



Contemporary studies of soils from Plovdiv district in the South-Central Planning Region, Bulgaria

P. Ivanov*, I. Lyubenova

Agricultural Academy, Institute of Soil Science, Agrotechnologies and Plant Protection "N. Poushkarov", Sofia, Bulgaria

(Manuscript received 23 February 2026.; accepted for publication 31 August 2026)

Abstract. *The paper summarises contemporary research on soils that have been formed under natural conditions or have been influenced by anthropogenic activity. The need to periodically obtain new data to prepare an up-to-date soil assessment was highlighted. Brief information is presented about the district in which the studies were conducted and the distribution of the different soils. The discussion of selected scientific publications is enriched with graphical representation of location of the soil profiles, studied by the authors, or the Municipalities in the selected areas of which the soil studies were carried out. For some studies, additional calculations were made regarding the clay and humus content of soils. The conducted scientific summary found that the discussed studies confirm the influence of the specific conditions of soil formation on various soil features, related to natural processes, creation of unfavourable soil conditions, morphological changes in the soil profile or alteration in ecological state of the soils.*

Keywords: soil studies, soil profiles, soil formation conditions, GIS

Introduction

Soil science research is important for the qualitative assessment of soils (Yolevski et al., 1989). Their periodic implementation helps to identify changes that have occurred, leading to alteration in various soil parameters (Ninov and Teoharov, 1989) and enrich the available information from previous studies (Kercheva et al., 2021). These changes may be result of the influence of natural factors or various anthropogenic activities affecting the soil formation process (Kolchakov and Glogova, 1994). Some processes are related to soil salinization, which is connected with accumulation of high amounts of easily soluble salts in the surface soil horizons or accumulation of exchangeable sodium in the soil absorption complex (Gyurov and Artinova, 2015). Other factors cover various anthropogenic activities that may pose ecological risk, leading to soil contamination with heavy metals and decrease in soil fertility (Marinova and Zlatareva, 2016). In all cases, obtaining new data is necessary for soil assessment and identification of possible changes that have occurred under the influence of natural and anthropogenic factors (Zheleva et al., 2012). This can be realised by identifying of relevant locations, establishing the impact, and conducting analytical study to predict future changes by utilising the collected information and applying Global Positioning Systems (GPS) to provide spatial visualisation (Dinev, 2016).

The aim of the paper is to summarise contemporary

research on soils developed under specific conditions of soil formation and those that are influenced by human activity.

Material and methods

In accordance with the aim, Plovdiv District was chosen as the object of study, as its geographical location creates a prerequisite for development of various sectors of industry and agriculture (Peneva, 2018).

A selection of publications presenting various soil studies was carried out, covering the soil profile in depth, and not only the surface horizon. In connection with the requirement for contemporary data, the starting date is set to 2009, when the Reference Database for Soils in Bulgaria was published (Teoharov et al., 2009).

The geographical coordinates of the soil profiles, which are given by the authors in some of the studies, are represented graphically within the boundaries of the respective Municipalities. In the remaining cases, the settlements and Municipalities in the area of which the studied soils are located are indicated.

The information about the soils distributed in Plovdiv District is reproduced from the available soil map of Bulgaria at a scale of 1:400000 (Koynov et al., 1968; ISSAPP "Nikola Poushkarov", archive). Soil names are aligned with their correspondences in the World Reference Base for Soil Resources – WRB (IUSS Working Group WRB, 2022) (Ivanov et al., 2025).

*e-mail: ipli@abv.bg

Digital processing is performed using the geographic information system QGIS, 3.40 and map data based on OpenStreetMap contributors, (<https://www.openstreetmap.org/copyright>).

Results and discussion

Basic information

Plovdiv District is located in central southern Bulgaria and together with the Districts of Pazardzhik, Smolyan,

Kardzhali and Haskovo, they form the South Central Planning Region (SCPR) in Bulgaria (Sapundzhiev and Mitreva, 2016; National Statistical Institute, 2024; Regional Administration Plovdiv, 2025). Plovdiv District covers 18 Municipalities with total area of 5972.9 km². The climate in the plains is transitional continental, and in the highlands, mountainous. Plant growing is related to production of vegetables, cereals, orchards, viticulture, etc. (Ministry of Agriculture and Food, National Agricultural Advisory Service, Plovdiv Office, 2025) (Figure 1).

