impurities. Overall, about 70 % of impurities was removed by using 12 M NaOH. As a result, indium concentration in the solid increase to 41.1 %.

For indium solvent extraction is needed to indium leaching. Hence, the solid residue from alkaline leaching was taken up in 0.3 M HCl in such an amount that the impurities were dissolved into their corresponding chloride forms, i.e. 130 % based on the stoichiometry. Indium extraction was carried out with pure PC88A and saponified by NaOH. Regardless of the degree of saponification, indium extraction yields were almost 100 %. On the other hand, the degree of saponification affects the impurities co-extraction yields, e.g. pure PC88A co-extracts Fe, Mo and Sn, and saponified PC88A – Cu, Al, Na, Cr and others. Generally, a more optimal option is to use unsaponified PC88A. It is not possible to extract indium selectively without co-extracting the impurities, and the extraction should be carried out with as little adicification as possible. At optimal parameters, which are ratio of organic to aqueous phase is 3:1 for 5 min, the indium extraction yield was up to 98 % and along with indium, mainly Mo, Fe and Sn are co-extracted. Indium re-extraction was carried out with the use mineral acid, whereby, regardless of the acid, the concentration of hydrogen ions is important, which should be at least 1 M. Finally, at 2 M concentration, indium solution is obtained, mainly contaminated with Fe.

The last step is the indium electrolysis. Due to the high purity of the indium electrolyte (>99.5 %), the electrolysis can be carried out without a diaphragm. Obtained electrolytic indium purity is 99.997 %.

Photovoltaic cells scraps. In fact, there are only a few industrial recycling indium processed from thin photovoltaic cells, consisting of mechanical-chemical treatment - SENSE and wet mechanical treatment – RESOLVED [14]. Depending on the type of cell modules, several strategies are distinguished [9] [14]: CIGS – waterjet cutting and chemical treatment; CIS, CIGS and CdTe – pyrolysis and chemical treatment; Si – grinding and pneumatic separation. RESOLVED, compared to SENSE, requires less chemicals and generates less wastes. The process that was the subject of the research on indium recovery from photovoltaic panels modules containing CIS and CdTe [9] consists of several stages: 1. Thermal disassembly, 2. Grinding, 3. Separation of semiconductor material from glass, 4. Flotation.

Gradual heating of photovoltaic panels modules with a size of 10x10 or 30x30 cm^2 to temperature 500^0C causes the laminate to be disassembled. The protective glass is separated and the support glass with a semiconductor (including indium) on its surface is further mechanical processing.

Grinding is a necessary process step in order to provide sufficient material for subsequent stages. The grain size must be small enough (less than 20 mm) for them quick and complete sandblasting or exfoliation of support glass during further wet mechanical processing. Photovoltaic panel modules containing CIS were processed in a rotary cutter and impact mill.

The separation of the semiconductor material from glass was carried out in two ways: either by sandblasting or by exfoliation. Sandblastings with glass beads, ZrO, Al_2O_3 and Fe were most effective in separating. Wet exfoliation runs at an average water content of 11.8 % by 30 min and the rotational speed of the mill and agitator 900 and 25 rpm, respectively. After exfoliation, the mixture of glass, semiconductor material and plastics was rinsed and sieved. Fraction <150 μm contains 2010 mg of indium per 1 kg.

Flotation of the fraction rich in CIS semiconductor material was performed most efficiently with KAX (potassium amyloxentogenate). By flotation process, which technological conditions were: mixing speed 1000-1500 rpm, air stream 150 l/h, KAX concentration 0.5-1 g/kg; even a 25-fold enrichment of indium was achieved [9]. Complete CIS separation in only possible by chemical treatment, during which the residual glass can be easily removed.

LED. Currently, several technological processes have been developed for the LED recycling. The vast majority of them are based on hydrometallurgy, mainly due to the very low concentrations of metals. They are focuses on gallium recovery. Only a few others take into account the indium co-recovery [10] [11] [15].

The research [10] concerned the indium and gallium recycling from LED diodes scrap by pyrolysis and mechanical processing. This method is based on the vacuum pyrolysis of gallium and indium nitrides contained in LEDs. As a result of pyrolysis and condensation, an organic fraction and a metallic condensate/solid residue are obtained. The latter is enriched by grinding and sieve separation. In this way, carbon, wires and metal frames are separated from the main product, which is a concentrate rich in rare metals. Main product is vacuum evaporated to rectify a fraction, one of which is a gallium and indium concentrate.

Vacuum pyrolysis was carried at temperature 500^0C. The metallic condensates containing Ga-In and Au were condensed in the temperature range 324-802 and above 802^0C, respectively. Since the pyrolysis temperature was lower than the metals condensation temperatures under vacuum conditions, the metals were remained in the solid residue, which was the material for the next stage of enrichment. At pyrolysis temperature, the weight loss was 57 wt. %.

The solid residue from the vacuum pyrolysis was ground and sieved on 18 mesh screen. Subsieve fraction was coal scrap. Oversieve fraction was ground and sieved though 40 mesh screen. The oversieve fraction was a concentrate rich in rare metals.

This concentrate was subjected to vacuum pyrolysis at the temperature 1100^0C for 60 min. Two condensates were obtained. Ga-In-bearing concentrate has lower condensation temperature. Along with Au, Cu was also subject to condensation in the zone of the highest temperature. Ga, Au and In recovery yields were about 93.5, 95.7 and 31.6 %, respectively.

In other study [15], which also aimed at recycling indium from LEDs scrap, were carried out in following order: 1. Alkalizing roasting, 2. Leaching. The purpose of roasting was to bring the Ga and In from the hard- to easy-leachable form.

During alkalizing roasting, wherein the alkalization agent was Na_2CO_3, the following reactions proceed:

$$4GaN_s + 3O_{2_g} \xrightarrow{\Delta T} 2Ga_2O_{3_s} + 2N_{2_g} \quad (1)$$

$$4GaN_s + 2Na_2CO_{3_s} \xrightarrow{\Delta T} 2NaGaO_{2_s} + CO_{2_g} + N_{2_g} \quad (2)$$

LED scrap roasting was carried out in the following conditions: 900^0C, 3 hours and the ratio of LED scrap to Na_2CO_3 was 1:1 (wt.).

Then, the calcined LED scrap was leached by using HCl. Leaching yields of gallium and indium significantly increase as acid concentration increases from 1 to 2 M, and a further concentration increasing does not affect efficiencies. The ratio of liquid to solid phase plays an important role during leaching. Leaching yields significantly increase with an increase l/s ratio from 10 to 30 ml/g, from 63 and 61 to 91 and 93 % for gallium and indium, respectively. Similarly, leaching duration has a important impact on the leaching yields. The greatest leaching yields occurred with increasing the duration from 16 to 32 min.

CONCLUSIONS

WEEE and manufacturing wastes are an important source of secondary indium. Contained indium in them is primarily in ITO form. Talking about ITO wastes, it should also consider spent etching solution and utilization cake. Recycling indium method is selected individually depending on the type and form (solid or liquid phase) of the scrap and by-product. Recycling indium methods are both pyro- and hydrometallurgical, or a combination of them. Often for technological and economical reasons, indium is one of many elements (for example gallium and gold) recovered from WEEE.

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MODELING OF DYNAMIC PROCESSES IN THE BLACK SEA AND ATMOSPHERE IN PERSPECTIVE OF THEIR COUPLING FOR THE BLACK SEA REGION

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ABSTRACT

At the modern stage of the development of Geosciences, the study of hydrothermodynamic and ecological processes occurring in the natural environment (sea, atmosphere, soil), their monitoring and forecasting become very relevant and are a necessary condition for sustainable development of society. The Caucasus region is one of the most difficult regions of the world from the point of view its physical and geographical features. These features include the Black and Caspian Seas and the complex terrain of the Caucasus. The Seas and the atmosphere are unified hydrodynamic systems, between subsystems of which processes of an exchange of energies, momentum and substances continuously take place. One of the most effective ways to study natural and environmental processes is methods of mathematical modeling, which allows reproducing these processes and phenomena and studying the quantitative contribution of various factors to the development of such processes.

The purpose of the paper is to discuss the models of the Black Sea and atmospheric dynamics developed at M. Nodia Institute of Geophysics of I. Javakhishvili Tbilisi State University, and some results of their implementation. The model of the Black Sea dynamics is based on a full system of ocean hydro-thermodynamics equations. Its high-resolution version, which is nested in the basin-scale model of the Black Sea dynamics of Marine Hydrophysical Institute (MHI, Sevastopol), is used to forecast main hydrophysical fields for the easternmost part of the Black Sea. The model of the atmospheric dynamics is based on a full system of atmospheric hydro-thermodynamics equations in hydrostatic approximation written in the terrain-following coordinate system and is realized for the extended territory including the eastern part of the Mediterranean Sea and Black and Caspian seas and for the Caucasus region.

These models, after some modification will form the basis of the coupled Black Sea-atmosphere limited-area modeling system.

Keywords: *circulation, hydro-thermodynamic processes, coupled modeling system, system of equations, boundary conditions*

INTRODUCTION

Scientific and technological progress, simultaneously with many benefits, has created serious problems related to increased anthropogenic impact and deteriorating ecological conditions of the natural environment (ocean, atmosphere, soil). Among the types of anthropogenic impact, it is especially important pollution of the sea and the atmosphere with impurities dangerous to humans, plants and animals, the main sources of which are transport, industrial, energy and agricultural facilities. The diffusion of different impurities into the Earth's liquid environment is a complex process and depends primarily on hydro and thermodynamic factors (circulation, turbulence, thermal stratification, *etc*.). Therefore, at the modern stage of development of Geosciences, the study of hydro-thermodynamic and ecological processes in the natural environment, their monitoring and forecasting becomes more relevant and is a necessary condition for sustainable development of society.

One of the most effective ways to study and forecast hydro-thermodynamic and ecological processes taking place in the natural environment is method of mathematical modeling, which allows reproducing natural processes and phenomena on a computer and quantifying the contribution of various physical factors to the development of environmental processes. Provided with real data, this method also allows predicting these processes.

The Caucasus region is one of the most difficult regions of the world from the point of view its physical and geographic features. These features include the Black and Caspian Seas and the complex terrain of the Caucasus. The Seas and the atmosphere are unified hydro and thermodynamic system, between subsystems of which processes of an exchange by energies, momentum and substances continuously take place.

The contribution of the Black Sea to formation of weather and regional climate is especially important for Georgia. In addition, the Main Caucasian Ridge plays a very important role in the formation of meteorological processes in the South Caucasus. The Main Caucasian Ridge protects Georgia from intrusion cold air from the north. Air masses flow around the ridge from the west and east, and under the influence of the Black Sea, more humid and less cold air masses enter the territory of Georgia.

The purpose of the paper is to discuss the numerical models of the Black Sea and atmospheric dynamics developed at M. Nodia Institute of Geophysics of I. Javakhishvili Tbilisi State University, and some results of their implementation. The model of the Black Sea dynamics is based on a full system of ocean hydro-thermodynamics equations. Its high-resolution version, which is nested in the basin-scale model of the Black Sea dynamics of Marine Hydrophysical Institute (MHI, Sevastopol), is used to simulate and forecast main hydrophysical fields for the easternmost part of the Black Sea. The model of the atmospheric dynamics is based on a full system of atmospheric hydro-thermodynamics equations in hydrostatic approximation written in the terrain following coordinate system and is realized for the extended territory including eastern part of the Mediterranean Sea and Black and Caspian seas and for the Caucasus region.

MODELING OF BLACK SEA DYNAMICS

Modeling of circulation and thermohaline fields of the Black Sea are carried out using basin-scale and regional versions of the Black Sea dynamics model.

Model description

The basin-scale model of the Black Sea dynamics is realized for the entire basin with 10 and 5 km spatial resolutions [1-3], but the regional model (RM-IG) - for the easternmost part of the Black Sea with 1 km resolution [4-6]. The regional water area is limited from the open part of the basin by the liquid boundary passing along the meridian 39.08^{0}E. Both models are based on a primitive system of ocean hydrothermodynamics equations in hydrostatic approximation, which is written in z-coordinates for deviations of thermodynamic values from their standard vertical distributions. The models take into account: sea bottom topography and configuration of shorelines, atmospheric forcing, absorption of solar radiation by the sea upper layer, spatial-temporal variability of the coefficients of horizontal and vertical turbulent viscosity and diffusion. In the basin-scale model water exchange between the Black and Marmara seas through the Bosphorus and the Danube river runoff are considered, while the RM-IG takes into account runoff of main rivers of Georgia.

To solve the system of equations, a two-cycle method of splitting with respect to physical processes, vertical coordinate planes and lines is used [7], [8]. The method allows the solution of a non-stationary spatial problem to be reduced to the solution of relatively simple two-dimensional and one-dimensional problems.

The RM-IG, which is a core of the regional forecasting system, is nested in the basin-scale model of MHI. All required input data with one-hour time step frequency corresponding to 3 days forecasting time period are available in a near operative mode from MHI via the Internet. These data providing initial and boundary conditions for the RM-IG are:

- 3D initial fields of velocity components, temperature and salinity;
- at the open boundary – values of velocity components, temperature and salinity predicted by the basin-scale model of MHI;
- on the sea surface – meteorological boundary fields predicted by the regional atmospheric models ALADIN or SCIRON.

Some results of modeling of the sea dynamics

Computational experiments on the basin-scale model to study average annual circulation and seasonal variability of hydrological fields were carried out with using average climatic data [1], [2]. In [3], [9], [10] detailed investigation of the vertical hydrological structure of the upper mixed layer of the Black Sea for different seasons were carried out.

The regional forecasting system makes it possible to calculate 3-days forecasts of the main hydrophysical fields - currents, temperature, salinity and density, but in emergency conditions, it is possible also to forecast the distribution of zones contaminated with oil products and other anthropogenic impurities in the Georgian coastal zone and the adjacent water area. The numerical experiments on modeling and forecasting hydrophysical fields were carried out using a computational grid covering the easternmost water area with a horizontal resolution of 1 km and with 30 vertical z-levels on depths 2, 4, 6, 8, 12, 16, 26, 36, 56, 86, 136, 206, 306,…,2006 m. The time step was equal to 0.5 h. The high-resolution of the regional model enables to reproduction of mesoscale and submesoscale eddies that are permanently generated throughout the year in the easternmost water area.

The model outputs (SST, currents) were compared with observational data – satellite SST and the Geostrophic currents reconstructed with use of satellite altimeter data [4], [5], [6].

As an example, Fig. 1 shows the prognostic fields of current, temperature and salinity by the time of July7 2020, 00:00GMT in the Georgian coastal zone and adjacent water area. Predicted fields correspond to t = 72 h after the initial time of forecast.

(a) (b) (c)

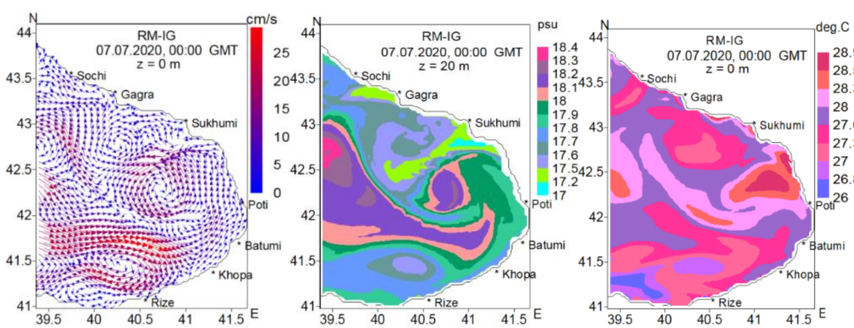

***Fig.1.** Predicted surface flow (a), salinity (b) and SST(c) fields on 7 July 2020, 00:00 GMT. Salinity is on depth of 20 m.*

Figure 1 clearly shows several mesoscale eddy formations of cyclonic and anticyclonic nature. In most of the water area the temperature is 27.3^0 – 28.9^0 C, relatively cold waters are observed in the southern part of the water area.

MODELING OF ATMOSPHERIC DYNAMICS

Model description

Hydrostatic model of atmospheric dynamics developed at M. Nodia Institute of Geophysics of I. Javakhishvili Tbilisi State University is based on a full system of atmospheric hydro-thermodinamics equations, written in the terrain-following coordinate system [11], [12], [13], [14]. A moving air mass in the troposphere is considered, which is limited from below by orographically inhomogeneous underlying earth surface and from above, at a height of the tropopause, by a free surface.

Numerical solution of the model equation system is based on Shuman-Hovermale and Crank-Nicholson schemes. The model is realized for the extended territory including the eastern part of the Mediterranean Sea and Black and Caspian seas and for the Caucasus region.

Some results of modeling of atmospheric dynamics

In the extended version of the model a non-uniform grid on a vertical covered the troposphere till 12 km with 32 calculated levels. the horizontal grid step was 40 km, the time step was 30 min. In Fig. 2 the relief is presented that was used in the model. The main features of the relief in the considered region is that the biggest and the lowest heights are in the Caucasian region. The maximal top (over 4500 m) is located on the Main Caucasian Ridge, and the lowest place is the level of the Caspian Sea, which is 28 m below the Black Sea level.

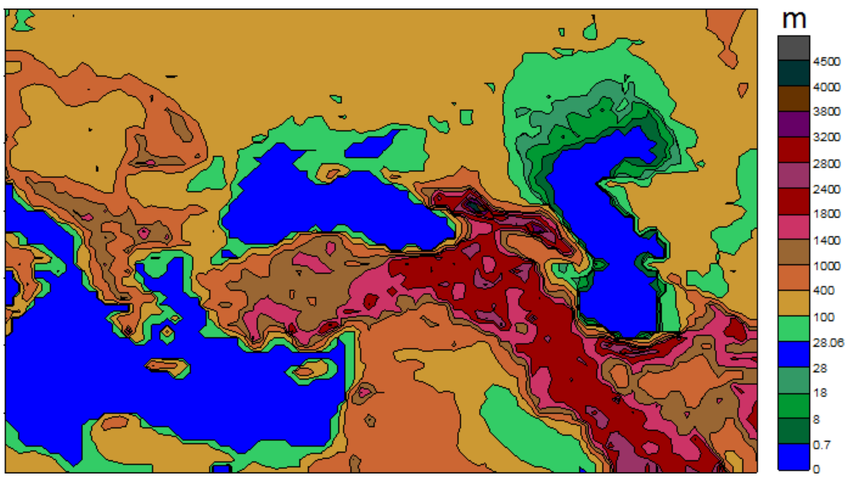

Fig. 2. *The relief of the extended area used in the numerical model.*

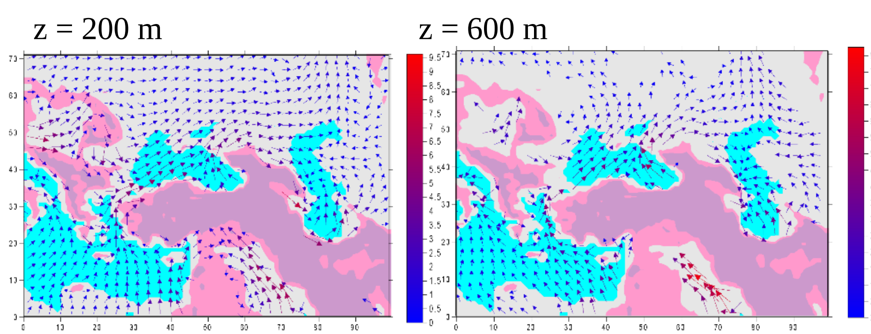

Fig. 3. *Computed wind field on heights of 200 and 600 m at t = 24 h.*

In Fig. 3 simulated wind field on heights of 200 m and 600 m are presented, when at initial time moment t = 0 zonal western wind was accepted, which increased from 2 m/s on a ground surface up to 20 m/s on the top of the troposphere.

From the Figure it is clear that the terrain makes significant changes in the airflow and substantially changes the wind direction and speed. When approaching mountainous terrain, the direction of the airflow changes sharply, and in some cases the disturbed airflow takes the opposite direction to the background current.

To simulate meteorological processes over the Caucasus region, a relatively high-resolution version of the model of atmospheric dynamics with spatial resolution of 15 km was used. The important role of the relief geometry and mutual orientation of mountain ranges in the formation of the wind velocity field in lower troposphere is shown.

For the purpose of illustration, in Fig.4 the simulated airflow over the Caucasus at a height of 3 km is shown in case of the background south-eastern wind equal to 10 m/s. From the Figure is clear that the relief significantly affects the direction of the airflow and the distribution of wind speed. The maximum speeds equal to 20 m are observed approximately in the territory of Western Georgia at the foothills of the Caucasian ridge. The formation of a mesoscale anticyclonic eddy is observed over the Georgian sector of the Black Sea.

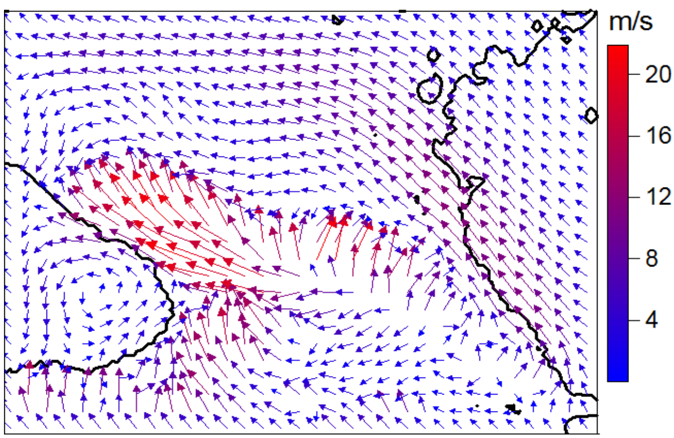

Fig. 4. *Simulated wind field over the Caucasus on height of 3 km in case of the background south-eastern wind.*

SOME ASPECTS OF A COUPLED BLACK SEA–ATMOSPHERE MODELING SYSTEM

The limited-area regional coupled the Black Sea – atmosphere model is considered for the area, which covers the Black and Caspian seas and some part of the Mediterranean Sea (Fig. 2).

The main components of the coupled modeling system will be above mentioned numerical models of the dynamics of the Black Sea and the atmosphere. Interaction with the underlying surface will be carried out with a quasi-one-dimensional model of the atmospheric boundary layer taking into account the active soil layer [15]. The goal of this task is to obtain vertical distribution of meteorological fields with very high resolution near the earth's surface, which is very relevant to adequately describe interaction processes with underlying surface.

The vertical structure of the model comprises the following layers:

1. Troposphere, which is considered above the surface layer up to the tropopause;

2. the atmospheric surface layer;

3. active layer of the soil;

4. Black Sea;

The equations describing processes in different layers are connected with one another with boundary conditions on a vertical, which basically express continuity of solutions and their first derivatives at transition from one layer to another. As one of boundary conditions on the underground surface (water, land) the equation of heat balance is considered.

Thus, the coupled model will be consist of separate modules, each of which describes hydro-thermodynamic processes in separate objects of the natural environment (sea, atmosphere, active layer of the soil).

CONCLUSION

The article provides a brief overview of the models of the dynamics of the Black Sea and the atmosphere, developed at M. Nodia Institute of Geophysics of I. Javakhishvili Tbilisi State University, which should become the basis for the development of a coupled modeling system for the Black Sea region. There are developed two versions of the model of Black Sea dynamics: basin-scale model, which provides to simulate main hydrophysical fields – the current, temperature and salinity for the entire sea basin with 5 km spatial resolution and regional model providing to simulate and forecast hydrophysical fields with 1 km spatial resolution for the easternmost part of the Black Sea covering Georgian coastal zone and surrounding water area. The hydrostatic limited-area model of atmospheric processes based on a full system of atmospheric hydrothermodynamics equations is realized for the areas of different scales.

The methodology to develop a limited-area coupled modeling system "The Black Sea - Land- Atmosphere" based on mentioned models of the Black Sea and the atmospheric dynamics is briefly described.

ACKNOWLEDGEMENTS

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MODELING PRESENT AND PROSPECTIVE DISTRIBUTION OF *PHYTEUMA* GENUS IN CARPATHIAN REGION WITH MACHINE LEARNING TECHNIQUES USING OPEN CLIMATIC AND SOIL DATA

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ABSTRACT

Species distribution modeling can be effectively carried out using open data and data analysis tools with machine learning techniques. Modeling of the distribution of *Phyteuma* genus in the Carpathian region has been carried out with data from the GBIF database, climatic data from the Worldclim database, and soil properties data from Soilgrids soil information system. Spatial distribution modeling was accomplished with machine learning techniques that have marked advantages over more traditional statistical methods, like the ability to fit complex nonlinear relationships common in ecology.

Four methods have been examined: Maxent, Random Forest, Artificial Neural Networks (ANN), and Boosted Regression Trees. AUC and TSS criteria calculated for testing data with cross-validation have been applied for assessing the performance of the models and to tune their parameters. ANN with a reduced set of predictor variables (6 from initial 21) appeared to fare the best and was applied for predictive modeling. Prospective data based on future climate projections from Worldclim were input to the model to get the prospective distribution of the plant taxon considering expected climate changes under different RCPs.

Keywords: *species distribution modeling, machine learning, Carpathians, open data*

INTRODUCTION

Accurate knowledge of species distribution is an important prerequisite for effective conservation practices, e.g. regarding the designation of protected areas. It concerns endangered species, as well as keystone species playing a critical role in maintaining the ecosystem integrity and umbrella species which protection indirectly protects many other species and the ecological community in general.

While counting and mapping species distribution in field is very laborious and cumbersome, species distribution modeling (SDM) becomes an indispensable tool, which application is facilitated nowadays by the availability of spatial data on factors determining species distribution, modern methods and techniques for data analysis, and processing capabilities of modern computers. Species distribution models estimate the relationship between species records at sites and the environmental and/or spatial characteristics of those sites [3]. There is a considerable amount of publications coming out recently devoted to the topic in general or some specific issues related to it (e.g. [3]).

Species distribution modeling can be effectively carried out using open data and open data analysis tools. It is especially of value for countries and projects with limiting research funding. Modern machine learning techniques are more suitable for the purpose comparing with more traditional statistical approaches due to the very nature of the problem: effects of predictive variables on target species distribution are usually non-linear, these variables are often highly interdependent and spatially autocorrelated, voids and errors in data are common, etc. Only quite recently did these techniques enter the mainstream of ecological modeling, mainly due to relatively high computational demands met only by relatively modern computers.

SDM results are not only helpful in delineating the presumable actual locations of target species, but can also be used as predictions of future distributions of species habitats, when data on prospective distributions of predictive variables are available. As climatic conditions are expected to change significantly in the course of the present century due to human-induced emissions of greenhouse gases, habitats of most species are expected to shift accordingly, as many climatic characteristics have direct physiological impact on plants and animals.

An objective of this study is to model the present and prospective distribution of *Phyteuma* (rampion) genus in the Carpathian region with open climatic and soil data, using a bunch of machine learning techniques. This genus, common for forested low- to middle altitude habitats in different parts of Carpathian region, could be regarded as umbrella taxon for the protection of most valuable Carpathian biological communities and ecosystems. The genus contains several species which were considered in aggregate due to insufficient number of records for single species and their similar ecological characteristics.

MATERIAL AND METHODS

Database maintained by the Global Biodiversity Information Facility (GBIF) was used as a data source for species observations [4]. Records were selected falling inside an arbitrary defined 600*800 km rectangle encompassing Carpathian mountain range as well as foothills and parts of neighbouring planes and hills (Fig. 1).

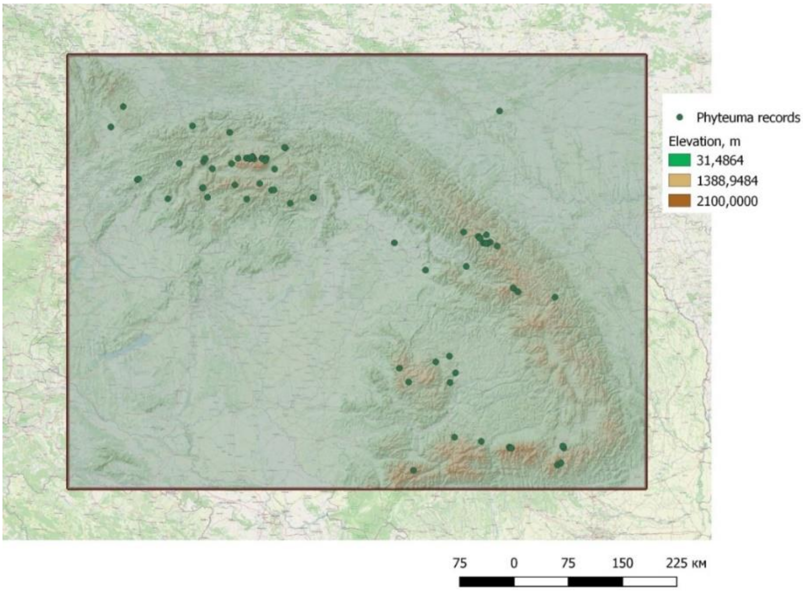

Fig. 1. *Study area and locations of Phyteuma records in GBIF database*

Data obtained from GBIF for the Carpathian region contained 148 records of *Phyteuma* genus in total. While the GBIF Secretariat claims to apply a set of semi-automatic steps to remove duplicates and false positives, this is still an issue, as became obvious after inspecting the records and founding many ones sharing the same species name and location. After removing duplicates, 80 records have been kept. Most of SDM algorithms require some kind of absence or background data to contrast the presence data to. A double of observation records (160 points) were thus designated as background, with random coverage of geographic space inside study area. Six data points (3 from observed data and another 3 from simulated background data) have subsequently been removed due to omissions in predictors data.

The choice of predictive variables for SDM was based on two considerations: 1) their relevance as ecologically meaningful characteristics related to ecological factors driving the distribution of species, and 2) the availability of respective open data in the form of global spatial layers.

The distribution of plant species is influenced by two types of ecological gradients: those related to climatic conditions (mainly to thermal and precipitation characteristics) and those related to properties of soils (nutrients availability, acidity, water retention capacity, aeration, etc.) Data on climatic conditions were derived from WorldClim database. It contains a set of global climate layers (grids) with a spatial resolution of about 1km^2 [2]. Among others, there are layers of 19 bioclimatic variables (coded as BIO1 to BIO19), which are derived from monthly temperature and precipitation with a consideration to have biological significance. While two of them (BIO3 and BIO7) are totally excessive being functions of some other ones, 17 out of 19 bioclimatic variables were taken out as predictive variables for SDM.

For data on soil conditions, SoilGrids digital maps of soil properties were used. These were produced for the entire globe at 250 m spatial resolution with state-of-the-art machine learning methods, taking as inputs soil observations data from about 240 000 locations worldwide and over 400 global environmental covariates [5]. From 11 available physical and chemical soil properties, 4 were chosen as the most suitable predictors: soil acidity, organic carbon stock, cation exchange capacity, and total nitrogen. Among six standard depth intervals available, 15–30 cm depth interval was chosen as the most appropriate for the purpose.

R free programming language and software environment for statistical computing and graphics provides for a number of packages with functions for spatial analysis and modeling, machine learning techniques, and specifically for SDM (e.g. sdm, dismo, etc.) A number of such functions were applied at different stages of data processing and analysis. The main analysis was carried out with SDMtune – a rather new R package that aims to facilitate training, tuning, and evaluation of species distribution models in a unified framework [6]. SDMtune package provides tools for tuning model hyperparameters with a novel genetic algorithm, and for data-driven variable selection to avoid model overfitting.

THEORY AND CALCULATION

Initially, *prepare SWD* function creates an SWD object, given the coordinates, the species' name and the environmental variables. *Train* function then applies to the SWD object one of a set of commonly used modeling methods, including Maxent (ME), Random forest (RF), Artificial neuron networks (ANN), and Boosted regression trees (BRT), which are derived from appropriate packages. A set of parameters specific to the method used can be added as arguments to the *predict* function. When *folds* parameter is specified after creating random folds, SDMmodel object is output that hosts all the models trained during the cross-validation. It can be used to subsequently make tests of the models to assess and compare their performance. With nonparametric machine learning algorithms, cross-validation is often the only means to assess the accuracy and reliability of their predictions.

Four commonly used SDM methods have been examined: Maxent (ME), Random forest (RF), Artificial neural networks (ANN), and Boosted regression trees (BRT), their performance being compared. A special R script has been written for the purpose that takes a SDM method and its hyperparameters as an input. First, presence/background data are randomly divided into 6 folds, one of which being designated as a validation data set. Model is then run with input method and its hyperparameters, and its performance metrics are calculated. The process is repeated 20 times (every time with different random folds and validation data sets), with the purpose of calculating metrics means and standard deviations. Metrics means thus calculated are more stable than metrics values obtained in any single run, while metric standard deviation characterizes the stability of metric estimates among the different runs.

The number of hyperparameters amenable to tuning varies from 2 for ME to 5 for BRT. All of them except the size of hidden layer parameter for ANN method have got default values, though these are not always guaranteed to yield an optimal performance for the purpose. While some of the hyperparameters were chosen to be kept at default values, others were tuned with a view to achieve better performance, as indicated by appropriate metrics. Tuning models hyperparameters was performed with grid search method implemented in the function *gridSearch*. This function creates all possible combinations from an input range of possible values for hyperparameters and returns the values of the chosen evaluation metric for every possible combination so that the user can see the effect of varying the hyperparameters on the model performance and choose those values for hyperparameters that maximize the metric chosen.

Metrics employed to evaluate model performance were 1) area under the receiver operating characteristic (ROC) curve (AUC), 2) the true skill statistic (TSS). AUC is regarded as a threshold independent measure that assesses the discriminatory power of the model in separating presences from absences. TSS is defined as the sum of sensitivity and specificity of the discriminating capacity minus one. It was introduced to the assessment of SDM results in [1], where it is recommended as a simple and intuitive measure for the performance of species distribution models. In comparison with more widely used kappa statistic TSS measure is insensitive to prevalence while still keeping all the advantages of the former.

Initial models include 21 predictive variables (17 of which are related to climate and another 4 – to soil properties), many of which are significantly correlated. It looks desirable to reduce this number without compromising model performance, as more parsimonious models are usually characterized by smaller variance of the parameter estimates and are less prone to overfitting. The importance of separate variables for the model performance can be assessed with *varImp* function from SDMtune package. This function randomly permutes one variable at a time (using training and absence/background datasets) and computes the decrease in training AUC. Here such a "pruning" of predictive variables was achieved with *reduceVar* function. It removes variables with an importance lower than a given threshold in a stepwise fashion, starting from the variable with the lowest importance; however variables are removed only if the model performance after this does not decrease compared to the initial model, according to a given evaluation metric.

After a model with optimal hyperparameters values and a set of predictive variables has been built, it can be input to *predict* function to obtain the prediction maps of species occurrences. Model predictions can be regarded as the relative probabilities of species occurrence in the area. However, in conservation and environmental management practices the information presented as predicted species presence/absence may be more practical. To transform relative probabilities into presence/absence maps, complementary-log-log (cloglog) link function was applied to detect a value that maximizes the sum of sensitivity and specificity. This value is then applied as a threshold to relative probabilities maps.

When data on prospective distributions of predictive variables are available, future distributions of species habitats can also be forecasted based on models built on present-time data. Climate projections from 14 CMIP5 global climate models (GCMs) for three representative concentration pathways (RCPs) derived from WorldClim database were used as a data source for future climatic conditions, while soil conditions were supposed to be relatively stable, thus present-time values were directly used in forecasts.

A special R script has been written that takes as input one of 3 RCPs and one of two prediction periods (2050 or 2070) for which data are available. For each of 14 GCMs it downloads a raster stack of bioclimatic variables for the respective year and RCP, reprojects and crops it to the study area extent, drops unnecessary variables leaving only those present in the final model, renames layers, adds to them relevant soil properties layer(s), runs the model with these layers as an input, and adds the model prediction into a raster stack. When the predictions for all of the 14 GCMs have been accumulated in a stack, the median value of the stack is calculated and output as a final prediction for the given RCP and year. Median was chosen instead of mean because it is less subject to possible outliers in some model predictions.

Final predictions can be presented as relative occurrence probabilities maps or as predictive presence/absence maps after applying a threshold to the former. Based on these maps, prospective habitats areas can be calculated.

RESULTS AND DISCUSSION

Tuning of model hyperparameters with *gridSearch* was the first stage in model-building process. For the ME model, default value 1 for the regularization multiplier appeared suboptimal, and 0.75 was used as the one producing better output. For the RF model, the optimal values of the number of trees lie in the range 200–1000, with the default value of 500 being close to optimal. The best results for ANN were achieved with 12 units in the hidden layer and weight decay = 6. As to BRT model, the default number of trees = 100 seems to be close to optimal, the shrinkage parameter gave best results in the range from 0.01 to default 0.1, while the bagging fraction default value 0.5 seemed suboptimal, with those in the range 0.6–1 producing slightly better results. Thus, values chosen for the tuned model were 100 for the number of trees, 0.05 for shrinkage, and 0.8 for bagging fraction. It was found in general that most models are not especially sensitive to moderate variations in hyperparameters values. The exception is ANN that produced nonsensical results with default value of weight decay = 0 while quite good results appear when increasing this parameters to 2 and above.

The initial results of applying four mentioned SDM modeling methods using a full set of 21 predictive variables are shown on Table 1. Maxent method appears as inferior, while three other methods gave results of comparable accuracy, as seen in *testing* columns. Random forest method appeared to be prone to overfitting, as implied by 1 values of *AUC* and *TSS* metrics calculated for training dataset. It was impossible to statistically prove performance differences between ANN and BRT methods (their metrics means plus-minus their standard deviations overlap). ANN still shows slightly better values for both of the performance metrics and slightly bigger differences in these values between testing and training columns, implying smaller variance (and smaller proclivity to overfitting).

Table 1. *Performance metrics of different SDM methods calculated on training dataset and with the aforementioned testing procedure. For testing case, standard deviations are given in parentheses.*

Method	***AUC (training)***	***AUC(testing)***	***TSS (training)***	***TSS(testing)***
Maxent (ME)	0.8162	0.796 (0.0138)	0.6114	0.5938 (0.0252)
Artificial neural networks (ANN)	0.9437	0.9369 (0.005)	0.7508	0.7891 (0.018)
Random forest (RF)	1	0.9321 (0.0076)	1	0.7851 (0.0261)
Boosted regression trees (BRT)	0.964	0.9304 (0.0062)	0.8145	0.775 (0.0162)

Applying *reduceVar* function to ANN model allowed to significantly reduce the number of predictive variables without compromising model performance metrics, thus making a model more parsimonious. Picking predictive variables was based on inspection of *reduceVar* function graphic output: variables were chosen that either were retained up to the later stages of the pruning algorithm run or which withdrawal led to relatively high decrease in values of performance metrics. Six variables out of initial set of 21 were thus chosen out for the final model; five of them relate to climate and another one to soil characteristics, that is: Annual precipitation (BIO12); Precipitation of wettest quarter (BIO16); Temperature seasonality (BIO4); Precipitation of coldest quarter (BIO19); Precipitation seasonality (BIO15); Soil acidity (phh).

Table 2 shows performance metrics of ANN model with these six predictive variables in comparison with a model with a full set of 21 variables. It can be seen that reducing the number of predictive variables to the six most important ones didn`t cause the decrease in performance metrics calculated with cross-validation on testing data. The direct result of applying *predict* function is a map of the relative probabilities of species occurrence in the area (Fig. 2, left). A threshold value 0.229 was used to convert it to habitat presence/absence map that looks more customary for practitioners(Fig. 2, right).

Table 2. *Performance metrics of ANN SDM method calculated with a full and reduced sets of predictive variables.*

Model	***AUC (training)***	***AUC(testing)***	***TSS (training)***	***TSS(testing)***
Full set of 21 variables	0.9437	0.9369 (0.005)	0.7508	0.7891 (0.018)
Reduced set of 6 variables	0.94	0.9381 (0.0036)	0.7384	0.7893 (0.0132)

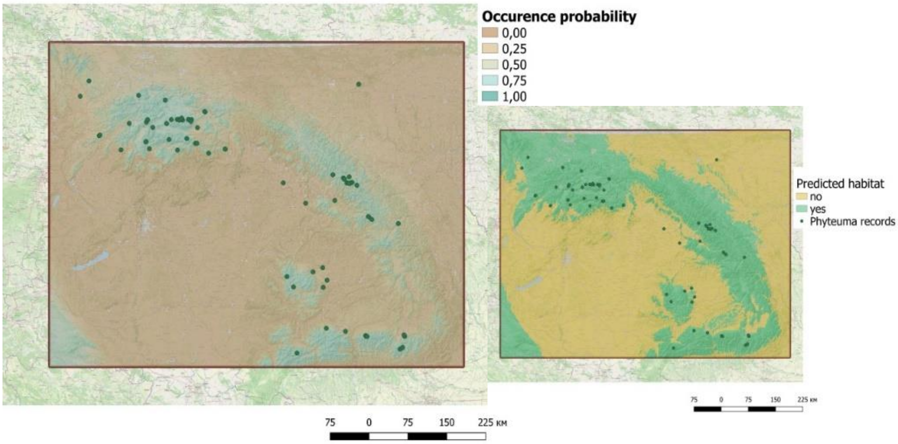

Fig. 2. *Relative occurrence probabilities (left) and predicted habitat (right) of Phyteuma.*

Predictions of future *Phyteuma* genus habitat under three different RCPs for years 2050 and 2070 were made with the same model, to which modified values of climatic variables reflecting assumed future climatic conditions were input. Results for RCP 50 and year 2050 are shown on Fig. 3. Comparing to Fig. 2, there are some spatial shifts: e.g. habitat area is predicted to somewhat increase in Eastern Carpathians while a decrease is expected in Southern Carpathians. Table 3 shows the expected habitat area changes for 2050 and 2070 under different RCPs. It shows that while habitat area for *Phyteuma* genus is expected to be stable or somewhat increase under moderate climate changes scenarios (RCP 26 and 45), the considerable decrease is expected for the most severe scenario RCP 85.

CONCLUSION

SDMs represent a valuable cost-effective tool to identify current important areas for threatened species that require attention from conservationists, and to forecast ecosystem impacts of rapid human-induced environmental changes. Machine learning approaches are becoming increasingly popular, facilitated by the recent availability of high computational power, and due to their ability to fit complex nonlinear relationships without requiring an a priori definition of a data model. Another important advance is the increased availability of open data on species observations and ecological factors. In the given case RF, BRT and ANN methods achieved results of similar accuracy, and reducing the number of predictive variables from 21 to 6 seemed feasible. An important prerequisite to successive modeling is the choice of predictive variables that are ecologically meaningful for the target species; the combination of ecological knowledge and statistical skill is thus needed to obtain reliable results.

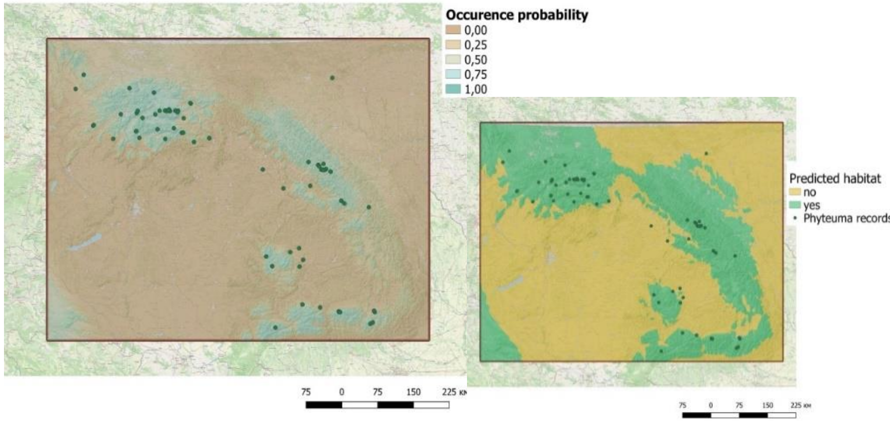

Fig. 2. *Prospected occurrence probabilities (left) and habitat area (right) of Phyteuma for year 2050 based on RCP45 climate projections.*

Table 3. *Predicted Phyteuma habitat area changes for years 2050 and 2070.*

RCP / Year	26	45	85
2050	178.9	166.9	149.2
2070	192.8	172.3	127.7

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POSSIBILITIES OF MUNICIPAL WASTE RECOVERY IN GEOPOLYMERS: A STUDY

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ABSTRACT

Growth in the production of industrial, agricultural and municipal waste is among growing global problems and it has recently reached very worrying levels. Solid waste arising from human activities significantly contributes to environmental pollution. The effort of the whole society is therefore its ecological, energy and economic recovery Hence, one of the possible uses is the incorporation of solid waste into geopolymer composites which are considered to be green material when compared to conventional Portland concrete. Geopolymers are nowadays referred to as green materials of the future and they consist of aluminosilicates activated by alkaline elements. Municipal solid waste can be used as an aggregate, precursor, filler, reinforcement which can have a positive impact on mechanical, physical or chemical properties of geopolymers. Geopolymer composites containing municipal waste have potential of application in the areas of concrete, noise and refractory materials, catalyst, adsorbent and many others. The present paper is an overview of scientific studies and research focused on the recycling and recovery of solid municipal waste in geopolymer composites together with the impact on the change of properties and their possible use.

***Keywords**: geopolymer, municipal solid waste, green material*

INTRODUCTION

The European Union set new and ambitious targets in 2018 for recycling and reducing landfill waste that represents the individual steps in building a circular economy. Things are not thrown away after the first use in this type of economy; however, they are reused and recycled. The average amount of municipal waste per one European is 502 kg. More detailed data on the municipal waste generation of the individual EU member states can be seen in Fig.1. The European Commission introduced the action plan for the circular economy in March 2020, the main aim of which is to make better use of potential resources and thus reduce the amount of generated waste. [1] An important aspect concerning waste is the assessment of the impact on the environment, health and to prevent further reintroduction of pollutants into the material cycle. [2] Municipal solid waste usually comes from residential life, institutional and commercial activities and is represented by, for example, food waste, glass, plastics, paper and many others. Much of municipal waste cannot be degraded naturally and needs a very long time to do so; hence there is an urgent need to find solutions for alleviating this issue. [3] Treatment and disposal of solid municipal waste are done by physical methods (incineration, evaporation, crushing, etc.), chemical methods (gasification, pyrolysis, etc.) and biochemical ones (decomposition, oxidation, absorption, etc.). However, the threat of secondary pollution persists even after this treatment and one of the appropriate possibilities appears to be the application of waste to new green materials; hence geopolymer composites.

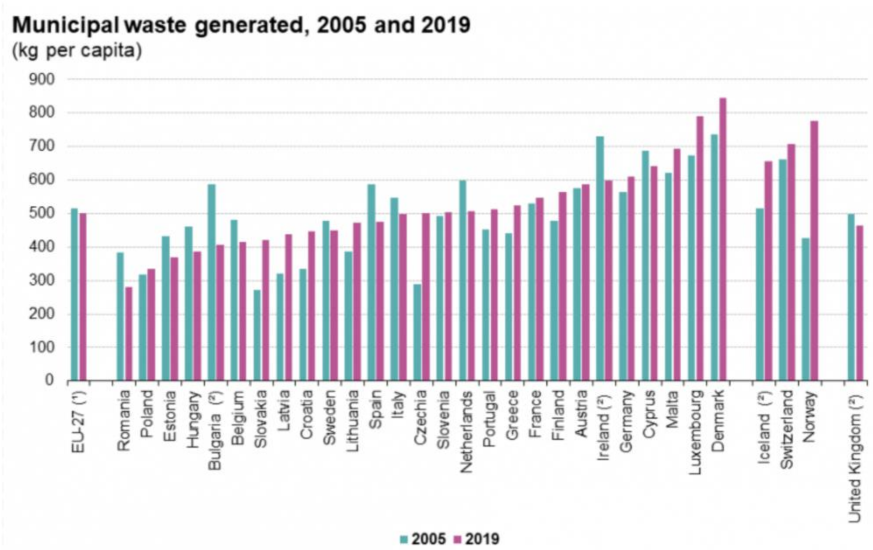

Fig. 1. *Municipal waste generated in the European Union in 2005 and 2019 [1]*

A French professor Davidovits introduced the term geopolymer in 1978 in order to describe the chemical reaction of an aluminosilicate precursor mixture together with alkaline polysilicates to form Al-O-Si bonds. [4] Geopolymers in literature are also referred to as alkali-activated polymers or inorganic polymers. Moreover, geopolymers are referred to as green materials and they are considered to be an alternative to concrete from classic Portland cement. The main advantages include the possibility of using waste raw materials such as slag, fly ash or tailings in the production of precursor geopolymer mixtures, resulting in a reduction in energy intensity and CO2 production when compared to Portland cement. Other benefits include heat resistance, excellent mechanical properties, acid resistance, the ability to encapsulate heavy metals and several others. Thus, thanks to these properties can geopolymer composites find their application as a sustainable and renovation material, thermal and acoustic insulant, material for additive printing, for immobilization of heavy metals and nuclear waste and pH regulators. [5] The issue of geopolymers is being addressed by an increasing scientific base that is discovering and examining in detail new properties on the basis of which they search for other possible applications. The preparation of geopolymers consists of several steps, including the preparation of activator solutions. An activator with prescribed molarity of 8-16 mol/l is produced by mixing and dissolving a certain amount of alkaline compounds in water. The given step must be performed at least 24 hours before preparing the geopolymers due to the need to stabilize and cool the solution. Nowadays, there are plenty of companies that supply alkaline activators according to specific requirements without the need for further processing. The second step of the geopolymer preparation is the homogenization of the precursor mixture in a mixer with additives, fillers, aggregates and all the bulk components that the resulting geopolymer should contain. It is possible to add superplasticizers, regulators and others to the solution prior to the last stage of the geopolymer preparation; thus the mixing of the bulk precursor mixture with the liquid alkaline activator. Mixing time, speed and mixers used are different and vary between authors. Individual steps of the geopolymer production are shown via block diagram in Fig. 2. [6]

The aim of the paper is to create an overview of scientific works that have influenced and improved the properties of geopolymers through the use of municipal waste in order to reduce the amount of waste and its negative impact on the environment.

