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Landscape Planning for "Kubratovo 1" Sand and Gravel Deposit Located on Alluvial Meadow Soil, Sofia Region, Bulgaria

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Abstract. The paper presents results of landscape planning and investigation on Fluvisols. The object is "Kubratovo 1" sand and gravel deposit, Bulgaria. Soil samples were taken from twenty-one soil profiles at a depth of 0-20 cm, 20-40 cm, 40-60 cm, 60-80 cm, and 80-100 cm. The changes in physicochemical properties were investigated at different soil depths and the relationships between different soil characteristics were tested. There are statistically significant positive or negative regressions. There are regression relationships between the soil texture fractions and bulk density, total porosity, soil organic matter, total Kjeldahl nitrogen, available phosphorus and available potassium.

Key words: Landscape planning, soil, Fluvisols, physical properties, chemical properties, urban green system.

Introduction

Rapid urbanization results in the increasing isolation of human populations from the natural world. For the majority of people green public areas are one of the few opportunities for direct contact with the natural environment.

The green spaces in open country are an integral part of the ecosystems of the urban areas and could generate significant environmental benefits such as carbon emission reduction, air pollution reduction, microclimate regulation as well as recreational use. These ecosystems help improve the quality of life and facilitate urban development (Jo, 2002; Bolund & Hunhammar, 1999; Jim & Chen, 2006; Miller, 1997; Jensen *et al.*, 2000; Li & Wang, 2003). Besides having environmental functions such as air purification, microclimate regulation, noise reduction, biodiversity preservation, etc., urban green areas also have a statistically significant impact on the sales price of real estate properties located in the vicinity of these areas (Lin *et al.*, 2005).

Quarries and ballast quarries, unlike other anthropogenic pollutants, are a source of fine and coarse particles (Hinds, 1999), and post-mining regions are poor in soil organic matter, N, P and K, and no significant changes in soil content are observed even years later. The vegetation consists mainly of grassy annual and biennial species (Jian-Gang Yuan *et al.*, 2006). Quarries that have not been rehabilitated after mining activities have ceased turn into untapped and

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unsustainable resources, and their reclamation becomes difficult due to the specific environmental conditions, which may vary even within the disturbed area (Jay & Handley, 2001). Gravel sand deposits are located under the soil group of Fluvisols (Koynov *et al.*, 1998). Fluvisols are found between Chernozems and Gray forest soils in Northern Bulgaria, along the rivers Danube, Lom, Ogosta, Iskar, Osam, Yantra, Rositsa and Kamchia (Teoharov *et al.*, 2015; Hristov, 2009). In Southern Bulgaria they are situated between Vertisols and Cinnamonic Forest soils, along the rivers Maritsa, Tundzha, Arda, Mesta, Struma, Iskar, and Erma (Antipov-Karataev *et al.*, 1959; Donov, 1993).

Alluvial soils can be represented by a gravel substrate although surface horizons are fine-textured (silty clay loam and sandy clay loam), the subsoil can be finer (clay loam, silty clay or clayey) (Casanova *et al.*, 2013), the soil texture depends largely on the speed of the water current where the soils have formed and their location along the river bed (Carating *et al.*, 2014). The bulk density of these soils varies from 1.2 to 1.35 g.cm^{-3} (Huq & Shoaib, 2013). Fluvisols are characterized by pH which ranges from moderately acidic to strongly alkaline. The soil organic matter and total nitrogen vary greatly. The soils are moderately supplied with phosphorus (Filipová *et al.*, 2010). Soil conditions are one of the factors that determine the species composition of the plant cover (Bogdanov, 2018a; b).

The purpose of the study was to make a landscape plan for the development of a highly recreational area on an undeveloped sand and gravel deposit site located under the soil group of Fluvisols as well as to characterise their soil properties.