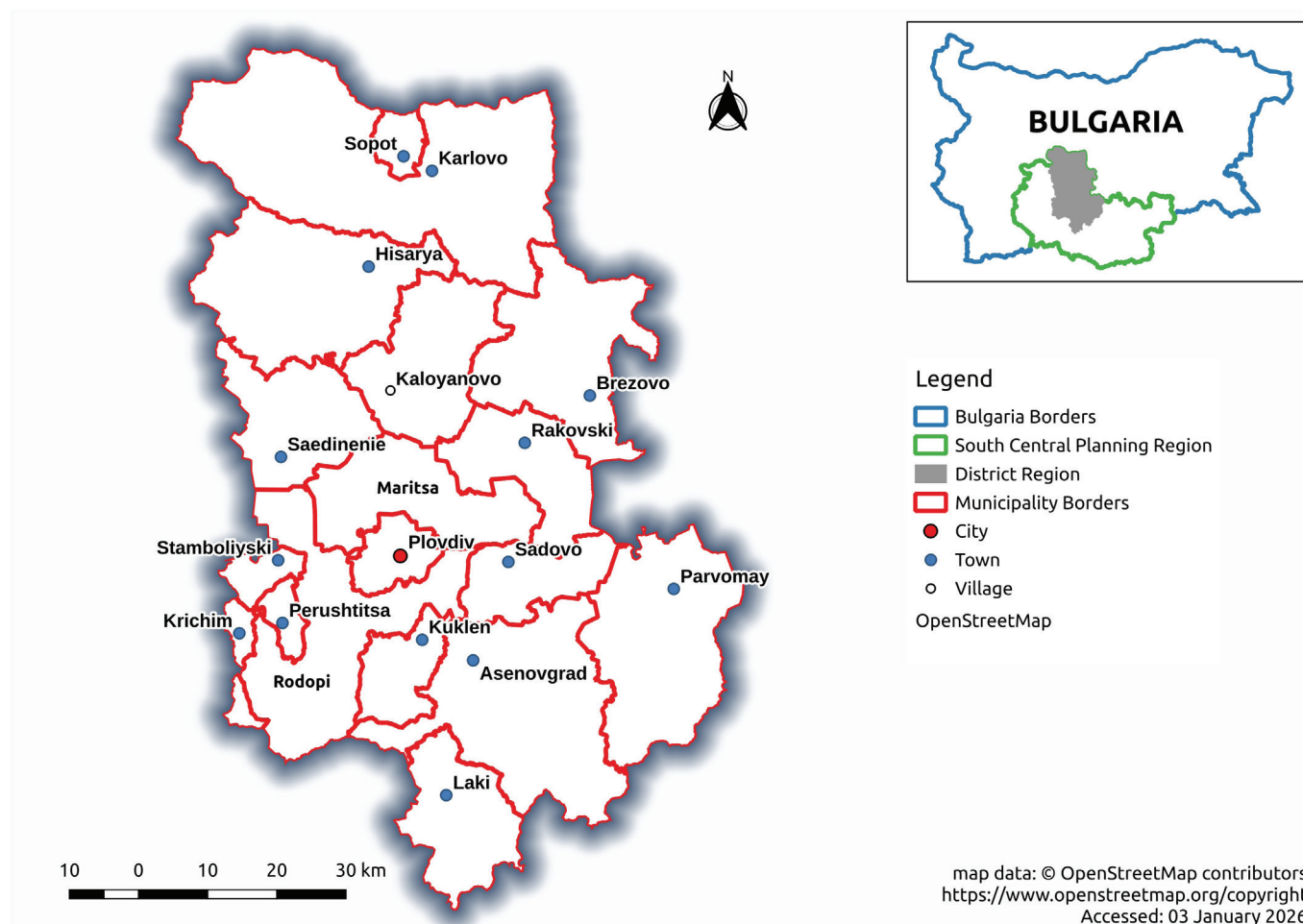


Figure 1. Plovdiv District in the South Central Planning Region, Bulgaria

Soils

The soil cover in Plovdiv District is diverse (Figure 2). Pseudopodzolic soils (Planosols) are the most common. They occupy total area of about 1512.30 km². In the plains, these soils are mainly unsaturated (Dystric), while the saturated (Eutric) varieties are located in the belt under the Brown Forest soils in the northern part of the district. The unsaturated Pseudopodzolic soils are also found in smaller areas adjacent to saturated Pseudopodzolic soils, in the plain areas.

Brown forest soils (Cambisols) are the second most widespread and occupy approximately 1450.63 km² in the high northern and southern mountainous parts of Plovdiv District (Figure 2). Their distribution follows the features of the relief (Figure 1) and corresponds to the established by Dokuchaev soil zonality (Gyurov and Artinova, 2015).

Cinnamon forest soils (Luvisols) cover total area of about 950.55 km². They are distributed in separate areas among the various Pseudopodzolic soils of the plains. This group of soils includes soil varieties with different grade of leaching, as well as Meadow cinnamon soils and eroded Cinnamon-podzolic soils (Figure 2).

Alluvial-meadow soils (Fluvisols) occupy the central part of the river bends towards the first non-flooded terrace, but are also found on the first low flooded terrace (Gyurov and Artinova, 2015). Their total area in Plovdiv District is within 679.62 km² with linear distribution, primarily in the central plain part of the district (Figure 2).

Smolnitsas (Vertisols) also occupy the flat part of Plovdiv District on total area of about 619.24 km². Their distribution is in separate sites between the areas with leached Cinnamon

Forest soils, Meadow cinnamon soils, Pseudopodzolic soils and Alluvial-meadow soils (Figure 2).

Regosols are mainly represented by unsaturated Deluvial and Deluvial-meadow soils in the foothills of Central Balkan in the northern part of the District, as well as by eroded cinnamon soils in minor areas around Smolnitsas. The approximate total area of these soils is 278.49 km² (Figure 2).

Shallow soils (Leptosols), which cover an area of about 226.90 km² in Plovdiv District, represent humus-carbonate soils – Rendzinas (Rendzic Leptosols) and Mountain meadow soils (Umbric Leptosols). Their distribution is in the areas of Brown

Forest soils, with Rendzinas being established in the southern part of the region, and Mountain meadow soils in the northern part (Figure 2).

Saline soils are found in the plains of the Plovdiv District. They are represented largely by Solontsi (Solonetz), which are established together with unsaturated Pseudopodzolic soils. These soils also cover a small area in the central part of the district, around the Alluvial-meadow soils, as well as separate areas, to the west and north of Plovdiv City, along with Solonchaks and Meadow cinnamon soils (Figure 2).

