SOIL SCIENCE ANNUAL
2023, 74(3), 175008

https://doi.org/10.37501/soilsa/175008

Application of portable colorimeter for identification of mollic horizon and mollic-based soil groups

Dorota Kawałko, Dariusz Gruszka, Jarosław Waroszewski, Cezary Kabała*

Wrocław University of Environmental and Life Sciences, Institute of Soil Science, Plant Nutrition and Environmental Protection,
ul. Grunwaldzka 53, 50-375 Wrocław, Poland

* Prof. Dr. Cezary Kabała, email: cezary.kabala@upwr.edu.pl, ORCID iD: https://orcid.org/0000-0001-9796-3716

Received: 2023-08-20
Accepted: 2023-11-08
Published online: 2023-11-08
Associated editor: Ł. Mendyk

Keywords:

Soil colour
Colorimeter
Munsell charts
Mollic horizon
Soil classification

Abstract

Identification of soil colours, which have crucial importance as diagnostic criteria for mollic horizon and mollic-based soil groups, is considered to be impacted by personal skill and experience of the researcher. The experiment with soil colour identification in the field using standard Munsell charts and the laboratory identification by four groups of experts, as well as using the electronic portable colorimeter was conducted using 30 loess- and alluvium-derived soils. The manual field identification of mollic horizons by individual highly experienced researcher, based on colour value and chroma (using the Munsell charts), may be overestimated up to 17% compared to manual identification by group of experts under laboratory conditions. The differences between groups of experts were statistically insignificant; however, a weak tendency to identify the lower value (dry) and higher chroma (moist) with increasing expert age or experience was observed (in the order: MSc students – PhD students – doctors – professors). No significant difference in soil colour identification was observed in relation to gender of experts. An electronic measurement of soil colours by portable colorimeter confirmed an overestimation of the manual identification of mollic horizons by 17% and 7%, compared to individual (field) and group (lab) recognition, respectively. The study confirmed the suitability of standard portable colorimeter for the verification of colours required for mollic horizon, in particular in soils those colour values are close to the classification threshold and their manual recognition depends on individual expert's skills.

1. Introduction

Soil colours have been applied to recognize soil composition and quality, and as one of basic parameters for soil classification since the beginning of the modern soil sciences (Linné, 1748). In particular soil colour may apparently reflect the origin and content of organic matter in soil (Łabaz et al., 2019; Łachacz and Załuski, 2023; Zhang and Hartemink, 2019), transformation/degradation of soil humus and humus horizons (Drewnik and Żyła, 2019; Łabaz and Kabała, 2016), mineral weathering and accumulation of iron compounds (Barajas and Ceron, 2022; Jankowski and Bednarek, 2022; Wakwoya et al., 2023), pedogenic accumulation of secondary carbonates and gypsum (Ayala-Niño et al., 2022), illuvial accumulation of humus, iron, and clay (Durn et al., 2023; Gus-Stolarczy et al., 2023), water stagnation and redox processes (Repe and Pristovsek, 2022; Świtoniak et al., 2022), morphological transformation of soil profile (Czigány et al., 2020; Krupski et al., 2017; Mendyk et al., 2020; Świtoniak, 2014), persistence of parent materials in soil, in particular the light-coloured limestones/dolomites (Łabaz et al., 2022), lithogenic stratification of soil profile from alluvial (Jonczak et al., 2023; Kawałko et al., 2021; Loaiza-Usuga et al., 2022) or glacial (Kabala et al., 2022; Woronko et al., 2022) sedimentation, and other.

Considering the relationships between soil colours and particular soil properties, researchers try to evaluate quantitatively these properties based on colour measurement alone, as the rapid and cheap technique, supported by advanced numerical data elaboration (Simonson, 1993). Most commonly and most successfully it has been applied to approximate the organic carbon (Gholizadeh et al., 2020, Zhang and Hartemink, 2019) and carbonates (Ibáńez-Asensio et al., 2013), but Kone at el. (2014) argued, that even some fertility measures may be approximated using soil colour, as for example potassium supplying capacity. Based on soil colours, which reflect single soil property or set of properties, a delineation of soil contours on soil maps may be done with precision and spatial scale unavailable with standard methods of soil cartography (Deumlich et al., 2010; Matecka and Świtoniak, 2020; Przewoźna, 2012; Žížala et al., 2019).