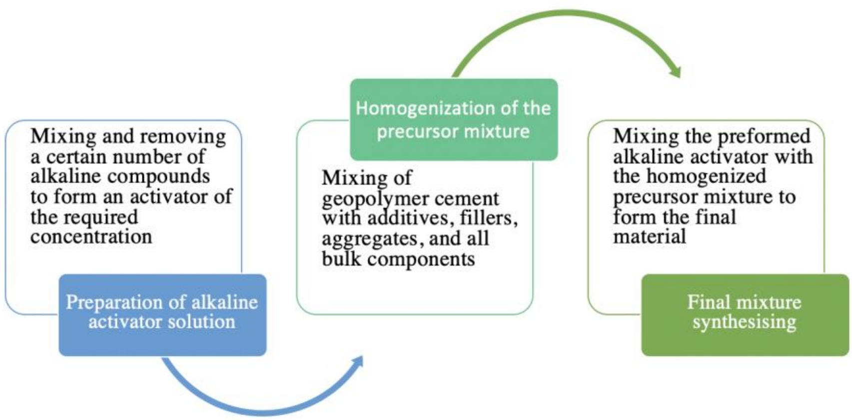

Fig. 2. *Block diagram of the geopolymer production process*

The current status of the given issue

One of the current methods of municipal waste treatment is incineration in order to reduce its volume and in some cases to produce green energy. The remaining ash is usually deposited into landfills; however, it is generally considered to be a hazardous waste due to the content of harmful heavy metals such as Cr, Cu, Pb, Zn, Hg and others. Jin and colleagues investigated in their research the immobilization of fly ash from metakaolin-based municipal solid waste and its resistance to acids and alkalis. The results indicated that geopolymers show very good stability in both types of environments; hence they could be a potential building material in aggressive environments without further secondary contamination. Analyses have shown the involvement of fly ash in geopolymerization, in which heavy metals have bound and improved the polymer structure of the geopolymer. This has resulted in improved impermeability and compressive strength; thus geopolymers are among the alternatives for reducing the amount of fly ash and stabilizing the heavy metals it contains. [7] Bottom ash from the incineration of municipal waste was used as an agent in the production of aerated light geopolymers based on metakaolin in another study; hence the expensive Al powder would be replaced. Samples of geopolymer aerated concrete formed with both types of agents were analysed in detail and subsequently compared. The result was that the bottom ash from the municipal waste incineration process can be used as an alternative agent in the production of aerated concrete geopolymers. [8]

Glass is another type of municipal waste that significantly pollutes the environment and creates so-called rapid landfills, since it usually can not be reused overdue to the mixing of colours and containing impurities. Scientific research by Xiao and colleagues was focused on the use of waste glass bottles that were crushed and synthesized together with class C geopolymer cement and activated with several concentrations of sodium hydroxide solution. The samples were cured at ambient temperature with no use of drying equipment. The geopolymer with the best properties was selected after evaluating the results of the experiments and it was activated with a solution of NaOH with a concentration of 5 mol and glass to cement ratio of 1:3. The sample reached a strength of 34.5 MPa and had the least impact on the environment. [9] Therefore, based on the above studies, it can be stated that glass waste incorporated into geopolymer composites has a great potential in the field of new building materials. Waste glass is in research considered to be a partial replacement for precursor mixtures, a fine or coarse aggregate and a replacement precursor for geopolymer activators as well. Various properties such as shrinkage, sulphate resistance, heavy metal immobilization, thermal conductivity, porosity and others have been observed. Simply stated, the synthesis of municipal waste glass and geopolymers seems to have a very favourable and promising future in the production of green materials due to its durability, efficiency and sustainability. [10]

Tires are also a challenging category of municipal waste. It is estimated that the life cycle of thousands of millions of tires ends each year, about half of them are recycled; however, the rest ends up in landfills without further processing or they are incinerated; thus presents an even greater environmental risk. Hence, these are the reasons why researchers decided to search for other solutions and application options. Aly and colleagues investigated the effects of adding crushed rubber in various percentages with focus on the properties of the slag geopolymer such as compressive, flexural and tensile strength. Several conclusions were drawn from the results of the experiments. The compressive strength was being increased to the limit of 10% of the rubber granulate content; however, the values decreased when above the limit. Tensile strength tests indicated a systematic decrease in values with increasing percentage of rubber aggregate. The elasticity of the geopolymer was increased due to the low stiffness of the rubber which resulted in a significant improvement in impact resistance. Thus, geopolymer composites containing rubber granulate have proven to be a qualified alternative green material that can find its application in the construction of roads and runways. [11]

Plastic is considered to be one of the most consumable materials in the world. However, there is a problem with its disposal due to its well-sustainable properties. There are millions of tons of plastics that float in the sea or they are just dumped in nature. Therefore, the treatment and disposal of plastic waste has become one of the most urgent global issues that needs to be addressed in order to maintain a healthy and clean environment. Several scientific teams have decided to make use of plastic waste and incorporate it into the production and research of new green materials which include geopolymer composites as well. Research led by Ganesha investigated the use of plastic waste in the form of polyethylene terephthalate (PET) bottles, which were crushed and subsequently used as a substitute for fine sand. Crushed plastic materials were added to the geopolymer in volumes of 5, 10 and 15 % while properties such as compressive and tensile strength, processability, water absorption, as well as behaviour and changes in samples at temperatures of 200, 400, 600 and 800 °C were being monitored. The results of the study showed a reduction in the processing ability of the geopolymer composite after replacing a certain amount of sand with plastic granules. The values of compressive and tensile strength increased by the level of 10% of replacement of sand by plastic granulate, as in the research by Aly and colleagues, Compressive strength increased by 5.8% and tensile strength increased as well, in particular by 24%. The absorption capacity of the geopolymers deteriorated with the presence of plastic in the matrix. The residual strength after heating of geopolymer composites containing plastic has a decreasing tendency. [12]

Table 1. *Overview of research dealing with the synthesis of municipal solid waste and geopolymers [13],[14],[15]*

Authors	Types of Additives	Curing Regime	Primary Findings
Jin et al.	MSWI ash CaO and Cl rich	20 ± 3°C a 60 ± 3% relative humidity for 28 days	• Strength reached 36.1 MPa after leaching 2 000 ml of simulated acid rain at pH 3.0 • excellent stability in acidic and alkaline environments without secondary contamination
Wongs et al.	MSWI ash CaO and SiO_2 rich	60°C for 24 h, subsequently for 7 to 28 days at 25 °C and 50% relative humidity	• the highest strength of 52.8 and 53 Mpa was achieved after 7 and 28 days by a sample containing 20% of ash • the sample with 20% ash has a higher hydrate phase of calcium silicate than the reference sample as the XRD analysis indicated
Tian et al.	MSWI ash CaO rich and coal ash with	60 °C for 6 h, then 7 days at room temperature	• during solidification of samples containing MSWI fly ash, it reacts with alkali to form H2 and subsequently

	SiO_2 a Al_2O_3 content		creates cracks and causes low strength. This effect can be mitigated by optimizing the sodium hydroxide synthesis process
Xiao et al.	Glass powder from municipal waste containers	20 °C for 24 h; 3, 7, 14, 28 days afterwards at room temperature	• the highest strength of 34.5 MPa was achieved by a sample containing waste glass powder together with class C fly ash in a ratio of 1: 3 • samples activated with solutions with high or low base content reduced reactivity due to electrostatic shielding of ions
Hajimohammadi et al.	Fine separated waste glass powder	7, 14, 28 and 56 days at room temperature	• fine glass powder increases the alkalinity of the matrix, which helps a higher range of dissolution and responds better near the aggregates • the amorphous portion of the glass in the later stages forms a strong compact matrix
Toniolo et al.	Fine waste sodium-calcium powder	60 °C for 48 h, then 7 to 28 days	• sodium-calcium glass shards are a viable substitute for commercial sodium silicate solutions • leaching of heavy metals meets the criteria despite the non-traditional composition of the geopolymer matrix
Aly et al.	Recycled crushed rubber from tires	28 to 60 days in water at room temperature	• the compressive strength was increasing up to 10% of the crushed rubber content limit • A significant improvement occurred in impact resistance due to the low stiffness of the rubber particles

Long et al.	Recycled crushed rubber from tires	20 ± 2 °C and above 95% relative humidity for 3, 7 and 28 days	• crushed rubber has a negative effect on the static mechanical properties • compressive strength decreased with increasing crumb volume by 31.3%, 32.6%, 35% • flexural strength decreased by 23.6%, 13.4% and 7.3% as well
Luhar et al.	Rubber fibres derived from tires	90 °C for 48 h, followed by 3, 7, 28, 90, 365 days at room temperature	• the compressive strength decreases by increasing the percentage of rubber fibres • flexural and tensile strength increases with the percentage of rubber fibres due to better bridging between enlarged cracks
Ganesh et al.	Fine powder from crushed PET bottles	Room temperature and before testing 1h at 200, 400, 600 and 800 °C	• compressive strength increased by 5.8% using 10% plastic powder • the absorption capacity decreases with the presence of plastic powder in the geopolymer matrix • the residual strength decreases after heating the samples
Posi et al.	Recycled packaging foam from household electrical appliances	25 °C for 1 h and then cured at 25, 40 and 60 °C for 48 h	• foam volumes had significant effects on the strength, density and thermal properties of the geopolymer • maximum strength was achieved at a solution concentration of 10M and a temperature of 40 °C

According to the overview of scientific studies presented in the table, the conclusion of several facts related to the properties of geopolymer composites can be done. Ash from the municipal solid waste incineration has a positive effect on mechanical and physical properties. However, there are many differences between them due to the composition of the waste from which the ash originates. Siliceous waste glass also had a positive effect on the properties of geopolymers, but the main importance is in what form and amount it is added to the matrix. Recycled rubber granulates added to geopolymer composites in larger quantities had a negative effect on properties in most studies. The maximum amount of rubber crumb, with positive effect on the geopolymer composite, is approximately 10%. The addition of plastic waste powder also has a positive effect on the geopolymer only up to this percentage limit. Possibility of combining individual types of municipal waste in the formation of geopolymers and how these variations would affect the resulting geopolymer is worth consideration. In summary, it can be stated that municipal solid waste can be used in production of geopolymer composites. The usage of this waste will not only reduce costs but also allow the reuse of raw waste material that would be landfilled. Synthesized geopolymers together with municipal solid waste can be considered as a way to improve and create a circular economy in individual countries of the world.

CONCLUSION

Geopolymers are gaining more and more attention around the world thanks to their excellent properties, low energy consumption and CO2 production when compared to conventional concrete. The present overview study is contained in several research dealing with the synthesis of geopolymers and municipal solid waste such as fly ash from municipal waste incineration, glass waste material, recycled rubber granulate and plastic waste. The use of waste materials promotes recycling and reduces their amount which leads to creating new sustainable green materials. However, there are some limitations that can occur when synthesizing municipal waste due to their different chemical, physical and mineralogical properties, treatment and curing methods. Therefore, establishing a standard that would help to use geopolymer composites on a commercial scale would be necessary. Clearly, creating such a standard for certain types of municipal waste is not easy due to their very different chemical composition; hence it is necessary to focus on the given issue and seek solutions. Another important step is the creation of a cost-effective precursor geopolymer mixture, which would enable the greater use of municipal solid waste and thus reduce the environmental impact on the environment. The search for specific application possibilities of geopolymer composites created by using municipal solid waste will also help the future direction and use of geopolymer composites.

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RECOVERY OF NEPHELINE FROM APATITE FLOTATION TAILINGS OF APATITE-NEPHELINE COMPLEX MINERAL COMPOSED ORES

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ABSTRACT

The recovery of all possible useful components from ores corresponds to modern approach to the mineral raw materials processing and provides a reduction in the amount of waste sent to tailings dumps. The increasing complexity of the mineral composition of the ore leads to the fact that the existing beneficiation methods and regimes do not provide the necessary quality of the obtained concentrates. This study shows the peculiarities of nepheline recovery from apatite flotation tailings of apatite-nepheline ores with low nepheline fraction.

Two reagent regimes were tested for nepheline reverse flotation: a mixture of pine and foliate tall oil, a mixture of tall oil and polyalkylbenzene sulfonic acid, which previously showed high selectivity of separation of nepheline and dark-coloured minerals. On the studied apatite-nepheline ore samples the necessary selection of flotation separation was not observed. Mineralogical analysis shows that losses of nepheline with froth products occur both at the expense of nepheline in intergrowths with associated minerals and at the expense of liberated minerals. Nepheline is quite actively floated, which is associated with a change in the surface properties of the mineral. The quality of flotation nepheline concentrates is reduced due to liberated grains of amphiboles, pyroxenes, and mica.

The high content of feldspar in the ore, which during flotation predominantly remains in the chamber product, also affects the quality of the nepheline concentrate. It was possible to increase the Al_2O_3 content in the concentrate to the required values only after magnetic separation in a strong field.

Keywords: *reduction of concentration wastes, integrated processing, apatite-nepheline ore, nepheline concentrate*

INTRODUCTION

Comprehensive processing of mineral raw materials with the extraction of all possible useful components makes it possible to reduce the volume of beneficiation wastes stored in a tailing dump and polluting the environment [1], [2]. Nepheline is the second most important mineral of the Khibiny apatite-nepheline ores; its content varies from 20 to 70% [3]. In the existing apatite-nepheline ore beneficiation technologies the recovery of nepheline concentrate is envisaged at the second stage from the apatite flotation tailings. However, obtaining nepheline concentrate that meets the requirements of the processing industry (Al_2O_3 content not less than 28%) can be difficult from ores with a complex mineralogical composition with a high proportion of pyroxenes, amphiboles, mica, as well as secondary altered minerals [4], [5], [6]. As a result of hypergenic processes, nepheline is subjected to destruction; clay minerals and hydromica appear in the ore, the main among which are potassium hydromica - libenerite and minerals of montmorillonite group.

RESULTS AND DISCUSSION

Two samples of apatite-nepheline ore from one of the Khibiny deposits (ANO-1 and ANO-2), characterized by significantly different mineral and chemical composition, and were considered as research objects (Tables 1,2).

Table 1. *Mineral composition of apatite-nepheline ore samples by X-ray diffraction analysis*

Mineral	Ore samples	
	ANO-1	ANO-2
P_2O_5, %	6.10	15.90
Fluorapatite	**14.98**	**37.39**
Nepheline	**29.99**	**12.32**
Feldspar, total	15.13	6.74
Aegirine	3.44	1.74
Aegirine calcium	2.95	1.46
Amphiboles, total	7.83	8.62
Titanite	2.69	2.22
Ilmenite	0.70	0.24
Magnetite titanous	0.56	0.23
Cancrinite	2.27	1.20
Sodalite	0.87	0.36
Lamprophyllite	1.01	0.76
Micas, total	14.51	24.77
Incl. hydromicas	4.49	3.46
Zeolites (natrolite, phillipsite)	3.07	1.95

Table 2. *Chemical composition of apatite-nepheline ore samples*

Ore sample	Content, %						
	P_2O_5	TiO_2	$Al_2O_{3tot.}$	$Al_2O_{3acid\text{-}soluble}$	$Fe_{tot.}$	Na_2O	K_2O
ANO-1	6.10	2.54	15.96	12.08	5.41	7.39	5.79
ANO-2	15.90	2.16	10.66	8.81	4.29	5.38	3.27

At the first stage according to the existing technology apatite concentrates were produced from ANO-1 and ANO-2 samples with 39.0% P_2O_5 content at recoveries of 70% and 86% respectively. Then the apatite flotation tailings were de-slurried, the yield of slurry was ~12.0% (ANO-1) and ~7.5% (ANO-2). Characteristics of nepheline flotation feed for the studied samples (Tables 3 and 4) have shown the closeness of the apatite flotation tailings in their characteristics in both cases, despite different nepheline content in the initial samples. At the same time the ANO-2 sample is characterized by higher mica content and lower feldspar content in comparison with ANO-1 sample.

Table 3. *Chemical composition of nepheline flotation feeding*

Product	Content of elements, weight %				
	Al_2O_{3tot}	$Al_2O_{3acid\text{-}soluble}$	Fe_{tot}	TiO_2	P_2O_5
ANO-1 feeding	18.80	14.00	6.78	2.95	0.55
ANO-2 feeding	18.67	14.16	8.35	3.12	0.45

Table 4. *Mineral composition of nepheline flotation feeding**

Sample	Mineral content, weight %										
	Nepheline	Feldspars	Pyroxenes Amphiboles	Apatite	Titanite	Micas	Titanium-magnetite	Ilmenite	Hydromicas	Zeolites	Other
ANO-1	42.0	16.0	27.5	2.0	3.0	1.7	1.0	1.7	3.0	0.8	1.3
ANO-2	42.0	10.0	26.0	2.0	5.0	6.5	1.0	1.5	4.5	0.5	1.0

*in the Nepheline field – joint content of nepheline and sodalite;

In the Micas field – content of lepidomelane and biotite, single plates of phlogopite

In the Other field – content of lamprophyllite, lorenzenite, aenigmatite, sulphides

Earlier studies have shown the effectiveness in the reverse nepheline flotation of the collection mixture (CM), which includes a reagent PABSA (polyalkylbenzene sulfonic acid) [7]. Therefore, two reagent regimes were tested for the studied samples:

CM_1 – 70%foliate tall oil + 30% pine tall oil;

CM_2 – 60% CM_1 + 40% PABSA (polyalkylbenzene sulfonic acid).

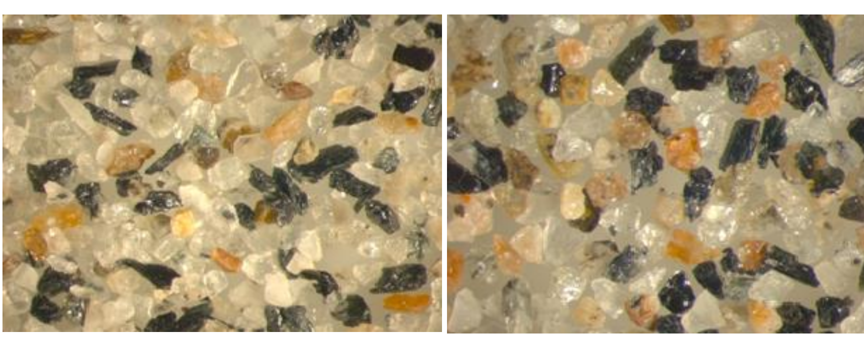
The results of reverse nepheline flotation (per feeding operation) are given in Table 5.

According to the results, a qualitative nepheline concentrate was not obtained in any of the cases. Increasing the collector consumption did not lead to a significant increase in quality, and there was no effective separation of the mineral complex: nepheline - dark-coloured minerals. In all cases there are large losses of nepheline with the froth product. Mineralogical analysis was carried out for the beneficiation products as well as the flotation feed itself. The content of intergrowths was assessed by an optical method.

The analysis has shown the proportion of altered nepheline in ANO-1 sample to be about 5-7% wt. (Figure 1a). The nepheline grains which have undergone secondary changes, in ANO -2 sample make about 10-15 % from the entire sample's mass (Figure 1b). Such grains have a cream, brown, or brownish-red colour due to the presence of hydromica scales coloured by iron hydroxides. The distribution of intergrowths for both samples is close, mainly in material larger than 0.1 mm (Table 6). The intergrowths are mostly rich (55-75% of grain volume) and very rich in nepheline (75-95%), less often medium-rich (25-55%). The morphology of nepheline intergrowths is shown in Figure 2.

Table 5. *Results of reverse nepheline flotation from apatite-nepheline ore samples*

Consumption in rough flotation, g/t	Chamberproductofscavenger flotation (flotationnephelineconcentrate)					Reagent regime
	Yield, %	Content, %			Recovery, %Al_2O_{3tot}	
		$Al_2O_{3\ total}$/ $Al_2O_{3ac.-soluble}$	TiO_2	Fe_{tot}		
Sample ANO-1						
400	42.8	23.91 / 17.73	0.76	2.62	54.8	CM_1: foliate tall oil - 70% pine tall oil - 30%
740	27.9	24.90 / 17.29	0.47	1.84	37.2	
1,000	24.4	24.19 / 16.77	0.49	2.14	31.6	
500	62.1	24.51 / 19.00	0.66	2.76	81.5	CM_2: CM_1 – 60% PABSA– 40%
740	50.5	25.10 / 18.92	0.53	2.47	67.9	
1,000	47.6	25.14 / 18.82	0.51	2.00	64.1	
Sample ANO-2						
600	46.4	24.20 / 18.80	1.01	4.60	59.7	CM_1: foliate tall oil – 70% pine tall oil – 30%
1,100	26.8	24.90 / 17.79	0.78	4.37	35.5	
2,000	19.1	24.37 / 16.44	0.76	4.15	25.1	
600	48.0	24.67 / 19.70	0.85	3.99	63.0	CM_2: CM_1 – 60% PABSA– 40%
1,100	41.9	25.92 / 20.39	0.67	3.34	57.8	
1,500	42.5	26.08 / 20.68	0.69	3.15	58.9	

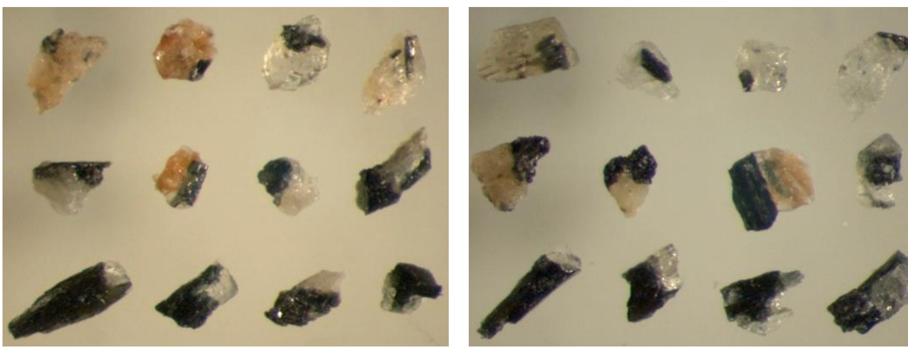


a) b)

Fig.1. *General View of nepheline flotation feed, class -0.315+0.20 mm a) ANO -1 sample b) ANO-2 sample*

Table 6. *Nepheline proportion in a liberated phase and in intergrowths in nepheline flotation feeding*

Classes, mm	ANO -1sample			ANO -2 sample		
	Yield of class %	Nepheline, relat. %		Yield of class %	Nepheline, relat. %	
		liberated	In intergrowths		liberated	In intergrowths
+0.20	6.8	80.0	20.0	7.7	70.0	30.0
-0.20+0.16	9.7	85.0	15.0	10.5	80.0	20.0
-0.16+0.10	22.0	92.0	8.0	21.8	90.0	10.0
-0.10+0.071	18.3	95.0	5.0	18.5	95.0	5.0
-0.071+0.050	10.7	98.0	2.0	10.8	98.0	2.0
-0.050	32.5	99.0	1.0	30.7	99.0	1.0
Total:	100.0	**94.0**	**6.0**	100.0	**92.0**	**8.0**



a) nepheline flotation feeding, ANO-1 sample

b) nepheline flotation feeding, ANO-2 sample

Fig. 2. *Nepheline intergrowths with rock-forming minerals: rich (upper row), medium (middle row) and poor (lower row), size class -0.315 +0.2 mm*

Mineralogical analysis of froth products of the rough flotation and flotation nepheline concentrates with 24.9% Al_2O_3 content for ANO-1 sample (collection mixture CM_1) and for ANO-2 sample 25.9% Al_2O_3 (collection mixture CM_2) is presented in Table 7.

The analysis has shown the nepheline presence in froth products mainly in the liberated state, as well as minerals contaminating nepheline concentrate.

The share of nepheline in intergrowths with silicate minerals in the froth product produced from the ANO-1 sample is 7.5-8.0%, with about 70% of intergrowths concentrated in the material larger than 0.1 mm. In the froth product of nepheline flotation, produced from the ANO-2sample, the share of nepheline in the intergrowths is 10.0%; about 66% of intergrowths are concentrated in the material larger than 0.1 mm.

*Table 7. Mineral composition of froth products of nepheline production**

Sample	Mineral content, weight%										
	Nephe-line	Feld-spar	Pyroxenes Amphiboles	Apa-tite	Tita-nite	Mi-cas	Titanium-magnetite	Ilme-nite	Hydro-mica	Zeo-lites	Other
ANO-1	38.0	11.0	36.0	1.0	4.0	1.8	1.5	3.5	2.0	0.2	1.0
ANO-2	29.0	6.0	42.0	1.5	8.0	3.0	2.0	5.0	2.0	0.6	0.9

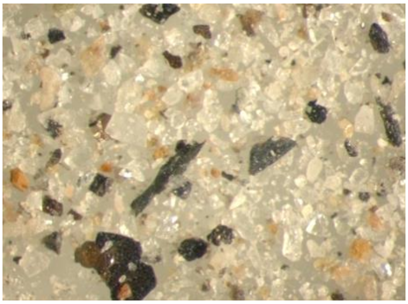
*in the Nephelinefield – joint content of nepheline and sodalite;

In the Micas field – content of lepidomelane and biotite, single plates of phlogopite

In the Other field – content of lamprophyllite, lorenzenite, aenigmatite, sulphides

The obtained nepheline concentrates are mainly represented by nepheline and feldspar - by 95-96% for the ANO-1 sample, and by 93-95% for the ANO-2 sample. The impurities in the concentrates are represented mainly as large, liberated, short- and long-prismatic grains of pyroxenes, amphiboles, and thick-medium mica beds. (Figures 3a,b). In the nepheline concentrate from the ANO-1 sample, the fraction of spreusteinized nepheline was 4-5%; in the nepheline concentrate from the ANO-2 sample 15-20% of nepheline was spreusteinized.

a)



b)

Fig. 3. *General view of nepheline concentrate a) ANO-1 sample, b) ANO-2 sample*

The unsatisfactory quality of nepheline concentrates, apparently, is caused by a large share of feldspar in the concentrate. With a low degree of selectivity of flotation nepheline goes to the froth product a greater extent. The ratio of nepheline / feldspar in the froth products for both samples is higher than in the flotation feed (Table 7). For ANO-1 sample in the froth product this ratio is 3.45 compared to 2.62 in the flotation feed. For the ANO-2 sample, the nepheline/feldspar ratio is 4.83 in the froth product of the rough flotation and 4.2 for the flotation feed. It can be said that as a result of flotation of ANO-1sample, chamber product (flotation nepheline concentrate) is "enriched" with feldspars to a greater extent, compared with ANO-2sample.

Subsequent magnetic separation of flotation nepheline concentrates (current strength 5A) has selected concentrates with content of 26.9% Al_2O_3 for ANO-1 sample, and 27.9% Al_2O_3 for ANO-2 sample into non-magnetic fraction. In the case of ANO-2 sample, for which the degree of "enrichment" of chamber product by feldspar is less, after magnetic separation it was possible to produce nepheline concentrate of proper quality (~28% Al_2O_3). While for the ANO-1 sample, it was not possible to bring nepheline concentrate to the required quality.

CONCLUSION

Thus, the studies have shown that the recovery of nepheline concentrate from apatite-nepheline ores with complex mineral composition is possible only after finishing the flotation concentrate by magnetic separation in a strong field. The high content of amphiboles, pyroxenes and mica in the initial sample leads to contamination of the flotation concentrate by these minerals, and the impurities are present in it in a liberated form. A decrease in the proportion of nepheline in the initial ore, an increase in the content of feldspar, and the presence of minerals secondary altered by nepheline also affects the content of Al_2O_3 in the concentrate. The ratio of $Al_2O_{3total}/Al_2O_{3acid\text{-}soluble}$ in the ore and produced flotation concentrates is about the same. At the same time there is a change in the surface properties of nepheline itself from this type of ore; its flotation activity increases, which leads to large losses of nepheline with froth flotation products.

It should be noted that the spreusteinized nepheline to a greater extent remains in the chamber product of the reverse nepheline flotation. As a result, from the apatite-nepheline ore containing 29.99% nepheline it was possible to obtain nepheline concentrate with 26.9% Al_2O_3. From the ore with nepheline content of 12.32%, nepheline concentrate was characterized by the quality of 27.9% Al_2O_3. Reducing losses of nepheline in the flotation cycle of nepheline concentrate recovery requires the development of new highly selective reagent modes of separation of dark-coloured minerals and nepheline.

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RECYCLING OF IRON ORE PROCESSING WASTES FOR REDUCTION OF INDUSTRIAL IMPACT ON THE ENVIRONMENT

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ABSTRACT

The paper presents the results of the research on the recovery of hematite from stockpiled tailings produced by the mineral processing plant of Olcon JSC (the northern-western Arctic zone of Russia). The authors investigated material composition of tailings samples and determined its granular and mineralogical characteristics. The content of total, magnetic and hematite iron in a sample of the tailings dump material is 8.76%; 1.53% and 3.67% respectively. The technology for hematite concentrate production from the tailings material has been substantiated, including several stages of spiral separation to recover the rough concentrate and its following concentration by a shaking table. The authors have determined optimal conditions for the disintegration of the middlings of the spiral separation, which made it possible to achieve selective liberation of the grains of valuable mineral. A recommended technological flowsheet for the processing of the tailings dump material provides for the production of hematite concentrate with a total iron content of more than 62% and through recovery of hematite iron of about of 76%. Involvement of the tailings in processing will help to reduce the human impact on the environment and improve ecological situation in the plant area.

Keywords: *industrial waste, tailings, hematite, spiral separation*

INTRODUCTION

The formation and accumulation of a significant mass of mining wastes containing ore and non-metallic components is an inevitable part of the development of most ore deposits. These wastes occupy huge land areas; change the natural landscape, soil and vegetation cover; negatively affect the atmosphere and water system, and pollute the environment.

Mining and mineral-processing wastes are one of the world’s largest chronic waste concerns. Their reuse should be included in future sustainable development plans, but potential impacts on a number of environmental processes are highly variable and must be thoroughly assessed. The chemical, mineral, granular compositions and physical properties of wastes determine which uses are most appropriate and whether reuse is economically feasible. If properly evaluated, mining waste can be reused to re-extract valuable minerals, supply construction materials, and repair surface altered by mining and mineral processing [1]. So recycling of industrial wastes which were generated after mining and mineral processing activities is a promising task for both ecology and mining industry.

More than 300 thousand hectares of Russia are occupied by mining-induced wastes. The mass of stored material varies in range from 40 to 80 billion tons according to various sources [2]. The amount of the wastes recycling does not exceed 10% of their annual generation. Most of the mining waste is used in the building industry and in few cases they are developed to recover associated valuable components which had not been recovered from the ores previously [3].

Today scientific interest in wastes recycling is increasing due to the depletion of rich iron ores at many deposits, the complication of the mining conditions, and the payments for the wastes generation and storage. Scientists are conducting research aimed at secondary recovery of iron minerals from tailings material [4], [5], [6], [7]. The results of these studies show the possible production of iron ore concentrates from mineral processing wastes. Waste rock minerals contained in the tailings can be used in the production of concrete, bricks, ceramics [8], [9], [10].

In this regard, the problem of utilization of iron-containing tailings dumps is of particular relevance. One of the promising objects is a tailings dump of the processing plant of Olcon JSC. It contains significant reserves of the valuable component in the tailings produced during iron ore processing at the processing plant with the magnetic-gravity technology. The tailing dump has accumulated more than 500 million tons of stored mining-made waste and their annual growth is up to 10 million tons. These tailings contain mainly one ore mineral which is hematite. The loss of hematite with tailings is caused by ineffective operation of the jigging machines at the plant. Therefore the study of additional recovery of iron from such wastes is a promising task, since they could become a potential source for production of both iron ore concentrate and quartz-containing product without the use of energy-intensive crushing and grinding processes.

RESEARCH OBJECT AND METHODS

Wastes of Olcon JSC are accumulated by two tailings dumps (main and emergency) which are located near Olenegorsk town and were formed as a result of processing of iron ore for 66 years. Figure 1 shows a satellite image of the tailings dumps.

Fig. 1. *Satellite images of waste dumps.*

The studies of recovery of iron ore concentrate from the emergency tailings dump were conducted earlier [11]. In this paper we examined the possibility of recycling of the main tailings dump. The area of this tailings dump exceeds 1,100 hectares.

A representative sample of tailings material was taken during drilling in various sections of the tailings dump with a grid of about 500x500 m. Only 17 boreholes instead of the planned 25 boreholes were drilled due to the water presence in some sections of the tailings dump. The depth of the secondary deposit varies from 15 m to 31 m. The authors analyzed the drilling samples from different zones at different depths using chemical analysis methods to estimate iron content. Analyzing the content of various forms of iron in the samples, they have found out absence of gravitational differentiation of the material in terms of density depending on the depth of occurrence, i.e. with an increase in the borehole depth, the content of hematite and magnetite in most boreholes does not increase. Calculation of the average content of valuable components in boreholes has allowed identifying areas of the tailing dump with the highest content of iron. Figure 2 shows the locations of boreholes and the average contents of total, magnetic and hematite iron. As can be seen, the richest areas with Fe_{hem} content up to 5.9% are located in the northern part of the tailing dump.

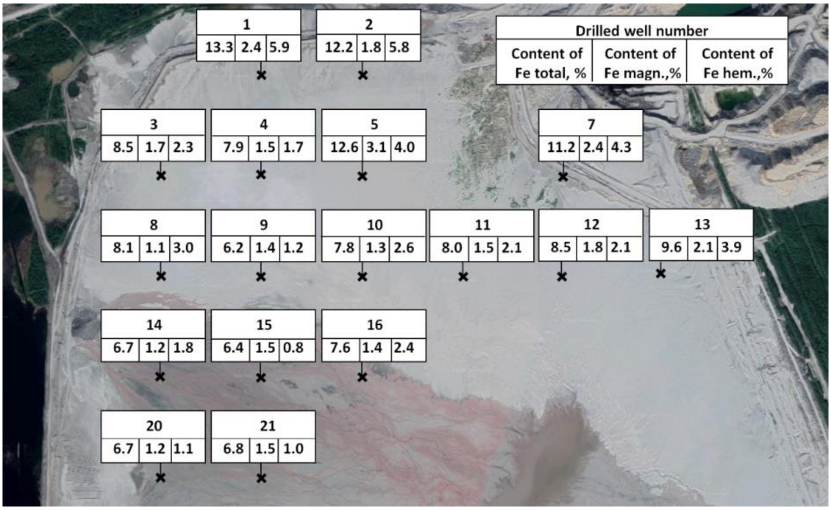

Fig. 2. *Average contents of various forms of iron for wells drilled at the tailing dump*

The content of total, magnetic and hematite iron in a combined sample of the tailings was 8.76%; 1.53% and 3.67%.

To determine the mineral composition of the sample, the authors have carried out its mineralogical analysis using X-ray phase analysis at diffractometer D2 Phaser. The main minerals of the sample are quartz with a mass fraction of 57.8% and silicates, represented by feldspars (13.0%), amphiboles (10.3%), pyroxenes (5.9%) and micas (3.8%). The content of hematite in the sample is 5.2%, and magnetite - 2.1%.

Figure 3 shows granular composition of the material, content and distribution of hematite iron by size classes. The most part of the sample is represented by particles with a size of -0.63 +0.1 mm, which yield is 61.8%. The amount of material with a grain size of more than 1 mm is about 13%, and the content of sludge particles (-0.071 mm) is about 10%. A slight increase in the mass fraction of iron with a decrease in the particles size can be noted. A significant part of hematite iron (up to 63%) is distributed in the fraction -0.63 +0.1 mm.

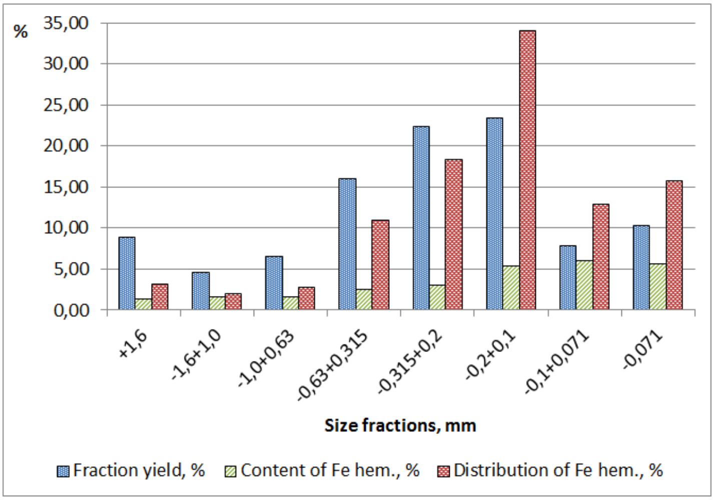

Fig. 3. *Granulometric characteristic of the tailings with Fe_{hem} content and distribution by size classes*

The results of mineralogical analysis conducted with use of stereoscopic microscope Leica MZ-6 have shown quite high total content of liberated hematite in the sample (about 70%), while about 98% of it is distributed in the material finer than 0.63 mm. The degree of liberation of hematite over 95% is achieved in the size fraction of -0.2 mm.

So, revealed features of the tailings material (difference in densities of waste rock and valuable minerals, low content of -0.071 mm fraction, high hematite liberation) create suitable conditions for its processing by means of gravity separation methods. In the following technological studies the authors used the spiral separators (SHV-500, VSR-500), shaking tables (SKO-0.5, Holman-Wilfley-2000), a ball mill and a vibrating screen to study the possible recovery of iron ore concentrate from industrial wastes.

RESULTS AND DISCUSSION

The spiral separation which is widely applied for hematite ore concentration [12] was used as the main processing method for the tailings. The authors have considered two-stage spiral separation in two different layouts: 1) recleaning of the combined concentrate and middlings of the first stage of the spiral separation at the second stage; 2) recleaning of only the middlings of the first stage at the second stage. The results of tailings dump material separation are shown on Figure 4. Both versions of the flowsheet have similar indicators in terms of recovery, but the variant with recleaning of the combined concentrate and middlings (Figure 4 (b)) provides for concentrate with higher content of total and hematite iron, so obtained separation indicators allow choosing this layout for the separation technology. The authors have recovered rough hematite concentrate with a yield of 13.73%, $Fe_{tot.}$ content of 34.95% and $Fe_{hem.}$ recovery of 70.54%.

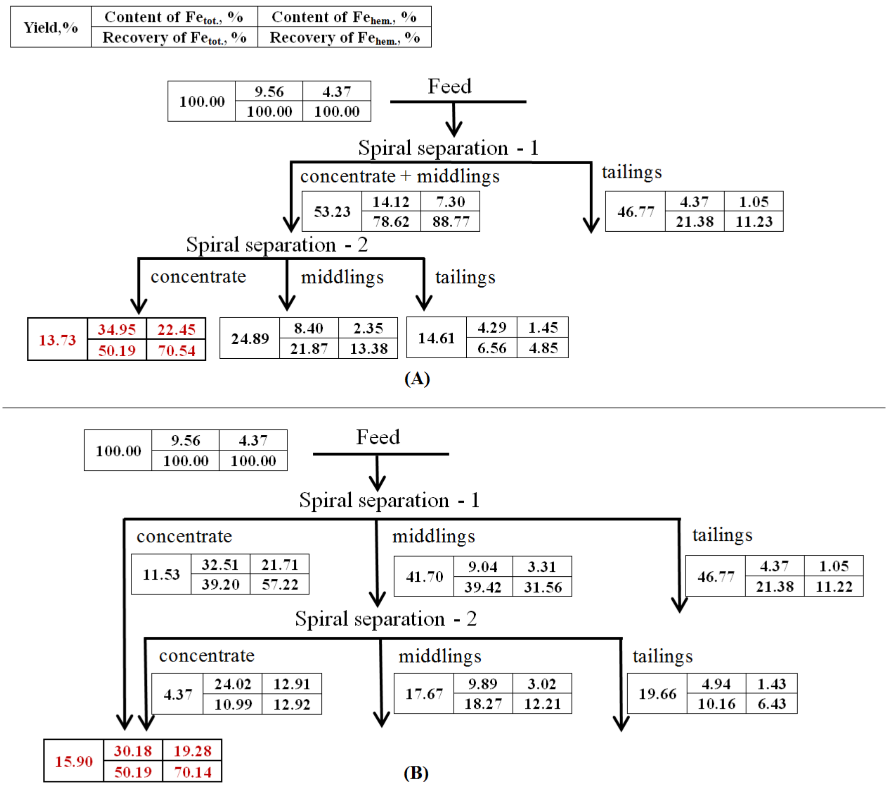

Fig. 4. *Different layouts of two-stage spiral separation (A – recleaning of the combined concentrate and middlings at the second stage; B - recleaning of the middlings at the second stage)*

The rough concentrates were processed using the shaking table. Achieved results indicate that the table concentrate contains more than 62% of Fe_{tot} with operation recovery of Fe_{hem} up to 80% when rough concentrate contained from 30% to 45% of $Fe_{tot.}$. Losses of Fe_{hem} with the tailings of this operation are 5-10%. Comparison of the obtained indicators with the results of high-intensity wet magnetic separation and spiral separation of rough hematite concentrates has shown higher separation efficiency of the concentration on the table. This fact determines the choice of this beneficiation method as a finishing operation.

During the operation of spiral separators, the middlings products are formed in addition to the concentrates and tailings. In terms of quality these products are comparable to the feed of the flowsheet; however, they accumulate intergrowths of hematite with waste rock minerals. Therefore the concentration of such a product will be difficult without milling and effective liberation of hematite intergrowths. To maximize the liberation of hematite in the middlings of spirals this material was grinded using a ball mill and a vibrating screen to a size less than 0.2 mm. Grinded middlings is favourable for gravity separation as the fraction of liberated hematite grains is 95% and the yield of the -0.071 mm size class did not exceed 17%. Further separation of milled middlings was conducted by the spirals and the shaking table.

As a result of conducted research, a technological flowsheet for hematite concentrate production from tailings dump material was developed (Figure 5).

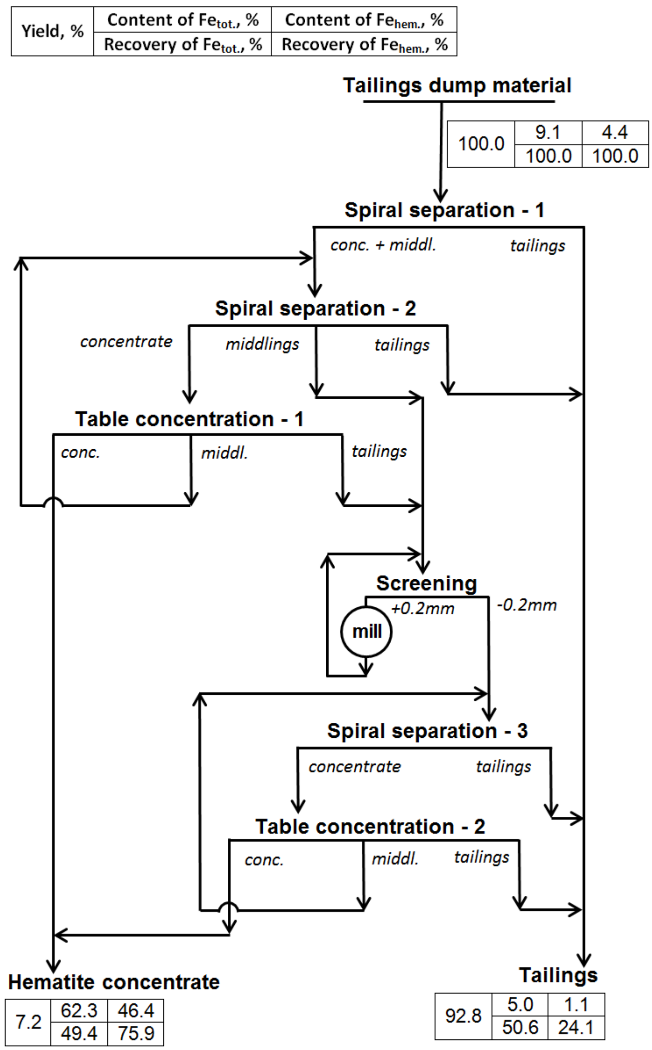

Fig. 5. *Flowsheet for production of hematite concentrate from tailings dump material.*

The technology provides for production of concentrate with 62% Fe_{tot} content and through recovery for Fe_{hem} of about of 76%. The yield of hematite concentrate is about 7%.

CONCLUSION

The problem of recycling of mineral processing waste is an urgent task both in Russia and worldwide due to reduction of mineral resource bases of mining companies and a decrease in the quality of mined ores. The study of the material composition of a representative sample has revealed the suitability of this material for gravity concentration due to the low content of fine particles with a size of less than 0.071 mm and the sufficient difference between the density of valuable and waste rock minerals and high hematite liberation.

It was shown that two-stage spiral separation allows recovering rough hematite concentrates with a 35% total iron content and hematite iron recovery of about of 70%. Separation of the rough concentrate with the concentration table provides for the hematite concentrate with a total iron content of more than 62%. The mineralogical and technological studies have substantiated additional grinding of middlings of the spiral separation for the hematite liberation. The feasibility of further separation of the milled middlings with the use of the spirals and the shaking table has been established, which has allowed increasing recovery of hematite into the final concentrate.

The technology for recycling of mineral processing waste has been developed, which ensures the production of hematite concentrate with a yield of about 7%, 62% total iron content and 76% recovery of hematite.

Thus, the processing of industrial hematite-containing wastes ensures the achievement of two significant goals at once: firstly, production of a marketable product in the form of hematite concentrates, and secondly, reduction of the negative impact on the vulnerable natural environment of the Kola Peninsula. The object of the future research is evaluation of possible options for the development of the tailings dump based on the analysis of geological and technical mining requirements, with the estimation of capital and operating costs.

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REMEDIATION OF A TAILING POND IN EASTERN SLOVAKIA

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ABSTRACT

In Eastern Slovakia, due to extensive chemical production in the past, especially production of explosives, and continuing combustion of coal, toxic chemicals, PCBs, fly ash and other substances are stored in a tailing pond. The current state of the tailing pond and the surrounding area, as well as its impact on the environment is analysed. Based on the results of the analysis remediation of the tailing pond is suggested. The closure of the tailing pond, including stabilisation of the pond material and the treatment of the pond surface, is designed. The result of the study proposes two possibilities of the use of pond after remediation – for growing crops as biomass and for building of a recreation and regeneration centre. In both the proposals, their advantages and disadvantages were evaluated. Reclamation will take place through a combination of technical and biotechnical stages. These proposals would be a great plus and benefit not only for the tailing pond but also for the environment and the surroundings of the pond.

Keywords: *tailing pond, toxicity, remediation, biomass, recreation*

INTRODUCTION

Due to adverse effects on the environment, tailing ponds are classified as a very problematic area. It negatively affects all compounds of the environment, including humans, animals, and plants. Tailing ponds mainly affect the bedrock, the quality of air, soil, groundwater, and surface water [1], [2]. People living near a tailing pond are afraid of the sludge as it may pollute the soils and water resources in the surroundings.

Before the sludge pond is closed it is important to decide on the use of the tailing after the remediation. This is mainly for practical reasons, so that we can plan a project for the reclamation of the tailing in the most efficient way. Reclamation should result in the restoration of devastated or contaminated land. The extent, and the requirements for the reclamation of the area depends mainly on the activity it will serve for in the future, which can be, for example, for sports or recreational purposes, for forestry purposes, for agricultural purposes, or for other purposes [1], [3]. The project of the reclamation of a closed tailing pond should be prepared based on the type and the amount of pollutants, for example heavy metals, in the material of the tailing. The project should identify the stages in which the reclamation will be carried out. When creating a project for sludge reclamation, it is important to follow these measures [1], [3]:

- minimize long-term effects on the environment on and around the tailing pond (including chemical stability),
- guarantee long-term safety, and stability of the pond (including geotechnical stability),
- integrate the tailing pond into the natural environment, e.g. forest (including biological stability).

In addition to the project of reclamation and remediation, the tailing pond must be monitored for a long time so that its safety is not compromised in any way. Monitoring is performed according to the specified schedule [1], [3].

The aim of the study was to propose a suitable method for reclamation of the devastated area, on which there is currently a tailing pond with pollutants and to choose the most suitable method of restoration for the tailing.

STUDY AREA

The tailing pond is located in the eastern part of Slovakia and geologically belongs to the volcanic formations of the Neogene Western Carpathians. Sediments consist mainly of clay, sandstone, gravel, etc. Neogene volcanic rocks are represented by formations with andesites, tuff rocks and rare rhyolites [4]. Next to the tailing is a stream that flows into the Ondava River basin. The source of contamination of these watercourses is the sludge pond. Arsenic contamination in this area has been reported since 1995 and represents one of the most serious environmental risks in Slovakia. The water in the watercourse has a high content of total As in the range from 300 to 11,000 $\mu g.l^{-1}$, as well as a high salinity. The high concentration of As, combined with the high salinity of water, threatens the potential use of water for the surrounding fields, but also for safe irrigation and drinking water [5]. The main consequence of the development of industrial activity is the growing discharge of polluting and toxic substances into water and soil. Heavy metals, which subsequently accumulate in the body, pose a major risk to human and animal health. They bind to the body and cause serious health problems. Some of these metals may not have a high concentration, but they still pose toxically. The most toxic cations include Be^{2+}, As^{3+}, As^{5+}, Cd^{2+}, Cr^{6+}, Hg^{2+}, and Pb^{2+}. It is these heavy metals that come from mining or other industrial activities, cause acidification of the soil and thus increasing problems in agriculture or forestry. Chemical pollution of watercourses is a major threat to aquatic organisms, including fish [6].

The total area of the tailing pond is approximately 0.38 km^2. The dam is 16 m high and the storage area is 0.328 km^2. The tailing pond was created for the storage of mostly waste in liquid form from industrial activities [7]. Ash generated as waste in the production of explosives and waste from coal combustion were also deposited at the tailing pond. Waste from the production of benzene chemistry, cyclohexanol, industrial fertilizers, nitrogen, ammonia, concentrated acids and others were mostly present in the sludge [8].

RESULTS AND DISCUSSION

Insufficient slope stability might be a problem. The degree of stability of the slope of the pond can be calculated or graphically represented based on the analysis of samples taken during the operation of the tailings pond. First, an expert opinion on the stability of the slopes is necessary. The most basic methods for solving slope stability are balance or deformation. If the bodies are unstable for a long time, landslides may occur. The degree of the stability factor of the slopes after the closure of the tailing pond should be at least 1.3, while, if there was a larger water cover on the tailing pond, this factor can also be 1.5. The higher this safety factor the better we can reduce the cost of long-term monitoring after the closure of the tailing pond [9].

The surface treatment of a tailing can be divided into two most basic stages: technical and biotechnical stage. For preventing unfavourable processes in the tailing, it must be insulated, drained from surface and rainwater, but also biological reclamation must be done, for example: soil movement, storage, spreading, etc. To prevent the formation of acids and bases, the sludge must be sealed and insulated properly [3].

It is important to develop selective disposal, so hazardous waste must be deposited in the lowest layer as far as possible. As a result, hazardous waste will not come into contact with fertile soil and will therefore not have any negative effects on plants or even animals. Waste that is not inert must not come into contact with groundwater or seepage liquids. The toxic material must be covered with a neutral material, or if necessary, the storage with toxic material can be covered with waterproof material for safety. In the final step of the reclamation of the sludge, the material, that is applied to the top layer, works for a long time, which means that it can be compressed or otherwise deformed. The sealing system must sufficiently work against certain water leaks, such as surface water or leak liquids. It is important that this system is resistant to physical and chemical influences at anytime. This sealing layer still needs to be enriched with other technological layers, e.g. drainage, separating, protective or reinforcing [3].

After closing and sealing the tailing, last stage, biotechnical, starts. The task of this stage is to stabilize and revitalize the reclaimed area with greenery. The most important thing is to cover it with fertile soil. As there is a shortage of fertile soils, more complex solutions, such as modifying the chemical, physical properties of soils (e.g. acidity or structural change) or supplying nutrients to the soil (such as fertilization) can be applied. If the soil has a low pH, less than 4.5, the pH must be increased to at least 6.0. The slopes of the tailing must be protected from erosion. This biotechnical stage depends mainly on the mineralogical composition of the pond. Low dumps are most suitable for agricultural crops, but medium-high dumps with acidic soils tend to be immediately afforested [3].

The merit of reclamation is to create a new surface, so it is an advantage to know from the beginning what the area will be used for. The following four steps must be followed when recultivating the tailing pond [1], [10].

- Geotechnical stability. It is necessary to secure and strengthen the dam of the tailing pond and at the same time stabilize the subsoil. It is also necessary to ensure the stability of the slope of the tailing pond, but mainly to ensure the entire sludge pond against further weathering and thus possible further pollution of the surroundings. A regime for groundwater and sand water, monitoring of their level and flow rate, must be introduced.
- Chemical and filtration stability. It is important to ensure the chemical stability of the materials, i.e. the construction of the dam on the tailing pond, to prevent further aggressive effects of deposited material, etc. The tailing must be secured against burning, penetration of pollutants, prevention of further degradation and the release of solid, liquid, but also gaseous emissions into the environment.
- Biological stability. From the point of view of biological stability, it is essential to ensure the restoration of the ecosystem.
- Ecological stability. Complementary step to minimize any further pollution in the area that could enter the air and spread the pollution.

In order to close a tailing pond with mostly acidic seepage liquids, the physical and chemical properties of the deposited material must be considered. Most reclamation and remediation methods are aimed at reducing the rate of sulphide oxidation, thus reducing the subsequent mobilization of weathering products to limit or even prevent further transport of oxygen to the sulphides, by using a barrier of either dry or wet cover. Other methods can also be used – removal of sulfidic minerals, addition of minerals with buffering ability, reduction of the surface of grains which weather etc. As a diffusion barrier against the transfer of oxygen from the atmosphere to the pond, the level of free water must be used. Thus, the oxygen diffusion coefficient for water must be less than the diffusion coefficient for air, and that is why the subsequent oxidation of sulphides is removed by the water layer. This method is conditioned by a relatively positive water balance, it also has a long-term physically stable dam, which is provided with sufficient drainage capacity to prevent the formation of further suspension due to waves that are on the surface. The water that is on the tailing pond is removed. The surface of the sludge is then allowed to dry, but the material in the body of the tailing is still in the form of saturated water (fine-grained particles are soaked in water, so the material is soft). The surface of the entire tailing pond is covered with layers of material, which must have the ability to bind water well and have low permeability. When covered with dry material, a separating and drainage layer can also be considered. This dry coating reduces the reaction rate by limiting the diffusion of oxygen present on the surface of the tailings and venting it to the intergranular spaces. This also reduces the formation of acidic seepage liquids, infiltration of surface water and consequently the transfer of reactive products is limited. This cover is composed of several layers, which are formed by different soils. The total thickness of the coating is in the range from 0.3 to 30 m and the permeability of the (sealing) layer is from

1.10^{-7} to 1.10^{-9} $m.s^{-1}$. The tailing pond must be sufficiently drained before coverage [9], [10].

Precautions must sometimes be taken against dust emissions before coverage. In order to avoid further collection of rainwater as well as water from surface runoff, the slope of the sludge pond must be adjusted to 0.5 to 1° towards the collecting ditches, which are intended for drainage. The layer, which is located completely on top, must serve to protect the cover, especially from drying out and erosion. The top part is in most cases green with grass [9].