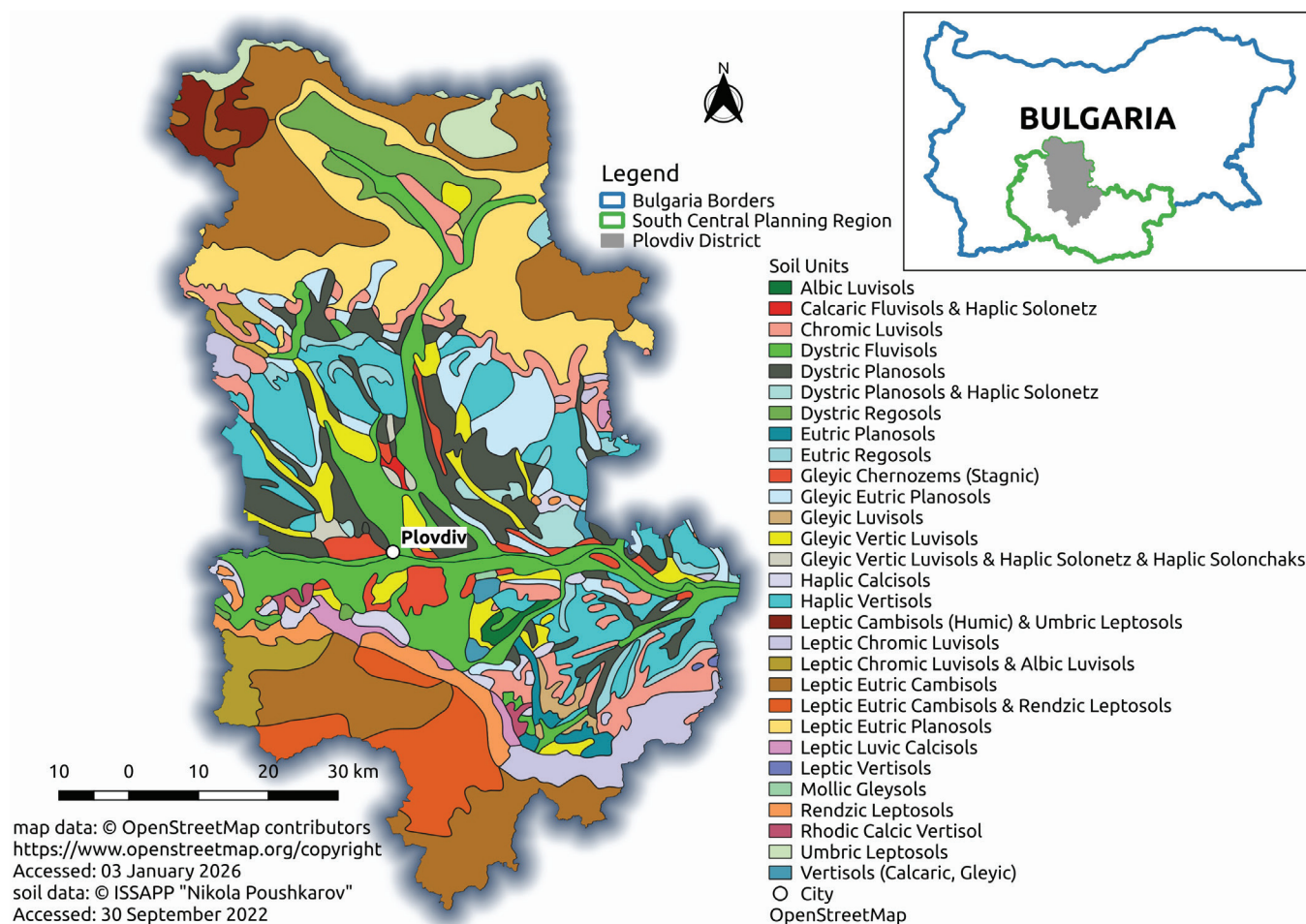


Figure 2. Soil map of Plovdiv District in the South-Central Planning Region, Bulgaria

Studies

The study conducted to select scientific papers that meet the criteria for contemporary data (after 2009), with studies of soil profiles, identified four Municipalities that include areas around settlements with specific soil conditions. These Municipalities are Rodopi, Kuklen, Rakovski and Hisarya.

Kercheva et al. (2017) study Alluvial-meadow soils

(Fluvisols) in the area of Tsalapitsa Village in Rodopi Municipality. In connection with the coverage of characteristic soil formation conditions, the study includes soil profiles from the first non-flooded terrace of the Maritsa River, which differ depending on the developing grass and forest vegetation, and additional soil profile with grass vegetation from the first flooded terrace (Figure 3).

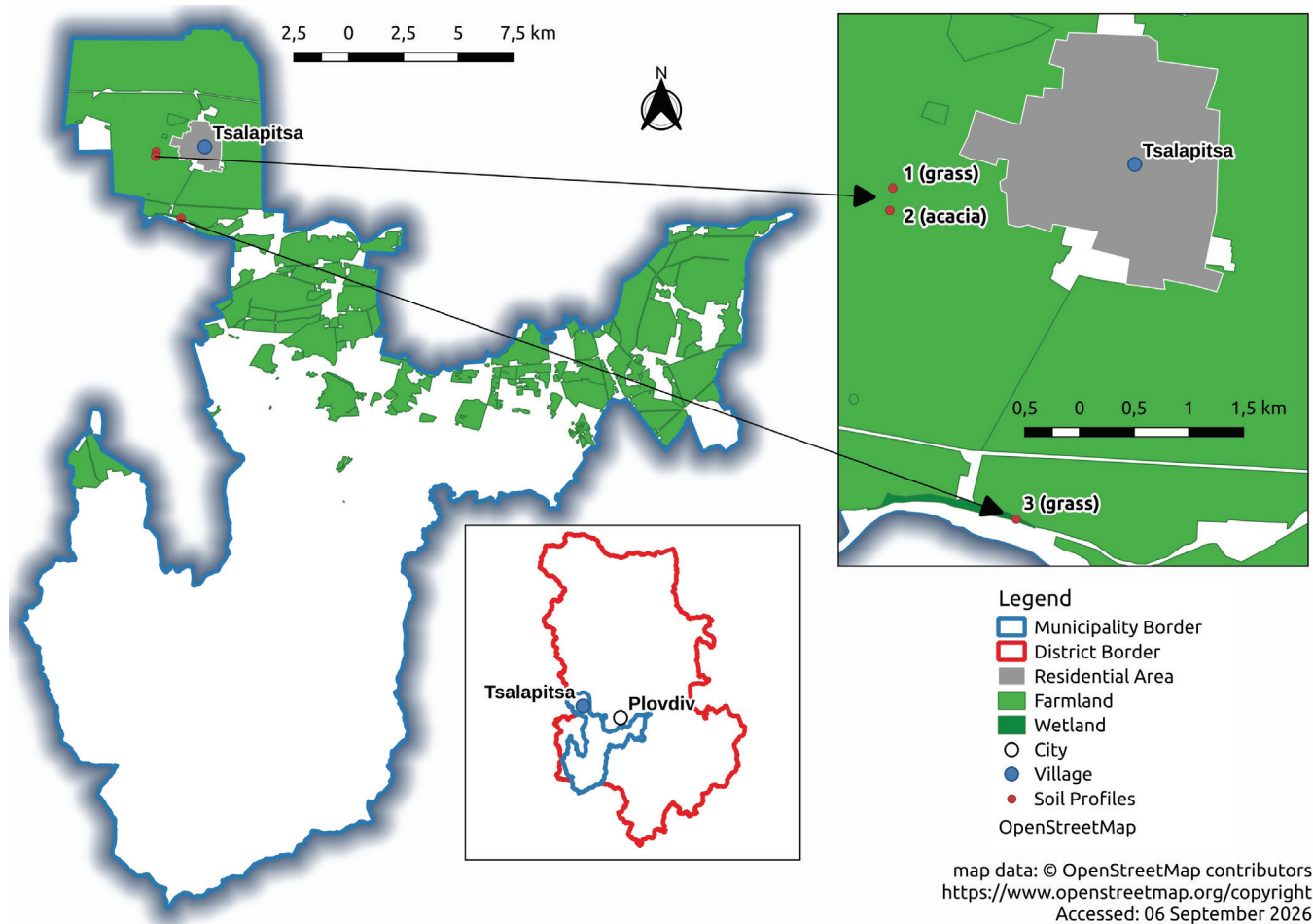


Figure 3. Rodopi Municipality in Plovdiv District and soil profiles from the area of Tsalapitsa Village