Materials and Methods

The object. Mollic Fluvisols (FAO, 2014) occurring on the territory of "Kubratovo 1" sand and gravel deposit, located east of the village of Kubratovo, Sofia Region, and west of the village of Negovan, Sofia Region, Bulgaria was the object of the study. The object is found in the Lower forest vegetation zone (0 - 600 m a.s.l.) of the Moesian forest vegetation area of Bulgaria (Zahariev *et al.*, 1979). The studied area covers about 378.41 ha.

Methods of study. Twenty-one profiles at a depth of 0-100 cm were done at representative plots. A systematic sampling design was used (Petersen & Calvin, 1996). The samples were taken at depths of 0-20 cm, 20-40 cm, 40-60 cm, 60-80 cm, and 80-100 cm.

The following soil characteristics were analyzed by using the respective methods:

Bulk density (BD, g.cm^{-3}), according to the DIN ISO 11272:1998, 2001; Total porosity (TP, %) by calculation of bulk density and relative density (Lorraine & Flint, 2002); Soil texture (Sand - 2 mm - 63 µm, %; Silt - 63 µm - 2 µm, %; Clay < 2 µm, %), using the sedimentation method (ISO 11277), texture groups were determined according to the Soil Survey Staff (1975); Plant available water capacity (PAWC, mm), by a laboratory method, with the calculation of field capacity and permanent wilting point (Donov *et al.*, 1974); Soil acidity (pH in water extraction) – measured potentiometrically by WTW 720 pH meter (ISO 10390:2002); Soil Organic Matter (SOM, %) by ISO 14235:1998; Total Kjeldahl Nitrogen (TKN, %) content, with a modified version of the classic Kjeldahl method (ISO 11261:2002); P_2O_5 (mg.100g^{-1}) – extraction with Ammonium Acetate and Calcium Lactate-pH 4.2 (Ivanov, 1984); K_2O (mg.100g^{-1}) – extraction with Ammonium Acetate and Calcium Lactate-pH 4.2 (Ivanov, 1984).

Data analysis. Descriptive statistics was applied using Numbers (Apple Co., 2018), Excel (Microsoft Co., 2016) and SPSS (IBM Co., 2016) for Mac. Linear and polynomial regression analysis was applied for testing for a functional relationship between the soil depth and the soil characteristics. Corrected variants of regression coefficients (R^2) were calculated and their statistical significance (significant difference from zero) was tested at $p<0.05$ with SPSS (IBM Co., 2016) and Excel (Microsoft Co., 2016).

Results and Discussion

Soil characteristics. Changes in soil characteristics with depth and soil assessment.

The soil texture at a depth of 0-20 cm falls mainly within the sandy clay loam category and partly within the loam category. At a depth of 20-40 cm it is predominantly sandy clay loam. The soil texture in the other horizons (40-60, 60-80, 80-100 cm) is predominantly sandy loam, where at a depth of 40-60 cm it is in the top half of the textural class (the most clayey), and the samples taken from the other two horizons (60-80 and 80-100 cm) fall within the bottom half (with minimum clay content) of the class. The variation in these classes has also been reported by other authors (Ilinkin *et al.*, 2018). There are significant statistical regressions between the soil texture fractions and bulk density on the one hand and depth on the other (Fig. 1). The sand fraction increases with depth (from 51.48%, which is the mean value in the 0-20 cm layer, to 67.86% in the 80-100 cm layer). The silt fraction ranges between 24.94 and 28.47 (mean values in the 0-20 and 80-100 cm layers). The clay fraction decreases significantly with depth from 23.59% to 3.67% (mean values in the 0-20 and 80-100 cm layers). The data show that the increase in the sand fraction with depth is at the expense of the clay fraction, whereas the silt fraction does not vary greatly. The changes in the sand and clay fractions are properly described by linear regression functions (for both $p<0.0001$), whereas the silt fraction is properly described by a second order polynomial regression function ($p<0.0001$). A possible hypothesis for the fact that the changes in the silt fraction are described by a polynomial regression is the nature of soil formation – periodic deposition of parent material. The soil texture variation is consistent with data reported by other authors (Carating, 2014).