These numerical approaches apply typically the colour models based on Cartesian-type coordinate systems, such as CIE (various) and RGB (Rossel et al. 2005, Zhang and Hartemink,

2019) and they avoid the non-linear projection by Munsell (Melville and Atkinson, 1985). Whereas, the Munsell system remains an international standard for general soil colour description and classification (Simmonson, 1993; Świtoniak et a., 2022). At present, not only the American (Soil Survey Staff, 2022) and international (IUSS Working Group WRB, 2022) soil classifications, but also many national systems (Kabala et al., 2019; Karklins et al., 2005; Repe, 2020, dos Santos et al., 2018; Volungevicius et al., 2016; Zádorová et al., 2020) apply the Munsell system to identify the diagnostic horizons, properties and materials, and to assign classified soils to respective taxonomy units.

Among many diagnostic horizons, whose criteria require a specified soil colours (Schad, 2023), the mollic horizon probably has the largest importance for soil classification, mapping and management; thus its criteria are most commonly applied and discussed, as they play a decisive role in an identification of mollic-based soil groups, such as Chernozems, Phaeozems and Kastanozems (Galović et al., 2023; Kabala et al., 2019; Khitrov et al., 2019; Kobza, 2022; Łabaz and Kabała, 2015, 2016) and, alternatively, in soil allocation to alternative groups (Drewnik and Żyła, 2019; Kawałko et al., 2022; Krupski et al. 2017, Miechówka et al., 2021; Zádorová et al., 2020). Identification and protection of these soil reference groups has been highlighted by Food and Agricultural Organization of the United Nations as being crucial for global food and social security (FAO, 2022).

Unfortunately, practical application of Munsell charts is not free of troubles, such as variation of chips' colours in subsequent editions (Kirillova et al., 2018) or in the charts from different providers (Sánchez-Marańón et al., 2005) and different identification of the same colour by individual researchers (Marqués-Mateu et al., 2018). These inconsistencies may influence soil identification, mapping and evaluation, thus may create false imagination of soil cover differentiation and productivity in particular areas (Arnold, 2006). The attempts have been undertaken to eliminate at least some of difficulties by using the electronic measurement devices such as colorimeters, but only few of the available devices are supplied with algorithm for direct displaying the colour parameters according to the Munsell system (Chen et al., 2019; Moritsuka et al., 2019).

The aim of this study was to analyse the correctness of field identification of mollic horizons to improve soil classification to respective Reference Soil Groups. The detailed aims were to: (a) compare an individual field determination of mollic horizon with its identification by various groups of experts, and (b) compare the determination of mollic horizon's colours made by humans and by portable conventional colorimeter to verify the benefits of its use.

2. Materials and methods

Thirty soil samples have been selected for analysis, fifteen representing loess-derived soils (all featured by silt loam texture) and fifteen representing alluvium-derived soils, featured by loamy and silt-loamy textured (Table 1). Samples were collected from topsoil A horizons and met basic physicochemical requirements for mollic horizon (the content of soil organic carbon at least 0.6% and high base saturation, reflected by pH_w at least 5.5).

In the field, soils were described according to Polish guidelines (Polish Soil Classification, 2019) and WRB guidelines (IUSS Working Group WRB, 2022). Soil colour has been described in the samples grinded in the fingers, moistened to stable colour ("moist state") or left in thin layer on sun for a half hour to dry ("dry state"). Moist and dry colours have been identified by comparison to Munsell colour charts (Munsell Color Charts, 2009). Mollic horizons have been identified by single, experienced researcher in 9 of 15 loess-derived soils and in 7 of 15 alluvial soils, thus the soils were classified to Chernozems, Phaeozems, Calcisols, Fluvic Phaeozems and Fluvic Cambisols, respectively to the presence or lack of mollic/chernic horizon and other diagnostics. According to WRB requirements (IUSS Working Group WRB, 2022), mollic horizon must have ≥ 0.6% soil organic carbon and, in ≥ 90% of the exposed area of the entire horizon, a Munsell colour value of ≤ 3 moist, and ≤ 5 dry, and a chroma of ≤ 3 moist (criteria differ somewhat for soils rich in gypsum or carbonates, but it is not case in the present study).