Because of the morphological study, the authors found differences in the thickness of the soil horizons, expressed in the possibility of using the letter symbol A (indicating accumulation of humified organic matter (FAO, 2006) to designate them at greater depth in the soil profile. Thus, the horizons and subhorizons A and AC reach over 70 cm in profiles 1 and 2 of the non-flooded river terrace, while in the flooded one, this total thickness is slightly over 20 cm (for soil profile 3) (Kercheva et al., 2017). The authors add that the observed differentiation also occurs in terms of soil texture, which is evident in the clay fraction (particles <0.002 mm (Soil Survey Staff, 1999). Therefore, from the published data we calculated the average values of the indicator for the studied profiles, which show that the lowest average clay content is in profile 3 (12%), in contrast to profiles 1 and 2 with 30% and 25% clay, respectively. These values can be related to the location of the soil profiles (Figure 3), since with the distance of the Alluvial-meadow soils from the riverbed, their mechanical composition becomes heavier (Gyurov and Artinova, 2015).

Kercheva et al. (2017) enrich the studies of soil profiles

from the area of Tsalapitsa Village with analysis of total carbon content. Its distribution between the horizons has accumulative nature, which is reflected by the authors with the letter suffix *h*, representing the accumulation of organic matter (FAO, 2006). Thus, in the surface *Ah* horizons the carbon content is over 1%, while in depth the values are less than 1% with gradual decrease (Kercheva et al., 2017). Of interest in the study is the morphologically determined surface 0-2 cm layer in profile 2, where the total carbon content is over 11%. This is most likely due to the accumulated forest litter from the acacia, as the authors report sharp decrease in the carbon content in the subsurface 2-8 cm horizon ($C=1.50\%$). Similarly, high carbon values characterize the surface layer of Technosols with pine plantation from the area of Pernik City (Ivanov, 2007).

The humus content, which we calculated with coefficient 1.724 ($C \times 1.724 = \text{humus}$) (Kononova, 1963) based on the published analytical data (Kercheva et al., 2017), is medium to very high in the surface horizons with accumulation of organic matter, according to Artinova (2012). In depth of the soil profiles, the amount of humus passes into low and very low (Table 1).

Table 1. Humus content in the studied Alluvial-meadow soils from Tsalapitsa Village

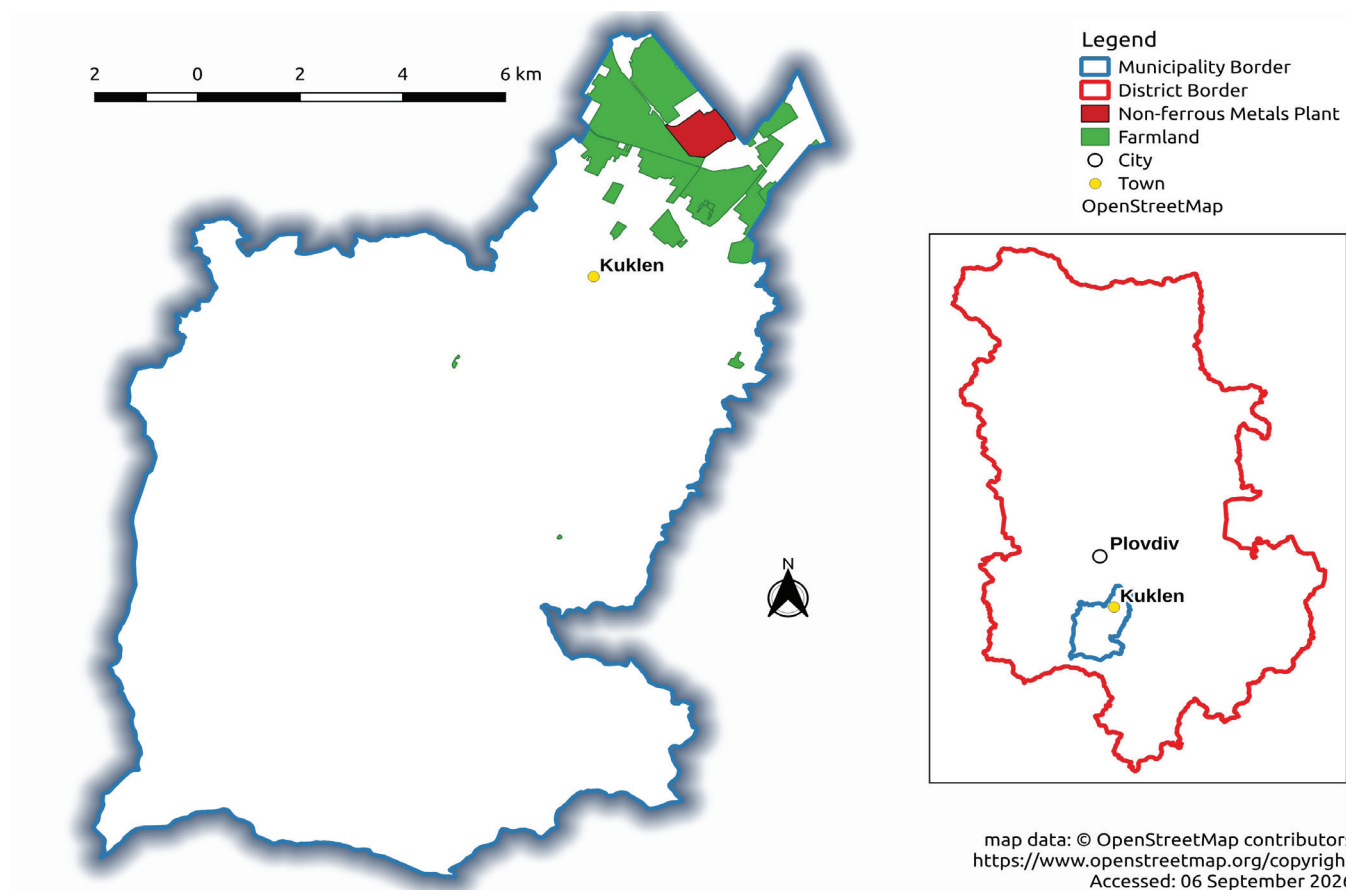
Soil horizon ¹	Depth (cm) ¹	Humus (%)	Meaning (content) ²
Profile 1 (grass)			
Ah	0 – 5	2.07	average
A1	5 – 17	0.88	very low
A2	17 – 20	1.03	low
	20 – 30	1.03	low
AC1	30 – 45	0.95	very low
AC2	45 – 56	0.88	very low
AC3	56 – 73	0.62	very low
C1	73 – 90	0.57	very low
C2	90 – 120	0.45	very low
Profile 2 (acacia)			
Ah1	0 – 2	20.46	very high
Ah2	2 – 8	2.59	average
A	8 – 17	1.10	low
AC1	17 – 30	0.88	very low
AC2	30 – 56	0.69	very low
AC3	56 – 82	0.55	very low
C1	82 – 120	0.52	very low
Profile 3 (grass)			
Ah1	0 – 6	4.22	high
Ah2	6 – 16	2.78	average
AC	16 – 23	1.52	low
C1	23 – 32	0.34	very low
C2	32 – 48	0.31	very low
C3	48 – 57	0.10	very low
C4	57 – 74	0.16	very low

¹ Source: Kercheva et al. (2017).