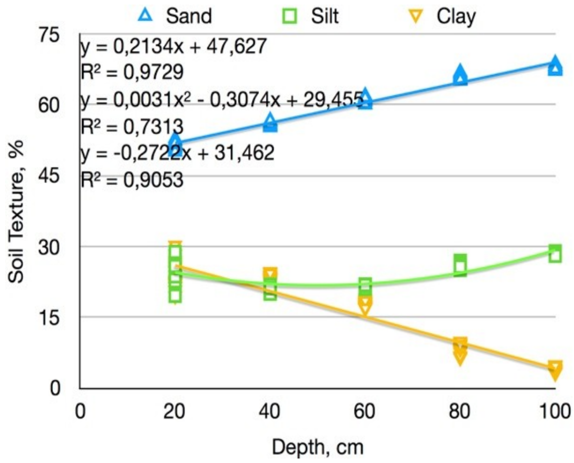

Fig. 1. Relationship between depth and soil texture.

The bulk density (Fig. 2) ranges within the averagely compacted class (according to the classification of AG Bodenkunde, 1982) and it gradually increases with depth from 1.26 $g.cm^{-3}$ (mean value in the 0-20 cm layer) to 1.45 $g.cm^{-3}$ (mean value in the 80-100 cm layer). There is a strong linear regression relationship between depth and bulk density ($p<0.0001$).

In the soils studied there is a clear trend towards a decrease in total porosity with depth (Fig. 3) $p<0.0001$, where it changes from averagely porous to slightly porous (according to the classification of AG Bodenkunde, 1982).

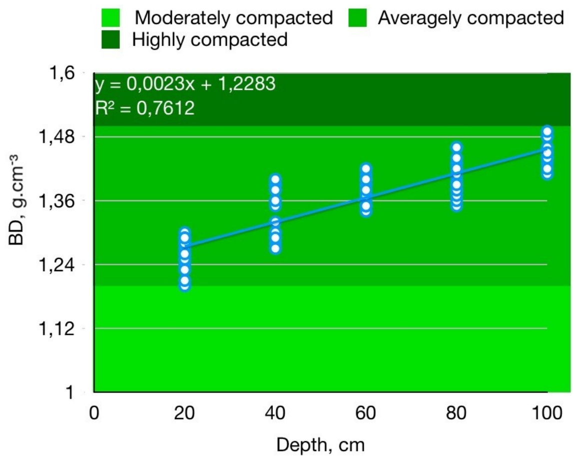

Fig. 2. Relationship between soil depth and bulk density.

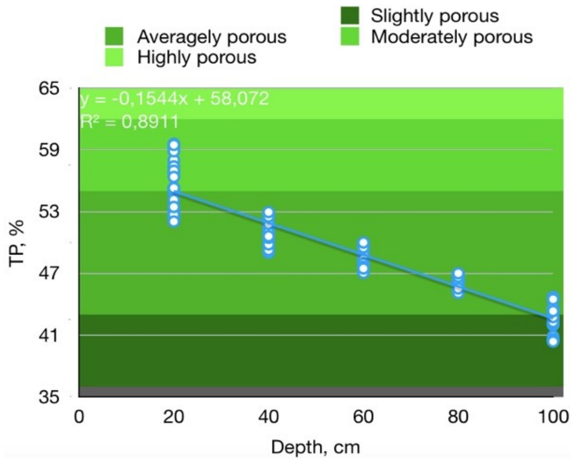

Fig. 3. Relationship between soil depth and porosity.

PAWC in the studied soils varies from medium to high (mean = 170.72) (Fig. 4), which is consistent with other studies on alluvial soils (ILINKIN *et al.*, 2018).