Soil samples collected for lab analyses have been dried, crushed and sieved (grid 2 mm). Randomly oriented soil samples were placed on the Petri dishes, in two sets, i.e., in dry and moist state. Twenty-five professionals (11 female and 14 male), experienced in soil description in the field, have been invited to identify colours of 30 soil samples. Experts represented the following four groups: professors (6 people), doctors (6 people), PhD students (6 people) and MSc students (7 people). Colour identification was done separately by each expert, in the same room, under natural light, and using the same copy of Munsell charts, which was used in the field. Only the chips apparently present in the Munsell charts were used for colour description and no "intermediate" identifications were allowed (e.g., 3.5/3.5), even if it is done unofficially by some pedologists in the field, because it is against the crucial rule of Munsell charts application.

In the second part of experiment, the colour measurement in the same, prepared soil samples was made in moist and dry states using Konica Minolta CM-600d standard portable colorimeter. According to the instruction of provider, the soil samples were wrapped with thin PE foil to protect the apparatus against possible contamination. However, due to unexpectedly readings of soil chroma of samples, the colours were measured once again without the protection foil, using the colorimeter placed vertically, directly on the soil sample in a Petri dish (Figure 1). In this case, the plastic ring was cleaned after each measurement to avoid a beam contamination with soil particles. Each presented result is averaged from three single readings. Value and chroma readings were intentionally rounded to one decimal digit. Hue readings were rounded to the nearest hue in Munsell charts, typically to 10YR or 2.5Y. For final decisions and identification of mollic horizons, the readings were rounded to the nearest hue, value and chroma specified in Munsell charts.

For detailed analysis of identification ability, the means of colour value and chroma were calculated and compared among distinguished groups using the Tukey test (for variable n) at $p<0.05$.

Table 1
General characterisation of soil samples used for colour analysis

Lp.	Parent material	Field Munsell colour		SOC	pH_w	2–0.05	0.05–0.002	<0.002
		moist	dry	%		%		
1	**loess**	**10YR 2/1**	**10YR 3/1**	2.1	6.8	10	**78**	**12**
2	**loess**	**10YR 2/1**	**10YR 3/1**	**1.5**	**7.3**	**12**	**68**	**20**
3	**loess**	**10YR 2/2**	**10YR 3/2**	**1.5**	**7.0**	**8**	**69**	**23**
4	**loess**	**10YR 3/1**	**10YR 4/2**	**1.7**	**6.1**	**6**	**71**	**23**
5	**loess**	**10YR 3/1**	**10YR 4/2**	**1.4**	**6.6**	**8**	**76**	**16**
6	loess	**10YR 3/2**	**10YR 5/3**	**1.5**	7.5	**10**	**73**	**17**
7	**loess**	**10YR 3/3**	**10YR 5/3**	**1.9**	**5.6**	**6**	**72**	**22**
8	**loess**	**10YR 3/3**	**10YR 5/3**	**1.5**	**5.5**	**17**	**66**	**17**
9	**loess**	**10YR 3/3**	**10YR 4/3**	**1.3**	**5.8**	**16**	**66**	**18**
10	loess	10YR 4/1	10YR 6/2	1.1	6.9	11	74	15
11	loess	10YR 4/1	10YR 6/2	0.9	7.5	11	65	24
12	loess	10YR 4/2	10YR 5/2	0.9	6.5	11	80	9
13	loess	10YR 4/2	10YR 6/3	0.7	8.1	10	72	18
14	loess	10YR 4/2	10YR 5/3	0.6	8.1	35	55	13
15	loess	10YR 4/3	10YR 5/3	0.7	6.5	14	70	16
16	**alluvium**	**10YR 2/1**	**10YR 3/1**	**11.6**	**5.5**	**13**	**62**	**25**
17	alluvium	10YR 2/1	**10YR 3/2**	**4.9**	**6.0**	**11**	**63**	**26**
18	**alluvium**	**2.5YR 3/1**	**10YR 5/2**	**4.9**	**5.5**	**14**	**55**	**31**
19	**alluvium**	**10YR 3/1**	**10YR 4/1**	4.1	**6.2**	**16**	**64**	**20**
20	**alluvium**	**10YR 3/2**	**10YR 5/2**	**1.8**	**7.1**	**60**	**28**	**12**
21	**alluvium**	**10YR 3/2**	**10YR 5/3**	0.9	6.6	73	**22**	**5**
22	**alluvium**	**10YR 3/3**	**10YR 4/3**	**2.9**	**5.5**	**17**	**59**	**24**
23	alluvium	10YR 4/2	10YR 5/3	1.2	5.7	61	26	13
24	alluvium	10YR 4/2	10YR 6/2	1.2	6.4	57	25	18
25	alluvium	10YR 4/3	10YR 5/3	2.1	5.9	14	58	28
26	alluvium	10YR 4/3	10YR 5/3	1.5	5.5	16	62	22
27	alluvium	10YR 4/3	10YR 6/3	1.2	5.8	52	31	17
28	alluvium	10YR 4/3	10YR 6/3	1.0	5.8	61	24	15
29	alluvium	10YR 4/3	10YR 6/3	0.9	5.5	13	57	30
30	alluvium	10YR 4/3	10YR 6/3	0.6	5.7	75	21	4