First, the tailing must be covered with a cohesive layer of soil. This is one of the simplest cases. In particular, this soil must have the lowest permeability. If this is not the case, a reduction in permeability for some soils can be achieved by spreading the soil over a thin layer or by compacting the soil at a suitable moisture content. The most effective way is to cover the compacted clay layer, which, however, must have a low permeability. The thickness of the clay layer depends on climatic conditions, such as potential evaporation, but mainly depends on precipitation. The local fauna and flora also have an impact on it. The third type is the reduction of infiltration, which can be achieved by building a drainage layer, which will be placed above the surface layer. This reduces infiltration, but there may also be some tendency to increase oxygen diffusion in the water-saturated zone, resulting in inappropriate use of the infiltration reduction method. The last fourth method is a coarse-grained layer, which will be located between the sealing layer and the tailings. The sealing layer can also act as a capillary barrier, which prevents drainage and diffusion transfer of dissolved components [9], [10].

Geotextiles are used for dry cover reclamation. Their durability can be quite problematic in the long-term perspective. When it is teared up, the layers can be mixed, and thus the drainage effects of the drainage layer are either reduced or eliminated. When afforesting the uppermost part, the roots must not negatively affect the permeable layer in any way. Thus, the thickness of this layer must be sufficient to prevent such disturbance. The effects that can be caused by frost when melting snow and ice must also be considered. This could cause an increase in permeability. To prevent erosion, it is also advisable to sow the area with grass [11].

Crops for biomass

During last years, before closing, wet ash and slug was stored in the tailing. After closing, the pond must be isolated from the surrounding environment to stabilize the impact. The top surface of the tailing is covered in stabilizer and soil to prevent the leakage of rainwater into the lower layers of solid pollution and thus also prevent the subsequent run-off of the accumulated liquid waste. If run-off occurred, the perimeter of the dam could be weakened by hydrostatic pressure and subsequently cause the dam to rupture. Growing some crops on a closed and remediated tailing pond would be very beneficial not only for the area of the tailing but also for the surrounding landscape. As this design has not yet been carried out experimentally, we cannot determine with certainty what thick layer of covering material we should use for the sludge pond [12].

The subsoil intended for sowing crops shall be prepared based on the needs of the plants. Plants that are planted on the remediated tailing not only stabilize it, but, with root system, also capture a large amount of rainwater, and thus serve to drain the sludge. For a successful and useful plant growing, a suitable subsoil for growing selected crops must be selected. To prevent water leakage, hydrolysing foils, and stabilizers, with a thickness of about 30-60cm (Table 1), are recommended. A 3mm thick hydrolysing foil is placed on the tailing pond and four large-scale plots are prepared in the required subsoil structures [12] as follows:

- stabilizer with a thickness of 30cm, 60cm and without stabilizer,
- subsoil, from 30 to 55cm thick, reflecting the subsoil profile of the reclaimed area,
- topsoil, from 15 to 30cm thick, reflecting the soil profile of the reclaimed area.

Table 1. *The structure of experimental seeding variants and the number of rooted individuals in the sludge pond [12].*

Plot	Stabilizer (cm)	Subsoil (cm)	Topsoil (cm)	Sum (cm)	Proportion of rooted plants (%)
1	30	55	20	105	87
2	60	50	30	140	91
3	-	45	20	65	92
4	-	50	15	65	95,5

A grass mixture, composed in a way suitable for the conditions of tailing, is used as the cover layer. The sowing must be in the given term, according to the climatic and agroecological conditions of the area. The composition of the suitable grass mixture is, therefore, as follows [12]:

- grass mixture composed of perennial mint – Barrage 35% and Bartwingo 20%, red fescue – Barustic 30%, and meadow grass – Brooklawn 15%,
- grass mixture composed of perennial mint – Barrage 25% and Bargreen 25%, meadow fescue – Baron 20%, and crawling clover – Barbian 10%.

The acceptance of these plants is individual, and it depends mainly on climate change or on consumption by animals in large quantities. However, we hope that such biomass cultivation as sludge reclamation will be beneficial for the area. The tailing pond will be monitored after planting these plants and prepare it for planting trees.

Building of a recreation and regeneration centre

Since there are mostly heavy metals, arsenic, PCBs substances and others, in the sludge pond, a compacted barrier formed of clay (bentonite) must be created. Bentonite is mainly used because it has a low permeability, lower than the permeability of waste in the pond [13]. One of the measures in reclamation is to prevent further disposal of waste to the tailing and subsequently its long-term monitoring. The entire surface of the tailing pond must be secured against flood, seepage, or disturbances, etc. All these, but also other measures are used to ensure the safety of the tailing pond [14].

After closing the tailing, these steps follow [3]:

- identify the possible environmental risks posed by tailing,
- identify a procedure to stabilize heavy metals, arsenic, PCBs, and other in the sludge,
- design and develop a specific reclamation plan for a recreation centre,
- verify the suitability of the reclaimed tailing pond for selected purpose and subsequent long-term monitoring of the centre.

After the application of bentonite to the surface layer of the tailing, another layer of soil of a specific pH is applied onto this layer to grow trees and plants. First, a grassy area and later also trees and plants (e.g. meadow flowers) are planted. Between these plants and trees, a multifunctional playground, where not only children but also adults can play, is build. Near the playground, a freshwater lake with fish, which will then be used for fishing is built. There are several benches around the lake.

Near the reclaimed tailing pond, a feeder for forest animals is placed. A few meters from the lake and the playground, a lookout tower, which will serve tourists and locals, is build, to enjoy the view of the whole area of dense forest and the village. If this project is implemented, a panel road will be built to this recreational and leisure zone, so that people do not have to wade through muddy and dirty fields. Unfortunately, cars at this resort will not be able to park. However, a parking lot will be in the nearby village. People will enjoy less cars and more relax in this resort and recharge their batteries.

CONCLUSION

Nowadays, the issue of tailing ponds is very topical. In Slovakia, there are several tailing ponds that pose not only a great environmental burden but also risk for people's lives. One of them is in the east of Slovakia. There were released polluting (toxic) substances such as PCBs, fly ash and other hazardous substances, which are still deposited in the tailing pond. If it is not closed, the sludge pond will have negative effects not only on the soil, groundwater and surface water around the pond, but also on the surrounding plants and animals living there. Therefore, it is proposed that the tailing pond be closed as soon as possible, secured against further leakage of pollutants and subsequently recultivated (reclaimed). When proposing the reclamation of the given site, it was found that two ways would be the best for the area, and they are: cultivation of biomass and building of a recreation and regeneration centre. At this resort there would be a playground, a small lake, but also a lookout tower. In both the proposals, their advantages and disadvantages were evaluated. Reclamation will take place through a combination of technical and biotechnical stages. These proposals would be a great plus and benefit not only for the tailing pond but also for the environment and the surroundings of the pond, as high concentrations of heavy metals were also found in the Ondava River.

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STRUCTURAL AND FLORISTIC CHARACTERIZATION OF THE OULED BECHIH FOREST (ALGERIA)

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ABSTRACT

The objective of this study is the rational management of forest ecosystems for sustainable conservation of floristic biodiversity. Two types of analysis are carried out: structural analysis and analysis of the main species. A total of 22 families were identified, divided among 32 species. The dominant woody species are *Quercus suber* and *Quercus canariensis*. Fagaceae is the most represented family. The average values of species richness and Shannon diversity index are 4 ± 1.8 and 0.9 ± 0.30 species/plot respectively. The average density of woody species in the Oueld Bechih forest was 158 ± 28 tree/ha with an average basal area of 32.67 ± 0.74m²/ha. The height structure shows that trees in height classes is ≥ 6 has very high density, evidence of almost no natural regeneration. The total structure indicates that larger trees are more abundant. In effect, this work provides a database for the forest, but it represents only one facet to be considered in protecting and restoring it.

Keywords: *Q. suber, Q. canariensis, diversity indices, height and diameter structure*

INTRODUCTION

In Algeria, cork oak and zea oak forests are particularly important as they constitute an essential element of the physical, climatic and especially socio-economic balance in rural areas [1]. From an ecological point of view, the cork oak and the Zea oak are the most important forest formations in Algeria and cover more than 278.000 ha [2]; their abundance, importance, distribution and their relatively unknown ecological value are major assets for their conservation. The present study focuses on the Ouled Bechih open forest, located in eastern Algeria. As this forest is used for cork production, the local populations cannot help but illegally take the various forest resources they need. Its conservation is thus compromised. In the context of the development and sustainable management of natural forest ecosystems in general and the Ouled Bechih clear forest in particular, this study is therefore necessary.

MATERIAL AND METHODS

Forest of Ouled Bechih is located north of Souk Ahras (Algeria). The study area is located between the coordinates 36°21'26'' north latitude and 7°50'08'' East longitude (Figure 1). It covers an area of 6582 ha, mainly composed of Zea oak and cork oak [3]. This forest accounts for more than 50% of the Souk Ahras subterranean forest. This region is characterised by a sub-humid climate. The average annual temperature is 16°C and the average annual rainfall is 625 mm, with an atmospheric humidity of 68%. The altitude of the Ouled Bechih forest varies from 790 m to 1050 m, with slopes of over 15% [4]. The hydrographic network is very important. Several wadis and watercourses cross this forest massif: Oued Hemimine, Oued El Ouarida and Oued Medjerda.

Fig. 1. *Area of study*

The plots chosen for this work have dimensions of 30 m x 30 m, which are in line with those recommended by Fonton [5] for spatial structure analysis studies in forest ecosystems. Measurements were made of trees with a diameter (at 1.30 m above ground level) greater than or equal to 5 cm. This includes their location, diameter and species. The ecological characterization of each plot was carried out using density, basal area and diversity indices: species richness (S), Shannon diversity index (H) and Piélou equitability (EQ). The density (N), for all species, is obtained with the formula:

$$N = 10000n/s$$

Where n is the total number of trees and s is the plot area (in m²).

The basal area (G, in m²/ha) is the sum of the cross-sectional area at 1.30 m above the ground of all trees with a diameter greater than 5 cm within the plot.

The species richness (S) is determined for each plot. It expresses the total number of woody species with a diameter greater than 5cm counted on each plot. The Shannon diversity index (H in bits) is obtained by the formula:

$$H' = 1 - \sum_{i=1}^{k} pi.\log_2 pi$$

pi = (ni/N) the proportional abundance or percentage abundance of a species present.

ni = the number of individuals counted for a species present.

N = the total number of individuals counted, all species combined.

S = the total or cardinal number of the list of species present.

The Shannon index is used to express the specific diversity of a stand studied. As a reminder, the specific diversity characterises the greater or lesser number of species present in a stand. If it is homogeneous (made up of one and the same species), then the H' index = 0.

Piélou's equitability index (EQ) is given by the relationship:

$$EQ = H/log_2S$$

where Log_2S is the maximum diversity.

RESULTS AND DISCUSSION

The inventory of the Ouled Bechih forest revealed 32 species belonging to 22 families. Angiosperms form the most important systematic group; they are presented by: Quercus suber and Quercus fagina. The most common families are the Asteraceae, Fabaceae and Fagaceae. These families represent 50% of the total number of species encountered (Table 1). The species inventoried represent the floristic procession of *Quercus suber* and *Quercus fagina* such as: *Asphodelus ramosus*, *Charybdis maritima*, *Calicotume spinosa*, *Phillyrea media*, *Rosmarinus officinalis,…*

Table 1. *Floristic diversity.*

Species	Family	Species	Family
Arum italicum	Araceae	*Galactites tomentosus*	Asteraceae
Asphodelus ramosus	Xanthrrhoeaceae	*Hypochaeris glabara*	Asteraceae
Bellis prennis	Asteraceae	*Hyoseris radiata*	Asteraceae
Bellis sylvestris	Asteraceae	*Lotus corniculatus*	Fabaceae
Calicotome spinosa	Fabaceae	*Quercus ilex*	Fagaceae
Calystegia sepium	Convolvulaceae	*Quercus fagina*	Fagaceae
Carataegus monogyna	Rosaceae	*Phillyrea media*	Oleaceae
Charybdis maritima	Asparagaceae	*Pteridium aquilinum*	Dennstaedtia
Cyclamen hederifolium	Primulaceae	*Notobasis syriaca*	Asteraceae
Cytisus villosus	Fabaceae	*Ranunculus muricatus*	Ranunculaceae
Daphne gnidium	Nanophanérophytes	*Romulea bulbocodium*	Iridaceae
Daucus carota	Apiaceae	*Rosmarinus officinalis*	Lamiaceae
Erica arborea	Ericaceae	*Rubus ulmifolius*	Rosaceae
Euphorbia peplus	Euphorbiaceae	*Silene coronaria*	Caryophyllaceae
Ficaria verna	Ranunculaceae	*Stellaria media*	Caryophyllaceae
Gagea pratensis	Liliaceae	*Theligonum cynocambe*	Rubiaceae

The management objective of modern forestry is to reconstruct the structure of artificial forests by simulating the structure of forests. For this purpose, the first question is how to express the characteristics of the forest structure. But it seems impossible to describe the structure of forests well by using only one parameter because of their complexity. Therefore, a system used to assess different aspects of spatial stand structure was created by combining a few indices: species richness, Simpson index, Shannon and Weaver index, relative density, relative basal area and Pielou segregation index in this study. A number of studies have indicated that they are available and can effectively interpret the spatial characteristics of different forest types. The results obtained show that basal areas vary from 25.71m^2/ha in plot 4 to 49.17m^2/ha in plot 1. The lowest average DBH of all living trees was found in plot 3 ($d_{1.3}$ = 38.30cm) and the highest in plot 1 ($d_{1.3}$ = 78.07cm). The highest average height was also found for cork oak in plot 1 (14.19m) and the lowest in plot 3 (Table 2).

Table 2. *Characteristics of the species studied.*

Parcelles	D	H(m)	N/ha	G (m^2/ha)	V (m^3/ha)
P1	78.07	14.19	89	49.17	369.81
P2	40.34	10.91	200	29.77	172.18
P3	38.30	9.38	178	26.14	129.97
P4	42.04	13.54	167	25.71	184.50

The distribution of individuals by diameter class was fitted to a polynomial function (Figure 2). This figure shows a high proportion of individuals with dbh between 27.5 and 47.5cm. This actually reflects the heterogeneity of dry forests with respect to woody diameters. However, it was observed that there are dry forests with many small-diameter trees and dry forests with very few large diameter trees. The vertical distribution is given by the distribution of the number of stems in all plots per hectare for each height class, and provides information on the vertical stratification of the stand [6]. A large proportion of the trees are between 10 and 15 m tall (low perch stage); this class has a large number of individuals due to regeneration, which remains fairly low (Figure 3). The 0-5m class has a smaller number of trees and the 20-25m class is the lowest.

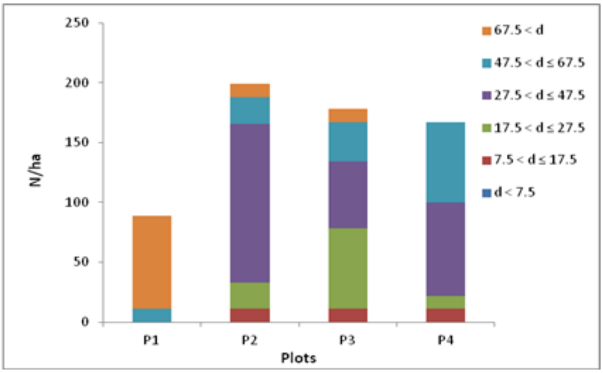

Fig. 2. *Density by diameter classes.*

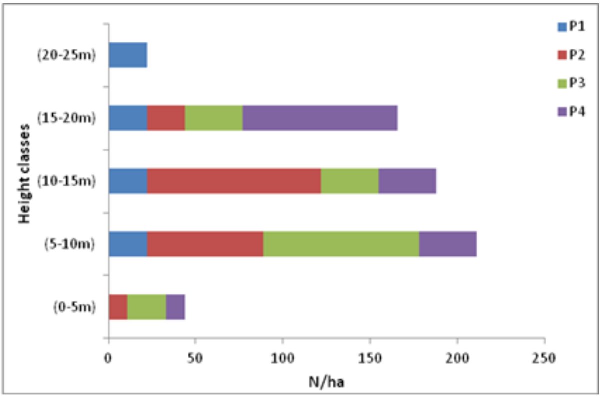

Fig. 3. *Density by height classes.*

CONCLUSION

The structural study and the floristic composition of the forest allowed knowing the diversity of the plant groups of this ecosystem. The forest of Chettaba functions today as an isolated ecosystem undergoing pressures at its periphery and justifies the need to conserve this ecosystem. The evaluation of the specific diversity by the index of Shannon index and equitability shows a certain relationship with the disturbance of the environment. In spite of a relatively average density of woody plants, the woody flora of the forest massif presents species with a strong socioeconomic use that is a priority for revalorization. These assets militate in favor of strengthening the strategies of development and sustainable management of the forest massif.

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STRUCTURAL CHARACTERISATION AND ASSESSMENT OF THE SPATIAL DISTRIBUTION OF *PINUS HALEPENSIS* IN THE EL HAMIMET FOREST (EASTERN ALGERIA)

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ABSTRACT

Aleppo pine plantations were studied in the region of El Hamimet, the diameter at 1.30m from the ground, the total height of *P. halepensis* individuals were measured on 4 plots according to an altitudinal gradient. The establishment and interpretation of diameter and height structures are essential for forest management decisions. Knowledge of these parameters is an essential step in their sustainable management. The diameter and height structures were established according to diameter or height classes. The stand on plot 4 is characterized by the lowest diameter and height values. The analysis of the diameter and height structures reveals an increase in the frequency of young individuals. These results contribute to the improvement of the knowledge on the indicators of the current state of the natural *Pinus halepensis* stands that can be used as a basis for the management of the El Hamimet forest.

Keywords: *Pinus halepensis, Diameter structure, Spatial location*

INTRODUCTION

Forests play a crucial role in sustaining life on the planet [1]. They play a role in the regulation of global and regional climate systems [2]. They are carbon sinks [3], are very rich in biodiversity, and provide vital resources to human populations. Despite these multiple functions, the management of natural forests, particularly in arid and semi-arid areas in Algeria, is faced with a lack of data to understand the functioning of these ecosystems in terms of floristic composition, demographic structure, and regeneration. Therefore, developing strategies and approaches to sustainable management based on reliable scientific foundations remains very difficult [4]. The study of the structure of a forest formation serves as a basis for its silviculture, guides forest economics, allows the assessment of the state of degradation of ecosystems, helps to understand the past management history of stands and forest dynamics [5]. This work was designed to try to address concerns closely related to our goal of conservation and management of Aleppo pine plantations of the forest of El Hamimet. We aim here mainly, the knowledge of the dynamics and the evolution in time of the growth of Aleppo pine by integrating the parameters of competition.

MATERIAL AND METHODS

Presentation of the study area

Forest of El Hamimet is located north of Oum EL Bouaghi (Algeria). The forest spreads over an area of 1460 ha. Extreme altitudes of the forest are about 1039 m (maximum altitude) and 800 m (minimum altitude). Its bioclimatic is semi-arid to arid. The average annual rainfall is estimated at 378.75mm. It is generally a rugged relief with an average altitude of 848 m, with a slope of 12.5%. The geology of the forest is dominated by clay-limestone to limestone soils.

Dendrometric parameters

The location of the sample plots is the most essential point in any work, as it is the strategic point for determining the dendrometric characteristics of the stands. Moreover, circular plots are more interesting and usable because of their easy and quick installation in the field. Thus, they allow reducing considerably the number of doubtful cases of trees belonging or not to the plot [6].

The demographic structure was analyzed using the distribution of woody individuals in diameter and height classes.

Spatial location was estimated by two main factors, the degree of cover and the spacing factor. The degree of cover estimates the percentage of the ground surface covered by the canopy in relation to the percentage of the surface where light reaches the ground. Hart Becking's spacing factor [7] is used primarily to quantify and specify the degree of the vigor of a thinning; it gives a relationship between the average spacing "a" of trees and the dominant height of the stand.

RESULTS AND DISCUSSION

For the first diameter class (diameter < 7.5cm), regeneration exists in plots 1, 2, and 4 for Aleppo pine (Figure 1). The class of diameter 17.5cm to 27.5cm has a high rate in plots 1 and 4 because this species is dynamic and regenerates quite well [8]. Also, many individuals of this species are only at a youthful life stage. On the other hand, large-diameter stems are low (Plots 2 and 3) and non-existent (Plots 1 and 4).

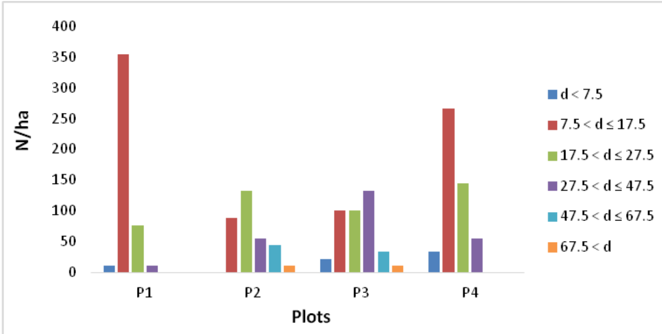

Fig. 1. *The number of trees by diameter classes.*

The height structure is given by the distribution of the number of stems in all plots per hectare for each height class and provides information on the vertical stratification of the stand. A large proportion of trees are between 4 and 10 m tall (saplings to low perch) with 1390 individuals, the 2 to 4 m class has a smaller number of individuals because of regeneration, which remains almost nil (Figure 2). There is an almost total absence of trees above 10 m (high perch to young forest or forestry).

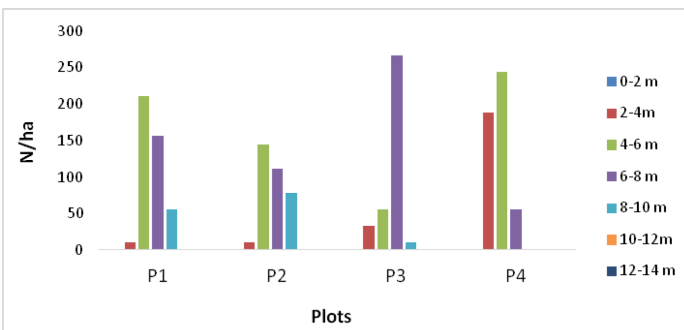

Fig. 2. *Distribution of the number of trees by height classes.*

The degree of cover represents the sum of the projections of the crowns of the trees of the stands compared to its total surface. When the degree of the cover of the stand is higher than 50%, the area is forested. When the degree of cover is less than 30%, the area is in principle non-forested. The degree of cover must be higher than 100% to judge the good stability of the stand. Indeed, a cover of 100% means a normal horizontal closure. The crown projection areas cover the entire land area under consideration [9]. The results obtained show that the degree of coverage of Aleppo pine is between 30 and 50% in all the plots, this shows that these stands have clear and open forest vegetation; the importance of the degree of coverage is due to the large extent of the tree crowns.

The spacing factor is expressed as a percentage and is mainly used to quantify the intensity of a thinning; it gives a relationship between the average spacing and the dominant height [10]. An average spacing around 4m is considered as an indicator of good viability for the spatial context [11]. Considering all diameter categories, the abundance of Aleppo pine is 425 individuals per hectare, which gives them an average spacing of 20.08 meters. The stands are thus characterized by a low density.

CONCLUSION

Monitoring a forest allows us to detect changes over time. Any living environment is constantly changing. The study of the dendrometric characteristics of *Pinus halepe*nsis according to the study plots showed that the density increased with the altitudinal gradient. The individuals of large diameter are totally absent in the different Aleppo pine stands. The silvicultural analysis provided knowledge on the forest stands, their size, their dynamism, their state of development, their structure. Finally, this state will constitute a reference for the next results of monitoring and decision for the foresters in the framework of management.

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STUDY OF THE VIABILITY OF ALEPPO PINE TREES BY USING PHF INDEX

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ABSTRACT

This work, which was conducted in the Chettaba forest about the viability of the stands can be given by the PHF index, a three-digit index that gives a judgment of the position of the tree (in relation to the others and thus indicating the dominance and the stage of competition or exposure to the dominant stage), of the general shape of the crowns, and of the shape of the shafts, it allows a more detailed silvicultural interpretation to predict the future of the stand and ultimately deduce the viability of the stands. Thus, there is an essential need for a study to be conducted in this regard to understand the existing problems and to bring about proposals on the appropriate intervention in logged surface. The slenderness coefficient of a tree is defined as the ratio of the total height (H) to the diameter at 1.3 m above ground level (d). For the stand level, the slenderness coefficient is calculated using the root mean square diameter and the average tree height as (H/D). It is well known that there is a direct relationship between the stand slenderness coefficient and the risk of stem breakage. It is well known that there is a direct relationship between the stand slenderness coefficient and the risk of stem breakage or tree fall due to abiotic factors such as wind or snow. Sustainability monitoring is crucial to the credibility, validation, value of the options implemented and should be considered early on in the planning process this allows us to say that these stands are stable in the forest and always in the 6 plots studied. Analyses results show a mid-viability for the forest and more of individual listed present instability which is indicated by a medium stability of forests stand's quality (PHF = 123) and a slenderness coefficient (H/D = 34.47).

Keywords: *Aleppo pin, stability, Viability, PHF. Slenderness coefficient (EC)*

INTRODUCTION

Aleppo pine (*Pinus halepensis* Mill.) plays an important role in the ecology and landscape of different countries around the Mediterranean basin. This pioneer and undemanding species is easily regenerated and capable of rehabilitating very poor and degraded soils. It is an essential component in reforestation strategy for limy soils in the arid or semi-arid climates around the Mediterranean basin, due to both its intrinsic ability to colonize and its effect in improving soils and microclimates [1]. In Algeria, the Aleppo pine occupies vast stands in Sidi Belabbes, Saida, Tlemcen, Tiaret, Medea and the Ouarsenis regions [2].

The Aleppo pine is a conifer native to the Mediterranean region. In Algeria, Aleppo pine, considered the most important and dominant local forest species covers a surface estimated at more than 800.000 ha. It is a typically Mediterranean species, easily adaptable to various eco-climatic conditions, which grants it the privilege of being the most often used tree species in the country’s reforestation programs [3].Our choice fell on the Aleppo pine which is one of the dominant species in this forest. Until now, no system of measurement or supervision of its viability was created so that the ecological status is unknown at all. The quality of the stands can be given by the PHF index, a three-digit index that gives a judgment of the position of the tree (in relation to the others and thus indicating the dominance and the stage of competition or exposure to the dominant stage), of the general shape of the crowns, and of the shape of the shafts [4], it allows a more detailed silvicultural interpretation to predict the future of the stand and ultimately deduce the viability of the stands.

MATERIAL AND METHODS

Presentation of the study area

Forest of Chettaba is located southwest of Constantine (Algeria). The estimate terrain elevation above sea level is 865 meters. The study area is located on the map topographic Constantine Scale 1/200 000 sheet N° 17 and located between the coordinates 36°19'4" north latitude and 6°28'36" East longitude. The forest of Chettaba spreads over an area of 2398 ha and 94a, and is perfectly limited and divided into six districts. Extreme altitudes of the forest is about 1104 m (maximum altitude) and 652 m (minimum altitude), corresponding to each of them respectively following map coordinates: (x = 839, y = 344), (x '= 839.9, y' = 340.3). Its bioclimatic is semi-arid to sub-humid. The average annual rainfall is estimated between 670 and 800 mm and the mean annual temperature of the region is 18°C, with an average of the warmest month above 35°C and the coldest month varies between 1.25 and 3.05°C. A large plant grouping as the forest of Chettaba can be studied in its entirety, especially when it concerns hundreds of acres to be treated in the detail.

Dendrometric data collection inventory and description of the stands are a prerequisite for any successful forest management and sylvicultural planning [4]. We are interested in achieving this inventory to highlight the structure, stand density and the difference of perspective development for each station. The structure of the stand is defined as the manner in which these are arranged dendrometric variables [5].The tree inventory was conducted in each plot.

Analysis of the quality of the stands

The slenderness coefficient (EC) is the ratio between total height and diameter that reflects the stability of a forest stand or a single tree [6]. According to

Rajoelison et al. [7], a forest stand is considered stable when the ratio h/d<100. There EC is given by the following formula: CE = H/D

Estimation of the vitality state of Aleppo pine by the PHF Index

The quality of the stands can be given by the PHF index (three-digit index) which gives a judgment of the position of the tree in relation to the others and thus indicating the dominance and the stage of competition or the exposure towards the dominant stage (P), the general shape of the crowns (H) and the shape of the shafts (F). It allows a more detailed silvicultural interpretation to predict the future of the stand [5] and ultimately deduce the viability of the stands [7].

RESULTS AND DISCUSSION

The results obtained for the P index show that 25 individuals/ha (P2) and 24 individuals/ha (P3), have a crown in full light, completely free from above and laterally, they are mostly dominant trees. Trees of Aleppo pine stands have a crown in full light from above but covered laterally are 39.87%; the maximum value is obtained in plot 2 (100 individual/ha) while the minimum value is 10 individual/ha is encountered in plot 6. For trees with partially free crowns and full light from above (intermediate) and trees with covered crowns, without light from above and partially illuminated laterally, their percentages are respectively 10.74 and 25.98%; while trees with fully covered crowns, without direct light, present the lowest percentage in plot 5 and 6 (Fig. 1).

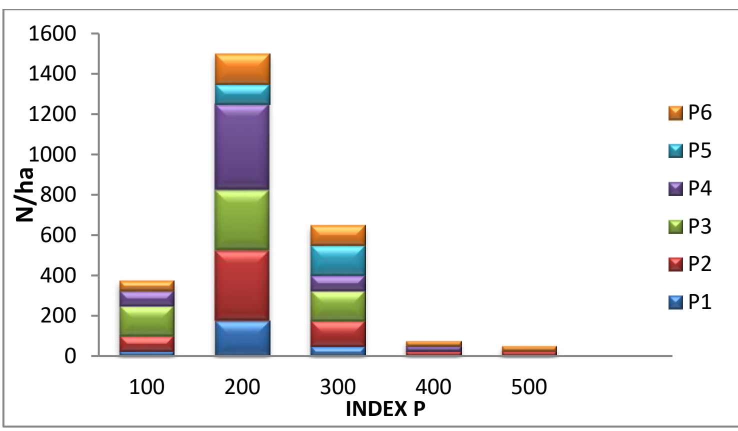

Fig.1. *Proportion of the number of stems by P index.*

The results of the H index indicate that the trees with a perfect crown, circular in symmetry, dense and extensive have a low percentage; they are trees of the dominant stage with a very good exposure to the sun. Half of the Aleppo pine individuals have a more or less circular crown in plan with some symmetry deficiencies or with some dead branches and their percentage is 60% (these are the co-dominant trees); the maximum values are obtained in plot 2 and 3 (100 and 175 individuals/ha) while the minimum values is 50 individuals/ha which is met in plots 1 and 5. For individuals have a tolerable, partially asymmetrical and open crown and trees have a strongly asymmetrical crown with only a few green and dense branches, but still having the appearance of a tree that can survive (Fig. 2).

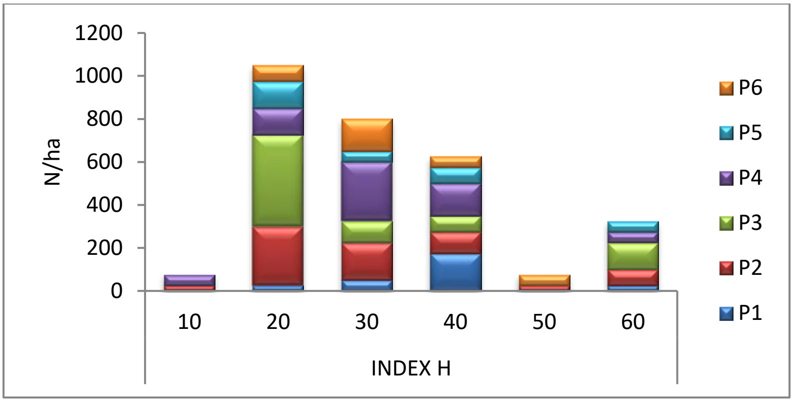

Fig. 2. *Proportion of the number of stems by H index.*

The results obtained from the F index show that Aleppo pine trees have a straight, round and full bole; cylindrical, without defects and without branches represent the majority of trees in the studied stand of trees have a straight, cylindrical, slightly bulging, full bole for division into sections, without defects and without branches. This type of bole provides partly veneer wood (Fig. 3). Trees with a partially straight, curved bole up to 1.8 meters high, partly cylindrical, generally conical and without defects and which have good saw wood, have a low rate. The trees have a very irregular, much forked and twisted, conical bole with clearly visible defects; they are mainly used as energy wood and have a rather low percentage (5.61%). The lowest percentage of the F index is obtained in plots (1) (5) and (6).

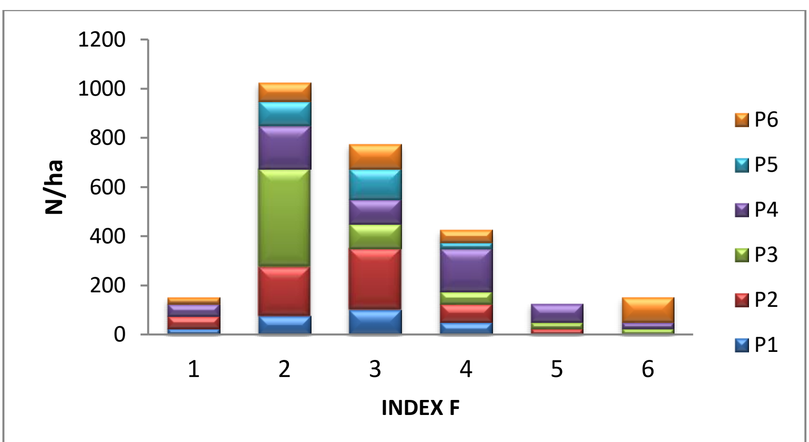

Fig.3. *Proportion of the number of stems by F index.*

The quality of the stands studied according to the PHF index is rather variable between the different plots. Plots 2, 3 and 4 has the best quality compared to other plots which allows us to deduce their good viability and their large competitor aspect especially towards the dominant stage.

The slenderness coefficient (EC) gives an idea of the ecological stability of forest species. For better stability, the value of the coefficient should be close to 100 [8]. The plots 4, 2, 3 and 1 with an average diameter between 24.39 and 30.59 cm, have slenderness coefficients between 30.59 and 41.90 and 28.94 therefore less than 100; this means that these stands are stable and regular [9]. Plots 5 and 6 with a slenderness coefficient of around 28.51 to 28.94 represent the most stable stand, the most resistant to wind; snow and wind throw with a strong competitive power [10]. This allows us to say that these stands are stable in the forest and always in the 6 plots studied (Table 2).

Table 2. *Quantitative characteristics of the stands.*

Plots	H (m)	D (cm)	H/D	N/ha
P1	9.03	30.61	30.59	250
P2	9.29	25.65	37.97	600
P3	10.02	26.42	38.88	600
P4	9.71	24.39	41.90	600
P5	9.28	32.99	28.51	250
P6	7.79	28.68	28.94	350

CONCLUSION

In conclusion, this research has proved that the forest of Aleppo pine has been the subject of anthropic and biologic pressures and analyses results show a mid viability of these species. This is indicated by a medium stability of forests stand’s quality (PHF = 123). And with have slenderness coefficients (H/D = 34.47 therefore less than 100; this means that these stands are stable and regular; this allows us to say that these stands are stable in the forest and always in the 6 plots studied. summarizes the quality of the stands studied according to the PHF index; this quality is rather variable between the different plots.

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THE CURRENT ECOLOGICAL STATUS OF ALEPPO PINE OF EL HAMIMET FOREST (ALGERIA)

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ABSTRACT

The forest of El Hamimet, Oum el Bouaghi is a forestry and ecotourism site. Managed by the Oum El Bouaghi Forestry Department, this forest is made up of several silvicultural species (conifers) spread over an area of 1460 ha. The objective of this study is to characterize the current ecological status of Aleppo pine in El Hamimet forest (Algeria). The inventory of softwoods allowing a complete knowledge of quantitative data on the basis of dendrometric parameters collected on 4 plots. The results indicate that the floral diversity is low, characterized by 3 species. The highest abundance is marked in plot 1 with 389 individual/ha, while plot P3 has the highest volume with about 211.58 m^3/ha. The vertical structure shows that the 3-5m class is the most abundant. Indeed, this work will provide a solid reference for future follow-up studies for Aleppo Pine.

Keywords: *Aleppo pine, Ecological status, Inventory, structure*

INTRODUCTION

The richness of the national biodiversity is a reflection of the ecosystem diversity. Algeria's mountainous massifs harbor significant biological diversity. Among the flora species, Algeria has a large number of trees and shrubs. Of the 70 tree taxa of the spontaneous Algerian flora, 52 species are found in mountainous areas. The forest wealth of the El Hamimet forest (Oum El Bouaghi, Algeria) is made up of a heritage that consists of Aleppo pine, holm oak, juniper, cypress and other trees of different species [1]. However, this richness is subject to latent degradation that can in the long term lead to harmful consequences both ecologically and socio-economically [2].

The most important risk factors for the reduction of biodiversity are, on the one hand, natural factors (drought, fires, floods, etc.) and, on the other hand, various human activities: destruction and/or overexploitation of biological resources, overgrazing, extension of cultivated land, development of the urban framework, development of infrastructure works, pollution, tourism, hunting and poaching. Forest biodiversity is in decline in most of Algeria's forest regions. Indeed, in addition to the natural vulnerability that characterises Mediterranean forests and sub-forestry formations, Algerian forests continue to be subjected to various and repeated pressures that considerably reduce their vegetal, hydric and edaphic potential.

The estimation of resources, at the level of a region or a country, is the prerequisite for any forestry policy worthy of the name. From this point of view, the forest inventory is a fundamental tool for obtaining quantitative data on these resources. The objective of this work is to obtain information on the characteristics of the woody resources (height, diameter, basal area, volume, etc.) and on the quantitative relationships between them. This will help to take care of this forest formation by considering all the ecosystems connected to it and by studying various alternatives for the development and conservation of all the forest species found in the El Hamimet forest, which would contribute to its protection.

MATERIAL AND METHODS

Presentation of the study area

Forest of El Hamimet is located north of Oum EL Bouaghi (Algeria). The forest spreads over an area of 1460 ha (Fig. 1). Extreme altitudes of the forest are about 1039 m (maximum altitude) and 800 m (minimum altitude). Its bioclimatic is semi-arid to arid. The average annual rainfall is estimated at 378.75mm. It is generally a rugged relief with an average altitude of 848 m, with a slope of 12.5%. The geology of the forest is dominated by clay-limestone to limestone soils.

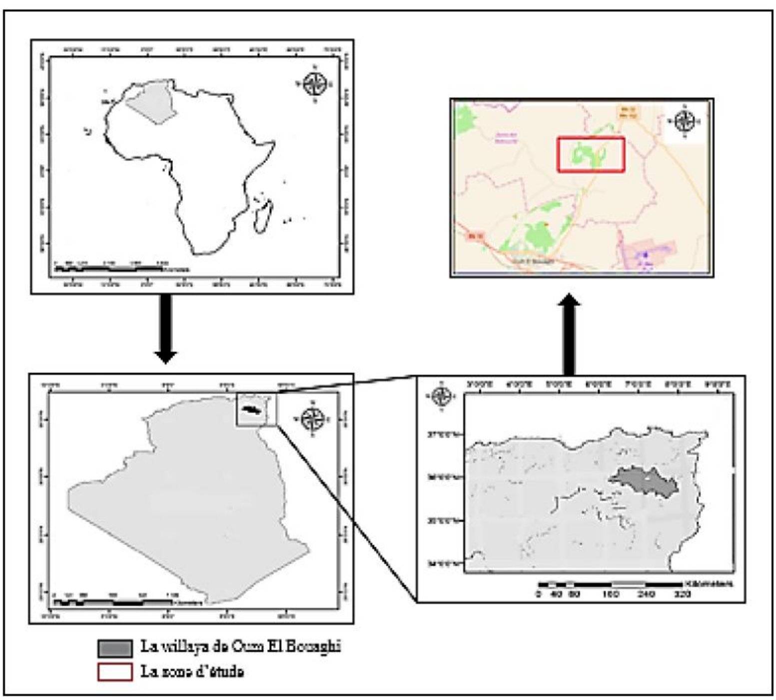

Fig. 1. *Study area (Forest of El Hamimet.*

Dendrometric parameters

Only individuals of *Pinus Halepensis Mill* present in the plots were measured. The dendrometric parameters measured were the circumference at chest height

DHP (1.30 m from the ground) and the total height. The diversity indices considered in this study are the most commonly used in the literature were selected in the (Table 1).

Table 1. *Diversity indices.*

Index	Formula	Measuring diversity
Abundance	$N = (n\ 10000)/(S)$	n: total number of individuals. S: the area (m^2) of the plot.
Dominance	$Gi = \Sigma\ g = \Sigma\ (\pi * Di^2/\ 4)$	g: Basal surface of individual i Gi: Basal area of the plot Di: DHP
Shannon-Wiener (H')	$H' = \sum_{i-1}^{S} \text{Pi} \ln \text{Pi}$	Pi: ni/N. S: number of species ni: number of individuals of a species N: total number of individuals of all species in the plot.
Simpson (Ds)	$Ds = 1 - \sum \frac{[ni(ni-1)]}{[N(N-1)]}$	ni: number of individuals in species i. N: total number of individuals.
Mixing Coefficient (MC)	$CM = \frac{S}{N}$	S: number of species. N: total number of stems inventoried.

RESULTS AND DISCUSSION

In order to determine the structure of the stand studied, inventory work is considered the best means, but it is the appropriate methods that are different according to the environments and data searched. The inventory of ligneous trees carried out in the 4 plots identified 3 species (*Pinus halepensis, Cupressus sempervirens, Eucalyptus sp.*), grouped into 3 families (*Pinaceae, Cupressaceae and Myrtaceae).*

The results show that the mixing coefficient (MC) is used to determine the distribution of species among the individuals present in each plot [3], the plot (P4) has the highest floristic diversity with (MC=2/378). This MC value indicates that after each (378) trees, two species appear. This mixing coefficient shows that (P4) has a high number of species in relation to the total number of trees inventoried. The species in the plot (P3) are the least diversified, with (CM=1/389), this can be interpreted by the abundance of the *Pinus Halepensis*, which makes this formation more or less homogeneous (Table 2).

In plots 4 and 3 (H'=1.30; H'= 1.27) the index is highest when all individuals are equally distributed over all species, which means the Aleppo pine dominates all four forest plots [4]. The results of the Simpson index are identically comparable to those of the presiding indices, the index is maximum (Ds = 0.7) for the plots (P4 and P3) this means that the species dominance for these two plots is assimilated.

Table 2. *Diversity indices.*

Plots	CM	H'	Ds
P1	2/467	0.85	0.58
P2	1/334	0.67	0.48
P3	2/389	1.27	0.7
P4	2/378	1.30	0.70

Only individuals of *Pinus Halepensis Mill* present in the plots have been measured. The abundance, dominance and total volume are used to determine the horizontal structure of forest stands [5]. Abundance is high in plot 1; while dominance is higher in plot 4. Diameter, height and total volume are highest in plot 2 (Table 3).

Table 3. *Dendrometric characteristic of forest stands.*

Plots	N/ha	D (cm)	H (m)	H/D	G (m^2/ha)	V (m^3/ha)
P1	389	15.31	5.72	39.23	7.80	44.62
P2	344	29.88	6.41	25.89	33.01	211.58
P3	156	24.54	4.64	26.47	8.87	52.75
P4	378	29.84	5.95	30.60	37.68	209.13

The vertical structure of the forest stand is determined from the determination of height classes. The most dominant height structure of *P. halepensis* is between 3 and 5m. The height/diameter ratio (H/D) is used sometimes at the stand scale, sometimes referred to as a "stability factor", to quantify the risks of significant windthrow. The slenderness coefficient gives an idea of the ecological stability of the softwood layer. For best stability, the value of the coefficient should be close to 100 [6]. Considering the H/D ratio, softwoods have the most favourable values. Therefore they are subject to too much competition and should not be able to withstand the wind well. They have a height that is far too high in relation to their diameter. This growth rate is explained by their strong competitive power [7]. For the four plots with an average diameter between 15 and 30 cm, the slenderness coefficients are between 25 and 39% and therefore below 100, which means that these stands are stable and regular. *Pinus halepensis* with a slenderness coefficient of around 26% (P2) represents the most stable stand, the most resistant to wind, snow and windthrow with a strong competitive power [8].

CONCLUSION

The forest of El Hamimet (Algeria), is considered a very rich forest area in terms of biological diversity. This forest is composed mainly by Aleppo pine and cypress which are currently in a healthy and sometimes stressed state. The Aleppo pine and cypress are very interesting reforestation species in terms of wood production, soil protection and the development of tourist and leisure activities. This study allowed the dendroecological characterization of natural stands of *Pinus halepensis* in plots at different exposures of the El Hamimet forest. This forest is characterized by the dominance of large diameter individuals and small diameters are rare in all plots. The results of this research constitute a descriptive and analytical diagnosis that deserves to be extended to other Aleppo pine forests in semi-arid zones in Algeria in order to obtain more information on the behavior of this species and to propose silvicultural treatments to ensure better protection of natural pine forests that have been threatened for several decades.

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THE EFFECT OF ALTITUDE ON THE STRUCTURE OF ALEPPO PINE TREES IN THE CHETTABA FOREST (ALGERIA)

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ABSTRACT

Knowledge of vegetation characteristics is necessary for the management of disturbed areas. The aim of this study was to investigate the effect of elevation on tree structure in Aleppo pine spatial systems in the Chettaba forest, located in northeastern Algeria. An inventory of trees of *P. halepensis* forest formations was conducted based on dendometric parameters (tree diameter and height) which were measured on 4 plots (30 m × 30 m). The results obtained showed that the average height varies from 7.79 cm to 9.71 cm, while the average diameter appears from 24.39 cm to 30.61 cm, respectively. The height-diameter relationship of the trees varies with the altitude horizons (774 m to 1023 m). The Weibull theoretical distribution was used to characterize stand structure, due to its flexibility and the wide variability of distribution shapes it produces. Management measures, such as full protection of forest relics, will have to be implemented.

Keywords: *Structure, Altitude, Aleppo pine, Dendrometric characteristics*

INTRODUCTION

Among the useful forest species recorded in Algeria, *Pinus halepensis* has a very wide geographical distribution, covering more than 850.000 hectares [1]. This species, which is present in all bioclimatic stages from the coast to the Saharan Atlas, finds its optimum growth mainly in semi-arid zones [2]. Its plasticity and robust temperament enable it to withstand drought and high temperatures. Thus, its great capacity for survival on poor and much-degraded soils permits a very heterogeneous spatial distribution according to bioclimatic stages. The spatial structure of tree species appears to be a determining factor in their regeneration, growth, resource use, and mortality processes [3]. Indeed, it helps to detect the local environment of each individual and consequently, through the processes of competition, its capacity to develop and grow, or its probability of exclusion [4]. Stand structure and biodiversity are two important and interrelated ecological and functional features of the forest ecosystem [5]. Tree diameter structure, density, basal area and height are influenced by environmental factors, such as altitude, slope, light [6], land use types or vegetation formations [7]. Therefore, the analysis of vegetation structure and variability are indicators for testing the ecological theory of ecosystem functioning [8] and understanding its dynamics.

The target of this research is to characterize the effect of altitude variation on stucture of *Pinus halepensis* populations of Chettaba forest.

MATERIAL AND METHODS

Presentation of the study area

Forest of Chettaba is located southwest of Constantine (Algeria). The estimated terrain elevation above sea level is 865 meters. The study area is located on the map topographic Constantine Scale 1/200 000 sheet N° 17 and located between the coordinates 36°19'4" north latitude and 6°28'36" East longitude. The forest of Chettaba spreads over an area of 2398 ha and 94a, and is perfectly limited and divided into six districts. Extreme altitudes of the forest is about 1104 m (maximum altitude) and 652 m (minimum altitude), corresponding to each of them respectively following map coordinates: (x = 839, y = 344), (x '= 839.9, y' = 340.3). Its bioclimatic is semi-arid to sub-humid. The average annual rainfall is estimated between 670 and 800 mm and the mean annual temperature of the region is 18°C, with an average of the warmest month above 35°C and the coldest month varies between 1.25 and 3.05°C. A large plant grouping as the forest of Chettaba can be studied in its entirety, especially when it concerns hundreds of acres to be treated in the detail (Fig. 1).

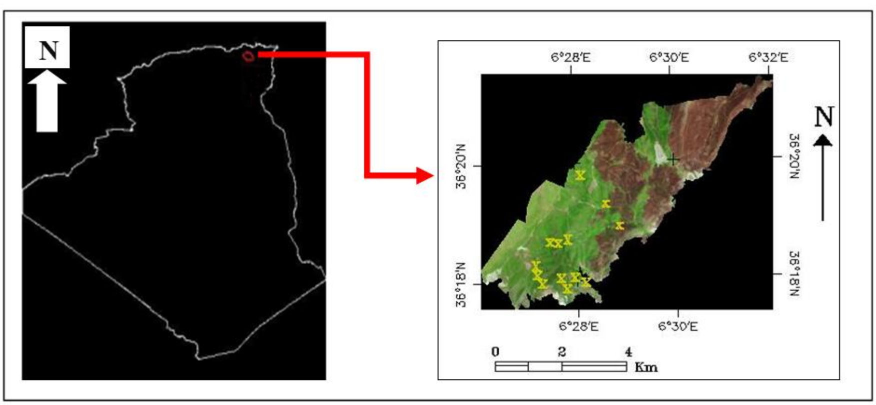


Fig. 1. *The map of study area.*

Dendrometric parameters

Dendrometric data collection inventory and description of the stands are a prerequisite for any successful forest management and sylvicultural planning. We are interested in achieving this inventory to highlight the structure. The structure of the stand is defined as the manner in which these are arranged dendrometric variables. The tree inventory was conducted in each plot. Dendrometric measurements are:

- The circumference (C) at 1.30 m is estimated with a tape measure.
- The total tree height (H) measured with the "Smartphone".

Data processing and analysis

The data obtained were entered into the Excel spreadsheet, which allowed us to determine the ecological characteristics and structure of the natural of Aleppo pine population.

- The density (N) or number of individuals per hectare.
- Basal area (G in m^2/ha).
- The total volume (V) depends on the basal area and the height of the individuals.

RESULTS AND DISCUSSION

In general, the dendrometric parameters of *P. halepensis* vary significantly ($P < 0.0001$) with the altitudinal gradient. The relative density of the stand is too high in plot P4 with 267 individuals/ha, whereas plot P1 shows a very low abundance with 78 individuals/ha. The basal area and total volume of *P. halepensis* are significantly different between the four plots; plot P2 has the highest average of 1.35m^2/ha and 12.53m^3/ha respectively. The smallest diameter is observed in plot P2 (25.65cm) (Tab. 1).

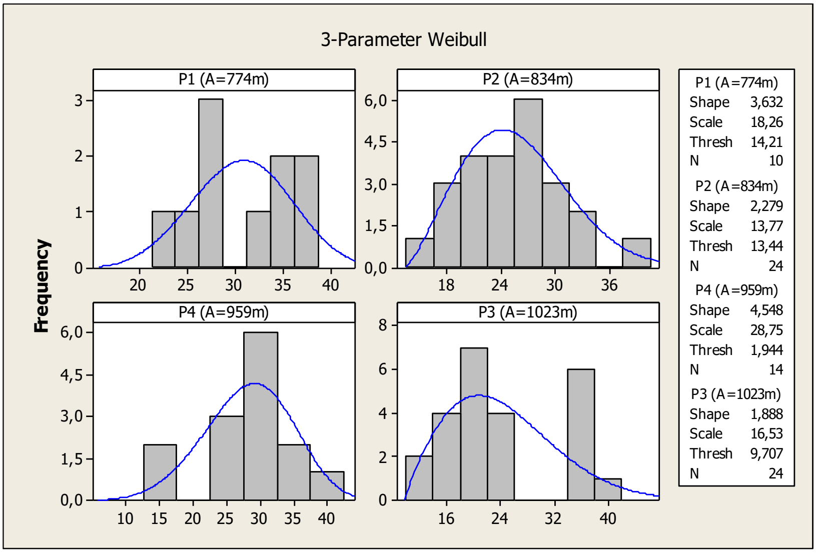
Table1. *Principal dendrometric characteristics.*

Altitude (m)	N/ha	D (cm)	H (m)	G (m^2)	V (m^3)
P1 (774)	78	30.61	9.03	0.76	6.86
P2 (834)	267	25.65	9.28	1.35	12.53
P3 (959)	167	28.68	7.79	1.02	7.79
P4 (1023)	267	24.39	9.71	1.24	12.04

The distribution of trees in diameter classes shows a different situation depending on the altitudes (Fig. 2). For each stand and each population concerned, tree diameter or height data were used to estimate the parameters a, b and c using the maximum likelihood method available in MINITAB (2018). The Weibull distribution can take several forms depending on the value of the shape parameter c. A very highly significant difference between the diameter classes in terms of their frequencies is noted in the diameter structure of different plots. This is quite obvious since in such a structure young individuals are clearly more frequent than mature ones [9]. In Figure 2, the distribution is right asymmetric or positive asymmetric, characteristic of monospecific stands with a predominance of young or small diameter individuals in plots 2 and 4; whereas the distribution is left asymmetric or negative asymmetric, characteristic of monospecific stands with a predominance of old or large diameter individuals in plots 1 and 3.