² According to Artinova (2012).

Alluvial soils (Fluvisols) together with Rendzinas are subject of another study in Kuklen Municipality, in the region of the town with the same name (Nikova and Hristov, 2020). In this case,

the authors identify an area between the town of Kuklen and Non-ferrous metals plant to assess the specific soil conditions related to anthropogenic impact (Figure 4).

**Figure 4.** Kuklen Municipality in Plovdiv District and location of Non-ferrous metals plant

Nikova and Hristov (2020) examine four soil profiles located at different distances from the plant to determine the content of heavy metals (copper, zinc, lead and cadmium). For this purpose, the authors establish the genetic soil horizons and further analyse their acidity, soil organic matter content and different clay fractions (particles <0.01 mm; <0.001 mm).

Nikova and Hristov (2020) represent the thickness of the humus-accumulative A horizons, which varies between 38 cm and 59 cm and divide them into subhorizons depending on specific morphological features. Clear examples of this are the established surface plough layers with thickness between 18 cm and 25 cm in all soil profiles, which are indicated in the study with the necessary suffix *p* (FAO, 2006). The authors observe variation in the thickness of the underlying AC horizons (between 16 cm and 35 cm) as well as in the total depth of the soil profiles reaching from 120 cm to 150 cm along with the soil-forming materials in C horizons. The differences between the studied soils are also manifested in terms of the average values of physical clay (particles <0.01 mm (Kachinskiy, 1965; Gyurov and Artinova, 2015) calculated by us, based on published data (Nikova and Hristov, 2020), which determine different names of the soils depending on the mechanical composition (Table 2).

Table 2. Average content of physical clay in the studied soils from the town of Kuklen

Soil profile	Physical clay ¹ (< 0.01 mm) (%)	Name ²
1	18.5	Clayey sandy
2	27.2	Sandy clayey, light
3	52.0	Sandy clayey, heavy
4	35.6	Sandy clayey, medium

¹ Average values.

² According to Kachinskiy (1965). Source: Gyurov and Artinova (2015).

Another feature of the studied Alluvial soils from the region of the town of Kuklen is the carbonate content established and noted by the researchers (with suffix *k* (FAO, 2006) in all horizons of the soil profiles. Thus, Nikova and Hristov (2020) define the soils as slightly alkaline (pH H₂O 7.3-7.8), which corresponds to the values according to the relevant classification (Koynov et al., 1980).

Regarding the specific anthropogenic factor related to the activity of the Non-ferrous metals plant, the authors found high concentrations of the studied heavy metals in the surface (0-25 cm) plough horizon of the soil profile located closest to

the plant, which they assume is the result of spreading and deposition of the elements through the air. Lower values, but again exceeding the maximum permissible concentrations (Regulation №3), are also found in the subsurface horizon (25-40 cm), for which Nikova and Hristov (2020) assume that this is due to the deep ploughing carried out, since in the depth of the soil profile the studied heavy metals are below the maximum permissible concentrations (Table 3).

Table 3. Heavy metals content in soil profile from the area of the town of Kuklen¹

Depth (cm)	pH (H ₂ O)	Zn	Pb	Cd	Cu
		(mg/kg)			
0 – 25	7.3	6875	6488	100	366
25 – 40	7.3	4875	4525	81	286
40 – 59	7.7	103	53	–	51
59 – 75	7.7	105	38	–	47
75 – 95	7.7	85	46	–	42
95 – 125	7.8	77	56	–	27

¹ Source: Nikova and Hristov (2020).

Interesting soils with specific soil formation conditions are Saline soils. Borisova et al. (2010) study the total amount of microorganisms in Solonetz from the area of Belozem Village in Rakovski Municipality of Plovdiv District (Figure 5), to clarify changes in the soil environment. The researchers conduct morphological study and identify surface A horizon with low thickness, which they divide into two subhorizons (0-3 cm, 3-7 cm). In the Solonetz, this horizon is dusty, but may have weakly pronounced leaf-like structure (Gyurov and Artinova, 2015). Below it, Borisova et al. (2010) define dense and clayey illuvial B horizon at depth of 7-15 cm and apply the corresponding letter suffixes related to illuvial clay accumulation (*t*) and exchangeable sodium accumulation (*n*) (FAO, 2006). Borisova et al. (2010) specify that the observed difference between the soil horizons is due to the strongly alkaline reaction of the environment, leading to dissolution of organic matter and its removal into the soil depth. Gyurov and Artinova (2015) add that this process affects the soil colloids, whose vertical movement leads to clearly pronounced differentiation of the soil profile. Indicator for this soil process is the different content of physical clay (particles <0.01 mm) in the surface A subhorizons (average value: 26.15%) and illuvial B horizon (42%) (Borisova et al., 2010).