Explanation: SOC – soil organic carbon, pH_w – soil pH in distilled water, samples in bold meet the criteria for mollic horizon

Fig. 1. Laboratory measuring of soil colour in dry soil samples by portable colorimeter.

3. Results and discussion

The recognition of colour hue by individual expert in the field and experts in the laboratory was nearly the same (with only two exceptions), thus the detailed data are not presented. The majority of samples had the hue of 10YR (Table 1), most common in soils of Poland, thus the experts could select this hue by default. However, Marqués-Mateu et al. (2018) reported that the differences or errors in colour identification are in general the lowest in case of colour hue. Mean readings of soil value and chroma (in moist and dry states) made by individual expert in the field were lower than the averaged readings made by experts in the laboratory, but the differences were not significant (Table 2). It may indicate a weak tendency to recognise colours in the field as darker and less saturated (paler), which may result in more common identification of mollic horizon. The differences between field and lab readings may result from different light conditions, different sample preparation and heterogeneity of soil colours in the field (Simonson, 1993). However, the samples under experiment were collected from topsoil horizons, free of stagnic/gleyic properties and relatively well homogenised by ploughing and animal activity. Moreover, the samples in the field were grinded in the fingers, that makes the sample preparation similar to this in the lab. It may be therefore concluded, that the differences in colour identification depend on personal skills of individual experts.

Practically no differences in mean readings of moist value and dry chroma were observed between particular groups of experts (Table 2). Whereas, the differences for moist chroma and dry value were statistically significant. Although the differences in mean values of particular parameters appear to be irregular and poorly marked among groups of professionals, the cluster analysis based on all individual measurements revealed a clear tendency (Figure 2). The colour identifications by students and PhD students were the most similar to each other and differed the most from the individual field identifications, while the professors' identifications were relatively most similar to field readings. This tendency may be only partly explained with mean results presented in Table 2 (as the growing moist chroma and decreasing dry value from students to doctors). It suggests however, that the colour identification may change with age or experience of the researcher: younger people (students, PhDs) more commonly identify colours as lighter and paler than older researchers, which has no clear confirmation in the research on changes in colour perception with age (Bosten, 2022; Satoh, 1998).

Table 2
Colour identification by different groups of experts (mean values for all samples)

Group	Munsell colour moist		Munsell colour dry	
	value	chroma	value	chroma
Individual (field)	3.3^{a}	2.1^{a}	4.8^{a}	2.4^{a}
All experts (lab)	3.4^{a}	2.5^{ab}	5.1^{ab}	2.6^{a}
Professors (lab)	3.4^{a}	2.4^{a}	5.1^{ab}	2.6^{a}
Doctors (lab)	3.3^{a}	2.6^{b}	4.9^{a}	2.7^{a}
PhD students (lab)	3.4^{a}	2.5^{ab}	5.1^{ab}	2.6^{a}
MSc Students (lab)	3.4^{a}	2.4^{a}	5.2^{b}	2.6^{a}

[a] Homogeneous group (no statistical difference) by Tukey test for different number of samples at $p<0.05$.