The soil reaction in water extraction for the different horizons is described by a linear regression function (Fig. 5) with high statistical significance ($p<0.0001$). The variation of pH with depth has also been reported in other studies (DONOV, 1979; ILINKIN *et al.*, 2018).

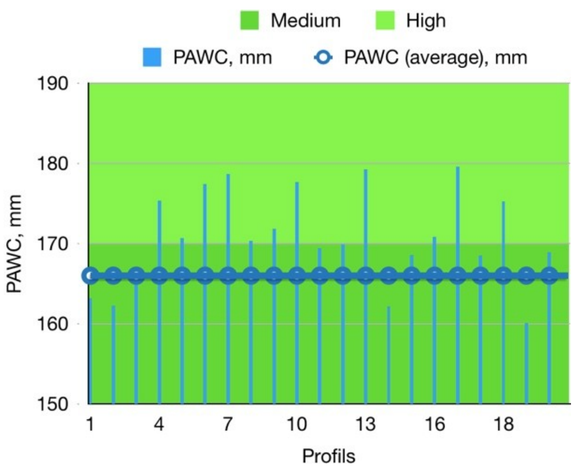

Fig. 4. PAWC variation.

There are statistically significant ($p<0.0001$ for both equations) second order polynomial regressions between the content of SOM and TKN on the one hand and depth on the other. SOM changes from low content to no SOM content (according to the classification of AG Bodenkunde, 1982). TKN in all horizons ranges within the very low availability class (according to the classification by PENKOV, 1996). These data are consistent with the data reported by FILIPOVÁ (2010) on the variation in SOM and TKN, as well as on their decrease with depth.

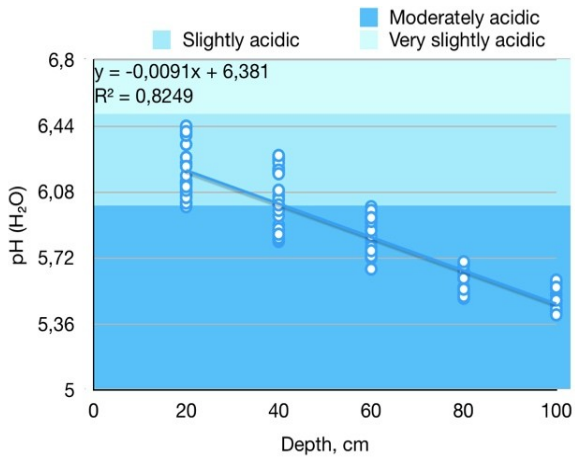

Fig. 5. Relationship between depth and pH.

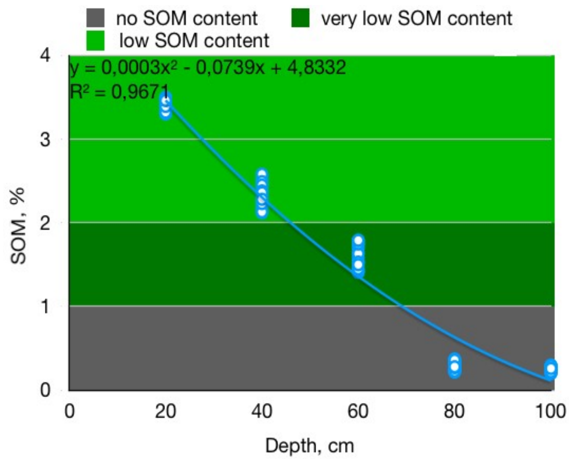

Fig. 6. Relationship between depth and SOM.

There are statistically significant ($p<0.0001$ for both equations) polynomial regressions between available phosphorus and potassium on the one hand and depth on the other (Fig. 8 and Fig. 9). The content of available phosphorus changes with depth from very good availability to low availability (according to the classification by PENKOV, 1996). The content of available potassium changes from very good availability to low availability (according to the classification by PENKOV, 1996).