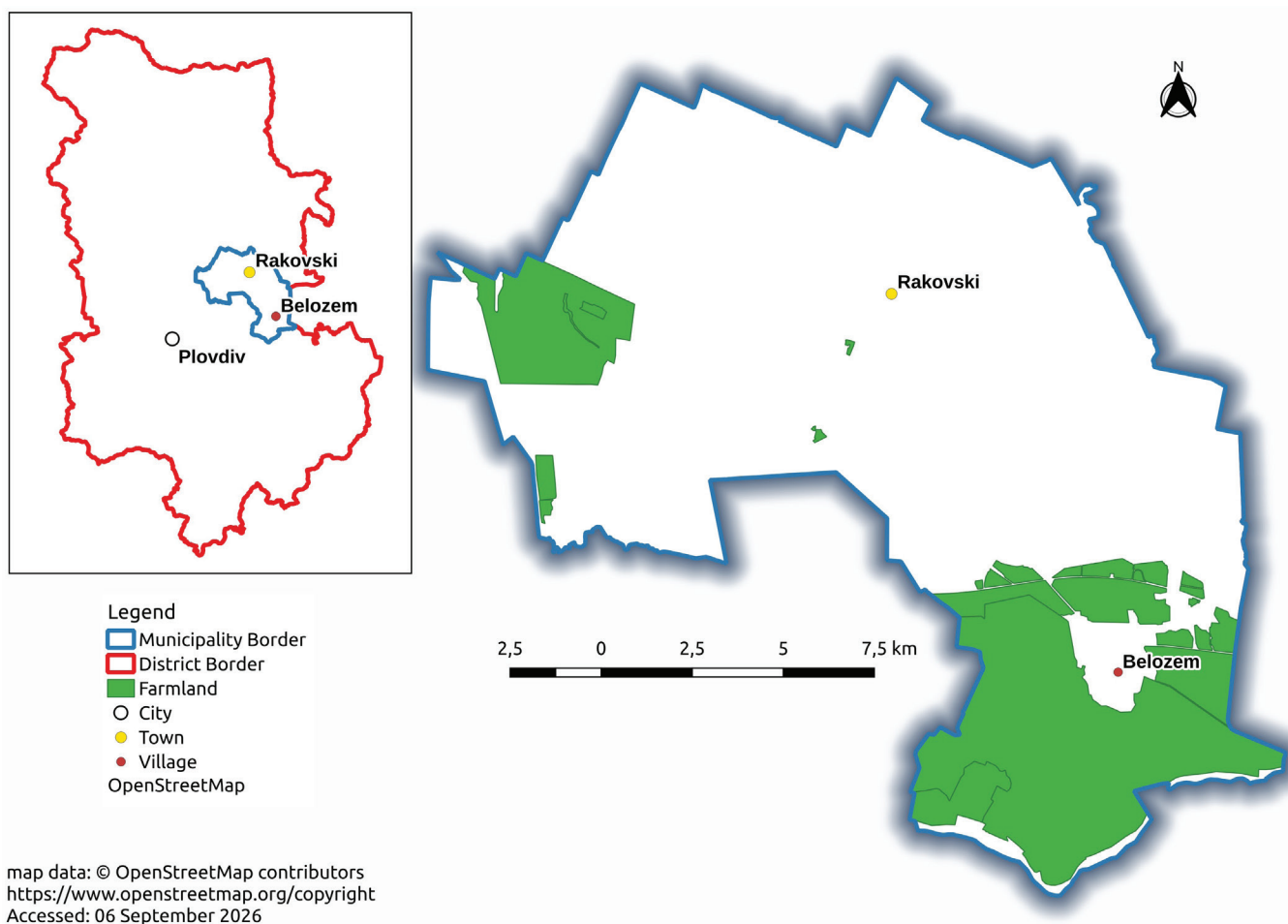


Figure 5. Rakovski Municipality in Plovdiv District and location of Belozem Village

Regarding microbiological characteristics of the studied soils, Borisova et al. (2010) note that the mechanical composition and density of the soils adversely affect the development of microorganisms, which they confirm with the relevant analytical data (Table 4).

Table 4. Soil microorganisms in the surface and subsurface horizons of Solonetz from Belozem Village in Rakovski Municipality¹

Soil horizon	Depth (cm)	Bacteria (mln/1 g)	Actino-mycetes (mln/1 g)	Microscopic fungi (ths/1 g)	Oligo-nitrophyles (mln/1 g)	Cellulose decomposing (mln/1 g)	Total (mln/1 g)
A _n	0 – 10	2.4	1.8	20000	22	0.14	26.36
Bt _{1n}	10 – 24	0.6	0.4	0.001	1	0.02	2

¹ Source: Borisova et al. (2010).

The state of soil organic matter, which plays an important role in soil structure, biological activity, water-air and temperature regime of soils, etc. (Hristova et al., 2016), is also subject of contemporary studies of soils in Plovdiv District.

Shishkov et al. (2016) determine the carbon content and

composition of soil organic matter in leached Cinnamon Forest soil (Luvisol) from the area of Hisarya Town (Figure 6). The authors establish humus-eluvial (AE) horizon with thickness of 20 cm, below which they define an illuvial-clayey (Bt) horizon, divided into three subhorizons due to the total thickness of 60 cm.