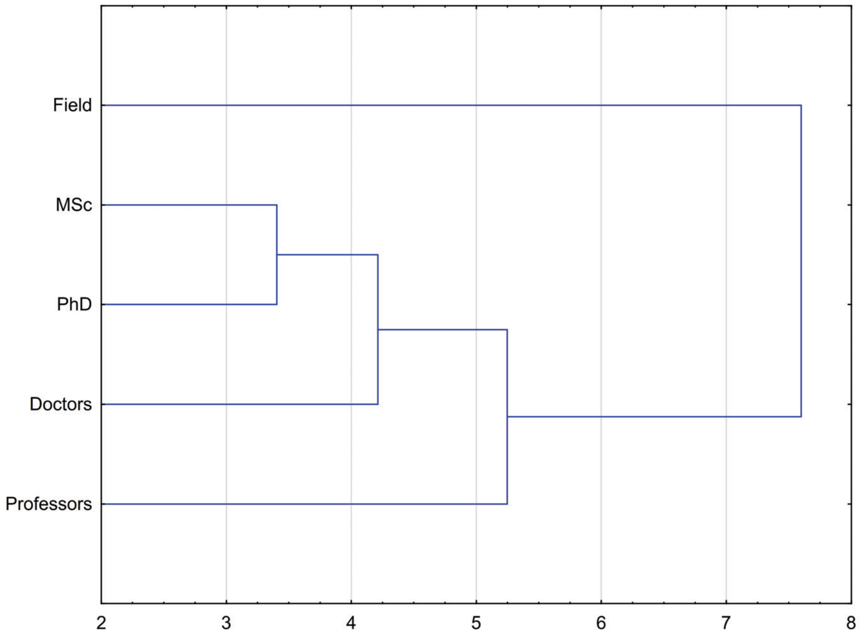


Fig. 2. Cluster analysis of colour measurements (all readings of value and chroma, moist and dry) in the field (individual) and by groups of experts (in the laboratory).

Colour identification by female and male experts differed more noticeably for colour value than for colour chroma, but the differences were statistically insignificant (Table 3). The obtained results suggest that women may identify colour as slightly darker in dry state, which may result in more common recognition of mollic horizon by women. Different colour perception by males and females has been confirmed for food and industrial products (Jaint et al., 2010) that makes it also probable for soil colours; however, no respective reports have been published yet.