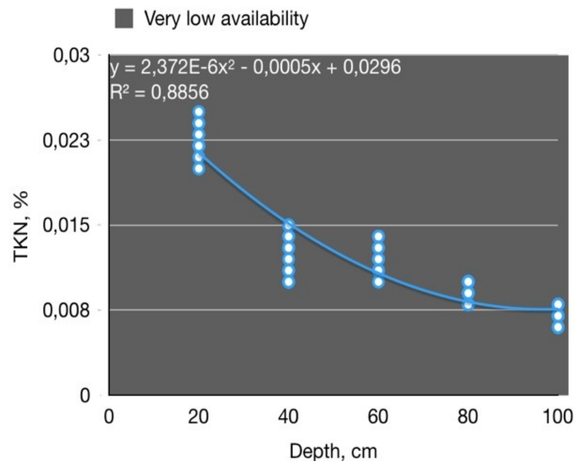

Fig. 7. Relationship between depth and TKN.

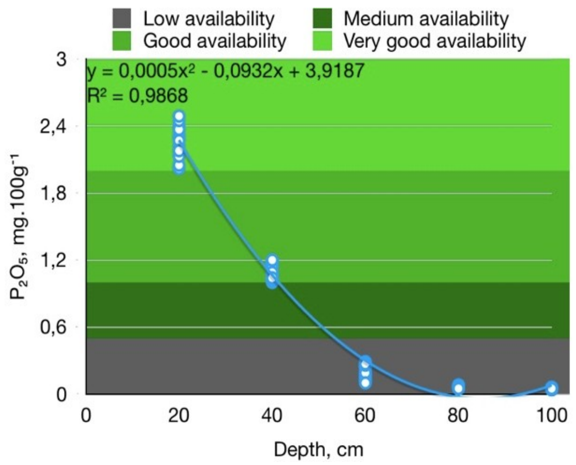

Fig. 8. Relationship between soil depth and P_2O_5 content.

The changes in chemical characteristics (SOM, TKN, P_2O_5, K_2O) with depth are better described by second order polynomial regression functions than by a linear regression. This could be explained by the decomposition of the organic matter, humus formation and the release of nitrogen, phosphorus and potassium.

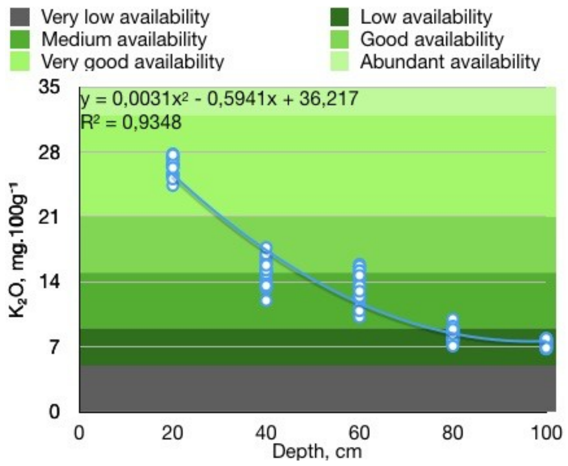

Fig. 9. Relationship between soil depth and K_2O content.

Soil characteristics. Regression relationships between some physical and chemical characteristics.

Soil texture is an important factor which affects soil fertility (DONOV, 1979). There are statistically signification regression relationships between some physical and chemical characteristics on the one hand and bulk density and total porosity on the other (Table 1). There is a positive correlation between the soil texture components (sand and silt) and bulk density and an inverse correlation between them and total porosity. In both cases the regression with the silt fraction is statistically significant. The regressions between the clay fraction and bulk density and total porosity are statistically significant (where the clay fraction is inversely correlated to bulk density and positively correlated to total porosity). SOM is strongly negatively correlated with bulk density and strongly positively correlated with total porosity. The correlation between soil texture and porosity has also been reported by other studies (DONOV, 1979; ILINKIN *et al.*, 2018; ILINKIN, 2018).