By analysing the height structure of 4 forest plots, it can be seen that the height distribution is in the form of an "inverted J", characteristic of multispecies or uneven-aged stands in plot 2. The shape parameter varies from 1.40 in plot 4 to 2.53 in plot 3; the diameter distribution for *P. haleensis* shows a negative exponential shape (Fig. 3), an "inverted J" and a straight skewness. The negative or left-skewed distribution in plot 1 is characteristic of monospecific stands with a predominance of older individuals. Trees with a height of 4 to 8 m are the most numerous per hectare. Trees taller than 36 m are poorly represented in the different plots.

Fig. 2. *Diameter structure of Aleppo pine stands.*



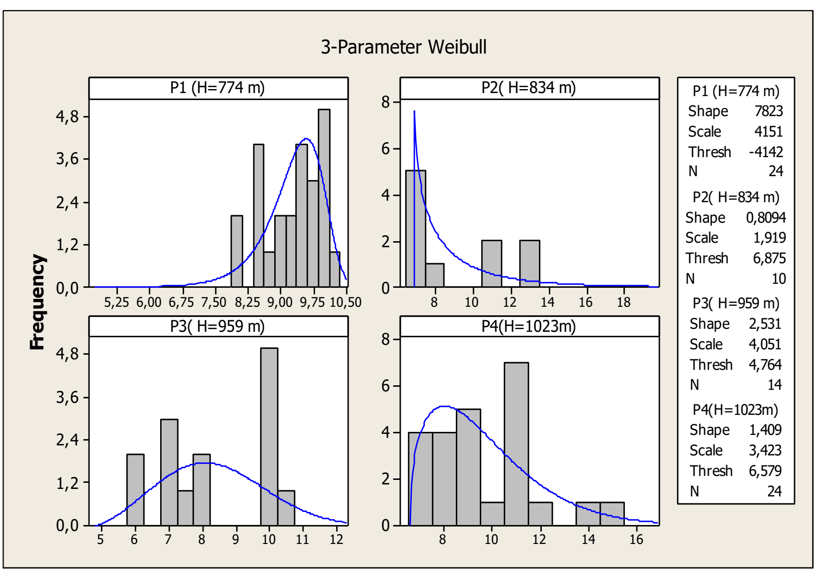


Fig. 3. *Height structure of Aleppo pine stands.*

CONCLUSION

The present study allowed for the structural characterisation of Aleppo pine in relation to the altitude of the Chettaba forest. The results revealed that the forest is still in an evolutionary dynamic but is under some selective pressure, especially from anthropic action and summer fires. This means that conservation strategies should be more oriented towards target species groups to ensure the conservation of the biological diversity of this forest. The structural variability of the vegetation of the Chettaba forest is evident and becomes more and more pronounced with increasing altitude. This variability should be taken into account when trying to understand the functioning of this ecosystem, especially its role in the accumulation of above-ground woody biomass, in order to mitigate the negative effects of climate change. But also with the aim of improving their management and development system.

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THE NORMALIZED DIFFERENCE VEGETATION INDEX AS AN INDICATOR OF DYNAMICS

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ABSTRACT

Mediterranean ecosystems are considered particularly sensitive to climate change. Any change in climatic factors affects the structure and functioning of these ecosystems and has an influence on plant productivity. The main objective of this work is to characterize one of the Mediterranean ecosystems; the Chettaba forest massif (located in the North-East of Algeria) from a vegetation point of view and their link with monthly variations using Landsat 8 satellite images from five different dates (June 25, 2017, July 27, 2017, August 28, 2017, October 15, 2017). The comparison of NDVI values in Aleppo pine trees was performed using analysis of variance and the use of Friedman's non-parametric test. The Mann-Kendall statistical method was applied to the monthly distribution of NDVI values to detect any trends in the data over the study period. The statistical results of NDVI of Aleppo pine trees indicate that the maximum value is recorded in the month of June, while the lowest values are observed in the month of August where the species studied is exposed to periods of thermal stress.

Keywords: *Pinus halpensis, NDVI, Friedman's test, monthly variations*

INTRODUCTION

Forest degradation has become a serious problem, particularly in developing countries. In 2000, the total area of degraded forests in 77 countries was estimated to be 800 million hectares, of which 500 million hectares had been converted from primary to secondary vegetation [1].

Among its various negative impacts, the process of forest degradation constitutes a significant part of greenhouse gas emissions. There is an urgent need to measure and analyze this process in order to design actions that can reverse it.

This work describes how a method combining the analysis of remote sensing data and field data to observe forest degradation has been put into practice. It presents a study conducted to identify the relationship between indicators of forest functions and the normalized difference vegetation index (NDVI). This index provides estimated values of the "green intensity" of forests, resulting from the analysis of satellite data. The approach is based on the principle that NDVI is an indicator of plant health, insofar as a degradation of the vegetation of an ecosystem, or a decrease in the intensity of green, would result in a decrease in the value of NDVI.

The forest massif of Chettaba (Algeria) is part of the Mediterranean basin, and it is constituted of a very important floristic richness, in particular a mixed forest of holm oak - Aleppo pine, maquis and grasslands accounting for a total area of 2398 ha. On the orographic plan, these forest groups are distributed between 755m and 1292m of altitude. The monthly climatic variations are effectively perceived, namely the thermal variability on the concerned massif. The objective of this work is to monitor the evolution of the degradation process by using GIS (Geographic Information System), aerial photos and satellite imagery will allow establishing maps of distribution, thermal and normalized vegetation index (NDVI).

MATERIAL AND METHODS

Description of the study site

The state forest of Chettaba belongs to the watershed Kebir Rhumel; it is located southwest of Constantine, south of Ibn Ziad, north of Ain Smara and east of Oued Athmania. It covers an area of 2398ha 94a 30ca. The altitude varies between 755 m to 1292 m (Figure 1) of which 34.63% of the area is represented by the class of altitude from 855m to 955m (Figure 2).

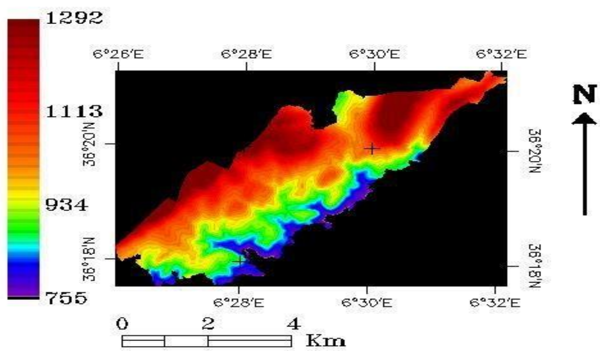

Fig. 1. *Hypsometric map of Chettaba forest using ENVI 5.1 software.*

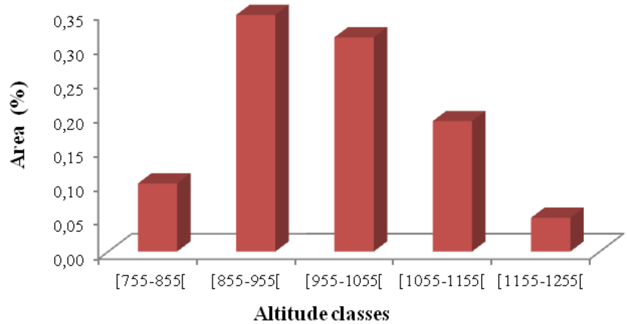

Fig. 2. *Distribution of altitude classes in the Chettaba forest.*

Study methodology

Choice of the stations

In order to carry out this work, field investigations have been adopted through observation. The objective is to determine the typology of these formations as well as the plant species that compose it. Stations of 30m by 30m were randomly selected in order to explain their phenological character with the help of satellite images (Figure 3).

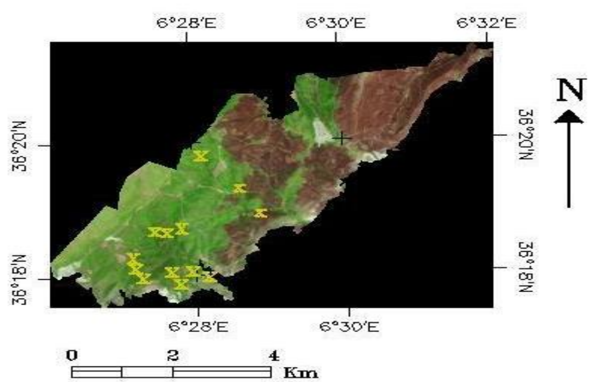

Fig. 3. *Location of study stations on a true color composition of the Landsat 8 (June 25, 2017 using ENVI 5.1 software).*

Calculation of the Normalized Vegetation Index (NDVI)

Before analyzing the selected images, it is necessary to correct them in order to make them usable and comparable. The pre-processing corresponds to a set of operations on Landsat 8 satellite images of five different dates (June 25, 2017, July 27, 2017, August 28, 2017, October 15, 2017), which aim to modify the raw images according to three aspects: a correction of geometric, radiometric and atmospheric distortions using ENVI 5.1 software. The calculation of the normalized vegetation index (NDVI) is based on two spectral bands, red R and infrared IR [2] using the following formula:

$$NDVI = (PIR - R)/ (PIR + R)$$

Statistical analysis

The comparison of NDVI values in Aleppo pine trees was performed using analysis of variance and Friedman's non-parametric test. The calculations were performed using the XLSTAT 2019 version 1.2 software.

The Mann-Kendall statistical method [3], [4] was applied to the monthly distribution of NDVI values to detect any trends in the data over the study period. It is a non-parametric statistical test well suited to measure changes in data over time [5]. Positive values (+) indicate an increase over time while negative values (-) indicate a decrease. The test observes whether a random response variable increases or decreases monotonically over time.

RESULTS AND DISCUSSION

The results of the descriptive statistical analysis of the variance of NDVI of Aleppo pine trees indicate that the maximum value is recorded in June, while the lowest values are observed in August (Table 1).

Table 1. *Results of the descriptive statistical analysis of the NDVI values of Aleppo pine.*

NDVI	Observations	Observations without missing data	Minimum	Maximum	Average	Type of Gap
25/06/2017	21	21	0.186	0.310	0.237	0.033
27/07/2017	21	21	0.185	0.285	0.231	0.029
28/08/2017	21	21	0.148	0.236	0.194	0.024
13/09/2017	21	21	0.155	0.268	0.215	0.028
15/10/2017	21	21	0.132	0.253	0.197	0.031

In order to determine whether the samples are from the same population or not, we applied the Friedman test (Figure 4). Applied the Friedman test, the proposed hypotheses are:

H_0: The samples come from the same population.

Ha: The samples come from different populations.

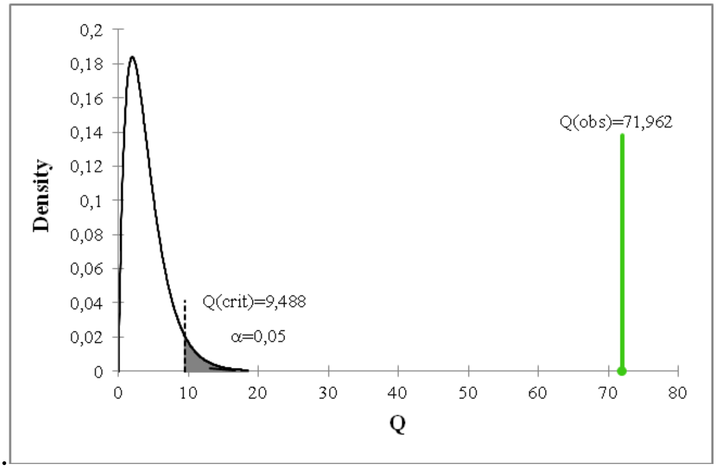

Fig.4. *Friedman's test of NDVI values of Aleppo pine.*

During the statistical calculations, the F-test of the analysis of variance (at the probability threshold (α=0.05) proved to be highly significant (*p* < 0.0001). Since the calculated p-value is below the significance level α=0.05, the null hypothesis H_0 should be rejected, and the alternative hypothesis Ha should be retained (Table 2). Great variability of the NDVI values of Aleppo pine trees has been highlighted. This is probably directly related to the months.

Table 2. *Friedman's test results.*

Q (Observed value)	71.962
Q (Critical value)	9.488
DDL	4
p-value (unilateral)	< 0.0001
Alpha	0.05

Pairwise multiple comparisons following the Nemenyi procedure indicate the presence of four Presences of four homogeneous groups, where group A corresponds to the NDVI values of August and October with the lowest values, and the last group includes the NDVI values of June with the highest values (Table 3).

Table 3. *Multiple pair-wise comparison of NDVI values following the Nemenyi/Two-Way Test.*

Sample	Workforce	Sum of the ranks	Average of the ranks	Groups
25/06/2017	21	29.000	1.381	A
27/07/2017	21	34.000	1.619	
28/08/2017	21	67.000	3.190	B
13/09/2017	21	89.000	4.238	BC
15/10/2017	21	96.000	4.751	C

Concerning the month effect, the analysis of variance showed a very highly significant effect on significant effect on the variation of NDVI values for the trees studied (Figure 5). The statistical analysis of variance revealed a very highly significant interaction (NDVI * Month). The month factor has a strong influence on the variation of NDVI values of Aleppo pine trees.

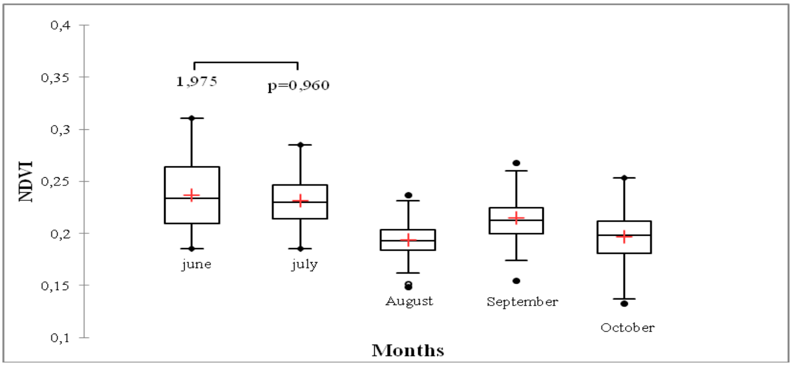

Fig. 5. *Box plots of NDVI values by month.*

CONCLUSION

There are limitations to the use of NDVI as a measure of forest degradation, but also areas of potential refinement. Since phenology plays an important role in the analysis of change processes, the dates of Landsat 8 satellite images used to assess these processes must be selected very carefully. These images are suitable for the analysis of changes resulting from degradation, when the impact has been large enough to be reflected in the radiometry, and thus in the NDVI. NDVI has an anticipated behavior and can therefore be used as an indicator.

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TREE SPECIES DIVERSITY AND SPATIAL DISTRIBUTION OF HOLM OAK STANDS IN CHETTABA FOREST (ALGERIA)

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ABSTRACT

The forest of Chettaba is for ecotourism. Managed by the Forest Conservation of Constantine, this site is formed of several forestry species (hardwood and softwood) spread over an area of 3010 ha. The objective of this study is to estimate the viability of this site through the permanent monitoring of the current state of the forest including biodiversity and pressures. The collection of data related to it had recourse to a forest inventory and an inventory of pressures. The condition was assessed by analyzing these components. The various analyses conducted during this study revealed that the forest is subject to biotic and abiotic pressures and average viability. This is induced by a fairly good stand quality (PHF= 333), medium stability (S= 44.45), low mortality (MR = 4.16%) and good future potential (high regeneration rate (RR =231.25%). Grazing, fire and illegal logging are the most important pressures. Despite these pressures, the forest is classified as a viable ecosystem. However, these potentials are insufficient: it is necessary to reduce the pressures and reforest the degraded plots for better conservation of the ecosystem. To this end, the present study suggests management primarily through silvicultural interventions that promote the regeneration of the various species and to include a permanent ecological monitoring system.

Keywords: *Quercus ilex, Viability, PHF, Pressions*

INTRODUCTION

Forests play a crucial role in sustaining life on the planet [1]. They play a role in the regulation of global and regional climate systems [2]. They constitute carbon sinks [3], are very rich in biodiversity and provide vital resources to human populations. Despite these multiple functions, the management of natural forests, particularly in arid and semi-arid areas in Algeria, is faced with a lack of data to understand the functioning of these ecosystems in terms of floristic composition, structure and regeneration. Consequently, developing sustainable management strategies and approaches based on reliable scientific foundations remains very difficult [4]. However, data concerning the structural characteristics and dynamics of plant species are unfortunately not documented. The study of the structure of a forest formation serves as a basis for its silviculture, guides forest economics, allows the assessment of the state of degradation of ecosystems, helps to understand the past management history of stands and forest dynamics [5].

The holm oak is the main species of the state forest of Chettaba which covers an area of 2398ha where it occupies 1127ha. However, during the last decade, particular attention and scientific and forestry interest have been expressed for this species.

The objectives of this paper are to collect data on the current ecological status of the Chettaba forest and identify its level of viability. This database will be a reference tool to assist in decision-making for forest service managers, because good management of forest stands, first of all, requires a good knowledge of their structures.

MATERIAL AND METHODS

Presentation of the study area

The forest of Chettabah is located southwest of Constantine (Algeria). The estimated terrain elevation above sea level is 865 meters. The study area is located on the map topographic Constantine Scale 1/200 000 sheet N° 17 and located between the coordinates 36°19'4" north latitude and 6°28'36" East longitude. The forest of Chettaba spreads over an area of 2398 ha and 94a, and is perfectly limited and divided into six districts. Extreme altitudes of the forest is about 1104 m (maximum altitude) and 652 m (minimum altitude), corresponding to each of them respectively following map coordinates: (x = 839, y = 344), (x '= 839.9, y' = 340.3). Its bioclimatic is semi-arid to sub-humid. The average annual rainfall is estimated between 670 and 800 mm and the mean annual temperature of the region is 18°C, with an average of the warmest month above 35°C and the coldest month varies between 1.25 and 3.05°C. A large plant grouping as the forest of Chettaba can be studied in its entirety, especially when it concerns hundreds of acres to be treated in the detail.

Dendrometric parameters

Dendrometric data collection inventory and description of the stands are a prerequisite for any successful forest management and silvicultural planning. We are interested in achieving this inventory to highlight the structure, stand density and the difference of perspective development for each station. The structure of the stand is defined as the manner in which these are arranged dendrometric variables. The tree inventory was conducted in each plot. Dendrometric measurements are:

- The diameter (D) at 1.30 m is estimated using calipers;
- The circumference (C) at 1.30 m is estimated with a tape measure;
- The total tree height (H) measured with the "Smartphone". The Swedish unit is, recommended in this type of study requiring maximum precision; the permissible error is negligible with direct readings that require no calculation. The measurement accuracy

depends on the quality of the inclinometer of Apps and stability with which the device is held.

- The basal area of a stand is the area of all cross-sections of trunks, 1.30 m tall, and the trees on one hectare of forest. It is expressed in m^2/ha. It should be noted that all dendrometric characteristics were measured on three stations of Holm oak.

Data processing and analysis

The data obtained were entered into the Excel spreadsheet, which allowed us to determine the ecological characteristics and structure of the natural holm oak population.

- The density (N) or number of individuals per hectare.
- Basal area (G in m^2/ha) is the sum of the cross-sectional area at 130 cm above the ground of all individuals.
- The total volume (V) depends on the basal area and the height of the individuals.

A multitude of indices are developed and those used in this article are the Shannon, Pielou and Simpson indices.

RESULTS AND DISCUSSION

The floristic composition allows us to highlight the list of species present in the study area. The surveys carried out at the level of the forest of Chettaba (Algeria) allowed to determine 5 woody species (*Quercus ilex*, *Juniperus oxycedrus*, *Phillyrea latifolia*, *Crataegus monogyna*, *Pinus halepensis*) distributed in 5 families (*Fagaceae*, *Cupressaceae*, *Oleaceae*, *Rosaceae*, *Pinaceae*). The majority species in terms of number of individuals is *Quercus ilex* (holm oak), which constitutes 84% of all trees observed (Figure 1).

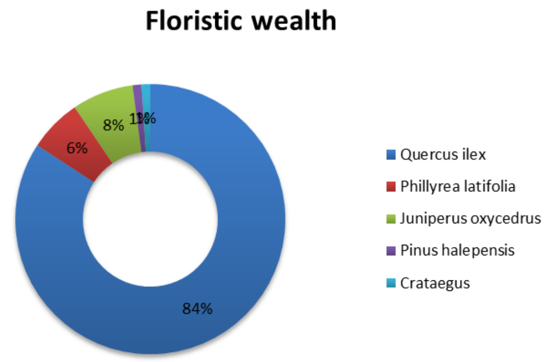

Fig. 1. *Species distribution in the Chettaba forest.*

The mixing coefficient is 0.05; this coefficient reflects the tendency towards homogeneity of the different stands. The values of the Shannon, Simpson and Pielou indices are not very significant and indicate a low floristic diversity; they are respectively (0.88, 0.40 and 0.38). The Shannon index is often accompanied by the Pielou equitability index. The equitability index measures the distribution of individuals within species, independently of the specific richness. Its value varies from 0 (dominance of one of the species) to 1. These two indices remain dependent on the size of the samples and on the type of habitat. It is therefore difficult to use them as a descriptor of the state of an environment unless threshold values are determined beforehand for each type of habitat and for a given sampled area, as proposed by Ramalanjoana, 2013 [6].

The average density of woody plants at Chettaba is 211 individuals/ha with an average basal area of 2.02m²/ha and an average volume of 3.30m3/ha (Table 1). The average diameter is 8.10cm; these stands present characteristics with high regeneration potential (RR = 231.25%) but with a survival problem during the transition between developmental stages [7] and the mortality rate is very low (4.16%).

The slenderness coefficient gives an idea about the ecological stability of the tree stratum [8]. Considering the H/D ratio, this factor is of the order of 41.50. Therefore, the trees are under too much competition and should not be able to withstand the wind well. They have a height that is far too high in relation to their diameter. This growth rate can be explained by their strong competitive power [9]. This observation allows us to assume that the slenderness coefficient is a function of the average diameter and therefore of the age of the stand. Therefore, the slenderness coefficient is less than 100, which means that these stands are stable and regular.

Table 1. *Characteristics of the species studied.*

Species	D (cm)	H (m)	H/D	g	gh	(g-gh)	N/ha	G (m^2/ha)	V (m^3/ha)
Crataegus	9.55	3.50	36.63	0.01	0.01	0.00	11	0.08	0.013
Quercus ilex	10.29	4.17	43.85	0.01	0.01	12.88	889	8.53	3.82
Phillyrea latifolia	4.56	2.30	53.45	0.00	0.00	3.52	67	0.13	0.04
Juniperus oxycedrus	8.44	3.46	47.38	0.01	0.01	9.50	78	0.51	0.17
Pinus halepensis	7.64	2.00	26.17	0.00	0.01	-6.14	11	0.85	0.00
Average	8.10	3.09	41.50	0.01	0.01	3.95	211	2.02	3.30

The graph in Figure 2 shows the wood productivity of each species. *Quercus ilex* is the richest with a volume of 3.82 m³ /ha.

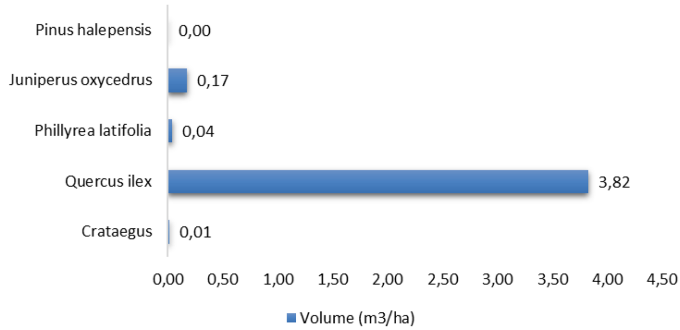

Fig. 2. *Wood Volume of each species.*

The number of stems in the plot is at the pole stage (their diameters do not exceed 17.5cm. This means that these species have not yet had time to reach large diameters. The *Quercus ilex* contains all three diameter classes' perches and small woods, the *Phillyrea latifolia, Juniperus oxycedrus, Pinus halepensis* and *Crataegus* are only found in the form of perches.

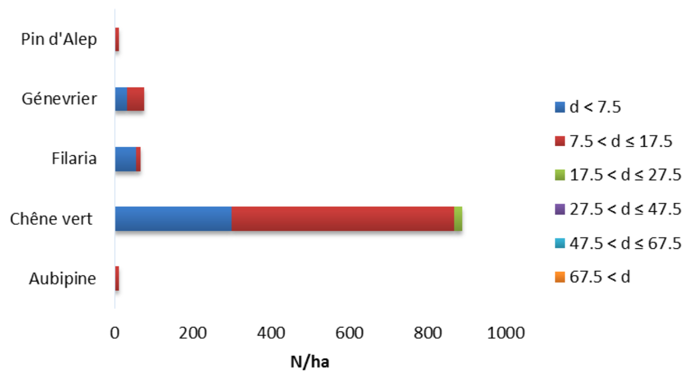

Fig. 3. *Tree density by diameter class.*

The quality of the stands can be given by the PHF index, a three-digit index that gives a judgment of the position of the tree (in relation to the others and thus indicating the dominance and the stage of competition or exposure to the dominant stage), the general shape of the crowns, and the shape of the shafts, It allows more detailed silvicultural interpretation to predict the future of the stand [7] and to deduce in the end the viability of the stands [8]. The average of the results of the PHF index is 333 for the whole of the studied species since which we deduced a rather good quality of our studied stands.

CONCLUSION

The structural study and the floristic composition of the forest allowed knowing the diversity of the plant groups of this ecosystem. The forest of Chettaba functions today as an isolated ecosystem under pressure at its periphery and justifies the need to conserve this ecosystem. The evaluation of the specific diversity by the index of Shannon and the equitability shows a certain relation with the disturbance of the environment. The analysis of viability suggests that, in general, the forest as an ecosystem is viable even if pressures have reduced floristic diversity. Therefore, if the degree of pressure increases and reduces the forest area, the sustainability of the forest will be threatened.

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TYPOLOGICAL FEATURES OF LANDSCAPE BY DISTINGUISHING LANDSCAPE TAXONOMIC UNITS

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ABSTRACT

Landscape as a whole of the components around us must be properly explored, analyzed, protected, managed and planned. All of this are necessary to ensure the sustainable (balanced) development of the state, which seeks a harmonious and responsible approach of the state and society to the landscape and spatial planning. Therefore, in this work, the author examines how landscape typological units are distinguished in different areas. Examining the works of different authors, it can be observed that often different and similar features of the landscape are chosen in order to distinguish taxonomic units. Also, even when distinguishing territorial units of a landscape with the same taxonomic level, the features identifying this unit do not always coincide. Therefore, it is necessary to harmonize landscape cognition practices in order to achieve a balanced landscape knowledge. The aim of this work is to contribute to the knowledge of the landscape. To achieve this goal, the following goals were set: 1. To perform literature analysis; 2. To determine the diversity of landscape features by distinguishing landscape typological units; 3. Identify the most commonly used landscape features; 4. To present the classification of landscape features according to the typological units of the landscape. The following methods were used in the work: literature analysis, cartographic analysis, database analysis.

Therefore, in order to harmonize the practices of landscape typological cognition, at first it should be defined which landscape features are considered essential. In other words, it is necessary to clearly distinguish and identify those features that are the most popular and provide the most information about the landscape itself. Thus, the aim of this work is to present the diversity of these features and to present their possible classification depending on the taxonomic units of the landscape to which they are assigned.

Keywords: *Landscape, landscape features, landscape taxonomic level*

INTRODUCTION

Landscape research is needed to ensure the sustainable development of areas. Therefore, the European Landscape Convention has led to more action to get to know the environment around us, thus encouraging states to explore and get to know the landscape in more detail. Although the Landscape as a whole of complexes in Lithuania has been studied since the 20th century the other half. on the other hand, its research was further stimulated by the European Landscape Convention, which aims to "establish and implement a landscape policy aimed at the protection, management and planning of the landscape" [1] as a result of which more different works and methodologies on landscape cognition topics emerged.

Therefore, when examining the works of Lithuanian and some foreign authors, we can notice a tendency to examine the landscape based on its morphological structure [2]. So, in this work the author examines the features of the landscape on the basis of which the boundaries of the typological units of the landscape are distinguished. To achieve this goal, the following goals were set: 1. To perform literature analysis; 2. To determine the diversity of landscape features by distinguishing landscape typological units; 3. Identify the most commonly used landscape features; 4. To present the classification of landscape features according to the typological units of the landscape. Also, it is common to divide landscape it into different taxonomic units of the landscape. For example sections, areas, districts, surrounding and what kind of landscape texnomic unit we traying to separate depends on the size of the area we are trying to get to know. And in order to define the boundaries of these units, landscape features are used. Therefore, this work examines which landscape features are distinguished most often, what is the diversity of these features and how their choice depends on the taxonomic level.

PRINCIPLES OF ASSIGNMENT OF LANDSCAPE TAXONOMIC UNITS

So, first we need to define what we consider to be a landscape in this case. According to Professor P. Kavaliauskas, the “landscape is the natural (surface rocks, ground air, surface and groundwater, soil, living organisms) and / or anthropogenic (archaeological remains, land use, buildings, engineering facilities and information field) components of the Earth's surface related to material, energy and information relations.” [2]. This is the concept of landscape that is used in this work as well. Therefore, based on the already presented concept of landscape, we can notice that the landscape is basically a combination of various environmental elements around us and the distinction of these compounds can be observed in the works of different authors [3], [4], [5], [6]. However, how the typological units of the landscape will be distinguished often depends on which concept of the landscape is followed, and what taxonomic rank units the author wants to distinguish (Figure 1). Thus, in this work, the author examined the scientific concept of the allocation of landscape territorial units. So, in this case, depending on the taxonomic rank, it will also depend what features of the landscape we will be able to define. If we are talking about units at the regional level, then we will be able to distinguish between natural and anthropogenic elements of the landscape, and if we are at the local level, we could additionally assess the artistic /emotional elements of the landscape. It should be noted here that the artistic features are based on an understanding of the landscape as an eye-pleasing image [5], [7]. Thus, more features can be emerged at the lower level of the taxonomic unit. So how many landscape features we can identify depends on what taxonomic rank units we plan to allocate.

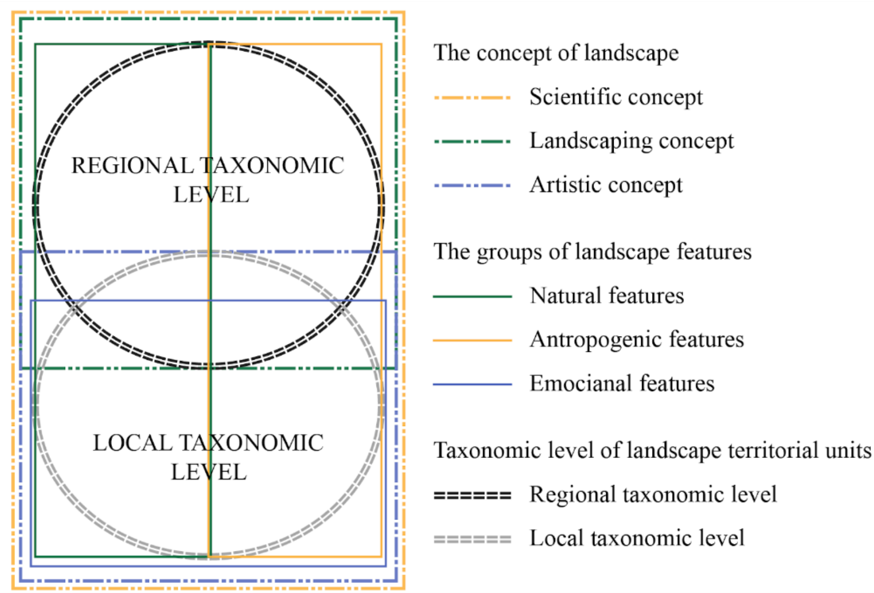

Fig. 1. *Landscape concept scheme. Author of the scheme Giedrė Kurmilavičienė*

LANDSCAPE FEATURES

When allocating landscape taxonomic units, there is often the problem of delimiting landscape boundaries, which often results from unequal selection of landscape features.

Fig. 2. *Boundaries between different landscape features in Anykščiai district. Author of the photo and the scheme Giedrė Kurmilavičienė*

Therefore, in order to level the knowledge of the landscape, it is necessary to describe the most common features of the landscape. So, question is what features of the landscape can we distinguish? First of all, we can look very simply and distinguish the boundaries between the visible different features of the landscape and as shown in the figure (Figure 2). However, when examining the works of different authors, we can observe that first of all the features of the landscape should be divided into two groups: natural and anthropogenic [3], [4], [5], [6], [8]. The most commonly used anthropogenic landscape

Table 1. Anthropogenic landscape features

Anthropogenic landscape features	
Degree of cultivation	Type of land use
Natural	Forests
Relatively natural	Fields
Cultured	Gardens
Relatively urbanized	Pasture
Urbanized	Built - up areas

components are presented in Table 1. The most common natural landscape components are presented in Table no. 2. There are also works that include a visual assessment of landscape perception, one of which could be considered the work of the Institute of Observatory of Catalonia and their work Landscape catalogues of Catalonia [6]. Thus, the frequency of the choice of landscape features depends on the author of the work and his team experience.

Table 2. Natural landscape features

Natural landscape features					
Nature of the surface	Ground	Geological origin	Hydrography	Soil	Flora
Hills	Clay	Glacial	Density of lakes	Velėniniai	Spruce
Waves	Sandstone	Fluvioglacial	Density of swamps	Jauriniai	Pines
Ridges	Sand	Limnoglacial	Density of rivers	Pelkiniai	Oaks
Valleys	Pebbles	Erosive			Willows
Plains	Peat	Aeolian			

THE USE OF LANDSCAPE FEATURESIN THE ALLOCATION OF TAXONOMIC UNITS

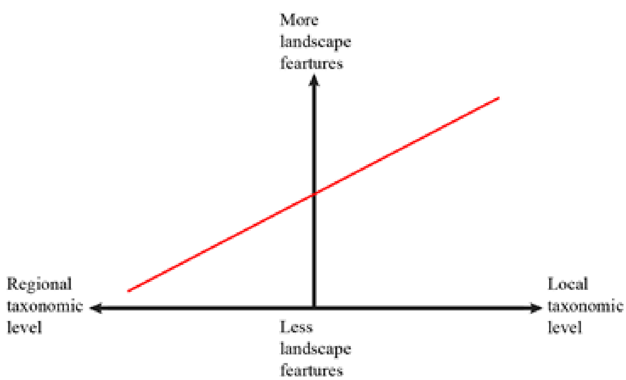

Fig. 3. Dependence of landscape features on taxonomic level. Author of the scheme Giedrė Kurmilavičienė

Thus, when distinguishing landscape taxonomic units, the authors' works show a tendency for fewer features to be chosen when assigning higher taxonomic units, for example, when distinguishing landscape areas, geological origin, orography andnaturalness are identified. Meanwhile, when allocating landscapes, geological origin, orography, naturalness, land use, flora are chosen for landscape features [3], [4], [5], [6], [8], [9], [10]. So in many cases, depending on what taxonomic level the units will be separated will depend on how many features of the landscape we will be able to identify. As you can see in the image (Figure 3), the more landscape features we try to use when allocating landscape territorial units, the lower the taxonomic level of territorial units will be and vice versa the higher the taxonomic rank, the fewer landscape features we can use. And finally, examining the works of different authors, it becomes clear that certain features of the landscape are used regardless of the taxonomic rank of the units assigned, and that would be: geological origin, nature of surface, cultivation, hydrography. And some features are devoted to examining the landscape in great detail at the local level. Typically, such landscape knowledge is done to ensure proper site planning or to identify the most valuable sites. Thus, the more detailed information about a landscape is identified by a landscape feature, the lower the taxonomic range will be used, but this does not mean that, in exceptional cases, features such as land use will not be used to allocate units at the regional level. And figure 4 (Figure 4) also depicts the relationship between the taxonomic rank and how often a particular trait is used to distinguish it.

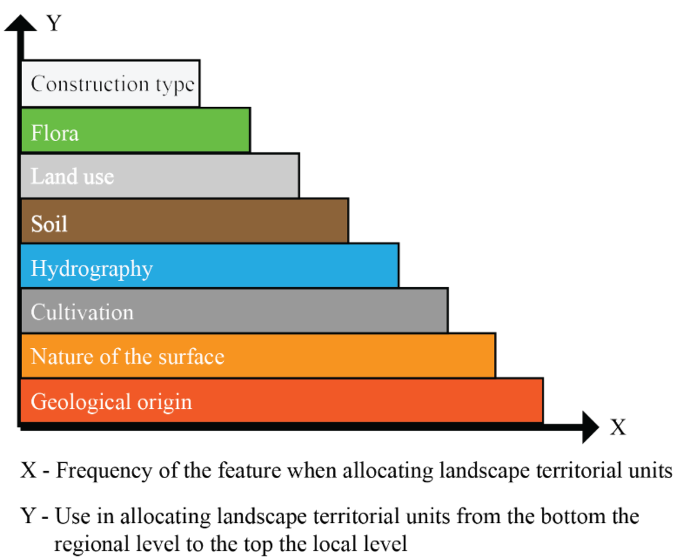

Fig. 4. *The popularity of landscape features use to distinguish different taxonomic levels. Author of the scheme Giedrė Kurmilavičienė*

Identifying landscape features to whom and when they are used is difficult, but we can see regularities and dependencies that the more we can summarize landscape features, the higher the taxonomic range we can use them, and the more landscape features we choose, the smaller the taxonomic rank units we allocate.

CONCLUSION

The different practices in distinguishing landscape taxonomic units in the works of different authors leads to problems of landscape concept and uncertainty of landscape boundaries.

The landscape features chosen by different authors for taxonomic units often depend on the authors' experience, the concept of the landscape, the taxonomic level of the landscape, and sometimes the desire to emphasize the uniqueness of the landscape in certain areas therefore, expert judgment is required at this time for the allocation of landscape taxonomic units.

In order to ensure a uniform level of landscape zoning and spatial planning documents, it is necessary to define the specific features of the landscape used to designate specific taxonomic units of the landscape and thus to reduce the differences between the levels of knowledge of the landscape.

ACKNOWLEDGEMENTS

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VALORIZATION AND CHARACTERIZATION OF THE FOREST OF EL HAMIMET (ALGERIA)

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ABSTRACT

This study focuses on the El Hamimet forest (eastern Algeria). Its ecological status is unknown until now and no system has been established to measure and monitor its viability. The objectives were to collect data on the current ecological state of this forest and to analyze the structure of the stands; for this purpose, we carried out an inventory in the field allowing the knowledge of quantitative data relating to these resources from dendrometric parameters collected on 4 plots of softwoods. The results obtained show that the species *Pinus halepensis* is the most abundant with 425 tree/ha or 95.41%; the average basal area is 23.41 m^2/ha and offers a significant quantity of wood 132.95 m^3/ha, and therefore it is the main species among all the species studied.

Keywords: *Pinus halepensis, structure, sustainability*

INTRODUCTION

The strong degradation of environments linked to human activities has prompted restoration initiatives for several decades [1]. The ecology of restoration addresses all-natural processes and is assisted by interventions that initiate or promote the recovery of degraded, damaged, or destroyed ecosystems [2]. A need to restore these forests is imposed because apart from their role as a reservoir of biodiversity, they ensure above all a regulatory function that is a determinant of the water regime of the area and the stabilization of soil degradation [3]. So far, human activities have destroyed the Earth's biological diversity. Changes in the existing politics, economy, technology, and ideological structures must then be made to encourage the increase of the population's quality of life, the quality of the environment, aesthetics, and culture. The standard economic approach has tended to ignore the costs of environmental damage and the degradation of natural resources [4]. Currently, the new field of environmental economics is developing methods to value biological diversity, and in the process is making the case for its conservation. The development of a forest ecosystem requires the design of a system of economic, ecological, human, and social interventions that will allow it to make regular profits while maintaining or increasing the potential of its property and ensuring the sustainability of its human and social benefits [5]. The general objective of the study is to collect the necessary information on the forest of El Hamimet for a proposal of restoration strategies.

MATERIAL AND METHODS

Presentation of the study area

The Forest of El Hamimet is located north of Oum EL Bouaghi (Algeria). The forest spreads over an area of 1460 ha. Extreme altitudes of the forest are about 1039 m (maximum altitude) and 800 m (minimum altitude). Its bioclimatic is semi-arid to arid. The average annual rainfall is estimated at 378.75mm. It is generally a rugged relief with an average altitude of 848 m, with a slope of 12.5%. The geology of the forest is dominated by clay-limestone to limestone soils.

Dendrometric parameters

The horizontal analysis consists of studying the spatial structure of the stand in terms of abundance and dominance.

- Abundance gives the number of stems of a species (here Pinus halepensis) in the stand. It is expressed in the number of N per hectare (N/ha).
- Dominance evaluates the basal area G.

It is formulated by $G = \Sigma g = \Sigma (\Pi d^2/ 4)$ and is expressed in m^2/ ha. D is the diameter of the tree at 1.30 m from the ground. The dominance gives an idea of the degree of filling of the forest, i.e. the part of the surface occupied by stems. It is then an index for the production of the stand. As for the number N, the basal area G is also established by the diameter class.

- The basal area of the average diameter tree is the area calculated from the average diameter of the population: $gh = \Pi^* Dg^2 /4$, where Dg is the average diameter of the stand [6].
- The comparison between the average basal area and the basal area of the average diameter tree allows us to qualify the productivity of the stand. A new parameter that we will note by (g - gh) where g is the average basal area of the population will be introduced in the horizontal analysis of the stands. The distribution of stems across the different diameters and the fact that the area is a function of the square of the diameter are at the origin of the difference between the average basal area and the basal area of the average diameter tree [7]. This parameter then characterizes the distribution of the number of stems per diameter. A positive (g - gh) means that the trees in the population occupy on average a larger basal area than the average tree. This can be translated to a gain in the basal area of each tree relative to the average diameter tree. In other words, the total area is relatively large compared to the average tree diameter and stand density.

The positive (g - gh) then characterizes the good productivity of the stand.

- The ratio of the height to the diameter qualifies the slenderness of the tree. It is called the "slenderness coefficient" and is noted: H/D = Htot* 100/D1.3 where Htot is the total height and D1.3 the diameter at man's height of the tree. The stability of the stand depends on both the density and the slenderness of the trees. The study of tree taper aims to determine the factors of variation of its value and its relationship with the stability of the stand. Generally, the slenderness coefficient of 100 corresponds to the stability threshold of a stand, but for a species sensitive to disturbances, this threshold goes down to 80 [8].

RESULTS AND DISCUSSION

The horizontal structure of a species combines the distribution of stems and the distribution of basal area by diameter class. Since density, basal area, and stand development are strongly linked, the study of one cannot be done without the introduction of another [9]. This study will be done by taking into account at least two of these factors. Table 1 summarizes the main characteristics of *Pinus halepensis* stands in each plot, concerning trees with the measurable basal area.

With an average diameter between 5.41 and 67.02 cm, these stands are in the young growth stage. The total density of Aleppo pine trees with a diameter at man's height greater than 5 cm varies from 344 to 489 individuals per hectare. The youngest of all is that of plot 1 with a diameter at a man's height of 15.31 cm on average. This stand contains a large number of young trees (389 trees/ha).

Table 1. *Quantitative characteristics of the stands.*

Plots	D (cm)	H (m)	H/D	g (m^2)	gh (m^2)	g-gh (cm^2)	N/ha	G (m^2/ha)
P1	15.31	5.72	39.23	0.02	0.01	1.13	389	7.78
P2	29.88	6.41	26.47	0.10	0.01	8.71	344	33.01
P3	29.44	5.95	30.60	0.10	0.01	9.10	378	37.68
P4	17.22	4.32	27.81	0.03	0.01	2.04	489	14.67

The (g - gh) value of these *Pinus halepensis* stands varies from 1.13 cm² for plot 1 to 9.10 cm² for plot 3. The stands all have a positive (g - gh). This means that in these stands the trees are on average larger than the average tree. These developmental states then correspond to a stage where the trees reinforce their stability by growing widthwise. The total density and the average diameter of the stand no longer explain the parameter (g - gh). We can say that the other development factors such as spacing texture and canopy influence the productivity of the stand largely. The average slenderness coefficients vary between 26.47 and 39.23 in the 4 plots. The variation in H/D is irregular; this finding suggests that the slenderness coefficient is a function of the average diameter and therefore the age of the stand. Figure 1 shows the slenderness coefficient as a function of the average diameter of the stand, as well as the polynomial trend line of the function.

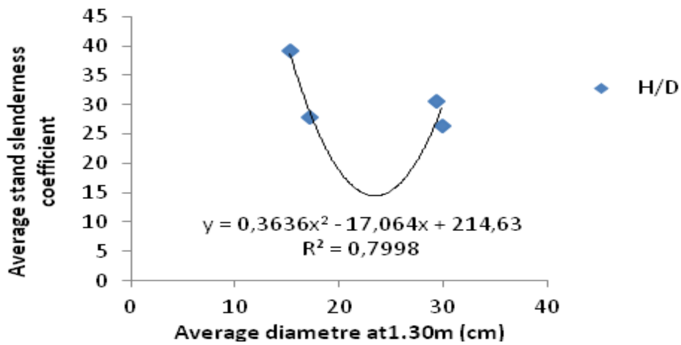

Fig. 1. *Slenderness coefficient as a function of average stand diameter.*

According to the previous results, the slenderness coefficient is a negative function of the mean diameter. The coefficient of determination $r^2 = 0.7998$ of the trend curve means that only 21% of the observed values are not explained by the trend curve. There is therefore a relationship between the average diameter and the average height of the natural regeneration stand, which we will try to formalize with the graph in figure 2.

According to the coefficient of determination, 99% of the observed height values are explained by the trend curve. We can then use this curve to predict the average height of a stand of natural regeneration left to itself if the average diameter is known.

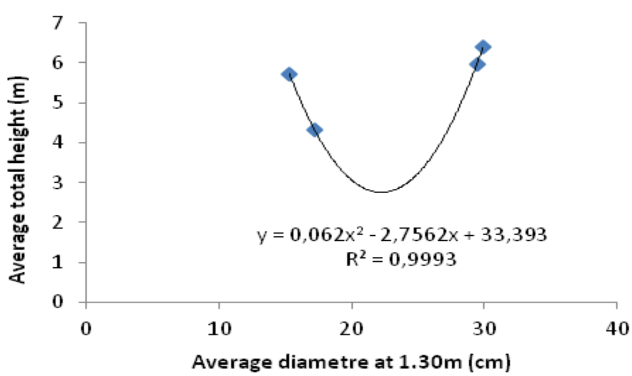

Fig. 2. *Average total height versus diameter at 1.3 m in the stand.*

The natural regeneration is presented by the young wood of less than 5 cm of diameter at man's height, thus of not yet measurable basal surface. It corresponds precisely to the state of the thicket. As in the previous studies, the study of natural regeneration of Pinus halepensis will be done in increasing order of average stand diameter. The study of natural regeneration consists of analyzing the abundance and spatial distribution of these young woods in the different *Pinus halepensis* stands inventoried. The natural regeneration of two stands with an average diameter at 1.3 m lower than 17cm, namely those of plots 1 and 4, is low. We can say that the abundance of regeneration decreases when the average diameter increases in these two stands. This may mean that these shrubs in the thicket state are not from the regeneration of the stand in which they are found. The diameter class at 1.3 m less than 5 cm is empty in the stands of plot 2. However, it should be noted that plot 4 contains too little regeneration (Table 2). This can be explained by the fact that in a naturally regenerating stand without any intervention, the trees all reach the measurable diameter at 1.3 m from 12 cm.

Table 2. *Regeneration and mortality rates.*

Plots	Mortality rate	Regeneration rate
P1	0	14.29
P2	3.23	0
P3	11.11	5.56
P4	0	15.9

CONCLUSION

The use of Aleppo pine in reforestation for timber production will not only be a way to value the various qualities of its wood, but also a way to diversify the products on the timber market and a way to protect the bare soil of the highlands. Due to its interesting physical-mechanical properties, the wood of *Pinus halepensis* has a multitude of possible uses that classify it in the category of quality woods. This species is particularly successful in the study site, with rapid growth and successful natural regeneration.

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WILDFIRES FORECAST PERFORMANCE IN ALBANIA DURING SUMMER 2020

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ABSTRACT

The Wildfire Risk Forecast (WRF) remains a daily procedure conducted by the National Centre for Forecast and Monitoring of Natural Hazards (NCFMNH), which is part of the Institute of Geosciences, Energy, Water and Environment (IGEWE) of Albania. WRF is generated on daily basis, by the country's administrative unit (prefecture) and disseminated to the General Directorate of Civil Emergencies (GDCE) in order to help better coordinate fire-fighting activities.

This study investigates the accuracy of the Wildfire Risk Forecasts during the 2020 summer season by analysing fire occurrences over each prefecture of Albania for two components of wildfire forecast Performance, i.e., The Prefecture Hit Probability (PHP) and the Average Fires per Hit (AFH).

The study has revealed a "VERY GOOD" Performance for the "High Risk Level" forecast alerts, "GOOD" Performance for the "Moderate Risk Level" and "Low Risk Level" forecast alerts, and VERY GOOD" Performance for the "No Risk Level"

Keywords: *wildfires, forecast, risk, natural hazards*

INTRODUCTION

Albanian territory is often affected by wild-land fires which result in significant economic and ecological losses differing from year to year. Therefore, building an accurate assessment system that forecasts the risk of forest fires over the country enabling the notification of risk levels is of key importance.

Several forest fire danger rating systems are already operational with this purpose worldwide. One of the most used fire danger rating systems is The Canadian FWI system which was the first subsystem developed in the CFFDRS [1]. Even though Canadian FWI is specifically calibrated to describe the fire behaviour in a standard jack pine stand Pinus banksiana typical of the Canadian forests [2], the index has successfully been used in countries where vegetation is dissimilar to Canada [3] such as Australia [4], New Zealand, and Malaysia [3]. Given such results, the Fire Weather Index module of the CFFDRS has been adapted for use in several countries.

Furthermore, the Fire Weather Index (FWI) is currently being used by the European Forest Fire Information System, which is developed in the framework of the Copernicus Emergency Management Services to monitor and forecast fire danger in Europe [5]. Yet, the FWI algorithms in EFFIS have been slightly changed to the original FWI System of the CFFDRS in order to better suit the remarkable differences in day length in European Union when going from the Mediterranean to the Boreal countries [6], [7]. Besides, EFFIS uses medium-range (1–10-day lead time) weather forecasts, instead of observations, to extend the advance warning.

As a matter of fact, the Centre for Forecasting and Monitoring of Natural Hazards (CFMNH), at the Institute of Geosciences, Water and Environment (IGEWE), started to provide information about the Forest Fire Risk in the summer of 2011 delivering daily information on the upcoming risk of fires for the following day. Starting from the beginning of 2016, the FWI index delivered by EFFIS has been used in order to define the daily fire risk forecasts for each prefecture in Albania. As such, in order to comply with the categories of the Meteoalarm platform, CFMNH rates the Fire Danger into four levels of risk, unlike EFFIS which rates the Danger in six classes. Table one shows the respective thresholds used for each level of risk by EFFIS and by CFMNH. As seen in the table, CFMNH uses the same thresholds as EFFIS in order to determine the two lower levels; while, for the two upper levels, CFMNH uses the EFFIS thresholds of two gathered levels for each. That is, CFMNH "Moderate Risk" level corresponds to EFFIS "Moderate" and "High" and CFMNH "High Risk" level corresponds to EFFIS "Very High" and "Extreme".

***Table 1**. IGEWE vs. EFFIS Fire Danger Classes*

EFFIS Fire Danger Classes	FWI ranges
Very low	< 5.2
Low	5.2 - 11.2
Moderate	11.2 - 21.3
High	21.3 - 38.0
Very high	38.0 - 50.0
Extreme	>= 50.0

CFMNH Fire Danger Classes	FWI ranges
No Risk	< 5.2
Low Risk	5.2 - 11.2
Moderate Risk	11.2 – 38.0
High Risk	>= 38.0

This study aims to evaluate the Wild-fires Forecast Performance (WFP) in Albania during the summer season of 2017 using these thresholds and contributing to future improvements of the forecast with recommendations and suggestions.

METHODOLOGY

The relationship between the FWI values and fire occurrence has been investigated by several studies. In most of them, moderate to high correlations between FWI values and fires occurrence have been found [8], [9], [10]. While studies that investigated the correlation between FWI values and burned area have found poor to moderate correlation between them [11], [9].