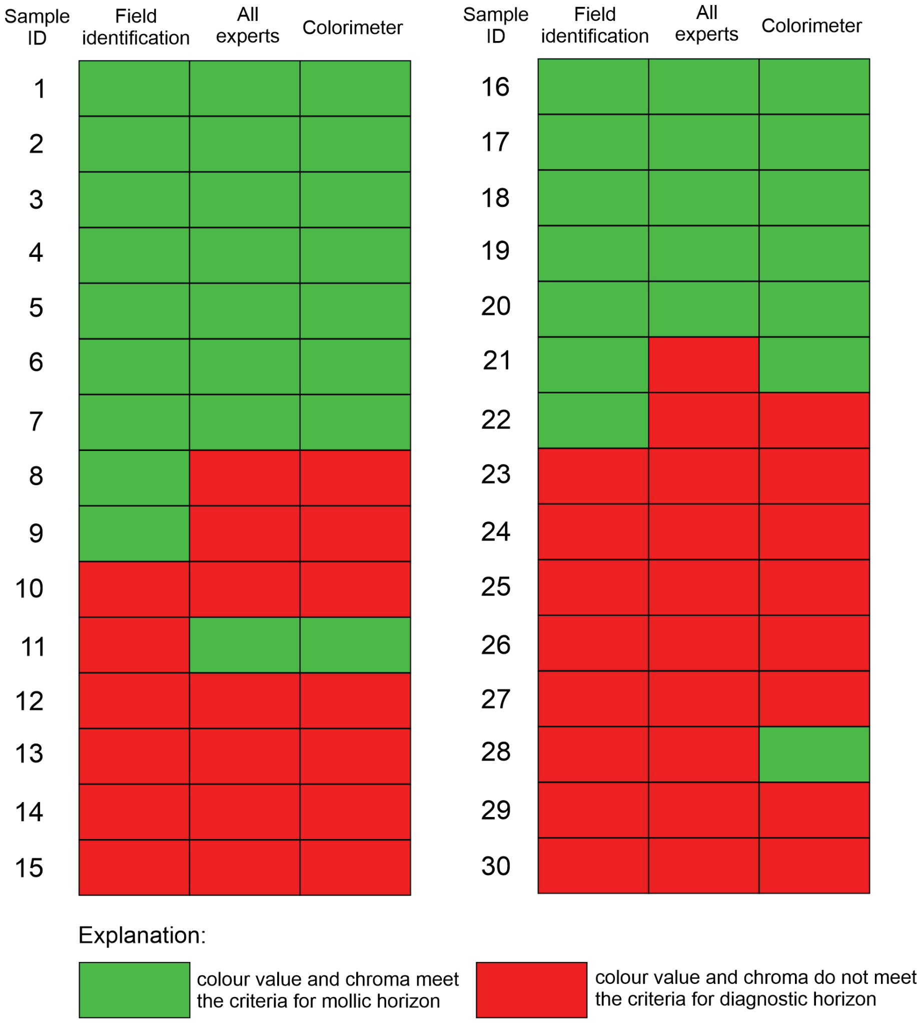
Slightly lower mean colour values and chromas from field identification compared to lab measurements (Table 2) resulted in somewhat more common identification of mollic horizons in the field in both loess-derived and alluvial soils (Figure 3). The positive or negative identification of colour criteria for mollic horizon agreed in 12 and 13 samples on 15 in each group, namely the loess-derived and alluvial soils, respectively, which means the total consistency of the results on the level of 83%. The individual analysis indicated, that irrespectively of the general tendency mentioned above (Table 2), not all mollic horizons have been identified in the field by individual expert, which was exemplified in the sample No 11 (Figure 3).

The initial measurement of soil colours in soil samples wrapped in PE foil to protect the electronic device against contamination with dust provides unexpectedly high readings of colour values and, in particular, low readings of chromas (Table 4). Experiments with other kinds of thin glass and foil gave somewhat better, but still unsatisfactory results (not presented here). One of experiments involved a measurement of the col-

Table 3
Colour identification by experts according to expert sex (mean values for all samples)

Group of experts (lab readings)	Munsell colour moist		Munsell colour dry	
	value	chroma	value	chroma
All experts	3.4[a]	2.5[a]	5.1[a]	2.6[a]
Female experts	3.3[a]	2.5[a]	4.9[a]	2.7[a]
Male experts	3.5[a]	2.5[a]	5.3[a]	2.6[a]

[a] Homogeneous group (no statistical difference) by Tukey test for different number of samples at p<0.05.



Sample ID	Field identification	All experts	Colorimeter
1	🟩	🟩	🟩
2	🟩	🟩	🟩
3	🟩	🟩	🟩
4	🟩	🟩	🟩
5	🟩	🟩	🟩
6	🟩	🟩	🟩
7	🟩	🟩	🟩
8	🟩	🟥	🟥
9	🟩	🟥	🟥
10	🟥	🟥	🟥
11	🟥	🟩	🟩
12	🟥	🟥	🟥
13	🟥	🟥	🟥
14	🟥	🟥	🟥
15	🟥	🟥	🟥

Sample ID	Field identification	All experts	Colorimeter
16	🟩	🟩	🟩
17	🟩	🟩	🟩
18	🟩	🟩	🟩
19	🟩	🟩	🟩
20	🟩	🟩	🟩
21	🟩	🟥	🟩
22	🟩	🟥	🟥
23	🟥	🟥	🟥
24	🟥	🟥	🟥
25	🟥	🟥	🟥
26	🟥	🟥	🟥
27	🟥	🟥	🟥
28	🟥	🟥	🟩
29	🟥	🟥	🟥
30	🟥	🟥	🟥