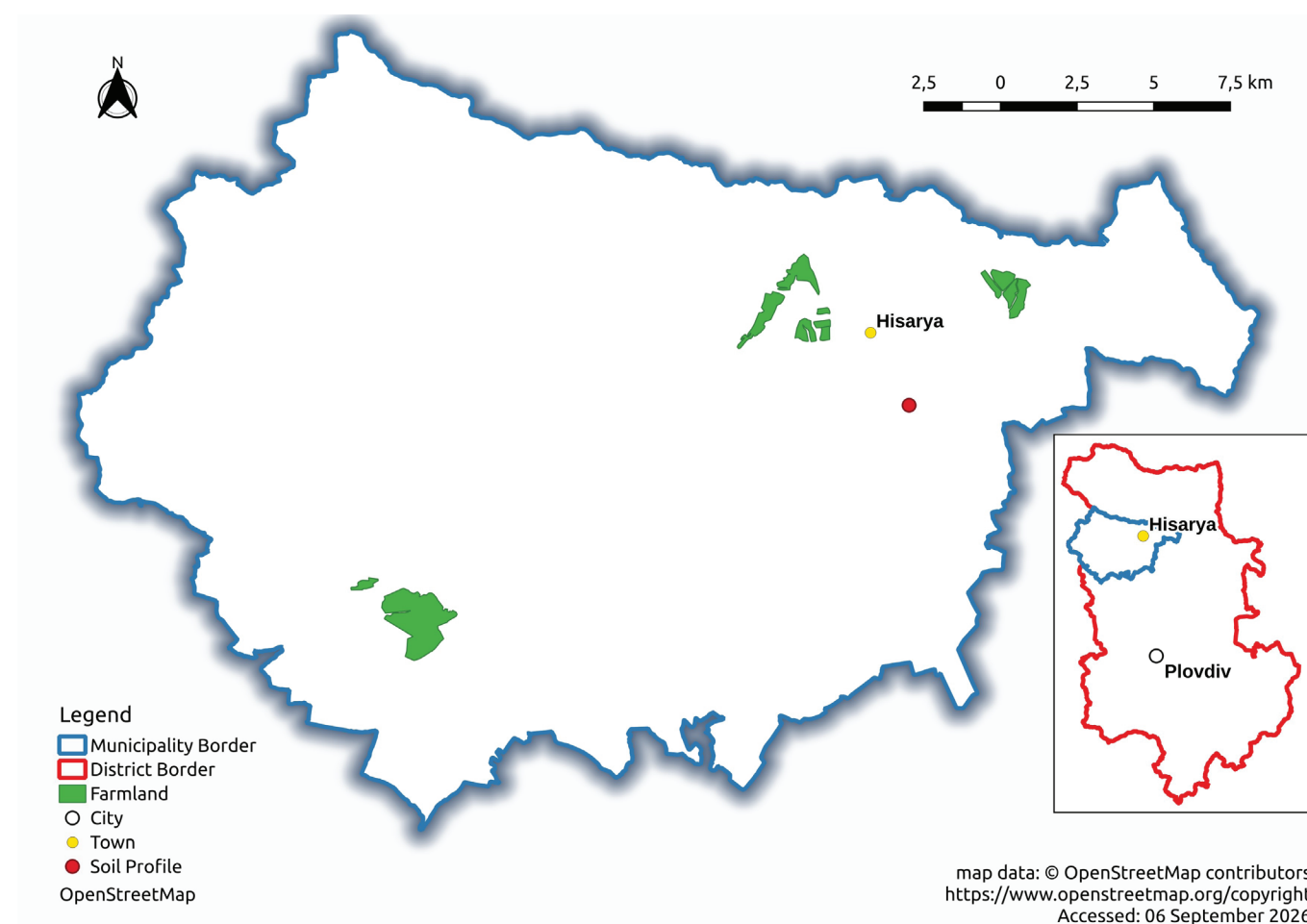


Figure 6. Hisarya Municipality in Plovdiv District and location of the soil profile

Depending on the amount of total carbon (Shishkov et al., 2016), as in the study of Kercheva et al. (2017), we calculated the humus content with coefficient 1.724 (Kononova, 1963) that highlights the surface horizon and shows gradual carbon decrease in depth of the soil profile (Table 5).

Table 5. Humus content in the studied soil profile from the region of Hisarya Town

Soil Horizon ¹	Depth (cm) ¹	Humus (%)	Meaning (content) ²
AE	0 – 20	1.48	low
Bt1	20 – 40	0.83	very low
Bt2	40 – 60	0.62	very low
Bt3	60 – 80	0.53	very low
BC	80 – 100	0.36	very low

¹ Source: Shishkov et al. (2016).

² According to Artinova (2012).

Shishkov et al. (2016) present data on composition of soil organic matter in the studied soil that determine almost equal

ratio between humic acids (HA) and fulvic acids (FA) in surface horizon (HA=17.44%, FA=18.60% of the amount of total carbon) and predominance of HA in subsurface horizon (HA=25.00%, FA=4.17% of the amount of total carbon). The authors found presence of only FA in the composition of extracted organic carbon at depth below 40 cm. Similar lack of HA, but at greater depth (under 90 cm), is reported by Artinova (2000) in profile of Cinnamon Forest soil in Plovdiv District. Significant point of the study of Shishkov et al. (2016) is the established difference in humus type, which is humic-fulvic in the surface horizon and humic in the first illuvial-clayey (B_{t1}) subhorizon. The authors assume the hypothesis that the observed feature of humus in the subsurface layer can be taken as evidence of change in conditions.

Conclusion

The discussed studies by different authors confirm that the specific conditions of soil formation can lead to different features

in the composition and properties of soils, even in small areas. Some of them are related to processes, in which, in certain cases, unfavourable soil conditions are created. Others are result of anthropogenic activity, which leads to morphological changes in the soil profile or to change in the ecological state of soils.