Given those findings, the wildfire forecast Performance (P) in this study, has been evaluated by investigating the fire occurrence over the prefectures of Albania. The fire occurrence has been investigated on each level of risk according to the forecasts conducted each day during the summer. Two components have been analysed: the first one relates to the assessment of the Prefecture Hit Probability (PHP), conducted for each level of forecast alert following [Formula 1]; the second component analysed relates to the quantity of Fires per Hits considering that in many cases more than one fire per hit occurs. This component was evaluated per each Level of risk as an average value (Average Fires per Hit, AFH).

The revealed PHP and AFH values have been assembled in three categories using the thresholds as shown in table 2 and table 3 rating the wildfire forecast Performance as "VERY GOOD", "GOOD" or "BAD" for both components (P_{PHP} and P_{AFH}).

$$\text{PHP}_{\text{Level}} = \sum_{i=0}^{n} \frac{n^0\text{Hits}}{n^0\text{Alerts}} \text{ x } 100\% \qquad [1]$$

Where:

PHP - refers to the Prefecture Hit Probability

Nr. of HITs - refers to the number of prefectures exposed to the respective level of risk affected by fires.

Nr. of Alerts - refers to the number of alerts of the respective level of risk.

Table 2. *Thresholds of PHP used for categorising the Wildfire Forecast Performance*

	P_{PHP}	**PHP**	P_{PHP}	**PHP**	P_{PHP}	**PHP**
High Risk	**VERY GOOD**	70% - 100%	**GOOD**	50 % -70 %	**BAD**	>50 %
Moderate Risk		50% - 70%		40 % – 50 % 70 % - 80 %		>40 % <80%
Low Risk		20% - 40%		10 % - 20 % 40 % – 50 %		>10 % < 50%
Very Low Risk		0 – 10%		10 % - 20 %		< 20%

Table 3. *Thresholds of AFH used for categorising the Wildfire Forecast Performance*

	P_{AFH}	**AFH**	P_{AFH}	**AFH**	P_{AFH}	**AFH**
High Risk	**VERY GOOD**	<1.5	**GOOD**	1.01-1.5	**BAD**	1
Moderate Risk		1.2 - 1.5		1.5-1.8 1-1.2		<1.8
Low Risk		1.02-1.2		1.2-1.5 1-1.2		<1.5
Very Low Risk		1-1.04		1.04-1.16		<1.16

Ultimately, a final Performance (P) has been estimated rating final wildfire forecast Performance as the rate of the component that performed better between P_{PHP} and P_{AFH}.

All evaluations were conducted for each Prefecture on a monthly and season duration basis.

RESULTS

The results are shown in two subsections: the first one containing general information with data on the number of forecast alerts issued by level and number of fires that occurred, and the second one containing the basic findings of the study.

Distribution of Forecast alerts and Fires by Risk Levels

A total of 360 forecast alerts has been considered for analyses during June, of which, a share of 10% indicated "Moderate Risk Level", 28% "Low Risk Level" and 62% "No Risk Level". The fires ignited countrywide were very scare, (only 6 fires were registered), of which, half of them in the "Moderate Risk Level" and the other half in "Low" and "No" Risk Level prefectures; (see table 4 and graph 1).

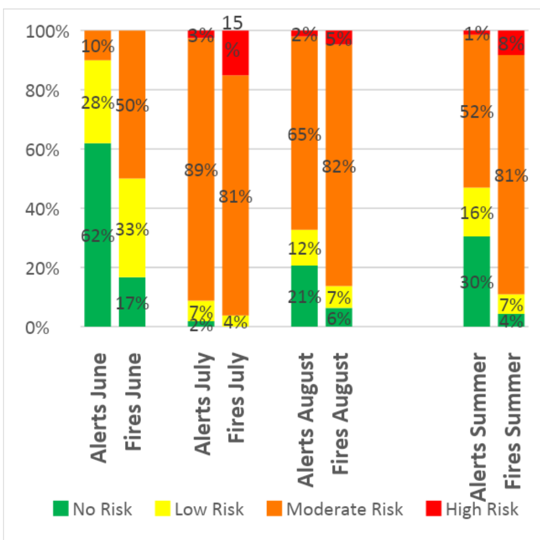

Fig. 1. *The distribution of alert forecasts fire occurrence by risk levels*

Table 4. *Data on Alert forecasts, Fire occurrence and HITS by risk levels*

2020		JUNE	JULY	AUGUST	SUMMER
High Risk	Alerts	No	7	7	14
	Fires	No	16	9	25
	Hits	No	5	5	10
Moderate Risk	Alerts	36	244	228	508
	Fires	3	86	155	244
	Hits	2	62	91	155
Low Risk	Alerts	101	19	42	162
	Fires	2	4	14	20
	Hits	2	3	9	14
No Risk	Alerts	223	5	72	300
	Fires	1	0	12	13
	Hits	1	0	11	12
TOTAL	Alerts	360	275	349	984
	Fires	6	106	190	302

During June, a total of 360 forecast alerts were considered for analyses, of which, a share of 10% indicated "Moderate Risk Level" and the rest indicated "Low" and "No" Risk Levels (28% and 62%). Meanwhile, only 6 fires were registered countrywide, of which, a share of 50% occurred in "Moderate Risk Level" (see table 4 and graph 1) while the rest occurred in "Low Risk Level" and "No Risk Level" prefectures (respectively 3 fires, 2 fires and 1 fire).

During July, a total of 252 forecast alerts were considered for analyses, of which, a share of 2.5% indicated "High Risk Level" and 88.7% indicated "Moderate Risk Level" and the rest indicated "Low" and "No" Risk Levels (6.9% and 2%). Meanwhile, a total of 98 fires were registered countrywide, of which, a share of 16% occurred in "High Risk Level" prefectures and 81.1% occurred in "Moderate Risk Level"; while only 4% occurred in "Low Risk Level" prefectures (see table 4 and graph 1).

During August, a total of 326 forecast alerts were considered for analysis: a share of 2% of forecast alerts indicated "High Risk Level" and a share of 65.3% indicated "Moderate Risk Level". Meanwhile, a total of 190 fires were registered countrywide, of which, a share of 4.7% occurred in "High Risk Level" prefectures and a share of 81.6% in "Moderate Risk Level" prefectures (see table 4 and graph 1).

Wildfire forecast Performance by Risk Levels

In June, Wildfire Forecast Performance of "Moderate Risk Level" forecasts ranked as "BAD" for the first component (Prefecture Hit Probability) but "VERY GOOD" for the second one (Average Fires per Hit). The low ranking of the Prefecture Hit Probability was due to a very low hit rate for the respective Risk level (PHP 6%); the other component values revealed to be in line with the level (AFH, 1.5).

The “Low Risk Level” revealed “BAD” Performance for the first component (Prefecture Hit Probability) but “GOOD” for the second one (Average Fires per Hit); both components were not satisfactory due to low values of PHP and AFH (respectively 2% and 1).

The “No Risk Level” ranked as “VERY GOOD” for both components.

In July, wildfire forecast Performance of “High Risk Level” forecasts ranked as “VERY GOOD” for both components; the Prefecture Hit Probability and Average Fires per Hit revealed high values (PHP, 71%) and (AFH, 3.2) that were in line with the respective risk level.

Wildfire forecast Performance of “Moderate Risk Level” forecasts ranked as “BAD” for the first component (Prefecture Hit Probability) but “VERY GOOD” for the second one (Average Fires per Hit). The low ranking of the Prefecture Hit Probability was due to the very low hit rate for the respective Risk level (PHP 25%); the other component values revealed to be in line with the level (AFH, 1.28).

The “Low Risk Level” revealed “GOOD” Performance for both components: the first component was not sufficiently satisfactory due to low hit rate (PHP values 16%) while the second due to the significantly high quantity of fires occurring per Hit (AFH, 1.33).

The “No Risk Level” was ranked as “VERY GOOD” for both components since no fire occurrence was reported in the prefectures exposed to this level of risk.

In August, wildfire forecast Performance of “High Risk Level” forecasts was rated as “VERY GOOD” regarding both components; the Prefecture Hit Probability and Average Fires per Hit revealed high values (PHP, 71%) and (AFH, 1.8) that were in line with the respective risk level.

Moderate Risk Level” ranked as “GOOD” for both components: the first component (Prefecture Hit Probability) was not satisfactory due to a relatively low hit rate inconsistent with the respective Risk level (PHP 40%)

Table 4. *Wildfire Forecast Performance on a monthly duration basis*

	JUNE 2020						JULY 2020						AUGUST 2020					
	PHP	AFH	P_{PHP}		P_{AFH}		PHP	AFH	P_{PHP}		P_{AFH}		PHP	AFH	P_{PHP}		P_{AFH}	
High Risk	-	-	-		-		71%	3.2	VERY GOOD		VERY GOOD		71%	1.8	VERY GOOD		VERY GOOD	
Moderate Risk	6%	1.5	BAD	VERY LOW PHP	VERY GOOD		25%	1.39	BAD	VERY LOW PHP	VERY GOOD		40%	1.74	GOOD	LOW PHP	GOOD	HIGH AFH
Low Risk	2%	1	BAD	VERY LOW PHP	GOOD	LOW AHF	16%	1.33	GOOD	LOW PHP	GOOD	HIGH AHF	21%	1.75	VERY GOOD		BAD	VERY HIGH AHF
No Risk	0.4%	1	VERY GOOD		VERY GOOD		0%	0	VERY GOOD		VERY GOOD		15%	1.09	GOOD	HIGH PHP	GOOD	HIGH AHF

Table 5. *Wildfire Forecast Performance on a two-month-duration basis*

SUMMER 2020						
	PHP	**AFH**	**P_{PHP}**		**P_{AFH}**	
High Risk	71%	2.5	VERY GOOD		VERY GOOD	
Moderate Risk	31%	1.57	BAD	LOW PHP	GOOD	HIGH AFH
Low Risk	10%	1.4	BAD	LOW PHP	GOOD	HIGH AFH
No Risk	4%	1.08	VERY GOOD		GOOD	HIGH AFH

while the second one (Average Fires per Hit) due to the relatively high value of fires per Hit (AFH, 1.74).

The "Low Risk Level" revealed a "VERY GOOD" Performance for the first component (Prefecture Hit Probability) but "BAD" for the second one (Average Fires per Hit).

The low ranking of the second component was due to the very high value of fires per Hit (AFH, 1.75)

The "No Risk Level" Performance revealed as "GOOD" for both components where both components performed relatively values for the respective level (PHP, 15%; AFH, 1.09).

CONCLUSION

"High Risk Level" forecast alerts, have had a "VERY GOOD" Performance for both components on both months the risk was alerted.

The "Moderate Risk Level" and "Low Risk Level" forecast alerts seemed to have generally low values on the first component (PHP). Nevertheless, while analyzing PHP in those forecast alerts, it is noticeable a decreasing rate from "Moderate" to "No" Risk Level, in line with risk fall. Hence, the low rating of Prefecture Hit Probability in those levels could be probably credited to lower fire lightings by villagers and/or pyromania than to lower performance of the forecasts. That's why, a revision of the rating criteria of the Performance, where estimates of the rate trend of this component could be included, would help in a better evaluation of P_{PHP}.

On the other hand, high values have been observed on the second component (AFH) in the three levels of Risk ("Moderate", "Low" and "No" Risk Level). A high Average of Fires per Hit, as revealed, could have been caused by a differing fire lighting activity amongst the prefectures, peaking probably in some of them, due to different awareness level and/or due to a different efficacity of the law and control on the irresponsible firelighters. As such, analyzes of the forecast Performance by Prefecture could help better understand the activity of the population in different prefectures in Albania and improve the view on forecasting performance.

The final results of forecasting performance were “VERY GOOD” for “High Risk Level” and “No Risk Level” forecast alerts, and “GOOD” Performance for “Moderate Risk Level” and “Low Risk Level” forecast alerts. The contributor component for those final results were P_{PHP} for “High” and “No” Risk Level forecast alerts, and P_{AFH} for “Moderate” and “Low” Risk Level forecast alerts.

RECOMMENDATIONS

- Another study should be conducted aiming to define better levels of risk thresholds. An improved risk level division is expected to bring more balanced exposure by risk level as well as a revised accuracy for forecasts related to “Moderate Risk Level” and “Low Risk Level”.
- Even though the affected area does not show a significant correlation with FWI Index, according to the literature, other studies on this topic should include an analysis on the relationship between forecast alerts and areas that have literally caught fire.
- Other studies should analyse the fire forecast Performance by Prefecture in order to better understand the population of lighting activities.
- The criteria used to categorise the wildfire forecast Performance should be revised.

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Section

ENVIRONMENTAL ECONOMICS

Economic and environmental objectives
Economic instruments in environmental policy
Cost-benefit analysis
Environmental expenditure of enterprises
Eco-innovations for sustainable development
Environmental evaluation and decision-making

BENEFITS OF REMOTE SENSING, ENVIRONMENTAL DATA AND IOT USAGE IN MANAGING SUSTAINABLE AGRICULTURAL SYSTEMS

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ABSTRACT

The purpose of this paper is to present the demarches performed and planned to be accomplished through the INSAC-AGRIS project (funded by EUREKA program) in regard to an integrated autonomous system able to correlate DAQ from ground and air and to design a pattern capable of triggering differentiated application of additives and/or water to proposed crops in order to achieve best-optimized harvesting yield. The debute phase of the study shows the steps and methodology of preparing the preliminary plot maps, soil sampling and soil characteristics maps. The very practical aspect of this research is to provide to farmers the opportunity for better supervision of plants by analyzing plant characteristics, plant population, weediness level, field health, growth problems, diseases, involved pest or insects, vegetation indices, all completing the necessary information portfolio for model creation and building the prediction algorithms, protecting in this way the nature and increasing soil protection as well as optimizing economic activities in the SMART agriculture area.

The experimental phase is developed in parallel in Hungary and Romania for a period of 4 years, using several experimental crops (wheat, rapeseed, green peas, corn, sunflower), the integrated system usability and scalability for later use being clear and proved.

Keywords: *remote sensing, crop management, harvest prediction, IoT, sustainability, extension*

INTRODUCTION

Precision agriculture has generated a very high profile in the agricultural industry over the last decades, but the fact of ‘within-field spatial variability’, has been known for centuries. The topic has been ‘technology-driven’ and so many of the engineering developments are in place, with the understanding of the biological processes on a localized scale lagging behind. Precision agriculture, as a crop management concept, can meet much of the increasing environmental, economic, market and public pressures on arable agriculture [1].

Precision agriculture refers to an emerging set of technologies to simultaneously help meet this demand and also promote sustainability. In this regard, Precision agriculture is a modern concept of agricultural management that allows decisions to be made assertively, fertilizers to be applied in the correct locations, and production costs to be reduced [2]. Precision agriculture uses intensive data collection, providing in this way high accurate tracking and helping to production adjustment by enabling the definition of management zones for the custom management of inputs [3].

Nowadays, after continuous development and evolution, precision agriculture aids in making more informed management decisions that may lead to greater profitability, being an alternative for reducing costs. Precision agriculture approach is multidisciplinary, involving multiple technologies and disciplines [4].

Traditional practices manage whole fields as a single unit, whereas in modern precision agriculture, the farm management unit is shifted from whole fields to small areas within fields, creating a systematic approach to managing variability by focusing on small areas within fields and involving the application of technology and agronomic principles to manage the spatial and temporal variation of all aspects of agricultural production to improve crop performance and environmental quality [5]. And success in precision agriculture is related to how well it can be applied to assess, manage, and evaluate the space-time continuum in crop production [6] that helps to overcome this threat in a smart way using modern information and communication technologies. It reduces the indecorous use of resources, pollution and hence improves the quality of life, which in turn helps to achieve sustainable development goals.

Existing trends are to reduce as much as possible human-work and replace it by robots - reflected in the final product costs. Thus, becomes imperative Sustainability - very strong related to carbon footprint, and Higher Production - world population is growing and hungrier. It is thus imperious to find solutions to increase, optimize and improve permanently the agricultural yield, being faster, more sustainable, more reliable and more efficient.

OVERALL CONCEPT

INSAC-AGRIS project objective aims to build an integrated autonomous system able to correlate DAQ from ground, plant and air and to design a pattern capable of triggering micro-differentiated application of additives and/or water to proposed crops in order to achieve best-optimized harvesting yield.

The system will be able to offers services able to collect, to correlate data acquisition systems from ground, plant and aerial levels and to predict crop properties from aerial collected imagery. Predicted data are able to trigger micro-differentiated or corrective application of additives or irrigation to crops in order to achieve one precision agriculture system for best-optimized harvesting yield.

The developed methodology stands on the following steps related to crop management & physical-chemical characteristics:

1. Preliminary aerial image-acquisition (VIS, UV, NIR);
2. Elaboration of orthophoto-maps;
3. Elaboration of ground sampling plan;
4. Elaboration of ground sensor typology and network;
5. Creation of a GIS system, based on parameters Database;
6. Algorithm/software development for data correlation;
7. Development of a map for variable distribution of inputs.

In terms of ground evaluation, data will be collected from soil sensors, validated by typical soil analysis, followed by plant monitoring, in vegetation and after harvesting. Data taken from mapping, consolidated with analyses and continuous monitoring, correlated with climatic parameters will constitute the patternable not only to suggest differentiated inputs application or micro-irrigation, but also to be able to predict the harvesting yield and production costs.

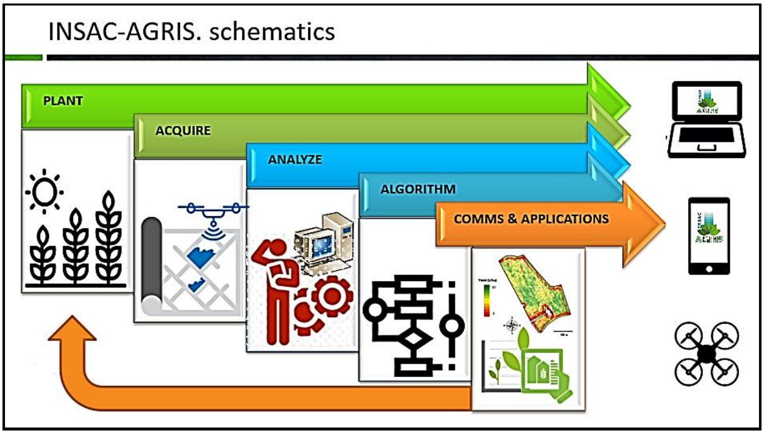

Fig.1. *INSAC AGRIS concept*

The proposed integrated system will provide farmers with the opportunity for better supervision of plants. So, the Consortium will develop a system able to analyze plant characteristics, plant population, weediness level, field health, growth problems, present diseases, involved pests or insects. Adding to the database the aerial imagery and ground data, analysis of soil and plants and adjust accordingly to climatic collected data, will create the base of the prediction system from only aerial data. Also, using a multi-spectral camera, several vegetation indices (e.g. NDVI, SAVI, etc.) and other plant physiology can be determined, completing the necessary information for building the prediction algorithms.

METHODOLOGY REPRESENTATIVE FOR SOIL SAMPLING

Soil analysis is a key practice to increase the efficiency of nutrient management in agriculture. Since the early 20th century, increasingly sophisticated methods have been developed to describe and manipulate the inherent spatial variability in soil chemical properties within the realms of classical and spatial statistics [7].

Soil sampling helps producers to develop management zones and prescription maps in precision agriculture, increasing the accuracy of rate and placement of necessary inputs (primarily fertilizers and lime to adjust pH) [8].

The total nutrient contents of the soil represent a sum of shapes with different degrees of mobility and accessibility, from the hard to mobilize form (present in minerals and compounds stable humic), to the relatively accessible one (present in altered minerals and organic matter in mineralization course) and to easily assimilable forms (elements changeable and solubilized in water from sol). Between these forms there is a dynamic, continuous balance, maintained by the continuous absorption of to plants of easily assimilable nutrients. Of the nutrients, N, P and K are frequently added to cultivated soils in the form of mineral and organic fertilizers, in various quantities, depending on the soil content in these nutrients and requirements of the cultivated plant. Also, in cases of occurrence of some phenomena micronutrient deficiencies in some cultivated plants, such as Zn deficiency in corn, deficiency of B to sugar beet and some trees, the lack of Mo to sunflower, completes the dowry natural micronutrients by administering mineral fertilizers with such elements chemicals. But to properly determine the need for macro- or microelements of soils, it is necessary evaluated (determined) the nutrient content of the soil. This operation is done within agrochemical mapping activity. It comprises three phases, one field, one laboratory and finally, an office one.

One of the functions of the soil is to produce phytomass, which is used as a matter basis for the production of food, clothing, fuels, etc. This function is set in value by appropriating the soil to be a continuous reservoir and supplier of water and nutrients, which are confers the general property of fertility. For plant growth, the soil provides many chemical elements necessary for development vegetation and crop formation. Of these, 14 are considered nutrients or essential nutrients. Depending on the quantity needed by the plants and their physiological and biochemical functions, nutrients are divided into macronutrients and micronutrients. In turn, macronutrients are divided in primary macronutrients (N, P and K) and secondary macronutrients (S, Ca and Mg). The group of micronutrients includes: Fe (a chemical element whose soil level is considered macroconstituent), Mn, Co, Cu, Zn, B, Mo, Cl. Soils contain different nature reserves of nutrients depending on nature parental material and soil type.

On another hand, soil testing is an integral part of a soil fertility management program. An effective soil testing planning provides information on the fertility status of soils within a field that can be used for making fertilizer recommendations, monitoring changes in soil fertility over time and even identifying and targeting low fertility soils within larger fields. The informative soil sampling highly improves on-farm nutrient efficiency, leading to increased return on investment for fertilizer and decreased risk of off-site nutrient movement. Regardless of the goal, reliable soil testing has to start with proper soil sampling and testing. In this regard, a proper soil sample collection relies on three principles, which constituted the basis of our methodology design, namely:

- ***Organization***: an orderly system for soil sample collection and handling simplifies the collection and minimizes the chance of human errors such as mislabelling or misplacing soil samples;
- ***Consistency***: collecting each sample in a uniform manner between the 3 years of project lifetime will greatly improve the quality and reliability of the results;
- ***Simplicity***: last, but not least, following simple procedures helped us to ensure sample collection which is consistent and easily organized.

But, in order to have a proper environment for digitalizing the reference data, first step to be taken is the experimental plots georeferencing and establish of the location of collection points for soil sampling.

RESULTS OF INVESTIGATION

The experimental plots are located one in Romania, the southern part of the country and exploited by AGROVET SA, having Mr. Laurentiu BERCA as leading the reasearches on their behalf and, the second in Hungary, the central part of the country and exploited by Kuspermezo Kft, Mr. Attila NAGY leading the reasearches and activity for this.

In the following are presented the results obtained after laboratory analisys for the experimental plot depictured in figure 2.

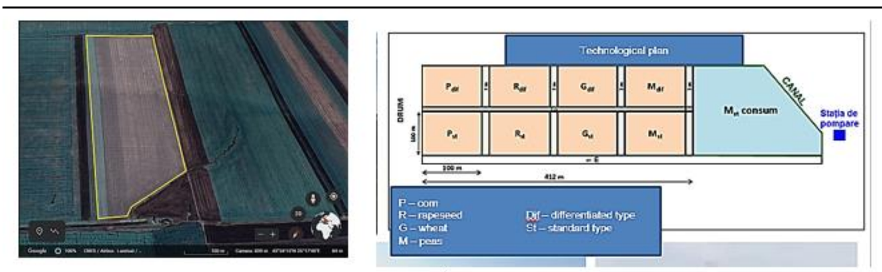

Fig. 2. *Georeferenced plot and crop planing*

The very practical aspect of this research is to provide to farmers the opportunity for better crop management by analysing plant characteristics, plant population, weediness level, field health, growth problems, diseases, involved pest or insects, vegetation indices, all completing the necessary information portfolio for model creation and building the prediction algorithms, protecting in this way the nature and increasing soil protection as well as optimizing economic activities in the SMART agriculture area.

The first stage of INSAC-AGRIS is to set up the parameters, analyse conditions and to adjust the triggers for the next year's stages. From this point of view, both teams from Romania and Hungary ran out of complementary field activities together with lab and office operations.

1. First step was to identify the parcels into a GIS software, measuring the borders and building the dimensional characteristics;
2. After identifying the experimental parcels, the soil samples map was built, using a grid of 50 m x 50 m and setting-up the GPS coordinates of the sampling points;
3. In the field, accordingly to the specific procedure, the soil samples were collected and labeled from the already mapped points using a GPS sensor;
4. Soil samples were minced and prepared in ampules for the lab, in order to keep the soil characteristics until the lab analyses;
5. Using the lab results, nutrients maps were made, loaded in the tractor computer and differentiated nitrogen soil enhancing was made;
6. The last operation made was sowing using the built maps introduced in the tractor computer.

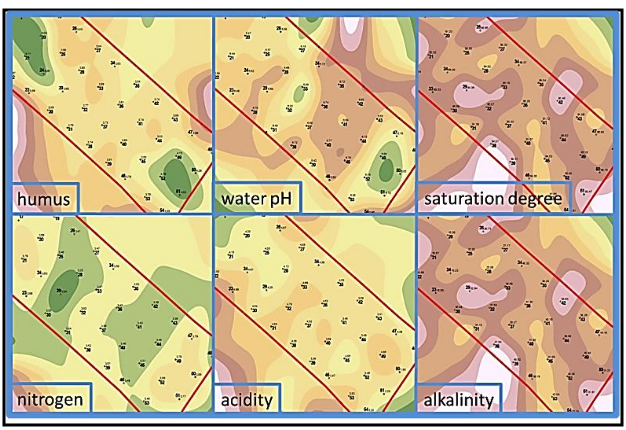

Fig. 3. *Soil composition characteristics for the Romanian experimental plot, before sowing*

CONCLUSION

Precision agriculture together with Internet of Things (IoT), can change the paradigm of agriculture from a manual and static approach to more dynamic and smart change, decreasing human efforts and leading to enhanced production.

The main conclusion following the activities made up until this moment in INSAC-AGRIS, is that keeping an organized approach of assessing the field, preparing for sowing with differentiated fertilization, brings an economy up until 80% of the sowing costs.

For the future research planned for the next two years, the benefit will be increased by including a cost-analysis evaluation for each sampling method used before sowing. This cost-analysis can include the time, money, and resources it takes to obtain the samples, as well as apply the recommended amount of material. This will help to further delve into the effect of soil sampling on management practices within farming operations.

The secondary conclusion is that automatized based agriculture machinery brings not necessarily a cost reduction, but an increase of agricultural works and more organized experimental plots.

The next step in the project is to bring the aerial assessment of the crops over the full vegetation period, before and after harvesting, so keeping regular feedback and allowing to intervene in a moment, when issues in soil quality or health status of the plant appear. In the future, INSAC-AGRIS plans to build a soil grid of sensors network able to alert in any moment the appeared issues.

This approach will become the basics of Agriculture 4.0, and building the framework for a sustainable agro-food system from Farm to Fork.

ACKNOWLEDGEMENTS

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DEVELOPMENT OF THE FUEL AND ENERGY COMPLEX IN CONNECTION WITH THE ADOPTION OF THE DECARBONIZATION LAW (ON THE EXAMPLE OF AUSTRALIA)

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ABSTRACT

The article, based on the current informational material, provides an overview of the mineral resource complex of Australia and the ways of its development in modern conditions. Modern requirements for the development of the fuel and economic complex of countries are caused by new challenges in connection with the need to follow the Paris Convention on Climate Change and the installation on decarbonization – a significant reduction and then a complete rejection of CO_2 emissions from the combustion of hydrocarbons. The work shows that the process of "greening" Australia provides for the creation and implementation of a completely new paradigm for the development of the fuel and energy complex. This is a complete rejection of the extraction and use of coal, an increase in gas production in compliance with environmental requirements, the development and implementation of new technologies, the expansion of gas storage facilities and a network of pipelines, as well as the parallel development and introduction of renewable energy sources.

Keywords: *Australia, fuel and energy complex, climate change, decarbonization, renewable energy sources*

INTRODUCTION

The Paris Agreement under the Framework Convention on Climate Change) was adopted on December 12, 2015 following the 21st conference of the United Nations Framework Convention on Climate Change (UNFCCC; 1992) in Paris. It was supported by all 197 members of the UNFCCC (193 UN member states, as well as Palestine, Niue, Cook Islands and the EU).

Decarbonizing the economy of the energy system is the reduction of CO_2 emissions per unit of energy generated (kg/barrel). The decision to minimize carbon dioxide emissions into the atmosphere during the development and production of hydrocarbon raw materials predetermines the need for the adoption of a new paradigm for the development of the fuel and energy complex in modern conditions. And this means a balanced and scientifically grounded combination of all types of energy raw materials. Australia, being a country with a low energy base (it has an insignificant resource of petroleum hydrocarbons, only 0.3% of the world's reserves), at the government level is taking on new challenges in connection with the doctrine of climate change. Develops and implements new global perestroika processes of updating the complex so that the country feels confident and self-sufficient in the near future and in the future.

In the history of the exploitation of various types of fossil fuels from the 19th century to the 21st century, the energy priorities of industrial development have repeatedly changed (Fig. 1) [1].

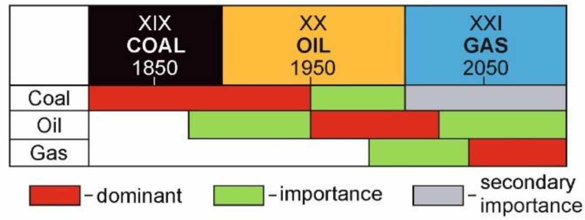

Fig. 1. *Epochs (eras) of domination (domination) of various types of fossil fuels in the world fuel and energy complex [1]*

Of all types of energy fuel, natural gas is the best type of natural resource for a number of reasons, in particular - environmental. Natural gas is becoming the means that contributes to the achievement of energy security, the growth of industrial production, the development of innovations, and the improvement of the environmental situation. Moreover, it is the environmental characteristics of natural gas as a fuel that are one of the main arguments in favor of its acquiring a key role in the global energy sector of the current century. Compared to other types of fossil fuels, natural gas emits a very significant amount of heat per unit weight, but at the same time it pollutes the atmosphere to a much lesser extent with combustion products [2].

RESULTS AND DISCUSSION

Overview of Australia's Energy Resources and the Direction of Their Development in Relation to Industry Decarbonization

Government and business structures of Australia, embarking on the path of the Paris agreements and in solidarity with the decision of the European Union on decarbonization, are taking tough measures to reconstruct their existing energy complex [3], [4], [5]. These actions go in three directions:

- complete rejection of the extraction and use of coal;
- developing and increasing gas production in compliance with environmental restrictions and expanding the construction of gas storage facilities and a network of pipelines for the domestic and foreign markets;
- powerful development of renewable energy sources based on wind, water and various modifications of solar panels.

There is a transition from a centralized system of large fossil fuels (mainly coal) to a decentralized system of widely dispersed, relatively small renewable sources in the form of wind and solar generators. And if by 2020 the energy produced by coal-fired power plants still remained high (although there is a noticeable decrease in the use of the most environmentally harmful brown coal) with a significant increase in renewable energy sources (Fig. 2), then over the next 15 years it is planned to further close two-thirds of all generating capacities of power plants working on coal [3], [4] (Fig. 3).

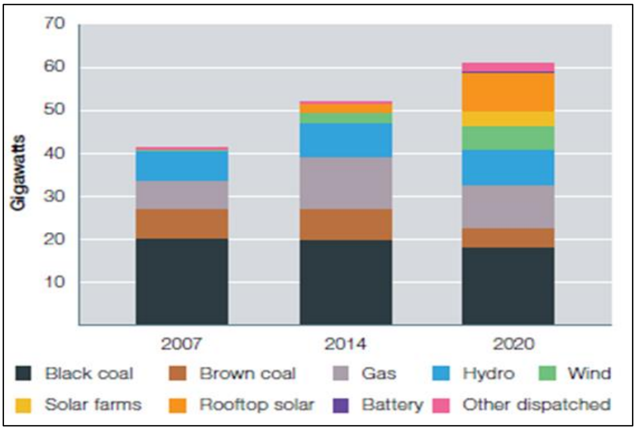

Fig. 2. *Changes in the energy sector: coal, brown coal, gas, water, wind, solar panels and other energy sources [3]*

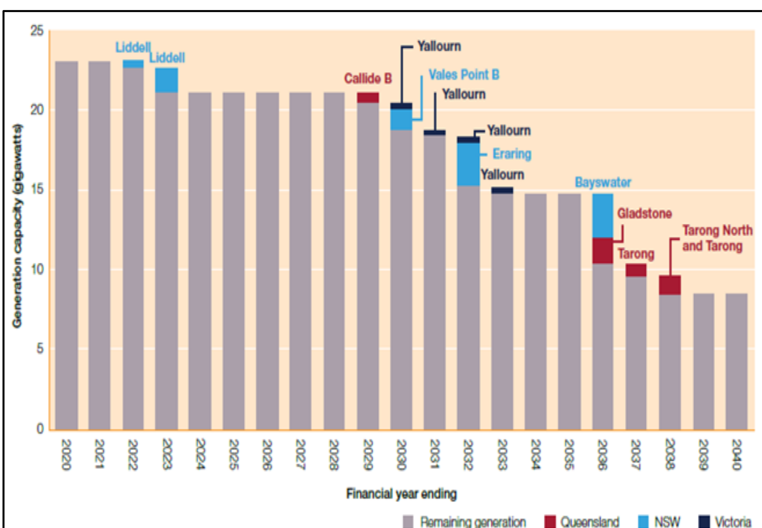

Fig. 3. *Schedule of planned reduction of coal generators in various states by 2040 (gray - residual capacity) [3]*

The first oil in Australia was discovered by a French expedition in shale rocks near Sydney in 1802. However, commercial exploitation of this field began only in

1865. The second was the discovery in 1885 of a similar Naguin field (Queensland), and the third (1886) – Salt Creek in South Australia. The beginning of commercial oil development on the island of Tasmania dates back to 1901, and in 1920 the first gas condensate well was launched in the same area on the island of Bruni. In 1907, the first offshore oil well was drilled in Albany Harbor (the drilling rig was on the shore, and the trunk went into the water) [6], [7].

A significant number of large and small proven and inferred oil and gas basins have now been identified on the continent. Thus, in the middle and eastern parts there is a vast Central Australian Basin associated with the foothill trough of the Late Paleozoic folded structures that frame the Australian Shield from the east. In this fold system in the southeast of the continent, there is a small intermontane South Australian Basin, otherwise called Gippsland, and a number of others. Australia currently holds about 0.3% of the world's hydrocarbon reserves. Most of Australia's identified hydrocarbon resources are condensate and liquefied natural gas (LNG) associated with the giant offshore gas fields in the Brouse, Carnarvon and Bonaparte basins. In addition, oil accumulations have been identified in the basins of the Perth, Canning, Amadeus, Cooper rivers (Eromanga, Bowen Surat, Otway, Bass and Gippsland oil and gas basins).

As of December 2018, oil production in Australia is 283 663 barrels/day. For comparison, the USA produces 10 961 718, Russia – 10 527 370, and Saudi Arabia – 10 058 000. The country exports 214 355 and imports 360 899 (in the same dimensions). At the same time, 51% of imported refined gasoline comes from oil refineries in Singapore, 18% from South Korea, 12% from Japan and other countries. The main proven oil reserves are located in the Gippsland oil and gas fields and nearby offshore oil fields in the Bass Strait, 65-80 km from the coast. In total, this area currently provides about 40% of oil production in Australia [8].

Australia has significant gas reserves, with gas being the third-largest energy resource after coal and uranium. Fourteen basins are gas-bearing, located both onshore and offshore (Fig. 4). The main types of gas produced in Australia are conventional natural gas and gas from coal seams. Advances in extraction techniques have improved the commercial prospects for the recovery of other forms of unconventional gas, including shale gas and gas in sandstones and tight gas carbonate reservoirs.

In Eastern Australia, almost 70 percent of the gas produced is converted into LNG for export, mainly to Asia. The remainder is sold on the domestic market. Some of the gas is stored in depleted gas fields or storage tanks. Gas sold to domestic consumers is transported from production sites to major demand centres or hubs through powerful pipelines. The lines are wide bore and high pressure to optimize lifting capacity. They supply gas for the power plants of large industrial and commercial customers, as well as for power supply companies that sell gas to their customers.

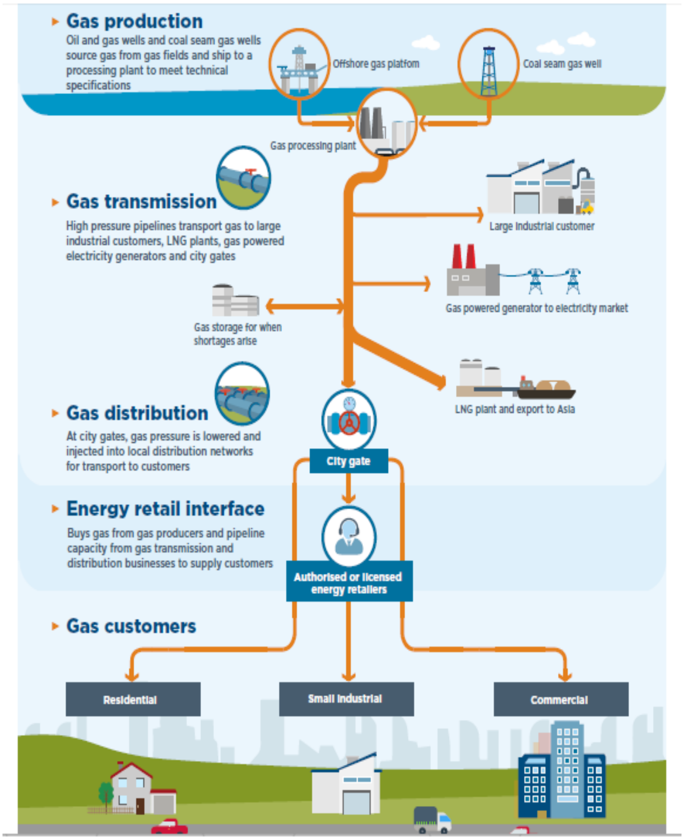

Fig. 4. *Gas supply chain [3]*

The energy market in Eastern Australia (Fig. 5) (practically all states: Queensland, New South Wales, Victoria, South Australia, Tasmania) is connected by main gas pipelines and supplies gas from the basins to industrial consumers in large settlements. The main production basins are the Bowen Surat Basin in Queensland, the Cooper Basin in northeastern South Australia and three basins off the coast of Victoria, the largest of which is the Gippsland Basin. Gas has become the main export industry in Eastern Australia. The industry has transformed the eastern gas market and has given producers the choice of exporting gas or selling it domestically. By 2018, about 61% of Australian gas production in the Eastern States was exported. When competing with overseas customers, prices in the domestic market increased. Higher gas prices are also affecting electricity markets, which have become more reliant on gas-fired generation following the closure of several coal-fired generators in 2016 and 2017 [9], [10], [11].

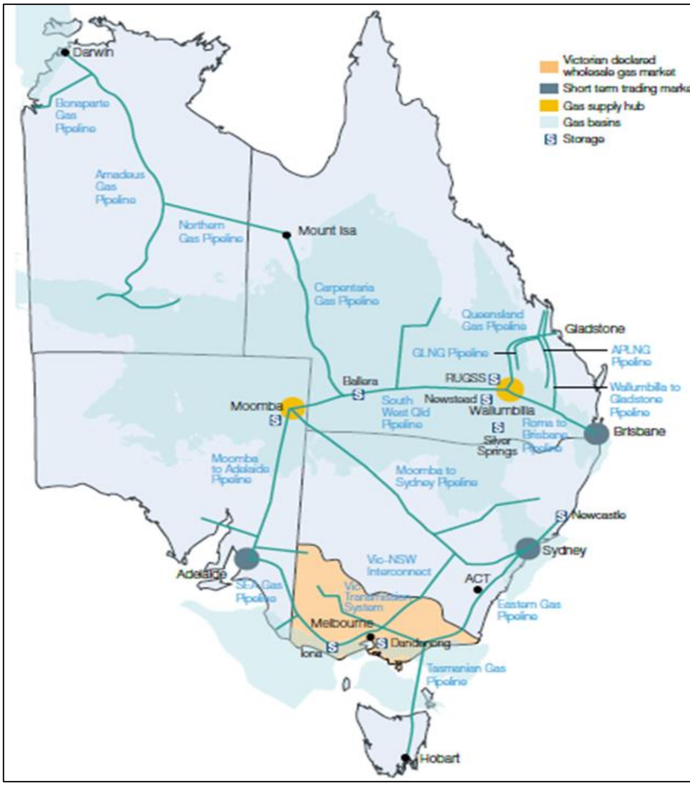

Fig. 5. *Eastern Gas basins, markets, major pipelines and storage (Eastern Australia) [3]*

CONCLUSION

Based on the example of the Australian fuel and energy complex, the article analyzes new challenges and global restructuring processes of the complex renewal, taken at the government level in connection with the decision of the European Union on decarbonization. These measures are being taken so that the country, having a not so high energy base, an insignificant resource of petroleum hydrocarbons (0.3% of world reserves), feels confident and self-sufficient in the near future and in the future. The decarbonization strategy must be well substantiated and calculated, supported by significant investments of budgetary and private capital with the involvement of a wide range of scientific research.

In Russia, such a scheme for changing the fuel and energy complex is planned for the near future (Fig. 6) [12].

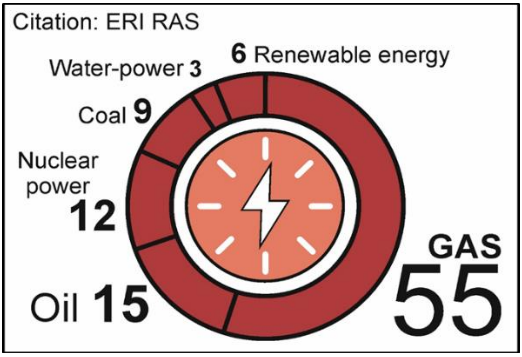

Fig. 6. *Forecast of the structure of primary energy consumption in Russia in 2040, % [12]*

Some ill-considered and politicized approach in making such global decisions leads to environmental and natural disasters. This is exactly what happened in the USA in the state of Texas in February 2021 (Fig. 7) Most of the state lost power during the historic "winter storm" [13], [14].

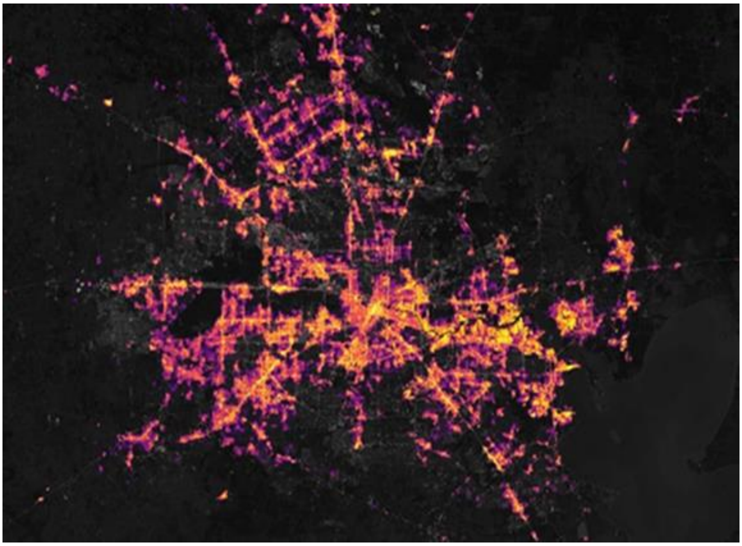

Fig. 7. *A partial blackout in Houston is captured Tuesday by a NASA satellite. Much of the state lost power during a historic winter storm (Credit: NASA [13])*

According to Emily Grubert [15], a professor of energy systems at the Georgia Institute of Technology, “The reason for this disaster stems from the fact that the country is seeking to make two energy transitions at the same time. One is the move from dirtier power plants to cleaner ones, and the other is an attempt to electrify buildings and cars that used to run on oil and gas”.

The main thing is to find a balance: not to underestimate the role of hydrocarbons and not to be late in the search for new technologies for generating energy [12].

In conclusion, it is worth citing the statement of Nikolai **Fyodorov,** a Russian religious thinker and philosopher (1826-1903): "A civilization that exploits, but does not restore, cannot have any other result than the approach of its own end."

ACKNOWLEDGEMENTS

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ECOLOGICAL AND ECONOMIC JUSTIFICATION OF THE INVESTMENTS' EFFICIENCY IN THE INTEGRATED DEVELOPMENT OF TERRITORIES

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ABSTRACT

Intensive human economic activity has led to decrese in the natural resource potential of territories and qualitative changes in the natural environment surrounding a person: a violation of the spatial and functional structure of natural systems, a decrease in the biological diversity of flora and fauna, a deterioration in the quality of water and land resources, a decrease in the ecological and economic sustainability of technical and natural systems and the quality of human life. Ensuring the sustainable functioning and development of territories is possible due to the complex arrangement of the territory (scientific organisation of the territory). It is the optimisation of the land using structure that will restore disturbed ecosystems to standard values, increase biological diversity, environmental sustainability and economic efficiency of landscapes. One of the limiting factors in the implementation of this measure is the lack of an effective mechanism for assessing the effectiveness of investments in land development. All this indicates the need to develop proposals for the development of methodological approaches to assessing the environmental and economic efficiency of investments in land development, taking into account the shortcomings that we identified when analyzing existing approaches to assessing the effectiveness of investment projects of social significance. At the same time, it should be noted that ensuring sustainable development of territories is impossible with the existing nature-intensive concept of economic development. A new approach to solving this problem is needed, which should:

- be based on a deep study of socio-economic and environmental problems, a retrospective analysis of the state of landscapes and a long-term forecast of the expected consequences of the impact of human activity on the state of individual components of the considered territory and the landscape as a whole;
- it aims to ensure the socio-economic and environmental safety of Russia.

The purpose is to develop proposals for the development of a methodological approach to assessing the environmental and economic efficiency of investments in the integrated development of territories which are aimed at ensuring the socio-economic and environmental security of Russia.

Keywords: *landscaping, scientific organisation of the territory, ecological effect, complex reclamation, efficiency*

INTRODUCTION

At present, all efforts to improve the environmentally sustainable development of territories are reduced mainly to combating the consequences by introducing the best available technologies (developing measures to reduce air emissions and discharges into water bodies, combating soil erosion, etc.), and not to clarify the reasons for the development of degradation processes and the development of preventive measures aimed at increasing the overall usefulness of the territory, taking into account inter-landscape connections. In addition, during solving these issues, such an important problem as the degree of disturbance in the structure of natural landscapes due to the transformation of forest and meadow ecosystems with high biodiversity into cultural landscapes as a result of economic activity falls out of sight. The research results showed that agriculture made a significant contribution to the violation of the structure of natural landscapes use due to the high degree of plowing of land (constituent entities of the Russian Federation included in the Central, Southern, Volga, North Caucasian, Ural federal districts). In these regions, the existing degree of disturbance in the structure of the natural landscape exceeds the permissible value of the anthropogenic load on the natural environment by 1.5 ... 2.5 times, and this, in its turn, led to a violation of one of the basic laws of nature - the Le Chatelier-Brown principle, such as the spontaneous destruction of natural ecosystems in the regions under consideration. The real way out of this situation is to abandon a pure consumer approach to the use of natural resources, reduce the technogenic impact on the natural environment and restore disturbed ecosystems to the extent necessary to maintain the sustainability and further development of natural landscapes and society. At present, the general opinion is that this problem should be solved through a comprehensive arrangement of the territory (scientific organisation of the territory). Optimisation of the structure of land using will restore disturbed ecosystems to standard values, increase biological diversity and ecological and economic sustainability of landscapes. One of the limiting factors in the implementation of this measure is the lack of an effective mechanism for assessing the effectiveness of investments in land development. And the existing approaches to assess the effectiveness of investments, set out in [1], are universal and do not sufficiently take into account the specifics of various sectors of the economy.

This is especially true for agriculture, which acts in two forms: on the one hand, it ensures the country's food security, on the other hand, it has a significant impact on the state of the environment. The absence in this document of a mechanism for accounting of environmental and social factors does not allow an objective assessment of the economic efficiency of investments in land development, which is a significant drawback of the regulatory document in the field of integrated investment support. These issues are not fully resolved in the departmental regulatory and methodological document [2], the significant disadvantages of which are:

- the assessment of the productivity of agricultural crops is carried out without taking into account the reclamation regime of agricultural lands and their ecological state;
- the list of reclamation measures proposed for taking into account when assessing the economic efficiency of an investment project is a set of measures, and not a system of interrelated and interdependent measures that function as a whole;
- when assessing the effectiveness, it is assumed that the complete restoration of the disturbed natural environment is achieved when carrying out environmental protection measures;
- It is proposed to determine the system of performance indicators without taking into account the assessment of the environmental sustainability of the natural system;
- when assessing the effectiveness of investments, preference is given to the economy, rather than the environmental factor (one of the laws of nature is violated - the principle of simultaneous efficiency and safety – don’t harm!).

There are also significant drawbacks in the proposed approaches to assessing the effectiveness of investments, set out in domestic and foreign works [3-17], the main of which are:

- lack of a system of indicators and models that would allow assessing possible long-term environmental consequences from the implementation of an investment project;
- lack of mechanisms for assessing the impact of the degree of disturbance in the structure of the natural landscape on the change in the land reclamation regime and the value of ecosystem services as a result of economic activities;
- lack of a systematic approach to the analysis of economic and natural processes in the implementation of reclamation measures.
- lack of a mechanism for taking into account the permissible degree of disturbance in the structure of the natural landscape when assessing the effectiveness of investments;
- lack of a systematic analysis of the reasons for the deterioration of the state of the main components of the landscape, etc.

All this indicates the need to develop proposals for the development of methodological approaches to assessing the environmental and economic efficiency of investments in land development, taking into account the shortcomings that we identified when analyzing existing approaches to assessing the effectiveness of investment projects of social significance. At the same time, it should be noted that ensuring sustainable development of territories is impossible with the existing nature-intensive concept of economic development. A new approach to solving this problem is needed, which should:

- be based on a deep study of socio-economic and environmental problems, a retrospective analysis of the state of landscapes and a long-term forecast of the expected consequences of the impact of human activity on the state of individual components of the considered territory and the landscape as a whole;
- it aims to ensure the socio-economic and environmental safety of Russia.

METHODS AND METHODOLOGY

The methodology for assessing the environmental and economic efficiency of investments in the development of territories is based on the accumulated knowledge about the functioning of techno-natural systems, a systematic approach to the analysis of economic and natural processes, as well as the principles of sustainable development and environmental management.

As a criterion for assessing the effectiveness of investments in integrated development of territories, it is proposed to use the increase in net discounted income:

$$\Delta ЧДД = \sum_{t=0}^{T_p} (\Delta В_t + \Delta Э_{1t} + \Delta Э_{2t} + \Delta Э_{3t} + \Delta Э_{4t} + \Delta Э_{5t} + \Delta Э_{6t} - \Delta И_t - K_t)(1 + E_н)^{-t} > 0$$

where

$\Delta ЧДД$ is the increase in net discounted income from the implementation of a set of measures for land development for the estimated period of time, rubles;

ΔB_t - increasing in proceeds from the production and sale of products on ameliorated lands in the year t of the billing period, rubles;

$\Delta Э_{1t}$ - the value of the prevented environmental effect formed by reducing erosion processes as a result of agroforestry and agrotechnical measures in the year t of the settlement period, rubles;

$\Delta Э_{2t}$ is the environmental effect generated by saving water resources in the year t of the billing period, rubles;

$\Delta Э_{3t}$ is the ecological effect of reducing the volume of discharge of collector-drainage waters as a result of land development in the year t of the settlement period, rubles;

$\Delta Э_{4t}$ - the ecological effect of reducing the area of the disturbed system and increasing the biological diversity of the landscape in the year t of the settlement period, rubles;

$\Delta Э_{5t}$ is the economic effect formed due to tax receipts to the budgets of all levels in the year t of the billing period, rubles;

$\Delta Э_{6t}$ is the increase in the multiplier effect in the construction sector, rubles;

$\Delta И_t$ - increase in production costs per year t of the billing period, rubles;

K_t - investments in complex development of territories in the year t of the billing period, rubles;

$E_н$ - discount rate.