Explanation:
🟩 colour value and chroma meet the criteria for mollic horizon
🟥 colour value and chroma do not meet the criteria for diagnostic horizon

Fig. 3. Identification of mollic horizons by humans (in the field and laboratory) and using the electronic colorimeter in loess-derived (samples 1–15) and alluvial (samples 16–30) soils

ours of original chips in Munsell charts covered with thin PE foil. This experiment confirmed that any separating material, including the thinnest available glass or PE foil, modified the readings of chroma by 1–2 units (towards lower numbers, i.e., paler colours) compared to measurement made without any separating material (Table 4).

Colour measurements made using the electronic portable colorimeter were slightly closer in moist state to the individual field readings, while in dry state – closer to readings made by the group of experts, but in majority the differences were insignificant in terms of statistical testing (Table 5). Mean moist value from colorimetric measurement was even lower than this from field reading, which may have importance for field identification of mollic horizons. Marqués-Mateu et al. (2018) found that users of the Munsell charts tend to report higher soil value and chroma than identified by measurement devices, which agrees with results obtained for the group of experts (Table 5).

Identification of mollic horizons based on colour measurements using the electronic colorimeter gave the results comparable with identification using the colours identified by humans (Figure 3). In the loess-derived soils, mollic was identified exactly as made by group of experts, i.e., mollic was confirmed in the sample 11 and was not confirmed in the samples 8–9 (apart from other samples where all three attempts gave similar results). Identification of mollic horizon in the alluvial soils was less consistent with the recognition made by group of experts, but the differences concerned 1–2 samples only. In general, the positive or negative identification of colour criteria for mollic horizon by electronic colorimeter agreed in 83% and 93% with individual (field) and group (lab) identification, respectively.

The criteria for diagnostic horizons in the classification systems (IUSS Working Group WRB, 2022; Soil Survey Staff, 2022; Polish Soil Classification, 2019) refer to colour values and chromas as they are presented in the Munsell color charts, i.e., rounded to integers. In mollic horizon, the colour value must be ≤3 and ≤5, in the moist and dry state, respectively, and chroma ≤3, both moist and dry. The researcher must select the chip (and rounded value and chroma) most similar to the soil under recognition based on a comparison of the soil sample to the collection of neighbouring chips. Whereas, the results of electronic measurements by colorimeter are more precise and require rounding to integers. Presumably, the results of measurements are rounded 'mathematically' that may include lowering of the precise result, which exceeded the nearest integer. Whereas, the criteria for mollic horizon require the colour value ≤3 (moist) and some experts are not sure, if the true measurement results exceeding the value of 3 may be rounded down to 3 (IUSS Working Group WRB, 2022). It was found in the present study (Figure 4) that in a majority (ca. 60%) of samples, whose colour values were measured by colorimeter as 3.1 (in fact, between 3.05 and 3.14), experts recognised the Munsell values of 2 and 3 (Figure 4). Whereas, in the soil samples with colour values identified by colorimeter as 3.2–3.5, experts recognised in majority the values of 4–5. It means that resignation of rounding of some precise results of colour measurement by colorimeter, which slightly exceed the value 3.0 (in a moist state), will lead to permanent disagreement of manual and electronic colour identifications and, finally, to the overlooking of horizons, surely identified in the field as mollic by using the Munsell color charts. It is therefore suggested to allow rounding of the soil

Table 4
Colour identification by colorimeter in samples wrapped and unwrapped in PE foil (mean values for all samples)

Measurement mode	Munsell colour moist		Munsell colour dry	
	value	chroma	value	chroma
Soil sample protected by PE foil	3.6 [a]	1.2 [a]	5.3 [a]	1.6 [a]
Direct measurement (without PE foil)	3.2 [b]	2.2 [b]	5.0 [b]	2.6 [b]

[a] Homogeneous group (no statistical difference) by Tukey test for different number of samples at $p<0.05$.