References

- Artinova N**, 2000. Humus Composition in Red Soils of the Upper-Thracian Plain. In: S. Rousseva, E. Filcheva, I Stefanova (Eds.). Proceedings of the First National Conference on Humus Substances and Soil Tillage (BHSS-BSTRS Conference' 2000), 11-12 May 2000, Borovec, Bulgaria, 36-38.
- Artinova N**, 2012. Humus Status of Different Soil Types in Bulgaria. Soil Science, Agrochemistry and Ecology, 46, 11-53, (Bg).
- Borisova D, Myanushev E and Hristov B**, 2010. Biological Activity of Saline Soil (Solonetz) from South Bulgaria. Agricultural Science, 43, 18-22 (Bg).
- Dinev N**, 2016. Study of Soil Contamination in the Srednogie Region. Remediation Practices and Risk Assessment. In: M. Teoharov and B. Hristov (Eds.). Geochemical and Agroecological Problems of the Zlatitsa-Pirdop Field and the Surrounding Area. Bulgarian Soil Science Society, Sofia, ISBN 987-619-90414-1-3, 81-120.
- FAO**, 2006. Guidelines for Soil Description. Fourth Edition, FAO, Rome, 97.
- Gyurov G and Artinova N**, 2015. Soil Science, 2nd Edition. Intelxpert-94, Plovdiv. ISBN 978-619-7220-01-8, 257 (Bg).
- Hristova M, Filcheva E and Nikolova P**, 2016. Reliability of the Method for Determination of Soil Organic Carbon. In: E. Filcheva et al. (Eds.), Fourth National Conference with International Participation, Humus Substances and their Contribution to the Climate Change Mitigation. Bulgarian Humic Substances Society, Sofia, ISBN 978-619-90189-2-7, 318-327 (Bg).
- ISSAPP** – Institute of Soil Science, Agrotechnologies and Plant Protection “Nikola Poushkarov”. Digital Soil Map of Bulgaria, scale 1:400000, <http://www.issapp-pushkarov.org/en/resources>.
- IUSS Working Group WRB**, 2022. World Reference Base for Soil Resources. International Soil Classification System for Naming Soils and Creating Legends for Soil Maps. 4th edition. International Union of Soil Sciences (IUSS), Vienna, Austria.
- Ivanov P**, 2007. Soil Formation Processes in Reclaimed Lands from Restored Landscapes, Destroyed by Industry in Different Ways of Using. PhD Thesis. National Centre of Agricultural Science, N. Poushkarov Institute of Soil Science, Sofia, 156 (Bg).
- Ivanov P, Hristova M and Hristov B**, 2025. The Soils of the South Central Planning Region in Bulgaria – Distribution, Characteristics, Limiting Degradation Factors. Bulgarian Journal of Agricultural Science, 31, 1079-1085. https://journal.agrojournal.org/page/en/details.php?article_id=5238
- Kachinskiy NA**, 1965. Soil Physics, Part 1, High School Press, Moscow, 323 (Ru).
- Kercheva M, Sokolowska Z, Hajnos M, Skic K and Shishkov T**, 2017. Physical parameters of Fluvisols on flooded and non-flooded terraces. International Agrophysics, 31, 73-82. doi: 10.1515/intag-2016-0026
- Kercheva M, Dimitrov E, Doneva K and Kolchakov V**, 2021. Soil Water Retention Properties of Genetically Different Soils from Agricultural Regions. In: M. Kercheva (Ed.). Thermal properties of Soils with Different Land Use and Land Amelioration Methods. ISBN: 978-954-749-121-2. PublishScieSet – Eco, Sofia, 68-82 (Bg).
- Kolchakov I and Glogova D**, 1994. Changes in Chemical Composition and Properties of Technogenically Impacted Grey Forest Soils. Soil Science, Agrochemistry and Ecology, 4-6, 91-93 (Bg).
- Kononova MM**, 1963. Soil organic matter. Its nature, properties and methods of study. USSR Academy of Sciences, Moscow, 314 (Ru).
- Koynov V, Trashliev H, Yolevski M, Andonov T, Ninov N, Hadzhiyanakiev A, Angelov E, Boyadzhiev T, Fotakieva E, Krastanov S, Staykov I, Dimitrov D, Treykyashki P, Kabachiev I, Tanev G, Dishovski T, Krasteva I, Hinov G, Ralchev A, Pophristov B, Grigorov L, Takov A, Achkov N, Konstantinov G, Andreevski D, Kostov G, Novakov B, Iliev P, Bakalova V and Vatrlov I**, 1968. Soil Map of Bulgaria, scale 1:400 000. General Directorate of Geodesy and Cartography, MapProject, Sofia (Bg).
- Koynov V, Gyurov G and Kolcheva B**, 1980. Soil Science. Zemizdat, Sofia, 300 (Bg).
- Marinova S and Zlatareva E**, 2016. Technological Solutions for Restoration of Fertility of Industrially Contaminated Soils in the Zlatitsa-Pirdop Field. In: M. Teoharov and B. Hristov (Eds.). Geochemical and Agroecological Problems of the Zlatitsa-Pirdop Field and the Surroundings. ISBN 987-619-90414-1-3. Bulgarian Soil Science Society, Institute of Soil Science, Agrotechnologies and Plant Protection “N. Poushkarov”, Federation of Scientific and Technical Unions, Scientific and Technical Union of Agricultural Specialists, Sofia, 121-131 (Bg).
- Ministry of Agriculture and Food, National Agricultural Advisory Service, Plovdiv Office**, 2025. <https://www.naas.government.bg/zanas/struktura/glavna-direkciya-teritorialni-oblastni-ofisi/teritorialni-oblastni-ofisi/ofis-plovdiv> (Bg).
- National Statistical Institute**, 2024. Regions, Districts and Municipalities in the Republic of Bulgaria 2022. <https://www.nsi.bg/publications/raionite-oblastite-i-obshtinite-v-republika-balgariya-2022-2195>.
- Nikova I and Hristov B**, 2020. Heavy Metal Pollution around the Village of Kuklen, Plovdiv, Bulgaria. Journal of Balkan Ecology, 23, 315-321.
- Ninov N and Teoharov M**, 1989. Contribution to the Classification and Diagnostics of Podzolic (Pseudopodzolic) Soils Affected by Anthropogenic Impact. In: L. Raykov et al. (Eds.). Fourth National Conference on Soil Science, Problems of Soil Science under the Conditions of Intensive Agriculture. BSSS, N. Poushkarov Soil Science and Yield Programming Institute, Sofia, 42-47 (Bg).
- OpenStreetMap contributors** (<https://www.openstreetmap.org/copyright>)

- Peneva M**, 2018. Agricultural Production in Plovdiv Region: Territorial Dynamics and Effects on Rural Areas. Agricultural University – Plovdiv, Scientific Works, 61, 7-16, DOI: 10.22620/sciworks.2018.02.001 (Bg).
- QGIS.org**, %Y. QGIS Geographic Information System. QGIS Association. <http://www.qgis.org>
- Regional Administration Plovdiv**, 2025. https://pd.government.bg/?page_id=1571 (Bg).
- Regulation № 3** on the Standards for Permissible Content of Harmful Substances in Soils. State Journal 71 from 12 August 2008 (Bg).
- Sapundzhiev D and Mitreva Z**, 2016. Agro-climatic Potential of the South Central Planning Region. Soil Science Agrochemistry and Ecology, 50, 120-127 (Bg).
- Shishkov T, Filcheva E and Hristov B**, 2016. Soil Organic Matter and Exchange Cations Composition of Soils from Sub-Balkans Valleys. In: E. Filcheva et al. (Eds.), Fourth National Conference with International Participation, Humus Substances and their Contribution to the Climate Change Mitigation. Bulgarian Humic Substances Society, Sofia, ISBN 978-619-90189-2-7, 105-115.
- Soil Survey Staff**, 1999. Soil Taxonomy. A Basic System of Soil Classification for Making and Interpreting Soil Surveys, second edition. Agriculture Handbook 436, United States Department of Agriculture, Natural Resources Conservation Service, 871.
- Teoharov M, Popandova S, Kancheva R, Atanassova T, Tsoleva V, Banov M, Ivanov P, Filcheva E and Ilieva R**, 2009. Reference Database for soils in Bulgaria. First Edition. Agricultural Academy, N. Poushkarov Institute of Soil Science, ISBN 978-954-9467-26-0. Poni Advertising and Publishing House, Sofia, 416 (Bg).
- Yolevski M, Hadzhiyanakiev A, Georgieva Ya, Kabakchiev I and Bozhinova P**, 1989. Agroecological Zoning of the Territory of the Republic of Bulgaria (Main Indicators). In: L. Raykov et al. (Eds.). Fourth National Conference on Soil Science, Problems of Soil Science under the Conditions of Intensive Agriculture. BSSS, N. Poushkarov Soil Science and Yield Programming Institute, Sofia, 136-142 (Bg).
- Zheleva E, Bozhinova P and Dinev N**, 2012. Remediation of Contaminated Soils and Overcoming Ecological Damage by "LZP" JSC – Kardzhali. First edition. ISBN: 978-954-92592-3-0, Ambrosia NT Ltd. Sofia, 104 (Bg).