RESULTS AND DISCUSSION

The results of the research showed that a special place among the main environmental problems of our time is occupied by changes in the structure of natural landscapes, an increase in the areas of disturbed ecosystems and a reduction in biological diversity, the main reason for the emergence of which is the transformation of natural ecosystems into cultural landscapes. All this indicates that the planned measures for the development of land should be aimed at preventing negative processes, namely, at reducing the areas of intensively used lands due to reforestation in areas where forests were previously cut down, transforming a part of arable land with slopes above 5 degrees into natural and semi-natural landscapes (in this territory, the ecological damage exceeds the economic effect due to the development of degradation processes), the elimination of abandoned lands in order to restore the operation of the Le Chatelier-Brown principle, that is, to stop the spontaneous destruction of natural ecosystems. When substantiating the size of the reduction in the area of intensively used lands, the ecological significance of various lands and the permissible degree of disturbance of the landscape structure are taken into account, the value of which does not exceed 0.15 for the conditions of the Northwestern, Siberian and Far Eastern districts, for other federal districts - 0.3 ... 0, 4 [18], [19], [20]. Solving the issues of optimizing the spatial and functional optimization of the structure of natural landscape use, on the one hand, should not infringe on the interests of economic activity (decrease in the production of agricultural and other products due to the reduction of arable land on the territory with slopes above 5 degrees), and on the other hand, not a single one. the type of activity cannot be justified if the economic effect from it does not exceed the caused environmental damage. In the event that the interests of the economy and nature do not coincide, it becomes necessary to find a compromise, but preference is always given to the conservation of nature, since it is nature that is a long-term factor in human habitation in the territory under consideration. In this regard, along with the optimization of the land structure, it is necessary to carry out a set of reclamation measures, including agrotechnical, agroforestry, biological, chemical and hydrotechnical reclamation on the remaining arable land in order to increase the productivity of land.

The basis for determining the increase in proceeds from the production and sale of agricultural products is based on the empirical dependence of the yield of agricultural crops on reclaimed land, which allows taking into account the main factors of life and development of plants, natural and climatic factors, the actual state of agricultural land, the farming system and the soil reclamation regime. The magnitude of the environmental effect (prevented environmental damage), formed by reducing erosion processes as a result of agroforestry and agrotechnical measures, is determined by the following formula:

$$\Delta Э_1 = \Delta S \cdot ц \cdot k \cdot F_{алм}, \quad (2)$$

where:

$\Delta Э_1$ - the value of the prevented environmental effect formed by reducing erosion processes as a result of agroforestry and agrotechnical measures, rubles;

ΔS - change in soil fertility due to agroforestry and agrotechnical measures, in shares of the original ;

$ц$ - cadastral value of land, rubles /ha;

k - an indicator that takes into account the type of land (for arable land, this indicator is 2.2);

$F_{алм}$ - the area on which agroforestry and agrotechnical activities are carried out, ha.

A special role in land development is assigned to hydrotechnical reclamation (irrigation and drainage of lands) as an integral part of complex reclamation. It is hydrotechnical reclamation that is an event that improves the environmental, social and economic conditions of the area under consideration. It should be noted that irrigated and drained lands should be used for vegetable crops, as hayfields and pastures, as well as for the cultivation of perennial grasses.

The basis for determining the environmental effect formed by saving water resources is based on additional costs associated with preventing or compensating for possible negative consequences as a result of land reclamation (irrigation), or saving financial resources (when using environmentally friendly irrigation standards for agricultural crops). The method for calculating the ecological effect is described in detail in [18].

The magnitude of the environmental effect from a decrease in the volume of discharge of collector-drainage waters as a result of land development is formed by reducing fees for negative impact on the environment as a result of the transition from the traditional irrigation regime, which is based on the principle of complete satisfaction of plants in water, to an ecologically safe water regime.

Comprehensive land development provides for a change in the existing structure of land in the landscape by reducing the areas of arable land located on an area with slopes of more than 5 degrees by converting them to hayfields and pastures and eliminating abandoned lands. Justification of the need to change the existing structure of land in the landscape, which is made by comparing the existing degree of disturbance in the structure of the landscape with the permissible values of this indicator. The assessment of the existing degree of disturbance in the structure of natural landscapes is carried out using an integral indicator, the value of which is determined by the ratio of intensively used lands to the total area of the region (landscape). The implementation of the above measures will contribute to a reduction in the area of the disturbed ecosystem, an increase in biological diversity, as one of the indicators characterizing the ecological and economic sustainability of the agricultural landscape and landscape in general, an increase in the value of ecosystem services in the territory under consideration, and this, in turn, will affect the improvement of the quality life of the population. The amount of increase in environmental damage formed due to changes in the area of the disturbed system and the biological diversity of the landscape without comprehensive land improvement and in the developed area is determined by the following formulas [18], [20]:

$$\varDelta Э_4 = Ущ_1 - Ущ_2, \ldots\ldots\ldots (3)$$

$$Ущ = F_{нэ} \cdot \beta \cdot F_{об} \cdot ц, \ldots\ldots\ldots (4)$$

$$F_{нэ} = а \cdot к_{нар} + в \cdot к_{нар}^2, \ldots\ldots\ldots (5)$$

where

$\Delta Э_4$ is the ecological effect of reducing the area of the disturbed system and increasing the biological diversity of the landscape, rubles;

$Ущ_1$ and $Ущ_2$ - environmental damage resulting from changes in the area of the disturbed system and the biological diversity of the landscape without carrying out a comprehensive arrangement of land and in a developed area, rubles;

$F_{нэ}$ - the area of the disturbed ecosystem,%;

β - coefficient taking into account the change in biological diversity as a result of plowing the natural landscape;

$F_{об}$ - the area on which the complex of measures for the arrangement is carried out, hectares;

$ц$ - ecological and economic assessment of agricultural land, rubles / ha;

a and $в$ - coefficients;

$к_{нар}$ - the existing degree of disturbance of the landscape structure.

The amount of tax receipts to the budgets of all levels is determined in accordance with the current legislation of the Russian Federation [20]. At the same time, it should be noted that when implementing a complex of reclamation measures, the budgets of different levels will receive taxes not only from direct participants in the investment project, but also from the construction complex. The reason for this is the large volume of construction and installation and other types of work performed during land development. Research results have shown [18] that the amount of tax revenues is 20% of the investment in the project.

The above approach to assessing the ecological and economic efficiency of investments in integrated land development makes it possible to take into account the diversity of climatic, socio-economic and ecological conditions of natural landscapes and agricultural landscapes, to substantiate the level of anthropogenic load on the landscape and the composition of measures for the reproduction of natural resources, as well as to estimate the value prevented damage (effect) from their implementation by increasing the biological diversity and productivity of agricultural land, improving the state of ecosystems, reducing the pollution of surface and ground waters, improving the quality of life of the population living in the territory under consideration, etc.

Below are the results of assessing the economic efficiency of investments in land development located in the constituent entities of the Russian Federation of the Central Federal District. The constituent entities of the Russian Federation, which are part of the Central Federal District, are located in forest, forest-steppe and steppe natural and climatic zones and have a high natural resource potential.

The research results made it possible to form a set of reclamation measures to improve the environmental sustainability of the territory and the efficiency of land use in the region under consideration, including:

- reforestation;
- prevention and control of soil erosion by planting field-protective forest plantations, carrying out agrotechnical measures and transforming a part of arable land into semi-natural landscapes;
- transformation of abandoned arable land into hayfields and pastures;
- reconstruction of reclamation systems.

Table 1 shows data characterizing the types and volumes of planned reclamation activities in the Central Federal District.

Table 1. *Planned system of reclamation measures, million hectares*

Events	Scope of events
Restoration of forest ecosystems	4,2
Prevention and control of soil erosion and deflation	11,7
including:	
shelter plantings	1,4
agrotechnical measures	4,3
tinning of arable land with slopes > 5^0	10,9
Transformation of abandoned arable land into hayfields and pastures	3,9
Reconstruction of reclamation systems, incl.	0,8
irrigation	0,4
drainage	0,4

The selection of priority reclamation measures in the complex land development is carried out by determining the social effectiveness of their implementation. Table 2 shows the results of calculating the social efficiency of a complex of land reclamation measures for the development of the territory of the Central Federal District.

Table 2. *The results of calculating the social efficiency of investments in land development, million rubles.*

№	Indicators	Indicator values, taking into account discounting for the estimated period of the project
1.	Outflows (item 2 + item 3 + item 4)	Outflows (item 2 + item 3 + item 4)
2.	Off-budget investments	10452
3.	Budget investments	86520
4.	The total increase in annual costs	104804
5.	Tributaries (item 7 + item 8)	370233
6.	The additional amount of proceeds from the sale of agricultural products obtained through the implementation of reclamation measures, excluding value added tax	131014
7.	An increase in the ecological effect due to the prevention of water and wind erosion of soil, saving water resources, reducing the volume of discharge of collector-drainage waters into water bodies, reducing the area of disturbed lands and increasing the biological diversity of the landscape	239209
8.	Increase in net present value (item 6 - item 1)	168447

The above results of calculating social efficiency allow us to conclude that the complex of measures for the development of land in the constituent entities of the Russian Federation that are part of the Central Federal District is highly effective (net discounted income for the calculation period in the considered district is a positive value).

CONCLUSION

As conclusion, generalisation of the available materials and numerical experiments performed using the developed models for the ecological and economic assessment of the effectiveness of investments in the development of territories made it possible to develop a set of measures to reduce the anthropogenic load on the natural landscape of the Central Federal District, increase biodiversity, increase the environmental sustainability and economic efficiency of the landscape. The research results have shown that the proposed set of reclamation measures for the development of the territory of the region under consideration will provide: an increase in crop yields from 60 to 80 ... 85% of the climatically provided yield; increase in biological diversity by 25 ... 30%; reduction of water pollution by 50 ... 55%; an increase in the moisture content of the territories by 5 ... 7%; reduction of the area of damaged systems by 15 ... 20%.

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GLOBAL TRENDS IN BIODEGRADABLE POLYMERS

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ABSTRACT

Recently, the rapid and almost uncontrollable growth in the consumption of synthetic plastics in many sectors of the economy, especially in the field of packaging, has been a serious concern. Plastic containers are used for packaging food products, medicines, electronic devices, liquids, including those with a higher hazard class, etc. [1]. According to the German Nova-Institute, the global plastic production in 2020 has reached almost 400 Mill. Tons. At the same time, the volume of biodegradable plastics obtained from renewable resources amounted to only 3.5 million tons, i.e., about 1% of the total volume production [2]. Considering that only 25% of plastic waste is recycled, the growing consumption of polymer products is forcing manufacturers to develop biodegradable polymer compositions [3]. The problem has economic and environmental aspects since it is interconnected with the growing need to protect the environment and reduce the cost of raw materials for the production of various products.

Keywords: *biodegradable polymers, biodegradable materials*

INTRODUCTION

It is considered promising to develop technologies for biodegradable polymer hybrid compositions (BGC) and products based on them [4], [5], [6]. One of the promising directions for the creation of BGK is the use of thermoplastic starch (TPS), as the main component for their base [7]. To obtain TPK, native starch is mixed with heating with various plasticizers [8]. It is known today that the use of TPK as a filler in polyolefin compositions instead of native starch is preferred due to better processability and higher thermal stability. In this case, the content of TPS in the compositions can reach 40-60 wt.% [9], [10]. Therefore, the purpose of this work is to improve the technology for creating biodegradable film compositions intended for use as packaging materials and to draw up a basic technological scheme for the production of biodegradable hybrid compositions (BGC).

MATERIALS AND METHODS

The materials used were: high-grade corn starch (GOST 32159-2013); corn amylopectin starch according to GOST 32159-2013, wheat starch according to GOST 31935-2012 .; pea starch (certificate of conformity, ROQUETTE, France); rice starch (LLC Vinh Thuan Trading Import-Export Co. Ltd (Vietnam), (JSC Bioprogress, Moscow, Russia); distilled glycerin grade PK-94 (GOST 6824-96); crystalline sorbitol; low density polyethylene (high pressure) grade 11503-070 produced by Kazanorgsintez PJSC (Russia); dry vermicompost according to GOST R 56004-2014; TU 9818-001-47294670-2015 glycerin, sorbitol.

Organoleptic evaluation of polymer films according to the norms of SanPiN 42-123-4240-86, GN 2.1.6.695-98, SanPiN 2.1.4.559-96. The breaking stress in tension and the relative elongation at break of the films from the compositions were determined at a temperature of 23 ± 2°C, a relative humidity of 50 ± 5%, and a speed of expansion of the clamps of the testing machine in accordance with GOST 14236-81. The experiment was carried out on a tensile testing machine RM-50. The limit of the permissible value of the load measurement error did not exceed ± 1%. Determination of vapor permeability according to GOST 33355-2015 (ISO 7783: 2011). Evaluation of biodegradation according to the modified Sturm method GOST 32433-2013. Water absorption was calculated according to where m, m1 are the mass of the dried sample and the mass of the sample after exposure in water, respectively, g, using an analytical electronic balance ViBRA AF-R220E (ViBRA SHINKO) according to GOST 24104-88.

AS A RESULT OF RESEARCH

The All-Russian Research Institute of Starch Products is conducting research on the use of starch to obtain biodegradable polymer products. The process of modification of various types of starches by the extrusion method in the presence of plasticizing agents has been investigated. The parameters of the technological regime for obtaining thermoplastic starch (TPS) have been developed. Mathematical models of optimal compositions of biohybrid compositions (BHC) based on polyethylene and TPK have been created, depending on the technological modes of film production. The physical and mechanical characteristics of BGC and the film were investigated at various ratios of components and the effect of ultrasonic treatment (US), considering the standard values of the maximum stress and elongation at break. During storage of BGK and films in bio humus, physical and mechanical properties were determined, indicating the accelerated decomposition of products. The microstructure of polyethylene-starch compositions obtained at different temperatures has been studied, an improvement in consumer and operational characteristics when exposed to the ultrasonic treatment of the composition due to more uniform distribution of components in the polymer matrix has been established.

The use of montmorillonite in the production of biodegradable film materials imparts hydrophobicity and makes it possible to significantly improve the physical and mechanical characteristics of film and other materials and allows to reduce the proportion of polyethylene by 2 times or more, which increases the biodegradability of polymer products.

A comprehensive study of the effect of the type of packaging on the processes of moisture migration, changes in lipase activity and microbiological indicators was carried out. It is shown that a new type of biodegradable packaging based on thermoplastic starch has similar barrier properties in comparison with classical polypropylene packaging, while the quality of the packaged products is guaranteed by the example of jelly marmalade glazed with confectionery glaze.

NATURAL ADDITIVES FOR BIODEGRADABLE MATERIALS

In his article, the author Sagdat Tazhibaeva [11] Assume a Gaeta that for regulation of structural and mechanical properties of the films proposed to use salts of calcium and magnesium. Influence of calcium and ions on strength and deformation characteristics. And they monotonously increase the strength characteristics of starch-agar films, and the curves of changes in these parameters in the presence of magnesium have a maximum at a concentration of 0.5%. The difference in the effect of ions on the structural and mechanical properties of the films is explained by the degree of hydration of these ions. The biodegradability of starch-agar films was controlled by the authors by changing their IR spectra. The most significant changes are observed in the intensity and localization of the peaks corresponding to the OH, CH, and CC bonds, which may indicate a change in the structure of the films due to the destruction of the network of hydrogen bonds and hydrophobic interactions, as well as the rupture of hydrocarbon chains and the destruction of the framework of carbohydrate molecules.

Josue Hernandez-Varela [12] The world is currently confronted with the effects of pollution from petroleum-derived plastics (plates, glasses, cutlery), prompting the search for new biodegradable materials based on agro-industrial lignocellulose residues that help reduce their use and create more safe waste for the environment The use of garlic peel (GS) as a raw material in the form of cellulose microfibers (CMF) and as a precursor of cellulose insulation to obtain microcrystalline cellulose (MCC) for the manufacture of the biodegradable composite film is presented below. To obtain biodegradable films, mixtures of potato starch, gellan gum and glycerin with CMF were used for future use as food utensils; on the other hand, chitosan (Q), alginate (A) and MCC were used to obtain a film capable of removing dyes from water and absorbing gases. These CMFs were used to make biodegradable films for food utensils, and garlic peel nanoparticles (CNP-GS) were used to remove the dye films. Both materials were easily analyzed using scanning electron microscopy (SEM) as a powerful technique for evaluating the surface and cross-section of materials and understanding the location of polymers.

A.S. Mohammed and al. [13]. The natural or hydrolyzed starch and mate extract (10 wt. % Or 20 wt. %) Phi investigated films obtained by extrusion and compression. Natural starch-based material (TPNS) showed lower water vapor permeability and higher Young's permeability. 's Modulus (I) compared to matrix hydrolyzed starch (TPHS), but deformation decreases with break (ε b) and toughness (T). The inclusion of 10 wt. The % extract in TPNS resulted in higher I and ε b and the result was the most hydrophobic material. In contrast, TPHS with 20 wt %. The additive gives phi I with the highest ε b and T, indicating the plasticizer e ff action of the extract in this concentration and system. All materials disintegrated after 10 weeks of burial, helping to reduce the amount of waste. The biodegradable film containing extract mate yerba demonstrated antioxidant activity and color variation in different pH, indicating that they are promising as an active role in the intellectual and packaging for food products in accordance with the new trends in the field of biodegradable and functional packaging.

ADDITIVES IN NON-NATURAL BIODEGRADABLE MATERIALS

Jordana Corralo Spada. [14] Among petroleum-based packages, the use of expanded polystyrene (EPS) stands out, which is characterized by low production costs, low density, high moisture resistance and dimensional stability. However, improper disposal and the complexity of their recycling together with their non-biodegradability can lead to serious environmental problems. Knowing that it is impossible to discourage the use of this material by the public, the present study focused on the production of environmentally friendly foams based on cassava starch and rice hulls (RH). Compared to EPS, materials developed using biopolymers are less flexible and more sensitive to water. The addition of rice hulls improved mechanical properties and reduced density and water absorption compared to foams made using starch alone. Foams were produced by temperature and pressure and it was investigated the effect of various proportions of tnositelnoy humidity (0,20,40 and 60% (wt/ Wt.)). The higher the relative humidity, the higher the density and the lower the water absorption capacity (WAC). Maximum tensile stress and tensile strain were negatively affected by the addition of 60% (w / w) RH. In contrast to the maximum bending stress, this was influenced positively. In addition, sorption isotherms showed that 40% and 60% RH samples adsorbed less water compared to unfilled foam. The 60% RH formulation was chosen for storing cherry tomatoes because of its higher maximum flexural stress and lower WAC, which is considered a promising material, the higher the density and the lower the water absorption capacity (WAC). At the maximum tensile stress and tensile strain negatively claim ovliyala additive 60% (wt. / Via).

Graft copolymerization was initiated with cerium ammonium nitrate (CAN) or potassium persulfate (KPS) resulting in modern reaction mechanisms. For each of the three initiators diByli used various synthetic routes. The structures of the new SAP on a biological basis have been characterized using IR spectroscopy. Thermogravimetric measurements were performed to check thermal stability, and the morphology of the samples was examined using scanning electron microscopy (SEM). Physicochemical measurements were performed to characterize the properties of new materials. The water absorption capacity of the obtained hydrogels was measured in distilled water and 0.9% NaCl solution.

Jordana Corralo Spada. Among petroleum-based packages, the use of expanded polystyrene (EPS) stands out, which is characterized by low production costs, low density, high moisture resistance and dimensional stability. However, improper disposal and the complexity of their recycling together with their non-biodegradability can lead to serious environmental problems. Knowing that it is impossible to discourage the use of this material by the public, the present study focused on the production of environmentally friendly foams based on cassava starch and rice hulls (RH). Compared to EPS, materials developed using biopolymers are less flexible and more sensitive to water. The addition of rice hulls improved mechanical properties and reduced density and water absorption compared to foams made using starch alone. The foams were obtained by thermal pressing and the effect of different proportions of relative humidity (0, 20, 40 and 60% (w /w)) was investigated. The higher the relative humidity, the higher the density and the lower the water absorption capacity (WAC). Maximum tensile stress and tensile strain were negatively affected by the addition of 60% (w / w) RH. In contrast to the maximum bending stress, which was influenced positively. In addition, sorption isotherms showed that 40% and 60% RH samples adsorbed less water compared to unfilled foam. The 60% RH formulation was chosen for storing cherry tomatoes because of its higher maximum flexural stress and lower WAC, which is considered a promising material, the higher the density and the lower the water absorption capacity (WAC). The maximum tensile stress and tensile strain were negatively affected by the addition of 60%.

Elzbieta Czarnecka [15]. Superabsorbent polymers (SAP) based on biopolymers are being synthesized and investigated as a biodegradable alternative to fully synthetic SAP, especially based on acrylic acid and its derivatives. This article focuses on the chemical modification of starch (S) and the synthesis of new potentially biodegradable polymers using acrylic acid (AA) as a side chain monomer and crosslinking mediator together with N, N '- methylenebisacrylamide (MBA).

CONCLUSION

The main essence of the studies studied is the fact that every year the study and development of biodegradable polymers becomes an important and necessary trend.

The practical widespread use of biodegradable films to produce packaging materials presents a real opportunity to save resources and minimize damage to the environment from the growing and irreversible harmful effects of solid household waste Change in the chemical structure of synthetic non-degradable polymers because of the introduction of natural additives into the film, including thermoplastic starch affects the fragmentation of packaging polymers in soil. Therefore, the use of biodegradable polymer products for packaging various types of food products requires further research.

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LATVIAN THEME PARK DEVELOPMENT IN KURZEME AND VIDZEME

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ABSTRACT

The economy of Latvia is experiencing rapid development in the European Union and is an active participant of the United Nations and North Atlantic Treaty Organization. In recent years there have been several changes in both sectors and national economic policy. The total population in Latvia was estimated at 1.9 million inhabitants in 2019 and a total GDP per capita was 63% of the EU average, the lowest GDP per capita in purchasing power parity was recorded in Bulgaria - 46% of the EU average, Romania - 60% and Croatia - 62%. Lithuanian and Estonian GDP per capita in 2019 was accounted for 74% of the EU average. Latvia has more than 12 theme parks, but the amusement offer is small. Most of the theme parks are mostly located in Kurzeme and Vidzeme. Attraction Parks historically evolved near the big cities, where the infrastructure is highly developed. The aim is to increase the influx of tourists in regions where tourism products are amusement parks, thus developing more local businesses and the city's environment, increasing the demand for an active economic environment, but regional laws often hinder this development.

Keywords: *regional development, tourism, economics, economic of regional, theme park*

METHODS

The following research methods are used in this article statistical data analysis method, questionnaire and data processing method.

The result of the study helps to analyze Latvian regional economic opportunities in the regions and to assess their contribution to local development.

INTRODUCTION

Latvia is a country on the Baltic Sea with a population of 1.9 million. There are four ethnographic regions in Latvia - Kurzeme, Vidzeme, Zemgale and Latgale. Theme parks in the Baltic region have been little studied, as they have only begun to develop in the last 25 years. The parks are related to the regional economy, business, tourism, as well as local government development plans. It is a large and new research object in the Baltic Sea region.

Latvian theme parks are poorly studied and there is no much information about their importance in the regional economy, as well with a contribution to the tourism and business sector. These are objects widely used by tourists, where often there is a connection to the regional business environment, because there are both shops and hotels and other types of service needed for visitors. Several theme parks are located in cities, such as " Lembergs Trilby" " or "Livu aquapark", others near the highways - entertainment park "The Emergency Brigade" [6], [8].

Worldwide, attraction parks have been formed already for centuries, so this sector and industry have developed traditions that produce long-term results. It is a cooperation between state institutions, local authorities and entrepreneurs. Today, the world's largest attraction parks are located in the United States and are located near large cities with millions of inhabitants, thus generating millions of annual turnover for the economy and park owners. The European amusement industry is thematically more comprehensive and much closer to nature or geographical features; it is more diverse. The most famous amusement park in France is Disneyland, in Germany are number of nature and amusement parks, in Denmark is Pippi Longstocking theme park, in Finland is Santa Klaus theme park. Each region of Europe highlights its own national and geographical specifics. Baltic national theme parks have historically been formed from fairs or city festivals. Although we have a small population that influences the industrial development of the entertainment industry, compared to most major cities in Europe, however the stable climatic conditions, the secure political environment can create new growth trends for the tourism industry. English scientist D. Edgar who has researched the dynamics of global tourism and the development of strategy, says, "... no matter how big or small you are, it matters how competitive and dynamic tourism product you can offer the world".[3] There are no research institutes in the Baltic States exploring the potential of this industry. Tourists are therefore offered other products that are more related to the Baltic Sea, with the extensive placement of guesthouses in beautiful nature locations.

Latvian theme parks are not industrially developed and large as European or USA parks. Our economy and the relatively small population are unable to ensure successful development for this sector. There are more than 12 theme parks in Latvia, but their entertainment offer is small.

Since 2004, when Latvia joined the European Union, guidelines for the tourism industry have played an important role in promoting the free market movement. In the regions of the country the establishment of active recreation and theme parks has developed. Lido theme park is established in 2003, "Livu aquapark" in 2004, "Lembergs Trilby" theme park in Ventspils in 2005. Therefore, it should be noted that the recreational opportunities of Latvian regional tourism have been studied by several authors (I. Silēviča 2007; J. Gaile, 2005; 2007; Karnītis K, Karnīte R 2006; Klepers A. 2009.; I. Bērziņa; 2012, I. Jēkabsone 2017.) (U. Plumite; 2019) As the amusement sector in Latvia is a relatively new tourism sector, there is no study on Latvia's regional amusement parks. [7]

Thus, the author working in this field and researching the development of the amusement industry in Europe and Latvia, raises several questions to which the answers will be given in this article.

- Whether a tourism product such as theme park needs to be developed in Latvia, whether these parks are able to successfully attract large quantities of visitors;

- Many regional theme parks are subsidized by municipalities but often managed by entrepreneurs. The work is looking for answers if in the long run it is gainfully both for the public sector and for regional businesses, what are the losses and gains;
- Latvia's average economic and social indicators are lower than most in the European Union, with population of 1.9 million inhabitants (of which 48.9% are in Riga region), total population decreases by 18.7 thousand in the last 3 years. That shows that sustainable and competitive sector policy in the long term is threatened;
- In regions where entertainment is a tourism product, there is higher influx of tourists, resulting in development of local business and urban environments, demand for hotels, guesthouses and other public sector products increases.

Latvia's gross domestic product (GDP) in 2019 at comparable prices, according to seasonally and calendar non-aligned data, has increased by 2.2% compared to 2018, the Central Statistical Bureau (CSB) informed. [2] Latvia's GDP at comparable prices was 30.5 billion euros last year. In the 4th quarter of 2019, compared with 3rd quarter, GDP at comparable prices according to seasonally and calendar non-aligned data increased by 0.1%. [2]

Whereas, in the 4th quarter of 2019, compared with the respective period of 2018, Latvia's GDP has increased by 1%, according to seasonally and calendar non-aligned data. An increase of 5.8% was observed in the arts, entertainment and recreation sector, most notably affected by a 7.9% increase in gambling and betting Product taxes - value added tax, excise duties and customs duties – amount increased by 0.2% in 2019. In 2019, compared to the previous year, total expenditure of households increased by 4.9%. Household expenditure on transport (public transport, purchase and operation of vehicles) increased by 9.6% and 6,9 % more households spent on leisure and cultural activities. (Central Statistical Bureau of Latvia; 2019)

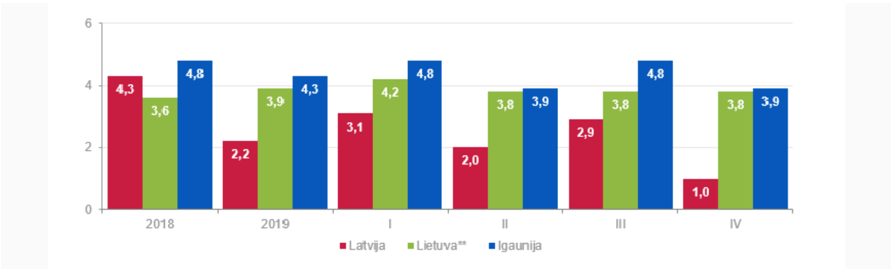


Fig. 1. *Changes in Gross Domestic Product in the Baltic countries (seasonally and calendar non-aligned, at comparable prices, in percentage of the corresponding period of the previous year). Source; CST data*

*** For Lithuania for 4th quarter of 2019 data of first assessment*

As a result, the tourism industry has been growing in recent years, influenced by the development of the Baltic and European economies. It should be noted that indicators of Latvia's economy and national economics are weaker than that of its two neighbours and we need to develop a stronger tourism strategy across the country and work more on marketing activities at theme parks. In the author's opinion, this also depends on the fact that there is little discussion and analysis at the national level about the entertainment industry and its contribution to regional development. Certainly, we cannot compete with the more developed regions of Europe and their theme park offers, but our country, with its quality and specificity, is able to compete in several segments of the niche product range.

By analyzing the theme parks in Latvia and the Baltics, the author has developed the basic types of theme parks in Europe.

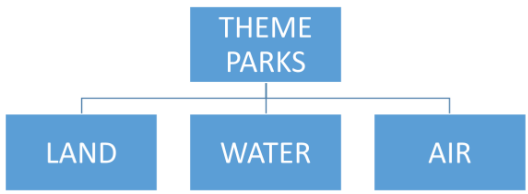


Fig. 2. *Types of theme parks. Source: scheme developed by the author*

These are basic types, but today they are further divided by the specific nature of park, and in the world these are technical, scientific, thematic, technological, entertainment sometimes named on according to the specific industry, such as car or aviation parks, water or underwater parks, cinema or marvel parks, etc. Each of these parks has developed its own trends and there is a process of factors that affect them both from a developmental point of view and from a supply perspective. The English scientist David Edgar (2001) refers to the following basic factors in the analysis of trends in theme parks in Europe; (1) external; (2) internal, and detailing what are under the groups of both factors.[5] (See Table Nr. 1).

Table 1. *Determinants of theme park development.*

External factors	**Internal factors**
Global organized economic system	Successful cooperation between local authorities and entrepreneurs
Development of urbanization	Organized regional policy
Use of science, technology, natural resources	Organized tourism environment and structure
National and regional authorities organized legislation	Strategically accessible location

Source: scheme developed by the author of the following study by D. Edgar: "Tourism in the 21 century"; 2001; p. 94-95.

These factors can be both historically inherited and acquired over time. If we look at Kurzeme and Vidzeme theme parks in Latvia, such as "Lemberga Trilby", located in Kurzeme in Venstpils, which is at the Baltic Sea and Vidzeme theme park, such as the "The Emergency Brigade", located at 65 km from Riga near the

Riga-Moscow highway, it should be noted that their development factors mentioned in the table above have affected the specifics of the operation. [4]

The first park offers a wide range of attractions for different age groups, including active recreation such as obstacle trails, trampolines, different types of amusement machines, sandboxes, swings and slides for the smallest ones. The park also has an active recreation area with outdoor exercise equipment and a bicycle path. The park has a wide range of dining options and there are hotels nearby. The other park - "The Emergency Brigade", has specific themed attractions, which are various types of dinosaurs, machines, labyrinths and other technical attractions for ages 12 to 70, but the rest is not as extensive as there is no city or Baltic seacoast.

Therefore, one of the main determinants of development is the geographical location of the park and the accessibility of the surrounding infrastructure. The park can develop better if its popularity and accessibility is as wide as possible and within reach to visitors. We can look at the regional factor of Latvia in picture No. 4 which represents Latvia in the context of the Baltic Sea coast. See the table below for the main questions the author included in his questionnaire. Analyzing the data by factor analysis, analyzing the existing parameters by rotation matrix principle, the following indicators characterizing the factors were obtained. Thus, 3 main components were identified which, on the numerical scale from - 5 to + 5 by the method of variation, identified the main factors.

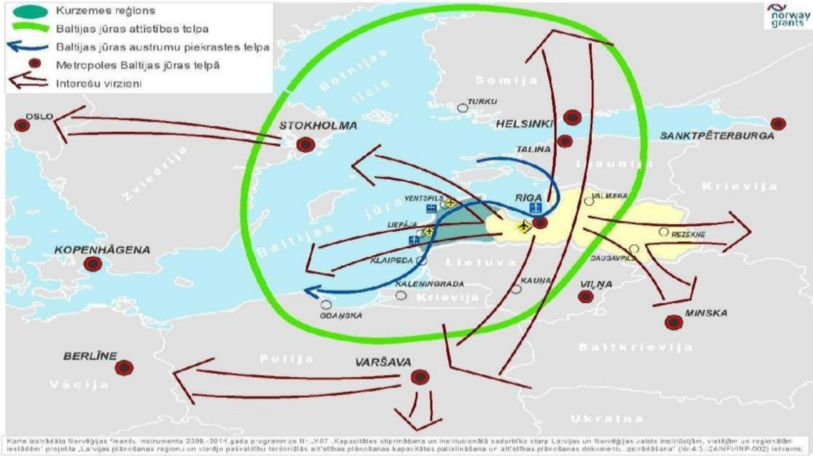
Table 2. *Rotated Component Matrix*

	1	2	3
Region	0,180	**0,869**	-0,133
Legal form of the company	0,300	**0,809**	-0,102
Foundation year	**-0,742**	-0,248	0,293
Company size	0,543	**-0,562**	-0,283
Size of the park	0,082	-0,290	**0,789**
Impact of seasonality	-0,054	-0,354	**-0,650**
Offering new attractions	0,01	0,202	**-0,419**
Offering new services	-0,449	0,227	**0,544**
General expert assessment of the site	**0,855**	0,072	0,211
Expert evaluation of object development	**0,677**	-0,049	-0,041
Expert assessment of the object's visibility	**0,842**	0,060	-0,007
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.			
a. Rotation converged in 5 iterations.			

Source: scheme developed by the author

The three main factors that result from the data analysis are: 1) theme park quality factor; 2) theme park status factor; 3) theme park innovation factor.

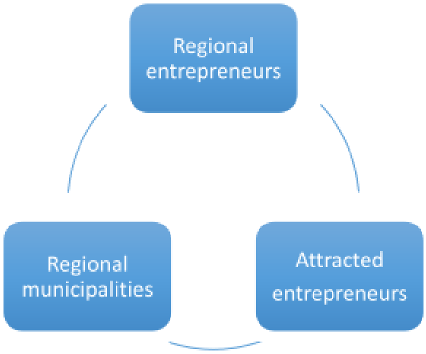
Fig. 3. *Possible directions of development of Latvian regional amusement parks in the coast of the Baltic Sea*



Source: Kurzeme Planning Region Sustainable Development Strategy for years 2015-2030.

The next factor that influences the development of parks is their model of cooperation with other structures in their regions. [4] Local governments and businesses close to the parks play an important role here. Municipal companies take an active part in the biggest theme parks in Latvia, as the parks have a strong seasonality principle, so the inhabitants of local towns and regions are the main visitors [5]. In summer there is a large inflow of tourists from European countries.

Fig. 4. *Regional cooperation model of theme parks in Latvia*



Source: scheme developed by the author according to the collected information

The development of parks is possible through the cooperation of several structures that complement each other. Their basic development indicators are defined by location, cooperation, consumer demand and entertainment supply, which should be as broad and comprehensive as possible for all consumer market groups. The variety of theme park types is determined by the location and how well the region is developed, both from the municipal and state infrastructure placement and from the business environment. However, while writing this article, the author concludes, as part of his doctoral thesis that theme parks in Latvia have been expanding rapidly over the past 5 years.

RESULTS AND DISCUSSION

In this article, the author has summarized and analyzed some of the theme park development factors affecting this industry in different regions of Latvia. The article is just one of a series of articles and of the author's works on theme parks in Latvia, as the industry is poorly studied and little has been discussed about theme parks in small countries for their contribution to the local economy and tourism.

CONCLUSION

European theme parks began to form at city festivals, fairs, thus the industry has a long tradition

Development of theme parks is influenced by several internal and external factors; which interaction ensures a successful development model.

Latvian theme parks have not been studied and there is a lack of data and legislation.

The sector is developing in close cooperation with municipalities and other regional economic participants.

The location of theme parks often influences their type and range of services.

Result of the study helps to analyze Latvian regional economic opportunities in the regions and to assess their contribution to local development.

In Latvia the amusement parks of the ethnographic regions Kurzeme and Vidzeme have been little studied scientifically and by several scientists in the field here and there are great opportunities to conduct various researches.

ACKNOWLEDGMENTS

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POSSIBLE DEVELOPMENT MODELS OF LATVIAN AMUSEMENT PARKS

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ABSTRACT

There are more than 14 amusement parks in Latvia, located in different areas. Latvia's amusement parks have been little studied and there is not much information about their importance in the regional economy, as well as the contribution to the tourism and business sector. These are places that are widely used by tourists, often related to the regional business environment, as there are shops and hotels nearby, as well as other types of service that visitors need. Latvian amusement parks can be divided into three groups: terrestrial, water and technical scientific amusement parks. Many of them are located near cities, for example, amusement park "Lemberga Hute" near Ventspils, city by the Baltic Sea with 38059 residents in 2019 (according to PMLP data), "Livu water amusement park" located in Jurmala, which is a city with 56696 thousand residents 2020 (according to PMLP data). One of the determining factors of the development of amusement parks is the growth of cities and their adjacent territories, which enables them to form both in terms of infrastructure and population growth. Regional economic indicators are an important factor for regional growth.

Keywords: *amusement parks, regional economy, development factors, factor analysis, development models*

INTRODUCTION

Latvian amusement parks are developing according to certain factors. Historically, they are near cities, waters or near major highways. Future factors influence theories of regional development and their adaptation to the specific infrastructure environment.

Environment Long-term regional development and the international economic situation, as well as tourism, will create new development models for the amusement park market.

The aim is to show the possible development opportunities of amusement parks.

The following tasks have been set - first of all to look at the development factors of existing parks and afterwards to determine the possible development models of future parks.

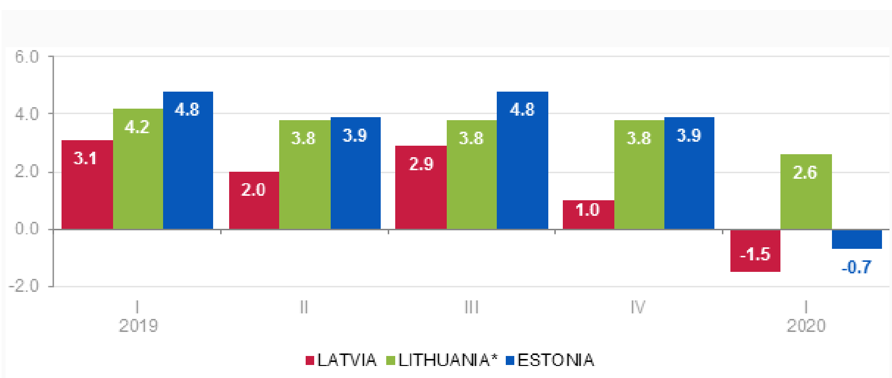
METHODS

The following study methods are used in this article: statistical data analysis method, questionnaire and data processing method, SWOT analysis and factor analysis according to SPSS computer matrices

Latvia has a population of 1.9 million, GDP at current prices last year was 30.5 billion euros. In the 4th quarter of 2019, compared to the 3rd quarter, GDP at constant prices increased by 0.1% according to seasonally and calendar adjusted data. In the fourth quarter of 2019, compared to the corresponding period of 2018, Latvia's GDP, according to seasonally and calendar unadjusted data, increased by 1%. An increase of 5.8% was observed in the arts, entertainment and recreation sector, which was most significantly affected by 7.9 % increase in gambling and betting industry. The amount of product taxes - value added tax, excise tax and customs duties - in 2019 has increased by 0.2%. In 2019, compared to the previous year, total household expenditures increased by 4.9%. Households' expenditure on transport (public transport, purchase and operation of vehicles) increased by 9.6% and 6.9% more households spent on recreational and cultural activities.[1]

Fig. 1. *Changes in gross domestic product in the Baltic States in 2019.*

At constant prices, seasonally and calendar unadjusted, as a percentage of the corresponding period of the previous year



Source: CST data

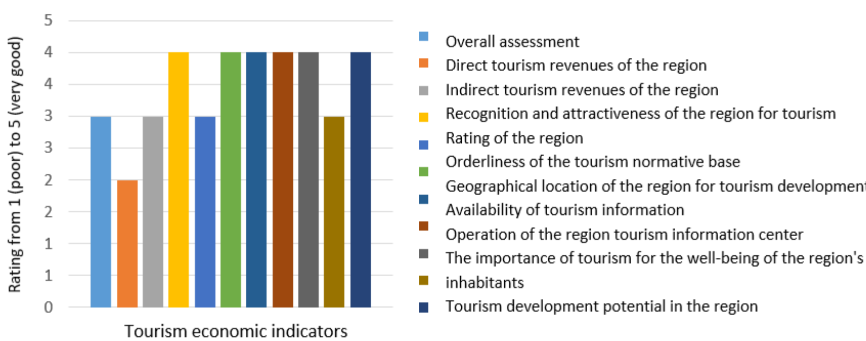
That way, the tourism industry has seen growth in recent years, which is influenced by the development of the Baltic and European economies. It should be added, that Latvia's economic and economic performance is weaker than that of the two neighbouring countries and we need to develop a stronger tourism strategy throughout the country and work more with marketing activities also in amusement parks. According to the author, it also depends on the fact that there is too little discussion and analysis at the national level about the amusement industry and its contribution to regional development.

The author has evaluated the opinions of Latvian administrative territorial units or local governments on the current tourism economic situation in the counties and priorities for tourism development, also evaluated the mentioned situation in the context of existing AP parks, establishment of new AP parks and development of the AP industry. The paper provides an assessment of local governments on the tourism objects in the territories of the administrative counties belonging to them, tourism development factors and priorities, on co - operation with the entrepreneurs of the counties. Using statistical data processing methods, the evaluation of the indicators characterizing the tourism economy of administrative territorial regions in the evaluation of the local governments themselves have been determined.

Municipal survey methodology and characteristics of respondents. The author used the survey method to obtain the initial research information in order to find out the opinion of local governments on the development of tourism in their administrative districts, their characteristic indicators and future priorities. According to the survey, municipalities had to provide answers on the tourism economy of administrative counties, assessing the current state of tourism economy, existing tourism objects and potential of these objects, including AP, according to various indicators, prioritize factors and main directions of municipal investments for tourism economy development, tourism entrepreneurs. The survey was conducted electronically, sending questionnaires to the municipalities of all 110 administrative regions and 9 cities of the Republic, total of 119 administrative units.[9]

In order to find out the self-assessment of the tourism economy of Latvia's administrative regions, local governments were offered to provide a general assessment of the tourism economy of the county and an assessment according to 10 characteristic indicators (Figure 2). The evaluation was offered in points from 1 (poor) to 5 (very good), where the respective intermediate evaluations are 2 (poor), 3 (average) and 4 (good).

Fig. 2. *Self-assessment of tourism economy of Latvian administrative regions*

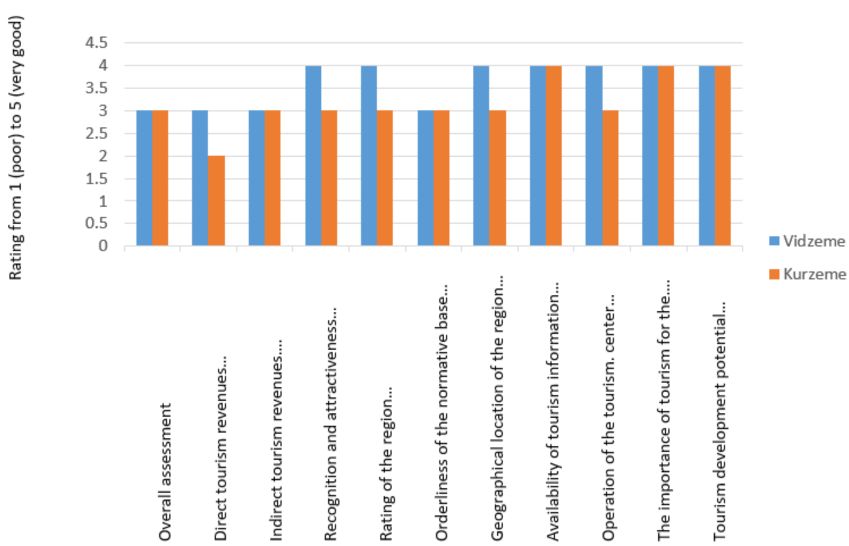


Source: the author's diagram based on the data of the survey of Latvian administrative regions

Based on the average indicators of the respondents' survey responses, the following are mentioned as the strongest sides of administrative regions with a rating of 4 (good): 1) recognizability and attractiveness of region for tourists, 2) orderliness of tourism normative base, 3) geographical location for tourism development, 4) availability of tourism information , 5) operation of region tourism information centres in those regions where such centres have been established and 6) tourism development potential in the region.[3] High assessment of the tourism development potential in the region indicates the opportunities of tourism entrepreneurs and the positive position of local governments for tourism development. The average rating with 3 (average) is given in these positions: 1) indirect income for regions from tourism, 2) general assessment of the region, 3) rating within the region and 4) importance of tourism for the well-being of the inhabitants of the regions. The direct income of tourism of administrative regions is assessed as the lowest with a rating of 2 (poor). Such data suggest that the potential of tourism could be used to improve the indicators currently underestimated.[2]

The data of the ethnographic regions of Kurzeme and Vidzeme on the self - evaluation of the tourism economy of the local governments of these regions reflect the common and different self - evaluation of these ethnographic regions (see Figure 3).

Fig. 3. *Evaluation of tourism economics of Kurzeme and Vidzeme ethnographic regions*



Source: the author's diagram based on the data of the survey of Latvian administrative regions

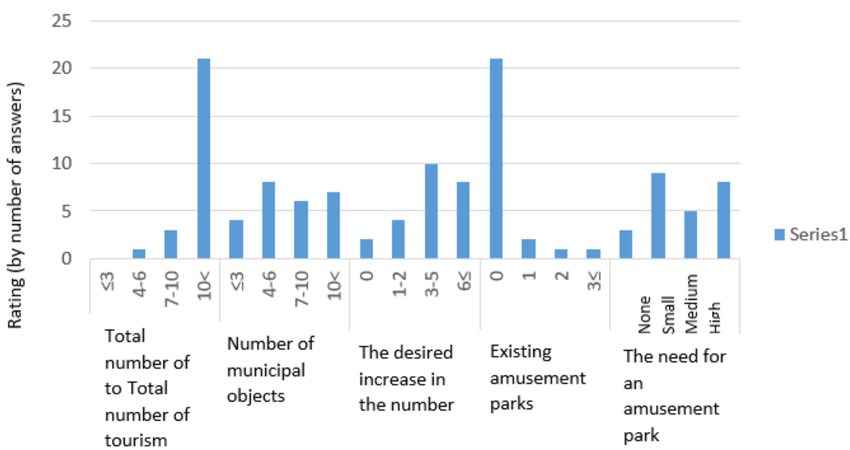
Looking at the evaluation of ethnographic regions of Kurzeme and Vidzeme , the self-evaluation indicators of Vidzeme region for five factors have an evaluation one point higher than for Kurzeme region.

These five factors are: 1) the region's direct income from tourism, 2) recognizability and attractiveness to tourists, 3) rating within the region, 4) geographical location for tourism development and 5) evaluation of the operation of tourism information centres. This allows us to conclude where the tourism economy of Vidzeme region is generally more positive than that of Kurzeme region.

In both regions, the importance of tourism for the well-being of the county's inhabitants is assessed higher than the average in Latvia.[4]

In order to determine the numerical characteristics of existing tourism objects and AP of Latvian administrative territorial units and AP development opportunities, municipalities were offered to fill in the questionnaire, marking with the "x" the most appropriate assessment of the following indicators: 1) total number of tourism objects, 2) number of municipal tourism objects , 3) the desired increase in the number of tourism objects, 4) the existing AP and 5) the need for AP (see Fig. 4).

Fig. 4. *Average number of tourism objects in administrative regions of Latvia.*



Source: the author's diagram based on the data of the survey of Latvian administrative regions

The total number of tourism objects in the administrative regions of Latvia basically exceeds 20 objects, of which the municipality agrees on average 4-10 objects, which is less than half. This indicates that tourist attractions are mainly a private business. According to the assessment of local governments, it would be desirable to increase the number of tourism objects in administrative counties by at least 1 to more than 6 tourism objects. 2 The data provided by administrative regions showed that in Latvia there is practically no AP, only in some places they are 1-2 AP. At the same time, AP are considered moderately necessary. It can be concluded that the establishment of a new AP in the territory of Latvia is desirable, thus increasing the number of tourism objects in the region.[4]

Taking into account this actual development in the region, the author of the article refers to some of the main regional theories that are the basis for the development of the territory of Latvia. In 1960s, theories representing economic determinism, based on the theory of regional development convergence, theories of regional divergence and theories of structuralism, have developed rapidly. Convergence theory is based on the belief, that each region, as it seeks to develop and reap its benefits, over time becomes similar to other regions and their social, economic and political systems converge (convergence takes place). By intensifying production, specializing and organizing more advantageous trade with other regions, any region is gradually becoming industrialized, thus similar to other industrial regions. The origins of convergence theory can be traced to a functionalist approach, which assumes that there are certain requirements in society for it to develop and function effectively.

Theories of diversity, as opposed to convergence theories, are based on regional differences and the conditions that make up these differences. They are largely the result of a critique of convergence theories. Empirical studies in the 1960s showed growing economic disparities between industrialized and less developed countries. The main theories of divergence are the theory of cumulative causality and the theory of growth pole.[3]

These theories are based on the importance of factor analysis. This analysis is a statistical method that allows to find the factors that are the basis of the relationship of several variables, but also allows to find out the proximity of this relationship between the factor and the observed traits, respectively, to answer the question, how big is the proportion of the factor in each trait.

The creator of the factor analysis is Michael Porter, a professor at Harvard University. He has paid great attention in his research to the analysis of competitive and territorial factors. He names the key factors found in each country and industry:

1) economic - inflation, unemployment, purchasing power of the population, standard of living, growth or downturn of the national economy;

2) social, cultural and demographic - social affiliation of the population, level of culture, increase of the population, national structure of the population, level of culture and education, religious and moral norms of nations;

3) technological - development of new production and communication technologies, development of science and technology;

4) political - the country's foreign policy, relations with other countries, economic and political situation in the world;

5) legal - these factors include the interaction between the companies and the government or legislators; legislation, tax policy;

6) institutional and informative - non-productive institutions and organizations necessary for the normal course of business: banks, insurance companies, service and consulting services, advertising agencies, market research agencies, business support centres, etc. The external business environment must be such as to encourage, not discourage.[7]

The author of the article, summarizing the mentioned data and the indicators that crystallize according to the survey and statistical methods, has come to the SWOT analysis, which allows to determine the current position of the current parks and the existence of factors determining future development. SWOT analysis is a popular method of situation analysis, which looks at the strengths and weaknesses of the analyzed case, as well as opportunities and threats.[8]

Fig. 5. *SWOT analysis*

Strengths	Weaknesses
Geographical location Ability to compete Potential Uniqueness High technical performance Resources, funds, people	Lack of experience Weak Legislation Lack of support from the banking sector Slow development Lack of systematicity and continuity
Opportunities	Threats
Mastering new markets Creation of new technologies System and process improvement Market segmentation and arrangement Improvement of national legislation Creating niche products	Political Economic International market fluctuations COVID Ecological and environmental Geo political

Source: Table created by the author

SWOT analysis reflects the indicators of internal and external factors. In the market, economic or larger geopolitical factors, these indicators may also change, as many of them are determined by the current market situation.[5]

When summarizing the indicators of the amusement park questionnaires, the following indicators and groups of basic factors stand out.

SWOT analysis gives us the opportunity to see strategic decisions and their progress, because many factors jointly shows the development of processes. The conditions, opportunities and data associated with it are easily transferable. SWOT analysis or SWOT matrix is a decision-making system to focus on strategically important elements at this intersection. SWOT represents **S** trengths, **W** eaknesses, **O** pportunities, **T** hreats. These four categories describe whether the aspect of the decision is negative or positive and whether it is an external or internal aspect of the organization.[6]

In the amusement park strategy from the SWOT analysis matrix, the author choose to put forward 4 determining factors based on the summarized results, to which apply the Factor Analysis computer software SPSS model. Twelve variable indicators were selected, which obtained the highest statistical data after summarizing the results of the survey. These variable indicators were summarized in the table and determined by 4 Factor analysis in the computer program SPSS by determining the matrix turning radius in numerical terms.[10]

Table 1. *Four-factor factor analysis according to SPSS*

Rotated Component Matrix[a]				
	Compo-nent			
	1	2	3	4
Size of the company	**650**	-246	-329	249
Type of park	159	-326	**757**	-190
Seasonality effect	-099	-161	**-659**	125
Offer of new attractions	001	063	-155	**939**
Offer of new services	-453	032	**708**	313
Expert general assessment of the object	**813**	230	180	-119
Expert assessment of the development of the object	**679**	183	056	517
Expert assessment of the object's recognizability	**796**	332	-033	016
Expert assessment of recognition abroad	**875**	216	132	-019
Expert assessment of the quality of service offers	**539**	482	-158	-033
Foundation year of the AP	-336	**-731**	-119	-154
Region	015	**901**	-066	-132
Legal form of the company	263	**728**	031	188

Source: Table created by the author[11]

According to the results of the factor analysis, it can be concluded that such variables as the size of the company, the year of establishment, the offer of new services are among the factors influencing the development of amusement parks.[5] One of the determining factors is also the seasonality and the offer of new attractions and services. Variables such as expert assessment of the object and the legal form of parks have less impact on the development of these parks. Thus, the following development models were formed: 1) amusement parks near larger cities with a larger offer of attractions and an earlier year of establishment; 2) amusement parks that have been established recently and have a new amusement offer; 3) amusement parks that are able to provide their offer all year around and do not depend on seasonality.