A well-known fact is the relationships between SOM and other soil characteristics (STOCKMANN *et al.*, 2013). The statistically significant regression relationships between the soil texture components on the one hand

and SOM and nutrients (TKN, P_2O_5, K_2O) on the other are presented in Table 2. There are statistically significant regression relationships between the soil texture fractions (sand and silt) and SOM, TKN, P_2O_5, K_2O, which are inversely correlated. There are statistically significant regression relationships between the clay fraction and SOM, TKN, P_2O_5, K_2O, which are positively correlated.

There are statistically significant polynomial regressions between SOM and nutrients (TKN, P_2O_5 and K_2O) (Table 3). The fact that SOM includes carbon, nitrogen and minerals (DONOV, 1979) as well as the soil-forming processes typical of alluvial soils (periodic deposition of sediment) are the most likely reasons for the existence of statistically significant linear regressions between SOM and the other nutrient sources studied. The correlations between SOM and TKN, P_2O_5 and K_2O have also been reported in other studies (ILINKIN, 2018; ILINKIN *et al.*, 2018).

Table 1. Regression relationships between soil texture and SOM and bulk density and total porosity.

		BD (x), g.cm^{-3}	TP (x), %
Sand (y), %	equation	y= 0.0105x + 0.7297	y= - 0.6989x + 91.044
	R^2	0.7522	0.8544
	p value	< 0.0001	< 0.0001
Silt (y), %	equation	y= 0.0081x + 1.1688	y= - 0.6266x + 64.121
	R^2	0.1118	0.1741
	p value	= 0.0004	< 0.0001
Clay (y), %	equation	y= - 0.0072x + 1.4744	y= 0.4904x + 41.387
	R^2	0.6132	0.7358
	p value	< 0.0001	< 0.0001
SOM (y), %	equation	y= - 0.0521x + 1.4477	y= 3.4838x + 43.316
	R^2	0.7274	0.8392
	p value	< 0.0001	< 0.0001

Table 2. Regression relationships between soil texture and SOM, TKN, P_2O_5, K_2O.

		SOM (x), %	TKN (x), %	P_2O_5 (x), mg.100g^{-1}	K_2O (x), mg.100g^{-1}
Sand (y), %	equation	y= - 0.196x + 13.418	y= - 0.0008x + 0.0611	y= - 0.1308x + 8.6411	y= - 1.0499x + 77.576
	R^2	0.9712	0.8109	0.8579	0.8674
	p value	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Silt (y), %	equation	y= - 0.188x + 6.1707	y= - 0.0004x + 0.0221	y= - 0.0552x + 2.0877	y= - 0.6065x + 28.956
	R^2	0.2266	0.0479	0.0387	0.0734
	p value	< 0.0001	= 0.025	= 0.044	= 0.0052
Clay(y), %	equation	y= 0.1393x – 0.5311	y= 0.0005x + 0.0048	y= 0.0828x – 0.5127	y= 0.6881x + 3.7234
	R^2	0.8582	0.584	0.601	0.6518
	p value	< 0.0001	< 0.0001	< 0.0001	< 0.0001

Table 3. Regression relationships between SOM and TKN, P_2O_5 and K_2O.

		TKN (x), %	P_2O_5 (x), mg.100g^{-1}	K_2O (x), mg.100g^{-1}
SOM (y), %	equation	y= 0.0014x^2 – 0.007x + 0.0082	y= 0.2652x^2 – 0.2575x + 0.0938	y= 1.4066x^2 + 0.501x + 7.7685
	R^2	0.8976	0.9697	0.9408
	p value	< 0.0001	< 0.0001	< 0.0001

Mathematical models could be significant even if the R-squared value is low (FARAWAY, 2015). In agrarian sciences authors have presented regression models with R^2<0,5; R^2<0,3 (KOZAR *et al.*, 2002; FANTAPPIÈ *et al.*, 2011; CRESPELL *et al.*, 2006).