CONCLUSION

Latvian amusement parks are relatively new and have little professional experience.

Amusement parks are closely linked to the regional economy, municipal and national common policies in the tourism industry.

Recognition of amusement parks, attractiveness and recognizability of a tourist attraction affect the operation of parks.

Amusement parks have several basic factors that allow for successful development.

Factor analysis with several variables puts forward the determining factors for the development of future park development models.

Factor analysis shows some data for one variable, but when other variables change, factor analysis may show other determinants.

There is little research on amusement parks in Latvia and the Baltic States and many scientists in this field would still have to do a lot of research.

ACKNOWLEDGMENTS

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Section

GREEN BUILDING TECHNOLOGY AND MATERIALS

Energy solutions and urban design planning
Building placement, sustainable building consulting, green architectural design
Economy, policy and regulatory standards in green design and sustainable architecture
Recycling technologies of the building materials waste
Renewable energy materials in construction production
Ecological building and environmental planning

DEVELOPMENT AND PRACTICAL APPLICATION OF A CONTROL UNIT FOR A TWO-CIRCUIT SOLAR SYSTEM WITH THERMOSIPHON CIRCULATION LOCATED IN THE CITY OF ALMATY (KAZAKHSTAN)

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ABSTRACT

An article describes the development and practical application of control unit of the solar plant, located in Almaty city (Kazakhstan). Such system envisages using an electrical pump for circulation in the transfer medium, connecting a flat plate solar collector with a tank. There has been developed a controller for solar system management, able to control the solar thermal system's current temperature. With the aim thereof in the proposed system the measurements are carried out from 6 digitizers (DS18B20 Dallas), using 16 wires. Using Dallas sensors and corresponding software it is possible to control the temperature level and heat amount. Usage of 4 digital sensors substantially increase the system control performance and raises data processing speed. There have been considered the possibilities of the configuration of the senstors for Arduino platforms, as well, the solar collector management scheme. This paper scientifically analyzes the work of the new controller for controlling the solar thermal system using 6 digital temperature sensors using the Arduino platform to determine the control of the entire solar thermal system.

Keywords: *solar collector, master controller, Arduino, monitoring*

INTRODUCTION

Renewable energy sources usage promotes constant demand increase on the energy and on ecologically friendly technologies outspread. Photothermal conversion in solar thermal systems is one of the most widespread means of that energy using [1], [2]. The necessity to submit the system's corresponding operating parameters maintains the usage of properly selected and adjusted controllers. Solar controllers are produced by many companies and firms [3], [4], [5], [6]. Despite the accessible solutions' wide spectrum, controllers are still the devices with a closed structure and practically they do not have extension flexibility. On the other hand, flexible solutions, based on the programmable controllers (PLC Programmable Logic Controller), are applicable only in large-scale systems due to very high cost of PLC [7]. However, currently there is the growing interest in modular controllers, completely programmable, which allow integrating several systems into a common operational system. Not of less importance for users is the implementation of several additional functions. The article [8] presents an exemplary prototype of a modular solar controller based on the freely programmable Arduino platform. For instance, the system of management and control via the Internet [9] or using the power supply source with photoelectric panels [10], [11]. In [12] there was elaborated mathematical model for hybrid power supply system, based on photo-solar-bioenergetics installation, permitting to cut power consumption by agricultural production. There have been submitted experimental outcomes of the researches on the performance of offered dilution hydraulic system. The research [13] considers the computation of heat amount in thermal pump in the combined solar heating unit. To compute the equalizing of thermal pump thermal balance in the solar heating integrated system there was developed technique of calculation, applying the above mentioned methodologies, defining equalizing of thermal and energy balance amount. The compressor is located in the evaporator impact zone. Key performance indicator (KPI) constitutes from 2,5 to 4,5 units.

The aim of the work herein is the development and practical application of the control management system of the solar plant, located in Almaty city (Kazakhstan).

METHOD OF RESEARCH

The solar heat supply system with a controller has been constructed at the Institute of information and computer technologies in Almaty city, Republic of Kazakhstan.

In 2019 there was developed the system of solar heating, the solar energy E with temperature t0 is absorbed by solar collector 1, with temperature t1, heating solar energy flow, goes through semitransparent insulation glass 2. The heat, received from the solar flow, heats the liquid in coils 3, which is removed from the collector, and cold water occupies its place from the pipeline with cold water tap 8, and from distributor tank siphon 7 there takes place constant circulation of thermal siphon by the usage of circulation pipe 10. Further, the liquid enters the thermal pump 11, which consists of condenser-evaporator 12 with temperature т2, in which a heat exchanger is fabricated in spiral form, absorbing the transfer medium heat, lowering its temperature below ambient temperature (Q2), by means of throttling valve 14, thereby promoting additional absorbing the heat from atmospheric air. The diagram also shows the solar irradiation, reflected from semitransparent coating (Q0) and absorbing panel surface (Q1). Transfer medium, having a relatively low temperature of condencer transfer medium 15 in the spiral form with higher temperature t2, increases square and speed of heat exchange. To fulfill such cycle there is used a compressor 13 with temperature т3 with electric drive 17. Further with the help condencer heat exchanger 15 with temperature t4 heat from the thermal pump (Q5) is transferred to the tank from heat exchanger Q6 with temperature t6 of heating 18. As the installation has two circuits, it is equipped with automatic circulation pumps 19 and 20 for liquid circulation between solar collector and evaporator, condencer and storage reservoir. Water temperature is adjusted up to the required technological level and supplied to a customer for hot water supply and heating.

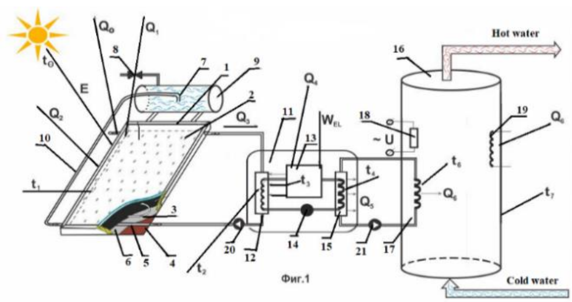

Fig.1. *Principal diagram of double circuit solar installation with thermosiphon circulation*

The given research originality is development of double circuit solar system with thermosiphon circulation, which has flat solar collector, representing heat insulating traansparent double-glazing unit with lower pressure, and transfer medium is made of a thin-walled corrugated stainless tube. Heat, obtained from solar flow, heats the liquid in colis, which is removed from the collector, and its place is occupied with cold water from the siphon and there occurs constant thermal circulation, which upgrades heat transfer efficiency, at the expense of eliminating additional webs between a panel and heat insulation. There exists also a thermal pump, where cindencer and evaporator are made in the form of heat exchanger of "spiral in spiral" type, heat exchanger pipelines are located one over another, increasig the square and heat exchange intensity.

As mentioned above, a double-circuit solar system with thermosiphon circulation can absorb heat from a solar source.

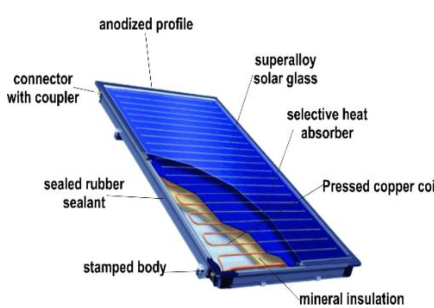

Fig.2*. Principal diagram of flat solar collector*

Figure 2 shows a model of a flat solar collector. The essence and novelty of the proposed one is that, unlike the well-known design principle, the collector contains a transparent double-glazed window 2 with double glass and with reduced pressure, as well as a perimeter frame 1. The bottom of the wooden frame 7 is made of 8 mm thickness plywood. and heat-insulating film 5 with foil is glued to it. In the gap, formed between the double-glazed window and the bottom of the frame, a flexible thin-walled stainless corrugated tube of 4-16 mm is laid in the coil form. The edges of the tube are attached to the inlet and outlet protruding pipes 6.

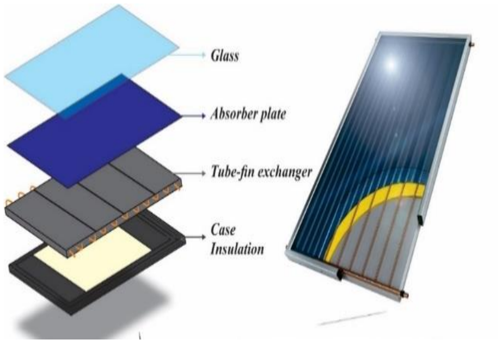

Fig.3. *Principal diagram of flat solar collector in parts*

As shown in Figure 3, the solar energy passes through the glass and hits the absorber plate, which heats up, converting solar energy into thermal energy. Heat is transferred to the working fluid, which passes through tubes, attached to the absorber plate.

Fig.4. *Flat solar collector mockup*

Figure 4 shows a full-scale model of a flat solar collector. The solar collector is the main heat-generating unit of the solar installation. To achieve this goal, we have developed a fundamentally new flat solar collector, on the basis of which various types of solar systems will be created, both according to sizes and design, applied to water heating and premises heating.

Table 1. *Selected performance capabilities of flat solar collector*

Parameters	Value
Absorbing plate material	copper
Absorber plate dimensions	2 m×1 m
Plate thickness	0.4 mm
Glazing material	Hardened glass
Glazing sizes	2 m×1 m
Glazing thickness	4 mm
Insulation	Foam plex (foam polyurethane)
Collector tilt	45^0
Absorber heat conductivity	401 W/(m K)
Insulation heat conductivity	0.04 W/(m K)
Transmittance-absorption factor	0.855
Apparent sun temperature	4350 K
Environmental temperature	303 K
Irradiation intensity	1000 W/m^2

COUNTERPART OF MODULAR CONTROLLER FOR SOLAR THERMAL SYSTEM

Controllers, designed for the solar thermal plants monitoring shall have a modular structure. It provides upgrading controller's functionality with the device further development. A chapter herein presents a modular solar controller counterpart, based on freely programmable platform. The controller block-diagram is shown on Figure 5. The controller prototype consists of a central module, uniting all main controlling functions and three principle extension modules: system monitoring, reserve electric power supply and meteorological station.

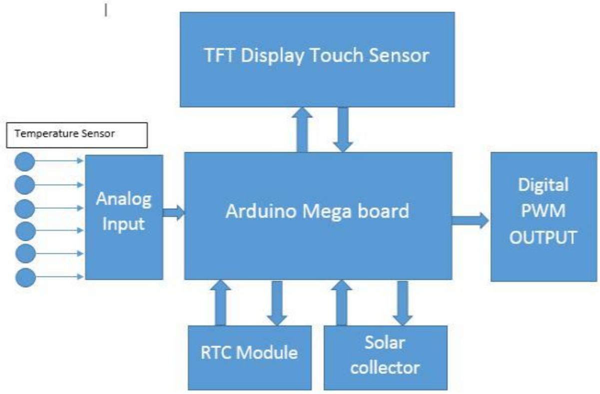

Fig. 5. *Block-diagram of managing controller of double circuit solar plant with thermosiphon circulation*

The control unit body has been designed as appropriate and implemented using 3D-printer, so that it can be easily assembled and disassembled.

Fig.6. *The solar system management controller*

Table 2. *Technical specifications of the solar system management controller*

Dimensions, (mm)	120x120x23
supply, (V)	AC110 / AC220
Consumption, (Wt.)	< 3
Temperature measuring accuracy, (°C)	-/+2
Collector temperature measuring range, (°C)	-10…220
Tank temperature measuring range, (°C)	0…+110
Tank maximum capacity, (Wt.)	3 pieces < 300
Inlets	1 piece pt1000, 2 pieces ntc10k
Outlets (relay for pump, valve, THE)	10 A
Working temperature, (°C)	-10 +50
Waterproof class	IP40

***Fig. 7**. Assessment of temperature external control unit accuracy*

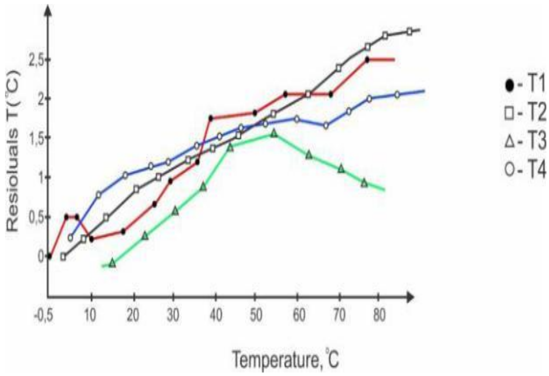

Figure 7 presents temperature external control unit accuracy assessment T1 and four sensors Dallas DS18B20 (T2 – T4). The controller can operate in the range of temperatures from −30 ° C to +100 ° C and maintain relative humidity from 10% to 90%. Sensor T1 shows values in the range from 35 to 55 ° C. Temperature sensor T2 shows temperature values from 45 ° C to 85 ° C. Temperature sensors T3 and T4 have the value 85 ° C.

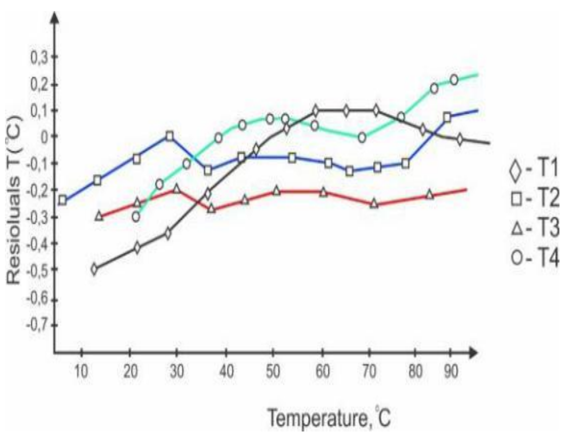

***Fig. 8.** Corrections for various temperature ranges*

Figure 8 shows the correction of temperatures for various ranges, necessary for using in a monitoring system. Each sensor has a linear equation. Equations have been included in the plate code of Arduino, installed inside the control and monitoring unit. In the result of research, we can note, that the sensors secure high accuracy along with the range, correcting, in particular, deviant behavior upon temperature rise.

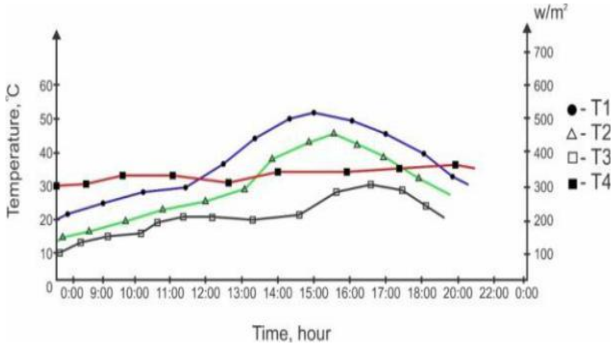

Fig.9. The temperature change of sensors and heat pump according to the time

Figure 9 shows different range temperature changes in the period from April 19 to June 9, 2021. As it is seen from Figure 14, indications, observed on April 19 from 07:30 to 09:00, are similar, though with less number of switching on / switching off cycles and with higher temperatures, comparing to June 9.

CONCLUSION

In the present work, we have developed the stages of designing and practical application of the solar plant control management system (Almaty city, Kazakhstan). To create and research the solar plant thermal system monitoring platform, based on using the platform Arduino Mega, we have described every element operation, on the basis of which the network controller control and monitoring has been executed. We have carried out assessing the accuracy of the controller, which can operate in the temperature range from −30°C to +100°C and maintain relative humidity from 10% to 90%. Sensor T1 shows indications in the range from 35 to 55°C. Temperature sensor T2 presents temperature values from 45°C to 85°C. Temperature sensors T3 and T4 have the value 85°C. As a result of research, we can note, that the sensors provide high accuracy along with an overall range, correcting, in particular, deviant behavior upon temperature raise. The control and monitoring system is implemented in the VHDL and VERILOG languages. The system found that the thermal efficiency of water in a thermosiphon tank for a flat solar collector increased by 5%. Solar radiation, depending on the thermal power of the installation and the time of heating the water, has achieved the greatest efficiency in the circulation of water in the metering tank.

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SIMULATION METHODOLOGY FOR PILOT MODEL OF SOLAR WATER HEATING UNIT

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ABSTRACT

In the given work there is shown the methodology of simulating the experimental model of solar water heating unit. Using theoretical and experimental outcomes, also, obtained rated values of transmittance medium in solar collector, there has been carried out predictive analysis of solar irradiation flow density, ambient temperature and temperature in the accumulator tank. Estimated and experimental daily characteristics of both systems have efficient accuracy of 7%, which proves reliability of constructive formula and engineering model. As well, there has been computed the unit capacity factor, plants' production growth constitutes from 0.5 to 0.85%. Computed the coefficient, which depends on heat flow and solar collector's surface, as well on convective heat exchange between solar irradiation and solar collector's surface. Experimentally executed computation of solar water heating unit's performance, which is fulfilled in compliance with hourly sums of direct and scattered irradiation and ambient temperature.

Keywords: *solar water, production growth, temperature*

INTRODUCTION

Flat solar collector consists of metal absorber in flat orthogonal body. Glass cover on the upper surface and insulation below and on each side decreases heat losses. Air is in the space between metal absorber and transparent cover. Flat metal plate serves as a heat exchanger, which absorbs solar irradiation, transforms it into heat and transfers the heat to fluid liquid [1]. Under northern climatic conditions mid-annual efficiency of well-designed solar water heating units usually constitutes about 35-40% [2]. Moderate climate is without extreme temperatures and precipitation (rain and snow), with changes between summer and winter. Both in summer and winter temperate weather might have variables. It might be either rainy, or afterwards, sunny. Those climatic zones are in the range of north latitudes from 40 to 60/70° [3]. Solar energy collector is the main component, therefore, its thermal characteristics assessment is of vital importance. In compliance with the standards EN 12975-2 and ASHRAE 93-86 there were carried out the tests on the performance in stationary and quasi-dynamic conditions [4], [5]. Comparative analysis of flat plate and evacuated tube collectors' thermal characteristics efficiency has been carried out in Padua, Italy, by Zambolin and DEL COL [6]. They submitted a new data set, obtained both for flat plate-type and evacuated tube-type collectors, which were tested simultaneously according to the standard EN 12975-2. In India Tiwari et al. [7] analyzed performance of solar water heating units with magnitudes in the range from 5,399 to 7,024. In [8] there was elaborated mathematical model for hybrid power supply system, based on photo-solar-bioenergetics installation, permitting to cut power consumption by agricultural production. There have been submitted experimental outcomes of the researches on the performance of offered dilution hydraulic system. The research [9] considers computation of heat amount in thermal pump in the combined solar heating unit. To compute the equalizing of thermal pump thermal balance in the solar heating integrated system there was developed technique of calculation, applying the above mentioned methodologies, defining equalizing of thermal and energy balance amount. Compressor is located in evaporator impact zone. Key performance indicator (KPI) constitutes from 2,5 to 4,5 units.

The aim of the given research is creating computation methodology of solar water heating installation's production initializing.

METHODOLOGY

In 2019 there was developed the system of solar heating, in which the solar energy E with temperature t_0 is absorbed by solar collector 1, with temperature t1, heating solar energy flow goes through semitransparent insulation glass 2. The heat, received from the solar flow, heats the liquid in coils 3, which is removed from the collector, and cold water occupies its place from the pipeline with cold water tap 8, and from distributor tank's siphon 7 there takes place constant circulation of thermal siphon by usage of circulation pipe 10. Further the liquid enters the thermal pump 11, which consists of condencer-evaporator 12 with temperature t2, in which a heat exchanger is fabricated in spiral form, absorbing the transfer medium heat, lowering its temperature below ambient temperature (Q2), by means of throttling valve 14, thereby promoting additional heat absorbing from atmospheric air. The diagram also shows the solar irradiation, reflected from semitransparent coating (Q0) and absorbing panel surface (Q1). Transfer medium, having relatively low temperature of condencer transfers medium 15 in the spiral form with higher temperature t2, increases square and speed of heat exchange. To fulfill such cycle there is used a compressor 13 with temperature t3 with electric drive 17. Further with the help of condencer's heat exchanger 15 with temperature t4 heat from the thermal pump (Q5) is transferred to the tank from heat exchanger Q6 with temperature T6 of heating system 18. As the installation has two circuits, it is equipped with automatic circulation pumps 19 and 20 for liquid circulation between solar collector and evaporator, condencer and storage reservoir. Water temperature is adjusted up to the required technological level and supplied to a customer for hot water supply and heating.

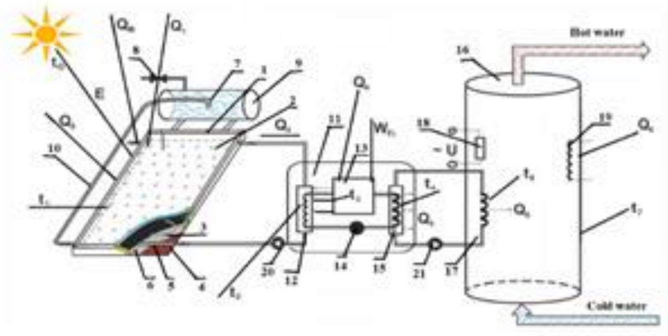

Fig.1. *Principal diagram of double circuit solar installation with thermosiphon circulation*

The given research originality is development of double circuit solar system with thermosiphon circulation, which has flat solar collector, representing heat insulating traansparent double-glazing unit with lower pressure, and transfer medium is made of thin-walled corrugated stainless tube. Heat, obtained from solar flow, heats the liquid in coils, which is removed from the collector, and its place is occupied with cold water from the siphon and there occurs constant thermal circulation, which upgrades heat transfer efficiency, at the expense of eliminating additional webs between a panel and heat insulation. There exists also a thermal pump, where condencer and evaporator are made in the form of heat exchanger of "spiral in spiral" type, heat exchanger pipelines are located one over another, increasig the square and heat exchange intensity.

As it has been mentioned above, double circuit solar system with thermosiphon circulation can absorb the heat from solar source. Fig. 2 shows the model of flat solar collector. Its content and novelty consists in the fact, that, as distinguished from the known construction principle, the offered collector contains double glazing window 2 with double glass and reduced pressure, as well, the frame 1 along perimeter. Lower part of wooden frame 7 is made of 8 mm thickness plywood. And to it there is glued thermal film 5, with foil, in the gap, formed between double glazing window and frame’s lower part of 4-16 mm diameter in the coil form. Tube edges are attached to input and output protrusive tubes 6.

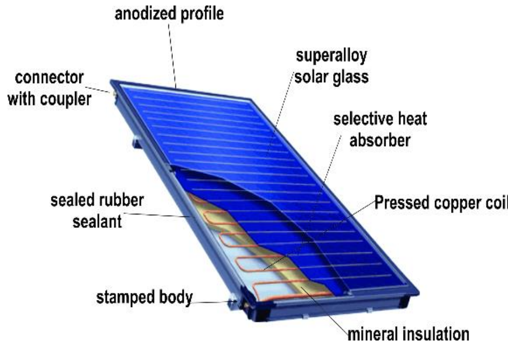

Fig.2. *Principal diagram of flat solar collector*

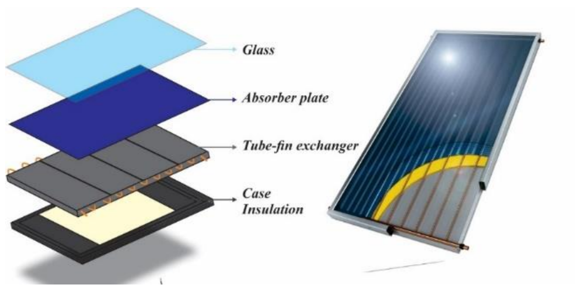

Fig.3. *Principal diagram of flat solar collector in parts*

As it is shown in Fig.4, solar energy goes through the glass and falls on absorber's plate, which is heated, transforming solar energy into thermal one. The heat is transferred to the working liquid, which goes through the tubes, attached to absorber's plate.

Fig.4. *Flatt solar collector mockup*

Figure 4 shows a full-scale model of a flat solar collector. The solar collector is the main heat generating unit of the solar installation. To achieve this goal, we have developed a fundamentally new flat solar collector, on the basis of which various types of solar systems will be created, both according to sizes and design, applied to water heating and premises heating.

Table 1. *Selected performance capabilities of flat solar collector*

Parameters	Value
Absorbing plate material	copper
Absorber plate dimensions	2 m×1 m
Plate thickness	0.4 mm
Glazing material	Hardened glass
Glazing sizes	2 m×1 m
Glazing thickness	4 mm
Insulation	Foam plex (foam polyurethane)
Collector tilt	45^0
Absorber heat conductivity	401 W/(m K)
Insulation heat conductivity	0.04 W/(m K)
Transmittance-absorption factor	0.855
Apparent sun temperature	4350 K
Environmental temperature	303 K
Irradiation intensity	1000 W/m^2

RESULTS

For hot water call-off quantity we can compute collectors' needed square according to the formula

$$A = \frac{1.16G(t_{w2} - t_{w1})}{H\sum_I G_i} \qquad (1)$$

where G – water mass (kg), heated to the temperature t_{w1}, to the temperature t_{w2}, °C; $\sum_i g_i$ – total solar energy, accepted for day of 1 m^2 solar collector, W*h/m^2; η – collector's efficiency factor. In addition, the collector efficiency coefficient is calculated using the following formula

$$\eta = 0.8c\left\{\Theta - \frac{9U\left[t_1 + {}^{t_2}\!/_{2} - t_e\right]}{\eta\sum_I g_I}\right\} \qquad (2)$$

where U – loss coefficient, collector's rating (W/m^{2}K);t_1 and t_2 – minimum and maximum transfer medium temperatures in the collector circuit, accordingly, and t_e – ambient temperature, °C;$\sum_i g_i$ – average daily incident flux, W/m^2; θ – the same as η_0 in the expression (1),t_{w2}, t_{w1} – temperature driving force between outlet and inlet temperature of water, being heated, t_1, t_2 – transfer medium temperature (set as equal to 5 °C). Square of absorptive surface of installation's collectors without second strings A, m^2, should be defined according to the formula

$$A = \frac{G}{\sum_I g_I} \qquad (3)$$

where G – daily hot water flow in hot water supply system G, kg; g_i – installation's hourly productivity, related to 1 m^2 surface of solar collector, kg/m^2 ; i – designed hours of installation operation.

Upon non-uniform consumption of hot water per months in the installation without second strings, solar collectors' square calculation should be fulfilled according to the value of daily hot water flow of each month and accept the biggest of obtained squares.

Installation's hourly performance g_i , kg/m^2, is defined according to the formula

$$g_I = \frac{0.86U}{\ln\frac{t_{\max_1}-t_1}{t_{\max_1}-t_2}} \qquad (4)$$

where U – reduced factor of solar collector's heat losses, W/(m^2·K), in case of passport data absence might be accepted as 8 W/(m^2·K) for single glass collectors and 5 W/(m^2·K) - for double glass ones; t_1, t_2 – transfer medium temperature at the solar collector inlet and outlet, °C.

Inlet temperature t_2 is defined according to the formula:

$$t_2 = t_{w2} + 5^0 C \qquad (5)$$

where t_{w2} – hot water required temperature.

Inlet temperature is defined according to the formula:

$$t_1 = t_{w1} + 5^0 C \qquad (6)$$

where t_{w1} – cold water temperature.

In single circuit systems: $t_1 = t_{w1}$ and $t_2 = t_{w2}$.

Every hour's equilibrium temperature t_{maxi} is defined according to the formula

$$t_{\max 1} = \frac{q_{\Theta I}}{U + t_{ei}} \qquad (7)$$

$q_{\theta i}$ – reduced intensity of absorbed solar irradiation, W/m^2; t_{ei} – outside temperature, °C.

Notes. At non-availability of absorptive surface value in technical specifications of solar collectors it should be accepted as equal to 0.9 – 0.95 off collector's overall square.

Square of installation's collectors absorptive surface with transfer medium natural circulation shall be specified according to the formula (5), and installation's hourly performance g, kg/ m^2, according to the formula

$$g_i = \frac{0.086\left[q_{\theta i} - U\left(t_{1i} - t_{ei}\right)\right]}{1 + \frac{5U}{q_{\theta i} - U\left(t_{1i} - t_{ei}\right)}} \quad (8)$$

In single circuit installations inlet temperature t, °C, is defined according to the formula

$$t_{1i} = t_{1,i-1} + 10^{-2} g_i IV \quad (9)$$

where V- volume of accumulator box (box volume per 1 m^2 of solar collector square), is accepted as equal to 0.06 for II, 0.07 - for III and 0.08 m^3 / m^2 - for IV climatic region.

In double circuit installations inlet water temperature is accepted as for 5°C higher, defined to the formula (9).

During the first hour of installation's operation the temperature at inlet is accepted as equal to water temperature in accumulator tank.

Upon deviation of solar collectors from southern orientation up to 15°, absorbed irradiation amount decreases for 5%, at deviation to 30° - 10%.

Square of installations' absorptive surface with a second string A, m^2, should be defined according to the formula

$$A = \frac{1.16G\left(t_{w2} - t_{w1}\right)}{\eta \sum_i q_i} \quad (10)$$

where q_i – intensity of incident solar irradiation on the collector's plane, W/ m^2 , is specified according to appl. 3 in the interval from 8 to 17 hours for southern oriented solar collectors. Upon deviation from south to the east or west the time interval starts earlier or later for 1 hour; η - efficiency factor of solar hot water supply installation. Installation's efficiency factor is defined according to the formula

$$\eta = 0.8\left\{\theta - \frac{9U - \left[0.5\left(t_1 - t_2\right) - t_e\right]}{\sum_i q_i}\right\} \quad (11)$$

where θ - collector's reduced optical characteristic. Upon absence of passport data it can be accepted as equal to 0.73 for single glass collectors and 0.63 - for double glass ones; t_e – average daily air temperature °C.

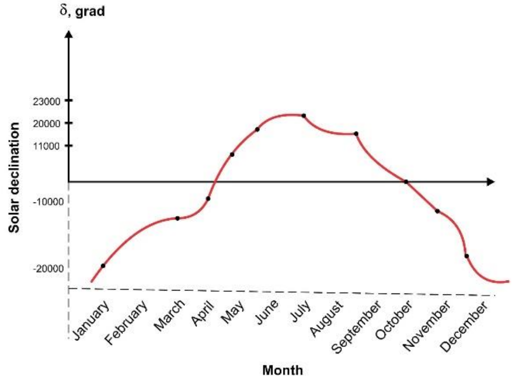

Fig. 5. *Solar declination amount for each month's 21 date on the territory of the Republic of Kazakhstan*

Figure 5 shows the number of solar declines on the 21st day of every month in the Republic of Kazakhstan. In summer, the solar declination is very high due to high solar radiation, and in winter, the solar declination is very low, since solar radiation is low.

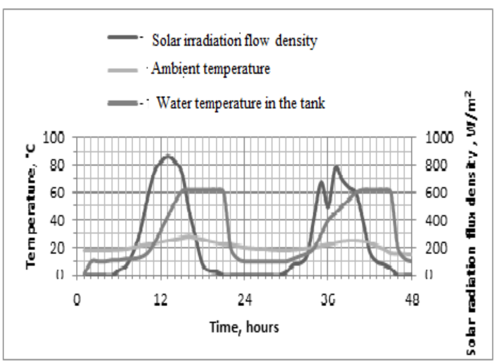

Fig. 6. *Dependence of temperature and solar irradiation flow density on time*

Fig. 6 shows dependence of temperature and solar irradiation flow density through time. As it is seen from the Figure, when solar light falls onto solar collector's upper part, the thermal flow increases due to high intensity of solar irradiation.

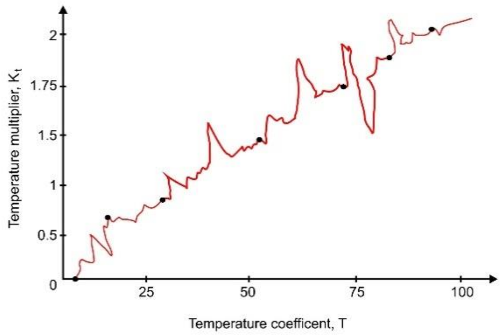

Fig.7. *Values of temperature multipliers on practically significant temperature range for computation*

Figure 7 shows the values of the temperature factors in a temperature range, that is practically significant for the calculation. As can be seen from the figure, the temperature factor depends on the heat flux from the solar collector's surface, as well on convective heat transfer between solar radiation and the surface of the solar collector.

CONCLUSION

In the research herein there has been computed temperature and solar irradiation flow density through time. As well, there has been calculated installation's efficiency factor and installation's performance.

As it is seen from the graphs, water heating temperature in the solar collector with thermosiphon through time has an exponent function, which confirms, that in summer time thermosiphon tank is heated faster than in winter season. In the course of number of experiments there was revealed dependence of solar irradiation flow density on the time, which achieved up to 800 W/m^2 and it proves, that engineering-development model of the solar collector operates in regular test regime.

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Section

GREEN DESIGN AND SUSTAINABLE ARCHITECTURE

Energy solutions
Urban landscaping and urban design planning
Building placement, sustainable building consulting, green architectural design
Economy, policy and regulatory standards in green design and sustainable architecture
Ecological urbanism

ANALYSIS OF SPATIAL URBAN STRATEGIES IN THE CONTEXT OF ADVANCING GREEN URBAN DEVELOPMENT IN BELARUS

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ABSTRACT

The structural differences and nature of the social, economic and environmental challenges of small and medium-sized cities of the Republic of Belarus demand to address the Green Urban Development in a locally tailored manner. The importance of climate adaptation and mitigation at the global level finds its contextualization in the new practice of the strategic sustainable development planning that was introduced by the Green Cities Project.

The paper describes the research in progress regarding basic trends for territorial urban development in the future. It analyzes three spatial strategies for the cities of Navahrudak, Polatsk and Navapolatsk which were elaborated by the Green City Project as a structural part of the Green Urban Development Plan – a local strategy that integrated energy consumption and CO_2 emissions reduction with spatial development. The main objects of the study are the spatial elements of the "sustainable urban development" paradigm: "land use", "density", "transport and mobility", "public and green spaces", "spatial model". The article argues that globally accepted spatial models of sustainable cities appear to match with the Belarusian context with necessary adjustments under the influence of some external and internal factors. Finally, the paper offers key directions for advancing green urban development in Belarus.

Keywords: *sustainable urban development, spatial urban strategy, Green Urban Development Plan, small and medium-sized cities of Belarus*

INTRODUCTION

Although the planning of urban sustainable development has been broadly theorized for the last decades, today implementation of concrete action plans encounter specific tasks considering spatial features of the cities. Since the New Urban Agenda and even earlier, mapping sustainable development actions in urban settlements has been a widespread global approach [1], [2], [3]. Settings for strategies improving the urban environment have found an increasing role in Belarus too. Even though the system of urban and territorial planning in Belarus is considered to be well developed, the UNECE international team of experts recommended to develop an urban planning policy for the next five years with the emphasis on achieving the UN Sustainable Development Goals (SDGs), the New Urban Development Program and the UN Geneva Charter on Sustainable Housing at a local level in Belarus [4].

In this context "green cities", "green economy" are strategically important concepts for Bealarusian cities, 50 of which have joined the European initiative Covenant of Mayors on Energy and Climate. The municipalities commit to reducing emissions, mitigate climate change and minimize energy consumption with the implementation of SECAP – A Sustainable Energy and Climate Action Plan. Recently, the traditional practice of General Planning has been enriched by experimental strategic planning at the municipal level aimed to advance green urban development in small and medium-sized cities in Belarus. Since 2017 this practice is sustained with the new experience of the strategic sustainable development planning on municipal level with the main emphasis on integrating goals of reducing energy consumption and CO_2 emissions with spatial urban planning. Contextualization of the SDGs and tailoring of social, economic and environmental targets with the local territorial potential and challenges were implemented under the Project "Belarus: Supporting Green Urban Development in Small and Medium-Sized Cities in Belarus (Green Cities)", which was implemented in 2017-2021 by UNDP in Belarus in collaboration with the Ministry of Natural Resources and financed by Global Environmental Facility. The three Green Urban Development Plans were developed for the cities of Navahrudak (29 424 inh.), Navapolatsk (107 479 inh.), and Polatsk (84 332 inh.) followed by four next small and medium-sized cities. These plans are local sustainable development strategies that sum up prospects of green urban development and formulate the unique vision of a green future. The strategies rely on the existing national (republican), regional and local long and medium-term programs and strategic documents, as well as on the current state of the city, trends, existing external and internal factors. According to the locally elaborated planning methodology [5] the specific set of the long-term development goals, as well as the priorities for a short-term horizon of 1-3 years go in line with the spatial strategy of each city.

This research in progress examines common and distinctive features of the three green spatial strategies as it is described in the plans. Specific spatial elements are considered within the local context to determine spatial innovations and trace basic trends for city territorial development until 2040. These trends compose the scalable recommendations for advancing green urban development in Belarus.

SPATIAL FEATURES OF THE CITY: GROUNDS FOR GREEN URBAN DEVELOPMENT

It is assessed that the current situation of the cities is characterized by a certain imbalance in the sustainable development components (the presented diagrams with 38 indicators evaluate the sustainability of urban development - the closer the figure is to the radius point, the more sustainable development the city has).

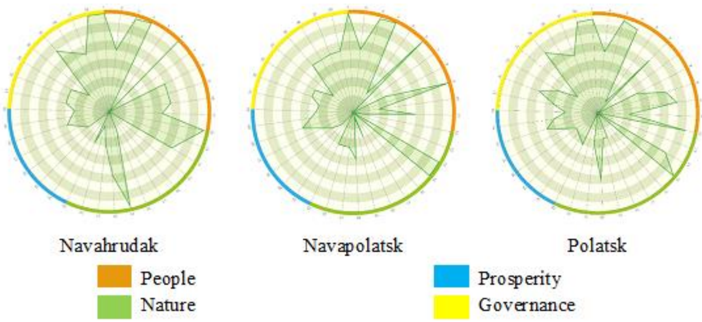

Fig. 1. Sustainability Profiles of the cities (source: assembled by the author with reference to the UNDP Green Cities Project materials [6], [7], [8])

Today, Navahrudak and Polatsk are facing natural population decline and ageing, the increase in the demographic burden borne by the working-age citizens, shortage of skilled workers and outflow of qualified personnel, combined with the reduction of a small and medium-sized businesses, lack of positive dynamics in the development of existing enterprises, as well as the lack of financing in order to modernize and develop the infrastructure, to maintain and protect natural and cultural heritage sites. The demographic situation in Navapolatsk is more stable, both in terms of natural growth rates and age structure. All the same, the existing demographic "scissors" are gradually increasing - the birth rate is lower than the mortality one, a negative migration balance is noted. Before the political crisis of 2020 the budget of Navapolatsk was one of the most well secured due to its own income sources if compared with other local budgets. Nevertheless, the share of the budget for environmental protection is equal to 0.0001%. Changes in the budgetary relations between the city and city-forming enterprises lead to a noticeable decrease in funding for the municipal infrastructure. The relative wealth of the urban economy in Navapolatsk is diluted by air pollution. However, industrial emissions tend to decrease (over 10 years, the total volume of emissions decreased by 45%). The main damage (more than 90% of total emissions) is caused by traffic. The patterns of climatic changes in the three cities are the same as in other settlements of Belarus, furthermore, in Navahrudak the effects of heavy rainfall and frequent ice-slicks are felt more acutely in combination with a marked terrain relief. The analysis of location benefits and risks reveals that solutions to many cities' problems go beyond their administrative borders.

Navahrudak has a “fan-like” spatial structure: it consists of several neighbourhoods located between the main streets of the radial direction. Inside the separate neighbourhood, density declines and acquires a "finger" shape. The streets are concentrated in the city centre where land use interventions are sporadic. The cross-links between sectors are poorly developed. The middle city belt is divided into smaller quarters with mixed use. The outer belt is characterized by the alternation of both free plots and those occupied by industrial and communal facilities.

Navapolatsk and Polatsk act as a shared centre being a large national and regional transport and industrial hub. According to the experts' estimates, the mutual labor migration flows between cities are approximately equal and make up about 25% of the working population. The social infrastructure of both cities is gradually acquiring the features of a cluster. Two cities exist in a single space under the harmful influence of the power and chemical industry enterprises. At the same time, the existence of two cities in a single ecosystem provides common mechanisms for neutralizing those negative anthropogenic environmental impacts. The initial “linear” model of Navapolatsk now has a clear-cut elongated shape of a fairly concentrated urban fabric with a central hub and uneven cross-connections. Consistently moving along the main axis one can visually fix the differences in the architectural look of the city - the "annual steps" of its territorial sprawl. Today's Polatsk has a fragmented and uneven structure of the scattered "archipelago of the islands", which are separated by the river and railways network. There is a diverse range of the building and neighbourhood typologies, however this ancient city can’t demonstrate effective land use nowadays.

SUSTAINABLE CITY PILLARS AND LOCAL CHALLENGES

Urban form, structure, and morphology have a great bearing on energy use and, therefore, on emissions [9], [10], [11], [12]. Having a goal to design a more safe, resource effective and climate-resilient city, the spatial strategy for each location was elaborated around the spatial pillars of the sustainable city: “land use”, “density”, “transport and mobility” and “public and green spaces” [13]. The following table names the main issues of concern about the city pillars.

Table 1. *Current challenges viewed through the lens of the sustainable city spatial pillars*

City pillars	Navahrudak	Navapolatsk	Polatsk
Land use	• mosaic structure • rugged borderline • dispersed industry and utilities • fire risky outdated estates	• one of the densest cities in Belarus • modernistic separation of residency and work	• loss of compactness, fragmentation and isolation of the parts • vulnerable wet areas • single-use and low-density new urban extensions
Density	• the major residential densities are far less than 50 people per hectare	• only 45% of the residential areas are densely populated gradiently distributing along the main city axis	• insufficient residential density for mass transit and public services efficiency
Transport and mobility	• radial streets pattern • not completed ring connections	• “a city of the one street” – daily rides along the main axis and to the distant workplaces	• transit going through the city; one-level railway crossings • inappropriate connections between

	• no off-street pedestrian and cycling infrastructure • poor street grid connectivity and insufficient crossroad frequency	• insufficient cycling infrastructure and use of mass transit • heavy air pollution and traffic jams	urban streets and external road network • poor connection between city districts
Public and green spaces	• limited availability of landscaped green spaces • separation of green areas • green-and-blue ecosystem with potential to provide ecoservices and enhance tourist attractiveness • street network unable to cope with the loads during festive events; city centre lacking vitality on regular days	• **limited availability of landscaped green spaces** • poorly noticable nature in the city despite alternation of built-up and nature areas and proximity to the river • significant asymmetry of the central nodes distribution impeding their accessibility	• historical and cultural heritage without tourist infrastructure • public spaces emergeing in the outskirts; paralysed district centres • sensibility of lakes and ponds to climate change • poorly accessible river; lack of connection with other green corridors

GREEN CITY MODELS: CASES FROM BELARUS

With regard to the international recommendations [1], [9], [10], [11], [13] the elaborated spatial models for Navahrudak, Navapolatsk and Polatsk followed the “compact city” and the “transit-oriented development” concept. But, as some international experts pointed out, talking about “compact city”, “axial”, and “decentralised concentration” models, there were no model concepts that could exclusively serve as “…one-size-fits-all recipe to guaranteeing mitigation, adaptation and resilience in their entirety or combined” [14], such concepts where adapted to the context of each city.

The spatial strategy of Navahrudak strengthens the existing “fan-like” structure by saturating the sectors with new social facilities and a variety of public spaces. The most densely populated sector becomes the main development axes with mix-use interventions. In order to preserve and enhance the cultural and natural heritage – the main priority of its of spatial development, Navahrudak focuses on three space-related domains as follows: (1) Customized economic development and comfortable neighbourhoods; (2) Accessible public spaces and green areas; (3) Energy-efficient and resources saving innovations.

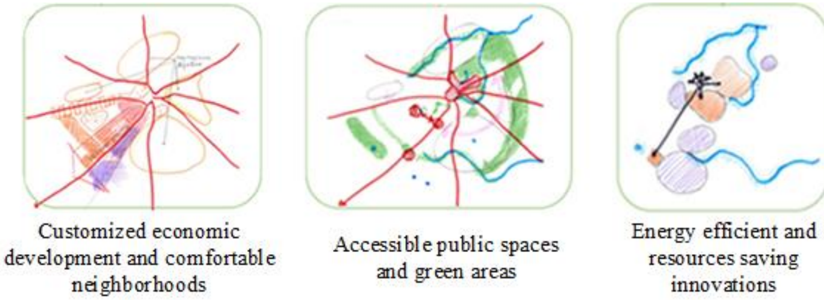

Fig. 2. *Space-related domains of Navahrudak spatial strategy (source: author's drawings with reference to the Green Urban Development Plan – Navahrudak-2040: Preserve the Future! [6])*

Navapolatsk aims to reshape the network of urban centres that serve as "nodes" on the linear "tape". Its spatial strategy is associated with renewal and enrichment of the urban environment, transit-oriented development, smart solutions for comprehensive improvement of the city, cohesive water-and-green ecosystem, new infrastructure for a circular economy. The strategy sees decaying residential and underutilized areas, as well as nascent public and green spaces as key action sites.

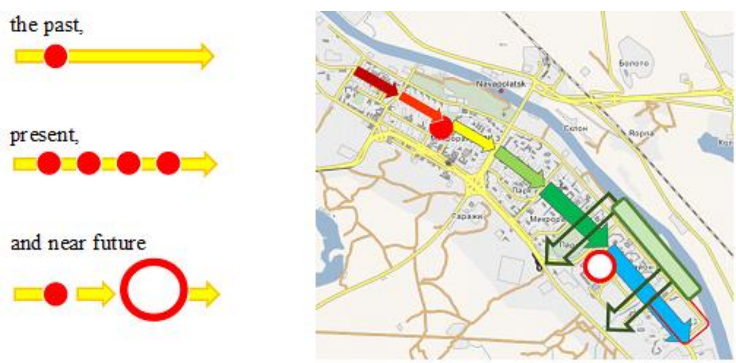

Fig. 3. *Conceptual model of Navapolatsk territorial development (source: author's drawings with reference to the Green Urban Development Plan – Novopolotsk: Renewed City. Version 2.0. [7])*

The spatial strategy of Polatsk operates with a polycentric model. It grounds on transit-oriented development and secure city centre and neighbourhoods interconnections. It is planned to implement 3 scenarios: (1) Revitalization of centres; (2) Cohesive districts and mobility without excessive car use; (3) Climate-resilient Infrastructure. Some of the neighbourhoods will develop in "urban village" mode.

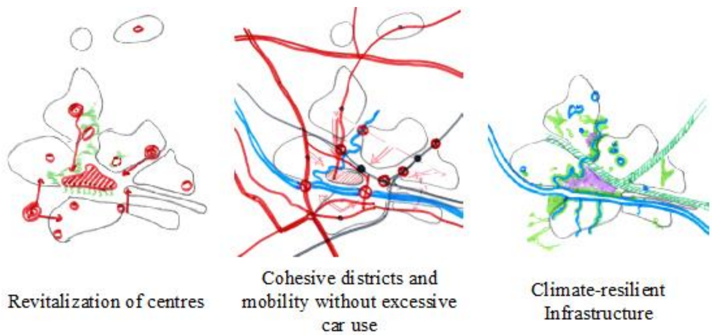

Fig. 4. *3 scenarios of Polatsk spatial strategy (source: author's drawings with reference to the Green Urban Development Plan – Polatsk: Bridging the Gaps. [8])*

The 3 cases above demonstrate the diversity of Belarusian cities, which made it imperative to tailored solutions for urban planning and development to the particular city. It was achieved through the effective collaboration of international and local urban planners, municipal authorities and citizens, which relied on studying the urban form, structure, morphology, and preferences of inhabitants. While comparing the spatial models of the green cities in Belarus with the Integrated Combination of Guiding Urban Concepts developed by the Cities Fit for Climate Change team [14], we can identify the implemented spatial elements, that ensure sustainability and play a significant role for the successful application of green urban development. The following table lists the fairly frequent features of the "linear-axial" model (corresponding to spatial strategies of Navahrudak and Navapolatsk) and "decentralized concentration" model (applicable to Polatsk case) [15], that are suggested as a combination of the elements to make a city fit well for climate change [14].

Table 2. *Common elements of the green urban development strategies*

Elements	Navahrudak	Navapolatsk	Polatsk
• Keep settlements and their elements coherent and adequately compact	√		√
• Keep settlements and their elements connected (but avoid sprawl)	√	√	√
• Keep short distances to foster and consolidate adaptive behaviour	√		
• Avoid mono-functional development and inadequately low development	√	√	√
• Allow polycentric structures and development		√	√
• Reduce CO_2 emissions by reducing waste and traffic		√	√
• Facilitate a resilient layout, infrastructure (and services) and building stock, fostering low energy consumption, or generating (renewable) and low-emission energy	√	√	√
• Identify autarkic structures/elements within the existing and planned system/layout	√		√
• Increase the adoption of development axes that allow further compact development, yet flexibility to respond to unforeseen disasters or erratic weather events	√		√
• Increase the adoption of relief corridors and spaces (i.e. ventilation)	√	√	√

CONCLUSION

The following conclusions are based on the previous survey of the current research focused on spatial urban strategies elaborated to promote green urban development in the cities of Belarus. Firstly, the considered green urban development plans contain a structural part – the spatial strategy, that allows integrating ecological aspects in urban planning and design while linking global challenges of climate change with urban and spatial development. In order to achieve green urban development, spatial elements and models of the sustainable cities should be applied in a contextually. Of course, this does not diminish the necessity to keep interconnection with its non-spatial elements, such as smart governance, public involvement and inclusion. That said, spatial planning and design are inevitably important for the provision of myriad unique solutions to climate change.

Secondly, Belarusian cities need to align with global goals and various international agreements during urban planning. Global knowledge and expertise should be leveraged to help make our cities sustainable. The “sustainable urban development” paradigm is valid for formulating locally tailored spatial strategies taking into account local conditions owing largely to the spatial pillars: “land use”, “density”, “transport and mobility” and “public and green spaces”. Moreover, green urban planning has the potential to adjust recognised sustainable city models like the “compact”, “linear-axial”, or “decentralized concentration” city to the very context where they will be applied according to it urban form, structure, morphology, and preferences of inhabitants. Inevitable adjustments have to be employed to globally accepted spatial models to match with the Belarusian context due to external and internal factors, such as diminishing population, climate specifics, urban heritage and planning traditions, etc.

Finally, the key recommended directions for advancing the green urban development in Belarus are determined by the above-named local specifics and could be summarised as the tasks to: (a) incent vertical and horizontal integration of urban strategic planning, facilitate strategic planning at the municipal level; (b) incorporate climate-related tasks with decisions regarding urban forms and structures, enhancement life quality and urban viability; (c) explore various land-use scenarios to intensify density and diversity for the future; (d) better integrate land-use and mass transit, as well as non-motorised transport modes; (e) build a holistic environmental city framework as a part of the regional ecosystem of interconnected multi-functional green areas with preservation of biodiversity; (f) promote adequate densities, compact polycentric city model with mixed land use and human scale; (g) introduce autarkic urban structures for decentralized and semi-centralized engineering infrastructure; (h) advance sustainable water management urban design solutions within the range of resource-saving strategies.

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DETERMINATION OF THE VOLUME OF THE TANK OF RAILWAY WAGON WITH RIBBING

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ABSTRACT

This article is aimed at comparing the effectiveness of testing the dimensional parameters of a tank wagon with an internal ribbing with a nominal volume of 85 m^3 in a production plant. One of the used methods is the traditional volumetric method, ie measuring the volume of water with a pair of flowmeters when filling the vessel. The second method is a method of computer processing of data obtained by 3d scanning of the interior of the tank from several positions and the subsequent composition of the tank model and calculation of its volume using the PolyWorks program. Evaluation of both measurement methods revealed that despite the non-trivial internal division of the measured object, both methods are sufficiently accurate, and even in this case the scanning method provides the measurement result several times faster compared to the volumetric method. In the reported example, measurement time spent to achieve results for the scanning method was approximately one third comparing with that of the water filling.