A high R-square does not necessarily mean that the model is useful (NETER *et al.*, 1996). The p-value, however, is considered to be a reliable indicator when it is lower than 0.05 (MANGIAFICO, 2016).

The climate has a direct impact on soil temperature and moisture, and an indirect one on the biota. "Kubratovo 1" sand and gravel deposit falls within the European continental climatic region, temperate continental sub-region, the climatic region of the high fields of Mid-Western Bulgaria (TROEVA, 2009). The territories around Sofia are characterized by retention and additional radiative cooling of air masses, and as a result temperatures can drop to -25 °C. In January the average temperatures are around 4 – 5 °C, and in June they are between 20 – 21 °C. The relative air humidity is 70%. The average annual temperature is around 11.5 °C, the average annual rainfall is approximately 837 mm, with a maximum rainfall in May and a minimum in July. The winter is cold and relatively dry with an average temperature in January of 2.6 °C. There is low precipitation (102 mm). The summer is relatively warm with an average temperature in July ~ 23.8 °C. There is considerably more precipitation in the fall than in the spring due to the basic features of this region (TROEVA, 2009).

Landscape planning. Public green spaces which include parks, sports grounds, riparian zones, municipal gardens, etc. (ROY *et al.*, 2012) are heterogeneously distributed within the urban environment. Access to them is often limited due to socio-economic or other reasons, which is becoming a serious problem (ABERCROMBIE *et al.*, 2008; JENNINGS *et al.*, 2012; JOHNSON-GAITHER, 2011; SISTER *et al.*, 2010; BYRNE *et al.*, 2009; MCCONNACHIE & SHACKLETON, 2010). Urban green spaces are multifunctional and have recreational, social, cultural and ecological characteristics (PAULEIT, 2003; PRIEMUS & HALL., 2004).

The conceptual landscape plan for "Kubratovo 1" sand and gravel deposit has been presented in Fig. 10. The proposed conceptual landscape plan aims to meet the need of the city of Sofia for an area with social, cultural, recreational and ecological functions by providing a place for active and passive recreation with increased species diversity (Table 5), and optimal relationship between under-trees spaces and open spaces (consistent with the climatic characteristics of the region and global climate changes). The landscape design also envisages the use of medicinal and aromatic plants (MAPs). Some authors (EFE *et al.*, 2018) recommend the use of MAPs, whereas others highlight their complex influence (cultural connotation, health care and health recovery) (QIAO & ZHANG, 2012).

Table 5. Species composition of the conceptual landscape plan for "Kubrotovo 1" sand and gravel quarry. Legend: [1] - species used for tree/shrub groups; [2] - species used for ornamental tree/shrub groups; [3] - species used for hedgerows; [4] - species used for grassing

Abies pinsapo Boiss. [1, 2]	*Clematis montana* D.C. [2]
Abies pinsapo 'Glauca' [2]	*Clematis montana* 'Grandiflora' [2]
Abies pinsapo 'Kelleriis' [2]	*Clematis montana* 'Rubens' [2]
Picea pungens 'Oldenburg' [2]	*Clematis patens* Morr. [2]
Picea pungens 'Omega' [2]	*Clematis patens* 'Fortunei' [2]
Picea pungens Engelm. [2]	*Clematis patens* 'Standishii' [2]
Picea pungens 'Białobok' [2]	*Berberis x ottawensis* C.K. Schneid [1]
Picea pungens 'Glauca' [2]	*Berberis x ottawensis* 'Superba' [2, 3]
Picea pungens 'Hoopsii' [2]	*Berberis julianae* Schneid. [2]
Picea pungens 'Koster' [2]	*Magnolia kobus* DC. [1]
Cedrus libani A.Rich [2]	*Philadelphus x lemoinei* Lem. [2]
Cedrus libani 'Atlantica Aurea' [2]	*Philadelphus x lemoinei* 'Erectus' [2]
Cedrus libani 'Fastigiata' [2]	*Philadelphus x lemoinei* 'Manteau d`Hermine [2]
Pinus nigra Arnold [1 2]	*Platanus orientalis* L. [1, 2]

Pinus nigra 'Fastigiata' [2]
Pinus nigra spp. laricio [2]
Pinus nigra 'Green Rocket' [2]
Metasequoia glyptostroboides Huet Cheng [1]
Taxodium distichum Rich [2]
Calocedrus decurrens Florin [1]
Calocedrus decurens 'Aureovariegata' [2]
Thuja orientalis L. [2,3]
Thuja orientalis 'Aurea Nana' [2]
Thuja orientalis 'Berckmanii' [2]
Thuja orientalis 'Fastigiata' [2]
Thuja orientalis 'Golden Surprise' [2]
Thuja orientalis 'Maturodam' [2]
Thuja orientalis 'Nusi' [2]
Juniperus sabina 'Blue Danube' [1]
Juniperus sabina 'Hicksii' [2]
Juniperus sabina 'Rockery Gem', [2]
Taxus baccata L. [1,3]
Taxus baccata 'Adpressa Aurea' [2,3]
Taxus baccata 'Baccatin' [2,3]
Populus alba L. [1]
Populus simonii Carr. [1]
Salix triandra L. [2]
Salix cinereal L. [2]
Betula pendula Roth. [1]
Betula pendula 'Fastigiata' [1,2]
Betula pendula 'Laciniata' [1]
Betula pendula 'Bibor' [2]
Alnus glutinosa Gaertner [2]
Alnus glutinosa 'Imperialis' [2]
Quercus petraea Leibl. [1]
Ulmus glabra Huds. [1]
Ulmus pumila L. [1]
Spiraea x arguta Zab. [1,2,3]
Spiraea media F. Schmidt [3]
Spiraea x bilardii Heringq [3]
Spiraea billardii 'Rosea' [3]
Cotoneaster horizontalis Decne [1,2]
Sorbus aria Crantz [1]
Crataegus oxyacantha L. [2]
Albizia julibrissin Durazz. [2]
Gymnocladus dioicus K. Koch [2]
Ailantus altisima Swingle [2]
Eunymus europea L. [2]
Acer tataricum L. [1]
Acer saccharinum L. [1]
Acer saccharinum 'Born Gracious' [1]
Acer saccharinum 'Wieri' [1]
Aesculus hippocastanum L. [1]
Aesculus hippocastanum 'Baumannii' [1]
Aesculus x carnea Hayne [2]
Tilia platyphyllos Scop. [1]
Tilia platyphyllos 'Delft' [2]
Tilia platyphyllos 'Orebro' [2]
Tamarix tetrandra Pall. [1]
Syringa vulgaris L [2,3]
Syringa vulgaris 'Mrs. Edward Harding' [2,3]
Cornus mas L. [2]
Agrostis capillaris L. [4]
Anthoxanthum odoratum L. [4]
Festuca rubra L. [4]
Lolium perenne L. [4]
Poa compressa L. [4]
Poa nemoralis L. [4]
Poa pratensis L. [4]
Poa trivialis L. [4]

Fig. 10. Conceptual landscape design for "Kubratovo 1" sand and gravel deposit.

Conclusions and recommendations

Soil characteristics vary with depth. These variations are described by statistically significant linear regressions (for the sand fraction, clay fraction, bulk density, total porosity and pH) and statistically significant polynomial regressions (for the silt fraction, SOM, TKN, P_2O_5, K_2O). There are regression relationships between the soil texture fractions and bulk density, total porosity, SOM, TKN, available phosphorus and potassium. There are positive linear regressions between SOM and TKN, P_2O_5, K_2O.

The conceptual landscape plan for "Kubratovo 1" sand and gravel deposit shows that if the deposit site is not going to be used, the territory could be turned into a recreational area. The analysis of soil resources and climate data indicate that the species composition can increase significantly.

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