Keywords: *volumetric method, water savings, 3D scanning, railway tank*

INTRODUCTION

Sustainable modes of transport could help reduce the costs of road congestion, as they are expected to increase by 50% by 2050. According to the European Environment Agency, CO2 emissions from rail transport are 3.5 times lower per tonne-kilometer than from road transport [1]. Therefore, sustainable modes of transport, especially rail, have become a key part of EU policy over the last 25 years. As early as 1992, the European Commission set the shift from road to rail as one of its main goals. In 2001, the Commission reaffirmed the importance of revitalizing rail transport, setting a target of maintaining the share of rail freight in the markets of Central and Eastern Europe at 35% by 2010. In 2011, it set a target of shifting up to 30% of road freight for distances exceeding 300 km for rail transport by 2030 and up to 50% by 2050 [2].

Tank wagons are used to transport gaseous and liquid substances. The tank wagon chosen for the measurement is manufactured by Tatravagónka Poprad and has a nominal volume of 85 $m^3 \pm 1\%$ with a length of 11970 mm and a tank diameter of 3100 mm. Until now, the volumetric method of filling water and simultaneously measuring its volume with flow meters has been used in many production plants to control the volume of the tank [3], which is a lengthy method requiring a special workplace with powerful pumps. During the measurement, there is a large consumption of water, which is contaminated with impurities from production after the measurement and it is necessary to ensure waste management for it. Electricity is used to drive the pumps during filling and draining and also to dry the tank after measurement. In recent years, an alternative optical scanning procedure has been used to reduce the environmental burden [4], [5]. In addition to the fact that the measurement can be performed without special requirements for workplace equipment, a significant benefit is also time-saving.

In the literature, analyzes of measurements of cylindrical vessels with a simple cylindrical surface [6], [7] are mostly described and there is a lack of studies with measurements of large vessels in which strengthening elements are used for stiffness reasons. The aim of this paper is to compare the measurement of the volume of such a tank by volumetric and scanning methods and to compare the accuracy and time efficiency of both procedures.

EXPERIMENTAL SECTION

The FaroFocusS 150 3D scanner was used for non-contact measurement of the tank volume. During scanning, it emits an infrared laser beam into the centre of a rotating mirror, which further deflects it into space in the field of view of 360˚ x 300˚. When it comes in contact with the object, it bounces back into the scanner. The distance from the scanner is determined by measuring the phase shifts of the laser radiation.

Measurements are processed on an HP Z840 Workstation Desktop containing 2x Intel Xeon CPU E5-2630 v4 @ 2.2 GHz with 128 GB RAM, 2x 4 TB LSI Logical Volume SCSI Disk Device and 1x 1 TB SSD, 2x NVIDIA Quadro P4000 64.0 GB graphics card. The software programs used are Polyworks Metrology Suite 2019 IR4 64-bit and Sceneversion 2019, API version. The highest quality scan of this system takes 118 min and 49 s, the lowest quality takes 1 min and 7 s.

Before scanning, the operator has to determine how many times the object will be scanned in order for 100% of the entire surface to be scanned. For some objects, one position is enough if it is scanned only locally, for others several dozen positions and relocations are necessary. Furthermore, reference balls need to be properly arranged to connect and register scans (Fig. 1). The balls are clamped on the place using a built-in magnet, so mounting them on steel parts is simple and stable. They have a precise spherical white reflecting surface and diameter ø 145 mm. To properly align two or more scans, the balls must be arranged in such a way that the scan of the space always contains at least three balls from each position.

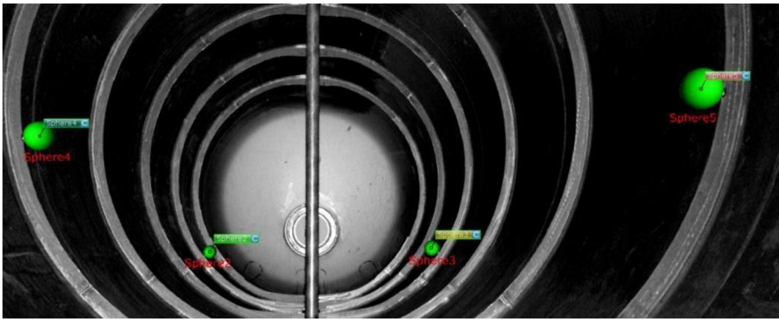

Fig. 1. *Named reference balls (left side)*

There are distributed 6 reference balls in the tank along the entire length of the tank and at different heights by using magnets. The entire tank was scanned for 6 positions, ie five relocations of the scanner. The first position was at the entrance hole and the last at the opposite end of the tank.

At the end of each scan, the scanner must be relocated between the other inner reinforcement ribs to be scanned from both sides. After each scan, it is necessary to enter the tank, relocate the scanner, turn the measurement on and get out. It takes about 20 seconds for the scanner to initialize and begin scanning after activating the next scan, so the operator has enough time to leave the measurement area. When selecting the All Scan profile, point density 1/4, repeating the measurement of each point 4x, scan size 10240 x 4267 points, measurement accuracy in the length of 10 m scattering of points 6.1 mm and scan duration 11 min 27 sec, the measurement took 75 min, respectively 105 min including the preparation.

In order to optimize the time and data load, the measurement was repeated with altered scanning and software parameters. Measurement at 6 positions with dot density 1/4 and repeated measurement of each point 2x, scan size 10240 x 4267 points, measurement accuracy in the length of 10 m scatter of points 6.1 mm result in scan duration 02 min 24 sec. The scanning of one tank was thus shortened to 15 minutes with preparation. The scans still need to be processed to measure the volume of the tank.

Data Processing

Registration is the process of all scans aligning into one overall scan using a reference scan and data from the sensor such as position, direction and height. The most common and accurate way is registering using the beforementioned reference balls, which are arranged in the scanned space. Each ball must be named the same in each scan, as the software connects and overlaps the scans on the base of the same designation and position of the reference balls in the space.

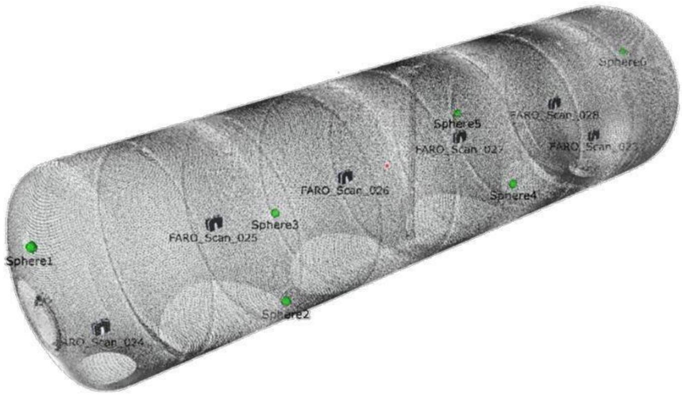

Fig. 2. *Reduced cloud of points*

After registration and alignment, a cloud of the contour points is ready for export. Fig. 2 presents a reduced cloud consisting of 459,000 dots, which is only 0.2% of the total scanned amount, to get semi-transparent picture showing the location of the individual scan device positions and reference points.

Data from the scanner are saved in a .fls file so that points are saved including the normal. Each point saved in this way contains six parameters: the coordinates x, y, z [mm] and the direction of the normal i, j, k [°].

In order to create the polygon model, PolyWorks software was used. When creating a polygonal model, the software always connects the two nearest points (vertices) into a vector. When three vectors are connected, a triangle - polygon is created. This procedure is repeated until all polygons are gradually connected and so polygonal model is created. The denser the points are, the more detailed and better dimensionally descriptive is the model. This is a procedure that lasts about 10 minutes.

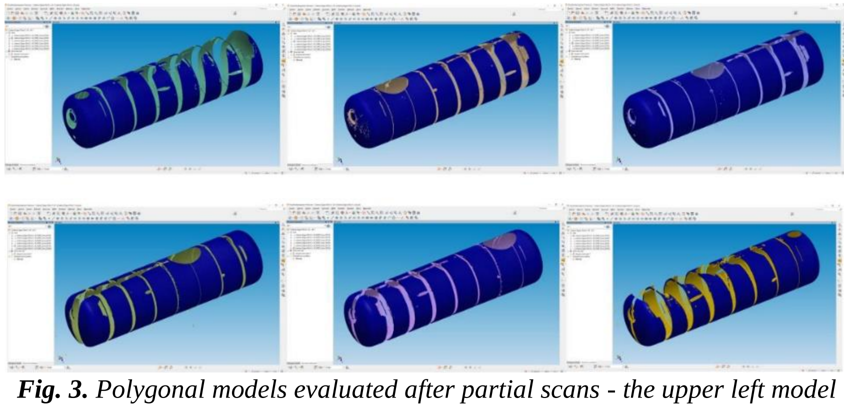

Fig. 3. *Polygonal models evaluated after partial scans - the upper left model corresponds to the location of the scanner in the left part of the tank, the scanner is gradually relocated to the right*

Fig. 3 presents a serie of six partial models after each scan, from which an overall polygonal model is created. This is an illustration of how the system is not able to scan the areas behind the ribs (or whatever obstacle) from individual scanning positions, so it is necessary to perform relocated scans to ensure measurement of the elements allowing to model 100% of the surface necessary for the calculation.

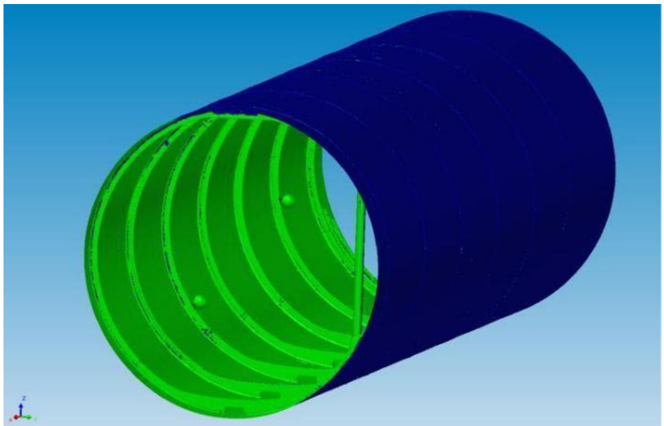

Fig. 4. *Reference balls and spacer bar inside the tank*

Before one can perform the calculation of the tank volume, it is necessary to clean the object from unwanted elements that could affect the result of the calculation of the total volume. In this case, in addition to small dirt and radiation reflections from dust particles that form kind of noise that is to be cut-out, there are six reference balls inside the tank, which would reduce the actual volume of the tank with their volume, as well as the middle spacer bar, which serves to pump the gas out of the tank and at the same time prevents deformation of the tank in the middle (Fig. 4). Since it has a hollow shape and also serves as a pipeline, there are two ways to regard it in the calculation. The first option is to keep it in, calculate its internal volume and add it to the total volume of the tank. The second option is to erase the rod and not to modify the calculation, because its thin wall negligibly affects the volume calculation comparing to the size of the tolerance limit. The second method was chosen as faster and more practical.

It is also necessary to set the Cartesian coordinate system in the data model. Since the basic elements for inserting a coordinate system are not predefined, namely: plane, vector and point, it is necessary to define them. The vector is also the axis of the cylinder, it is possible to create it in two ways:

1. By defining a nominal CAD model and then extracting it as a data element

2. By defining a data model and creating an average cylinder from the measured elements.

To calculate the volume, it is still necessary to determine the reference plane, contour, direction and sampling step.

According to the Reference plane, the perpendicular direction of the orientation of individual intervals (sampling) of volume integrals (cubature) to the reference plane is determined. It must pass through the object in such a way that the integrals count through the entire volume of the body. Its orientation must be determined according to the coordinate system in the XY, YZ or ZX directions. In our case, the ZX direction was chosen to avoid undercutting the data behind the ribs inside the tanks.

Each data point is projected to a reference plane to determine which grid the square belongs to. Each data point in the grid square is calculated as the intersection of the vector starting at the centre of the grid element and the plane passing through the point containing the normal.

The sampling step are intervals (cross-sections) of integrals that fill the entire volume of the object. A value of 1.00 mm means that it is a square in cross-section with sides 1 mm x 1 mm. In general, the smaller the value, the more accurate the volume measurement result, but also the longer the calculation time, which increases exponentially with decreasing sampling step size. It is also necessary to create intersections with the side lids on the tank, so that the data object can be fitted on the CAD model in the longitudinal axis. Since the side lids have the shape of a spherical surface, they can be defined as a round cut with a certain diameter.

The total volume is the sum of the positive and negative volume as presented at Fig. 5 and Table 1. The two values are not the same because the tank is unevenly deformed and also depends on the position of the reference plane, which does not pass exactly through the central X-axis. Ultimately, this does not affect the accuracy of the tank volume calculation.

To determine the actual value of the tank volume, the following procedure for processing measurements for individual sampling parameters was chosen: a polygonal model is created from the processed scans, subsequently, it is possible to calculate the volume, which e.g. it takes 40 min with a selected sampling size of 0.5 mm. When sampling is changed to 0.45 mm, the calculation takes 2 hours, which is not very efficient in time, because the value of the total volume has changed by only 10 dm^3, which is a negligible value in terms of the permissible tolerance of the tank volume. Anyway, in order to calculate the actual volume, 14 calculations of volumes were evaluated from sampling 100 mm x 100 mm descending to 0.45 mm x 0.45 mm. A graphical dependence and a linear trend line were created from the calculated volume measurements - see Fig. 6. The intersection of the linear regression line and the zero vertical axes represents the extrapolated theoretical actual value of the tank volume.

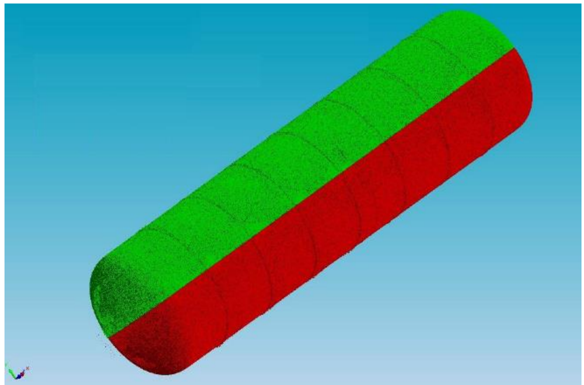

Fig. 5. *Calculated tank volume with a nominal volume of 85 m³*

Table 1. *Integrated parts of the total volume*

Volume measurement results	Tank with nominal volume 85 m^3
Positive volume (green) [m^3]	42.5637
Negative volume (red) [m^3]	42.5709
Total volume [m^3]	85.1346

Fig. 6 Displayed measured values of volumes depending on the sampling step with regression line

The graph shows the trend of the calculated volume depending on the step, corresponding to the linear function

$$f(volume) = -247.2*step + 85430$$

After substituting the zero value of the step, it is possible to determine the theoretical value of the total volume of the tank, which corresponds to the position of the intersection of the values trend line with the vertical y-axis. That means that the calculated actual value of the tank volume is 85,430 dm^3. The difference between the theoretically calculated value and that measured at 0.5 mm sampling is 123 dm^3, which is an acceptable value from the point of view of tolerance ± 850 dm^3. Therefore, it is not necessary to use the calculation of the extrapolated value in the paragraph when checking the volume of the measuring tank, but it is possible to use that procedure if the result needs to be refined.

Based on the evaluation of the measurement, the value for the reduction of points was adjusted from 1/4 to 1/24, the parameter for creating a polygonal model was optimized and the sampling step for the volume calculation was adjusted from 0.5 mm to 1 mm. The evaluation time was thus reduced from 90 minutes to 21 minutes, which is 36 minutes altogether with the scanning time. The reported time of 15-20 minutes referred in the literature [4], [8] was achieved by measuring simpler objects without ribbing. From this point of view, we consider the achieved result to be satisfactory. If further optimization is required, other reductions are possible with respect to the measurement parameters and the calibration recalculation of the result based on trend extrapolation.

The determination of the volume for the given parameters is characterized by the uncertainty of determining the result ± 101 dm^3, which is an acceptable value from the point of view of tolerance ± 850 dm^3, as even the most unfavourable value of the measurement result falls within the given interval.

Comparison of Tank Volume Measurement by Scanning and Flow Meters

In the production of wagon tanks, the technological process of production also includes the measurement of the internal volume, for which two measuring flow meters operating simultaneously were used in practice:

- MID 2-25/16-F/St-PT-MEL/HC-St M10AR with maximum flow 4.5 m^3/hod
- MID 2-100/16-F/St-HG-ML/HC-St M20AM with maximum flow 70 m^3/hod

Filling time: t_i = 68 min 28 s

Emptying time: t_o = 45 min

Total time: t_{i+o} = 113 min 28 s

Measured volume of water 85 075 m^3 ± 84 m^3

According to the calibration sheet, the MID 2-25 / 16 flowmeter has an uncertainty of the measurement result ± 0.05% and the MID 2-10 / 16 flowmeter under the same conditions the uncertainty of the measurement result ± 0.105%.

These results show that the actual volume of the tank meets the nominal requirements within the prescribed tolerance as measured by both methods, while the scanning method is more time-efficient and at the same time more environmentally friendly. Testing the tank for leaks and resistance to mechanical stress remains the advantage of the volumetric method over scanning.

CONCLUSION

The aim of this work was to verify the effectiveness of measuring the internal volume of the railway tank with ribbing using a 3D scanner Faro FocusS150, as a reference measurement was used the currently used system of measuring volume flow meters MID 2-25 / 16-F and MID 2-100 / 16-F.

By comparing the two measurements in terms of accuracy, method of design and time, it can be stated that both methods of measurement are suitable for volume measurement and their accuracy meets the technical requirements for tank volume tolerance. From the point of view of time, the measurement with the FaroFocusS spatial scanner is more advantageous, because the measurement of the tank (observing the prescribed deviation of the volume tolerance) lasts altogether with the evaluation 36 minutes, ie it is 3x faster than the measurement with flow meters (113.5 min.). Another benefit of measuring with a scanner is the acquisition of data enabling the creation of an object model for other measurement possibilities along with significant water and electricity savings. As for the possibilities of further streamlining of measurements, in the case of the volumetric method, it is possible to use higher flows, but the total amount of water and energy consumed will not change. In the case of 3D scanning, there could be tested another option to adjust the data processing process, however, related to the calculation accuracy.

This work fulfilled the original intention to use the FaroFocusS exterior scanner to measure the volume of tanks in the production process in a practical way. It is, therefore, possible to recommend this method of measurement and incorporate it into the technological method of production, respectively control of tank volumes in practice.

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GREEN DESIGN AND EDUCATION OF STUDENTS AT UNIVERSITIES IN THE SLOVAK REPUBLIC

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ABSTRACT

Buildings represent a sector with huge energy consumption. It is necessary to reduce this consumption, therefore green buildings have become a global trend in recent years. Green Building Councils in various countries, which are members of World Green Building Council global network, develop and administer many of the world's ratings tools. World Green Building Council was founded in 1998. There are four predominate ranking systems: LED, BREEAM, GREEN STAR and CASBEE. Slovak Green Building Council was established in November 2010. The first green building in the Slovak Republic received LEED certification in 2012. In the paper it is referred to about 17 new and in-use green buildings in Slovakia which received in period 2012-2019 LEED or BREEAM certifications. In fact, there are more green buildings in Slovakia, where there is still the huge potential in applying a green concept in the sector of existing residential buildings and the public buildings sector. There is a lack of legislative and financial support instruments for green buildings in Slovakia, which are under the consideration and do not exist in practice.

The BBC 1 Plus – Offices in Bratislava, the first certified green office building in Slovakia, which received in 2012 the second-highest certification – LEED Gold, is described and analysed in details. The necessity of improving the education process in the green design and sustainable architecture of students at Faculties of Civil Engineering and Faculties of Architecture is outlined. The plans for how it is possible to achieve it are presented.

Keywords: *green building, Slovak Republic, LEED, BREEAM, education*

INTRODUCTION

The author successfully finished in 2010 3-years bachelor study in study program Environmental Engineering at Faculty of Civil Engineering (FCE), Slovak University of Technology (STU) in Bratislava in. Later in 2015 she finished 3-years bachelor study at the Department of English Language and Literature and 2-years master study at the Department of Romance Languages and Literatures in study program English and Spanish Languages at the Faculty of Education, Comenius University in Bratislava. Currently the author is teacher of English language at the Department of Languages, FCE, STU in Bratislava and also external PhD student at the Department of Romance Studies, Faculty of Arts, Comenius University in Bratislava.

As a teacher, the author is responsible for the courses which are primarily focused on terminology of 20 various FCE departments. In every of 4 semesters, the terminologies of 5 different departments are analysed. It is extremely difficult for students to understand the meaning of special terms, which are not in basic dictionaries and to apply them in solving their task also in other subjects. There are up to 200 Slovak students and up to 25 foreign students in the several study groups. Foreign students consist of small groups of Greek and Spanish students and individuals from various countries: Brazil, Kazakhstan, Kenya, Poland, Russia, Ukraine and others. The participants of the courses consist of Slovak and foreign regular students studying normally 5 years and also Erasmus foreign students studying only 1-2 semesters.

Experience from a 4-years teaching period shows that there is an urgent need to enlarge the amount of part of education relating to environmental engineers and particularly to emphasized the importance of green design and sustainable architecture.

Slovak Green Building Council (SKGBC) was established in November 2010. The ranking of V4 countries relating to number of green buildings is as follows: 1. Poland, 2. The Czech Republic, 3. Hungary, 4. The Slovak Republic. This is also an evidence that in the Slovak Republic there is still the huge potential in applying a green concept in the sector of existing residential buildings and the public buildings sector. Information about the importance of green design and sustainable architecture in the education of the young generation should be therefore substantially improved. The ideas how to improve the the education students and the consciousness of designers in practice as well in this direction is presented below.

MATERIAL AND METHODS

Extremely important is to inform students about the following facts. Green building rating tools – also known as certification – are used to assess and recognise buildings that meet certain green requirements or standards. Rating tools vary in their approach and can be applied to the planning and design, construction, operation and maintenance, renovation, and eventual demolition phases of a green building. Rating tools can also differ for different building types such as homes, commercial, administrative, tall buildings, etc. Green Building Councils (GBC) in a given country, which are members of the World Green Building Council (WGBC) global network, develop and administer many of the world's ratings tools [1]. The WGBC was founded in 1998. In 2008 it was comprised of national councils from twelve countries. Of these countries, there are four predominate ranking systems (see Figure 1): (i) Australia and New Zealand follow GREEN STAR; (ii) the United Kingdom, Building Research Establishment Environmental Assessment Method (BREEAM); (iii) Japan, Comprehensive Assessment System for Building Environmental Efficiency (CASBEE); and (iv) the United States, Brazil, Canada, and India use Leadership in Energy and Environmental Design (LEED), with slight variations [2].

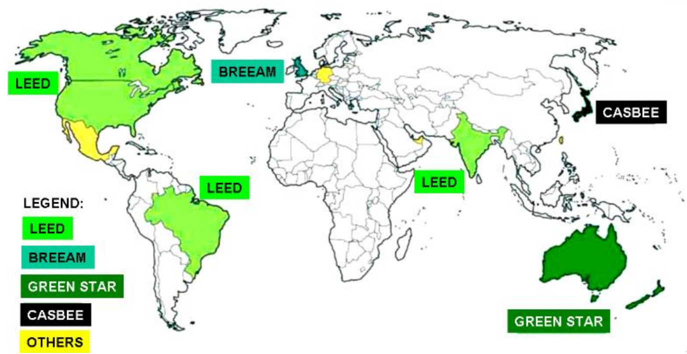

Fig. 1. *World map showing countries using the four predominate ranking systems [2].*

Table 1. *Four rating systems [2]*

LEED points	Certified 40 – 49	Silver 50 – 59	Gold 60 – 79	Platinum 80 +	-	-
BREEAM % of benchmark	unclassified below 30%	pass 30% – 45%	good 45% – 55%	very good 55% – 70%	excellent above 70%	outstanding above 85%
GREEN STAR points	One Star 10 – 19 minimum practice	Two Star 20 – 29 average practice	Three Star 30 – 44 good practice	Four Star Green Star 45 – 59 best practice	Five Star Green Star 60 – 74 Australian excellence	Six Star Green Star 75+ world leadership
CASBEE	CASBEE buildings are designated with the following ratings: C, B-, B+, A, S, with C being the lowest and S the highest.					

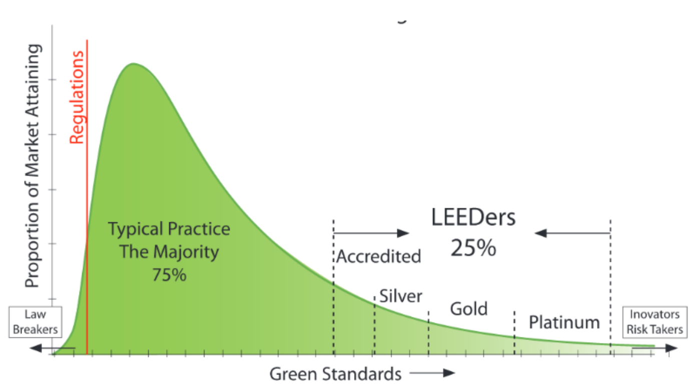

Fig. 2. *Green building markets estimated by USGBC in 2006 [3], [4].*

Currently the WGBC membership directory contains 69 countries. There are a lot of items in the WGBC list of green building rating tools. But number of green building rating tools and certifications that exist are not administered by a WGBC member GBC [1].

Background of LEED. The U.S. Green Building Council (USGBC) was established as a non-profit organization in 1993. The council is made up of construction industry stakeholders including owners, contractors, architects, engineers, product manufacturers, and environmental groups. The USGBC established LEED in 1998. After extensive revisions by the council, LEED New Construction and Major Renovation version 2.0 was released in 2000. Since then, development of different LEED assessment categories has occurred along with version revision.

Information about state of art in the Slovak Republic is also very important.

Examples of some new and in-use green buildings in the Slovak Republic:

1) BBC 1 Plus – Offices in Bratislava [5], Plynárenská street 1, 821 09 Bratislava, is the first certified green office building in Slovakia. It received LEED Gold;

2) Project Forum Business Center I in Bratislava with 18.800 m^2, obtained in 2013 as the first office building in Slovakia certification BREEAM excellent;

3) CBC III, Bratislava, 12.000 m^2, BREEAM in-use very good, 2013;

4) CBC IV, Bratislava, 12.000 m^2, BREEAM in-use very good, 2013;

5) Apollo BC II, Blocks A, B, Bratislava, 32.400 m^2, BREEAM in-use very good, 2014;

6) Project EcoPoint Office Center Košice received in 2014 with 73 points certification LEED Gold;

7) Westend Gate, Bratislava, client J&T Real Estate, 50.000 m^2, BREEAM good 47,4%, November 2016;

8) Zelené átrium, Trnava, client ISOVER, LEED platinum, June 2017;

9) Business Centrum Tesla 2, Košice, client Penta Real Estate, 14.538 m^2, LEED gold, December 2017;

10) Einpark, Bratislava, client Corwin Capital, 16.560 m^2, LEED platinum, January 2018;

11) Blumental offices, Bratislava, client Corwin Capital, 18.000 m2, LEED gold, May 2018;

12) EcoPoint 2, Košice, client Bischoff & Compagnons, BREEAM excellent 77,2 %, May 2019;

13) Panorama Business III, Landererova 12, Bratislava, client J&T Real Estate, 22.000 m2, LEED gold, August 2019;

14) Poštová offices, Žilina, client Reinoo, a.s., 15.000 m2, LEED gold V4, October 2019;

15) Green Bay Residence, Trenčín, client TAW, 8.000 m2, LEED silver, October 2019;

16) Klingerka, Bratislava, client J&T Real Estate, 15.000 m2, BREEAM excellent 76,5%, October 2019.

Two longer lists of Slovak green buildings may be found in [6]. The first list contains 10 green buildings with LEED certifications. There are another 21 projects registered for LEED certification [6, 7]. The second list contains 20 new green buildings with BREEAM certifications. Certification of existing buildings, valid for 12 months - BREEAM in-use, includes other 23 projects [6, 8]. In [6] there is also a table with the most significant projects, architects, investors and key local companies in Slovakia related to green buildings.

THEORY

The goals of improved study programs could be: a) to help local students cope with and benefit from international challenges and practices, i.e., “internationalization at home”; b) to attend to the needs of international students and effectively support their learning; c) to address SEDA (Staff and Educational Development Association) values: c1) developing understanding of how people learn, c2) practicing in ways that are scholarly, professional and ethical, c3) working with and developing learning communities, c4) valuing diversity and promoting inclusivity. Continually reflecting on practice to develop ourselves, others and processes; d) to meet SEDA specialist outcomes: d1) to use a variety of appropriate approaches to enable learning, d2) to use a variety of methods for evaluating their role in supporting learning, d3) to inform their professional role with relevant strategy, policy and quality considerations.

The author decided after her university studies to work in 2016 in Henkel company which is located in BBC 1 Plus to have her own experience with such architecture. The paper presents all details of this building and the author may confirm that BBC 1 Plus is really a unique building providing its tenants a high-quality, healthy and comfortable working environment with a pleasant micro-climate.

It is necessary that students should have also their own experience with realised green buildings and sustainable architecture. An example is: thirty students of STU in Bratislava and foreign students from Greece, Ireland, Spain and Syria took part in International student real estate workshop organised by Management Institute, STU in Bratislava, Institute of Technology in Dublin and a leading real estate agency. Students tried to find the convenient administration building in given area. They visited three buildings including BBC 1 Plus green building. The students were happy to see all advantages of this green building. The author plans to organise excursions of students in project and architecture bureaus having experience with green building designs and in green buildings too.

DISCUSSION

Internationalization and innovation of teaching is necessary to apply, therefore the author would like to concentrate more on the most actual problems of human beings: ecological and environmental problems with application in green design and sustainable architecture. These topics are surely the most important ones for students from all countries and the author expects that they will attract their attention.

For young generation in all counties it is extremely important to be acquainted with ecological and environmental problems and their solution. The students at FCE should be better educated in building green design and sustainable architecture. Author plans to use the proceedings of Geolinks Conference together with videos [7], [8] in pedagogical process as efficient tools to increase the student knowledge in this area.

In education of students specific examples are important as it is for example **BBC 1 Plus – Offices** in Bratislava, Plynárenská street 1, 821 09 Bratislava, is the first certified green office building in Slovakia [5]. Details of this green building:

Certification: For certification and evaluation system LEED buildings several aspects are assessed: 1. sustainability, 2. water management, 3. energy consumption and the impact on air environment, 4. the materials and resources, 5. indoor environment quality, 6. innovative approach and 7. regional priorities. Certification was carried out through the American system LEED and the building received the second highest certification - LEED Gold (Table 1).

Fig. 3. *BBC 1 Plus in Bratislava in Slovak republic*

(Courtesy of Tomáš Manina, WOOD & Company).

Building facts: Developer/Investor: CA Immo Group is one of SKGBC founding members; general contractor: Bilfinger Berger; architect: Bogár, Králik & Urban (BKU) in Bratislava; construction start: 6 December 2010; construction end: September 2012.

Building characteristics: Floors: 1 underground / 13 upper floors; total effective area: 15,900 m^2; parking places: 313 indoor parking spaces. The mixed-use building contains: administrative premises: 14 568 m^2; storage premises: 805 m^2; retail premises: 485 m^2; self-service restaurant: 400 seats; café, tobacco shop, pharmacy, hairdresser, nail studio, sport bar with billiard, table tennis and table football, terrace with seating and smoking zone. High standard, use of modern technologies and high energy efficiency of BBC 1 Plus will provide its tenants a high-quality, healthy and comfortable working environment with a pleasant micro-climate.

Standard floor plan: Flexible partitioning – up to 8 separate lease units per floor is possible; independent office units from 130 m^2; individual metering of energy consumption for lease units enabling a transparent summarising through the BMS system.

In building there are: Entrance hall with elevators featuring natural stone façade; two reception desks; entrance into parking space secured by ramps, access to elevator hall through turnstiles;10 personal elevators – 3 elevators in 2 halls, one elevator with extended capacity for cargo transport, 4 elevators (2 x 2) for transport between parking house floors; parking house – machine-smoothed reinforced floor sloping down towards evaporation gutters, intelligent ventilation with CO2 detector; fire detection system throughout the building, electronic fire signalisation (EPS), electronic security signalisation (EZS); intelligent building management system (BMS); building's critical systems have a backup diesel power supply unit; connection to optical line; aluminium-glass façade with isolation glass, raster at 1.3 metres; bicycle stands in monitored-access area; changing rooms; showers.

Reduction of thermal gains and losses: Costs of heating, but especially of cooling represent a large portion of total operating costs of a building. The glass used on BBC 1 Plus has excellent isolation characteristics, which significantly contributes to the reduction of thermal intake in summer, and losses in winter, thus helping to achieve an economic operation of the building. In the southern and western sides, where the thermal gains are the greatest, BBC 1 Plus features semi-automatic exterior blinds.

Cooled ceiling system: Administrative premises are cooled with a cooled ceiling system, which naturally dissipates coolness into the environment and it gradually and evenly cools the individual offices. Unlike the usual cooling systems that use fan-coils, the cooled ceiling does not create unhealthy airflow, does not stir dust and does not create noise and it contributes to overall comfort and healthier working environment.

Green environment: The quality of interior environment in BBC 1 Plus is supported not only by the cooled ceiling system, but also by an air humidification system which improves air quality especially in winter. Heating is executed via low-heat radiators that heat up the premises evenly, without local overheating and undesired larger thermal differences within individual offices. The overall positive micro-climate is achieved also thanks to green roofs and terraces that make up over 50% of all roof area. In order to reduce water consumption, the sanitary facilities feature economic faucets and flushers. Certain mutual premises are lighted with motion-activated sensors that reduce energy consumption as well. The building is prepared for waste separation. BBC 1 Plus also supports alternative modes of transportation – it offers bicycle stands and relevant accessories (changing rooms, showers).

CONCLUSION

The importance of green design and sustainable architecture in education of young generation in all countries is analysed and stressed. The plans how to improve such education are outlined. The results and effectivity of proposed education improvement could be evaluated after next semester.

The paper gives basic information about the WGBC global network, its history and about Green building rating tools – also known as certification. Details of four predominate ranking systems (Fig. 1): LEED, BREEAM, GREEN STAR and CASBEE are given too (Table 1).

Slovak Green Building Council (SKGBC) was established in November 2010. 17 Slovak green buildings with LEED and/or BREEAM which received certifications in the years 2012-2019 are presented. They are located in the capital Bratislava (12), Košice (2), Trenčín (1), Trnava (1) and Žilina (1). About more green buildings with LEED or BREEAM certificates in Slovak Republic it is referred in [6].

Details are given about BBC 1 Plus – Offices in Bratislava, the first certified green office building in Slovak Republic (Figure 3). Total costs 30 millions EUR.

In Slovak Republic there is still the huge potential in applying a green concept in the sector of existing residential buildings and the public buildings sector and related education at universities as well.

ACKNOWLEDGEMENTS

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TRANSFORMATION OF HIGH-DENSITY GREEN ENERGY WITH SIMULTANEOUS DECONTAMINATION OF THE ENVIRONMENT

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ABSTRACT

In recent years, there has been an increased emphasis worldwide on the quality of the environment, especially with an orientation towards the application of renewable energy sources. In addition, we are increasingly encountering experimentation aimed at obtaining new green energy sources. One of such sources is biomass. Biomass has been used since the middle ages as a source of heat and light energy. Today, however, we have technologies that allow us to obtain not only heat but also electricity from biomass, or to convert biomass into materials with high energy density and purity. The energy thus transformed can then be used, for example, as a propellant. At the same time, this valuable source of clean energy can be easily transported to the place of consumption. By applying biomass as a source of green energy, we can make a significant contribution to relieving the environment from harmful effects. In recent years, an increased interest in energy obtained from biomass can be observed in Slovakia. Its technical potential is the greatest among other renewable energy sources, and its non-use would essentially be wastage. Therefore, the aim of the paper was to describe two possibilities of transformation of biomass in the form of its energy recovery into the type of energy used for the production of mechanical, thermal and electrical energy. At the same time, in addition to obtaining a suitable form of energy from biomass, another environmental benefit was sought in the form of soil decontamination. In this regard, there is an energetically important crop, which is known under the Latin name Amaranthus caudatus. It is an energy crop that can be grown on slightly contaminated soil with some restrictions. Two methods of energy recovery of this crop were compared. In the first case it was its compaction into briquettes, in the second case it was a process of anaerobic fermentation with subsequent production of biogas. Based on the performed analysis, it was found that these are almost equivalent energy sources. Although both methods of transformation and energy recovery of the green part of Amaranthus caudatus crops have a number of advantages and disadvantages, it can be clearly stated that the positives significantly outweigh the negatives. Therefore, it is recommended to apply this crop as a valuable source of energy for use in real conditions.

Keywords: *biogas, calorific value, efficiency, energy, environment*

INTRODUCTION

New energy sources are being sought due to the ever-tightening of emission limit quotas. The primary attention is paid especially to the so-called green energy sources, which are obtained on the basis of renewable energy. The main reason is that these energy sources make it possible to produce environmentally friendly energy [1]. At the same time, by changing the legislation in Slovakia towards improving the quality of the environment by supporting the use of renewable energy sources, we are increasingly encountering the search for reserves of the potential of renewable energy sources. We see this reserve especially in the area of green biomass [3]. Of course, the advantage is that these new renewable energy sources have the least possible negative impact on environmental degradation. The ideal case is if their use not only does not harm the environment but on the contrary, can eliminate the amount of emissions in the air or harmful substances in the soil. In terms of geographical location and the current level of agriculture, Slovakia has a number of advantages in the field of obtaining energy from renewable energy sources [7]. It has free energy potential mainly in the field of biomass production [2]. At the same time, it is mainly the cultivation of the so-called energy crops. In addition to ecologically clean energy production, its ecological transformation into mechanical, thermal or electrical energy is also important. One of the alternative ways of ecological use of energy crops grown in Slovakia is their energy recovery through compaction in the form of briquettes or in the form of anaerobic fermentation with subsequent production of biogas.

ENERGY POTENTIAL OF BIOMASS IN SLOVAKIA

Currently, the total available technical potential of biomass in Slovakia is estimated at more than 160 PJ (25.10^6 t) [9]. Of this potential, approximately 56.8 PJ falls on purpose-grown biomass in the form of energy crops, e.g. cereal straw represents 10.4 PJ ($0.7.10^6$ t), rapeseed straw 2.9 PJ ($0.2.10^6$ t), corn straw 9.4 PJ ($0.6.10^6$ t), sunflower straw 2.8 PJ ($0.2.10^6$ t). Various crop species characterized by high yields are bred, the calorific value of which ranges from 8.1 to 18.6 $MJ.kg^{-1}$ depending on the water content, e.g. straw with a water content of about 15% has a calorific value of 14.3 $MJ.kg^{-1}$ (4.0 $kW.kg^{-1}$), winter rapeseed straw 17.5 $MJ.kg^{-1}$, rapeseed oil 37.1 $MJ.kg^{-1}$ (10.3 $kW.kg^{-1}$)

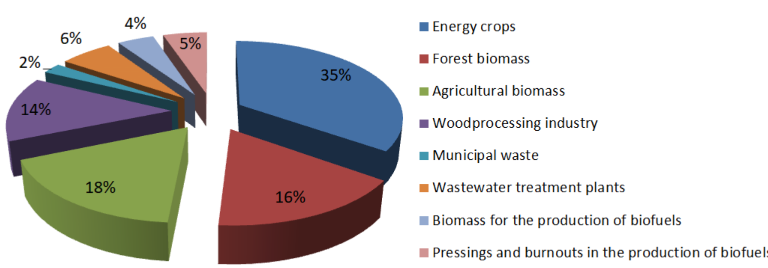

Fig. 1. *Technically usable potential of biomass in Slovakia*

However, of the current technical potential of biomass, only a small amount is actually used in Slovakia. There are considerable reserves, especially in the use of green biomass and its transformation for ecologically clean energy [5]. In this regard, the situation can greatly improve the cultivation of so-called energy crops. One such energy crop is also Amaranthus caudatus.

BASIC DESCRIPTION OF THE ENERGY CROP AMARANTHUS CAUDATUS

Amaranthus caudatus is an annual monocotyledonous crop with a height of the aboveground part in ripeness from 0.30 to 0.80 m. The stem is recumbent to erect, densely leafed with a short inflorescence. The fruit is a small, broadly ovoid stem or capsule. In terms of soil quality requirements, it is a crop with minimal requirements. Based on several analyzes performed, the crop Amaranthus caudatus was generally assessed as an energetically important and fully valuable crop. Therefore, it is quite realistic to assume that this crop can become a valuable renewable energy source in Slovakia in a few years.

Fig. 2. *Energy crop Amaranthus caudatus*

Both the above-ground part and its root are considered to be energetically valuable parts. In addition to the above-ground part, its root can also be used for energy. The advantage of this crop is also the ability to extract a lot of heavy metals from the soil, while its energy treatment can permanently remove these harmful substances from the contaminated soil. Table 1 shows the values of the heavy metal content in the soil before sowing and after the harvest of the Amaranthus caudatus crop in comparison with the limit values of the heavy metals in the soil.

Table 1. *Heavy metal content of soil before sowing and after harvesting of Amaranthus caudatus*

Element	Original contamination [mg.kg^{-1}]	Residual contamination [mg.kg^{-1}]	Limit values [mg.kg^{-1}]
As	50.0	26.0	25.0
Cu	321.0	300.0	60.0
Hg	1.2	1.2	0.5
Pb	66.0	30.0	70.0

From the above overview in table 1, it can be observed that in three of the four monitored parameters of heavy metals in the soil (As, Cu and Hg) the limit was exceeded before sowing of the Amaranthus caudatus crop. In the case of the metal Pb, its value approached the limit value. After the collection of the energy crop Amaranthus caudatus with both above-ground and underground parts, a decrease in the content of heavy metals was recorded. At the same time, a sub-limit value of the monitored parameter was reached in all monitored parameters. Subsequently, the crop was analyzed for heavy metal content. The values recorded are given in table 2 below.

Table 2. *Recorded content of heavy metals in individual parts of the energy crop Amaranthus caudatus*

element examined [mg.kg^{-1}]	uncontaminated crop	contaminated crop	crop root
As	0.03	0.06	1.68
Cu	8.00	31.00	25.00
Hg	0.05	0.06	0.12
Pb	do 0.50	1.11	3.59

When examining the content of heavy metals, which the energy crop absorbed from the soil, it was found that for all monitored indicators, the highest values were recorded in the underground part. The above-ground part absorbed less heavy metals. At the same time, Table 2 shows the differences in the recorded values of heavy metals, which the energy crop absorbed when growing in uncontaminated and contaminated soil.

Crops with a height of 0.30 to 0.80 m and a weight of 0.01 to 0.05 kg were used in the experiment. The weights of the individual laboratory crops in the dehydrated state are demonstrated by the following graph in figure 3.

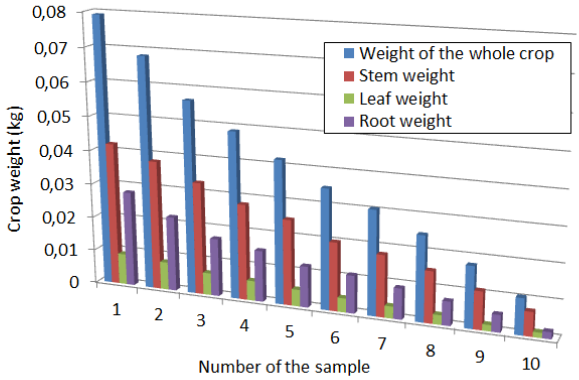

Fig. 3. *Weights of individual parts of energy crops with relative dry matter moisture of 15%*

From the point of view of the practical application of the energy crop Amaranthus caudatus for energy purposes, it is necessary to compact it in the form of pellets or briquettes. For demonstrative purposes, laboratory pressing of the crushed dry matter was performed using a pressing jig at a pressure of 400 kN, which is shown in figure 4.

Fig. 4. *Laboratory pressing preparation for the crushed powder of the energy crop Amaranthus caudatus*

The volume of the cavity in the laboratory pressing preparation was 160 ml (16.10^{-6} $m^{3)}$. Dry crushed powder with a moisture content of approx. 15% was used for pressing the briquettes.

ENERGY BALANCE OF AMARANTHUS CAUDATUS CROP

An experimental sample of the compacted dry matter of the energy crop Amaranthus caudatus in the form of briquettes was examined from an energy point of view. The parameters of its combustion heat and calorific value were identified using a calorimeter. Combustion heat can generally be understood as the amount of heat in kJ that can be obtained by perfectly burning a certain amount of fuel with air, at a constant pressure, all the flue gases being cooled to the initial temperature of the input components [12]. At the same time, in the case of combustion heat, it is considered that the water formed by the reaction and originally contained in the fuel is in a liquid state. The condensing heat of water that is released during combustion is then added to the energy balance. Based on the experimental value of combustion heat Q_s, it is possible to calculate the calorific value of dry matter Q_i of the potential energy raw material Q_{ir} at the actual humidity. It is the value of combustion heat reduced by the heat of vaporization. It is advantageous to convert the combustion heat of the combustible fuel Q_s to the calorific value of the dry matter Q_i and then to convert this value to the water content of the fuel. This procedure is very advantageous in case we have a significantly moist potential energy raw material, which is a relatively common case for biomass. At the same time, from the point of view of achieving the highest possible calorific value, the optimal value of dry matter moisture is important. The combustion heat of the fuel then represents for a given type of fuel, resp. energy raw material constant expressing the quality of the energy carrier [8]. The combustion heat of the combustible then represents for a given type of fuel (energy raw material) a constant expressing the quality of the energy carrier. The table 3 shows a comparison of the calorific value of briquettes from Amaranthus caudatus with selected types of biomass.

Table 3. *Comparison of calorific value of briquettes from Amaranthus caudatus with selected types of biomass*

Biofuel type	**Water content [%]**	**Calorific value [MJ.kg^{-1}]**	**Bulk density [kg]**
Wood chips	10 - 40	16.4 - 10.1	170 - 225
Cereal straw	15 - 20	15.5	120 pcs
Oilseed rape straw	15 - 20	16.0	100 pcs
Amaranthus caudatus	15 - 20	14.0	127 pcs

Among other things, the overall energy potential, which includes fast-growing crops, also depends on yields and energy content in dry matter.

Another possibility of energy recovery of the Amaranthus caudatus crop is its anaerobic fermentation in order to obtain biogas. It is a biochemical process that results in a mixture of methane (CH_4), carbon dioxide (CO_2) and by products [4]. The decomposition of organic substances through the fermentation of the green parts of the crop occurs without the access of air in a humid environment by the action of anaerobic cultures of microorganisms [10]. Ideal conditions for these anaerobic bacteria are temperatures close to 50°C. In general, it is a relatively complex chemical process, while biogas as a final product is usually produced only in its final phase [11]. Anaerobic fermentation takes place in four phases, which are referred to as hydrolysis, acidogenesis, acetogenesis and methanogenesis. The following diagram in figure 5 describes in detail the biochemical process of anaerobic fermentation, which results in the formation of biogas (CH_4 + CO_2).

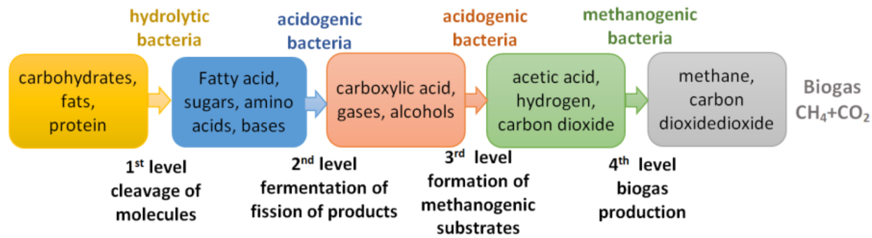

Fig. 5. *Biochemical process of biogas production through anaerobic fermentation*

The time course of a given biochemical process is closely related to many factors. Constant temperature is especially important, as anaerobic bacteria often die during rapid temperature changes. Another important parameter is the appropriate pH. For these purposes, it is advisable to maintain a pH in the range of 6.5 to 7.5. It is also necessary to ensure the presence of trace elements such as iron, cobalt, selenium, molybdenum and tungsten. It is also important to maintain the required ratios of nitrogen, carbon and phosphorus, as well as the overall quality of the biomass in terms of dry matter content. At present, a predominantly wet anaerobic fermentation process is applied in the production of biogas from the green parts of crops [6]. It processes a substrate with a water content of 85% or more. In the following figure 6 is a diagram of a process for the wet anaerobic fermentation of green parts of crops.

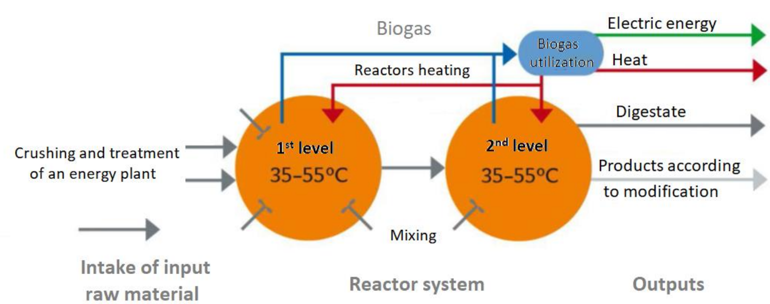

Fig. 6. *Scheme of the process of wet anaerobic fermentation of green parts of crops*

In the following table 4 shows selected properties of biogas produced by the process of wet anaerobic fermentation of green parts of crops.

Table 4. *Selected properties of biogas produced from green parts of crops*

Selected properties of biogas							
Parameter	Calorific value	Density	Density relative to air density	Ignition temperature	Range of ignition concentration of gas in the air	Theoretical need for air	Maximum speed of flame advance in the air
Biogas	6kWh.m^{-3}	1.2kg.m^{-3}	0.9	700°C	6 - 12%	5.7 m^3.m^{-3}	0.25 m.s^{-1}

From the above overview in table 4 it can be observed that the calorific value of biogas produced from green parts of crops reaches a value of 6kWh.m^{-3} at a density of 1.2kg.m^{-3}.

FINAL EVALUATION OF THE GREEN ENERGY APPLICATION

Based on experimental research and subsequent analysis, it can be stated that the calorific value of briquettes from the dried crop Amaranthus caudatus is 14.0 MJ.kg^{-1}. The calorific value of biogas obtained by the process of wet anaerobic fermentation of green parts of Amaranthus caudatus crops is 6kWh.m^{-3}. Although the amount and calorific value of biogas obtained by the wet anaerobic fermentation process of green crops of Amaranthus caudatus is slightly lower compared to the amount and calorific value of briquettes obtained from dried crops, this process is less energy-intensive. In the case of briquette production, a large amount of energy is required to dry the green parts of the crops, to crush them and then press them. This significantly reduces the overall energy balance. Therefore, it is not possible to unambiguously recommend the first or second method of energy recovery of the crop Amaranthus caudatus. From our point of view, these are energy-equivalent energy sources. At the same time, we offer a simplified overview of the significant pros and cons of both types of green energy obtained.

Benefits: obtaining a valuable renewable energy source, the possibility of transforming the obtained source into mechanical, thermal and electrical energy, possibility of energy storage, soil decontamination, job opportunities.

Disadvantages: for the energy recovery of the Amaranthus caudatus crop, the application of highly sophisticated technological equipment is required, retrofitting of installations using this transformed green energy source is often required, there is a risk of recontamination of soil if the waste product of green energy transformation is improperly handled.

It is therefore evident from the above overview that the advantages of energy recovery of the crop Amaranthus caudatus significantly outweigh its shortcomings. Therefore, this source of green energy can be clearly recommended for practical application in both ways.

CONCLUSION

Growing crops for energy purposes is undoubted of societal importance. The main reason for the production of energy crops not only in the world, but also in Slovakia is the production of clean energy from renewable sources. At the same time, this energy source provides a wide range of job opportunities for local people. The use of biomass as a source of green energy, of course, requires active and flexible cooperation with the Ministries of agriculture, the Ministry of finance and the environment. It also requires support from national and international legislation. A certain limitation in obtaining green energy through energy crops is their technological processing. This is mainly due to the need for technologically advanced infrastructure. In many cases, the adaptation of existing technological equipment is also required for their use. Therefore, especially for the above reasons, the environmental and regional benefits of these energy crops are currently not fully appreciated. On the other hand, due to the constant tightening of emission quotas and rising fossil fuel prices, increased pressure on the massive expansion of green energy production and use can be expected in the future. Therefore, the aim of the paper was to provide an extended view of two basic possibilities of energy transformation of the crop Amaranthus caudatus, which can be easily grown in Slovakia. The possibility of producing briquettes and biogas was described, while the two products of the energy crop Amaranthus caudatus were compared not only from an energy point of view, but also from an environmental point of view. Based on the performed analysis, it can be stated that each of these methods of energy recovery of green parts of the crop has its benefits and disadvantages. Therefore, it is not possible to exclusively recommend one or the other method of its energy recovery.

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