Table 5
Comparison of colour identification by humans and using the electronic colorimeter

Group	Munsell colour moist		Munsell colour dry	
	value	chroma	value	chroma
Individual (in the field)	3.3 [a]	2.1 [a]	4.8 [a]	2.4 [a]
All experts	3.4 [a]	2.5 [b]	5.1 [a]	2.6 [a]
Colorimeter	3.2 [a]	2.2 [ab]	5.0 [a]	2.6 [a]

[a] Homogeneous group (no statistical difference) by Tukey test for different number of samples at $p<0.05$.

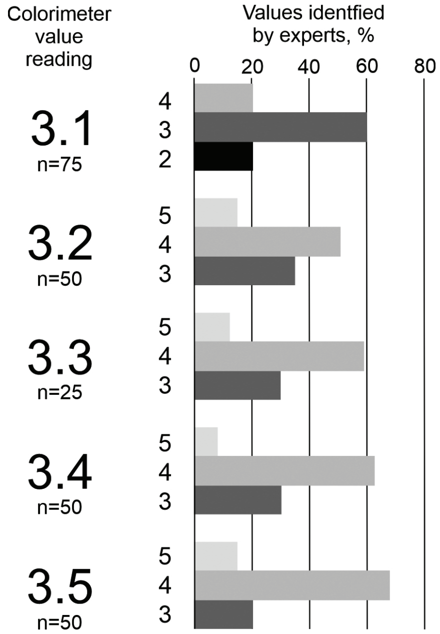


Fig. 4. Identification of colour value (moist) by experts for value reading by electronic colorimeter in a range of 3.1–3.5. Values identified by experts are given as integers (2–5), following the descriptions of colour chips in the Munsell color charts.

value measurements in a range 3.01–3.14 (moist) to a Munsell value 3. Similar conclusions were derived for the colour values exceeding 5 in dry state (data not presented). Whereas, chroma rounding to 3 has not been analysed, because the number of soil samples with chroma 3 and higher in this study was too little for reliable concluding.

5. Conclusions

The experiment with soil colour identification in the field and laboratory by humans and using the electronic portable colorimeter led to the following conclusions. The manual field identification of mollic horizons by individual highly experienced researcher, based on Munsell colour value and chroma, may be overestimated up to 17% compared to manual identification by group of experts under laboratory conditions. The differences between groups of experts were statistically insignificant; however, a weak tendency to identify the lower value (dry) and higher chroma (moist) with increasing expert age or experience was observed (in the order: MSc students – PhD students – doctors – professors). No significant difference in soil colour identification was observed in relation to gender of experts. An electronic measurement of soil colours by portable colorimeter confirmed an overestimation of the manual identification of mollic horizons by 17% and 7%, compared to individual (field) and group (lab) recognition, respectively. The study confirmed the suitability of standard portable colorimeter for the verification of mollic horizons, in particular in soils those colour value and chroma are close to required threshold and their manual recognition depends on individual expert's skills.

References

Arnold, R.W., 2006. Soil survey and soil classification. [In:] Grunwald, S. (Ed.), Environmental soil-landscape modeling: Geographic information technologies and pedometrics. Taylor & Francis Group, Boca Raton, FL, 37–60.

Ayala-Niño, F., Maya-Delgado, Y., Salamanca-Sánchez, M., Troyo-Diéguez, E., 2022. Soils of the southern tip of the Baja California Peninsula: An example from drylands in Northwest Mexico. In: Świtoniak, M., Charzyński, P. (Eds.) Soil Sequences Atlas V. Uniwersytet Mikołaja Kopernika, Toruń, Poland, 11–26.

Barajas, A., Ceron, A., 2022. Soils of coffee agroforestry systems in Southern Mexico. [In:] Świtoniak, M., Charzyński, P. (Eds.), Soil Sequences Atlas V. Uniwersytet Mikołaja Kopernika, Toruń, Poland, 27–45.

Bosten, J.M., 2022. Do you see what I see? Diversity in human color perception. Annual Review of Vision Science 8, 101–133. https://doi.org/10.1146/annurev-vision-093020-112820

Chen, J., Yuan, D., Yan, Z., Lü, Y., Weng, Q., Fu, H., Zhang, J., 2019. Comparison between Colorimeter and New Standard Soil Colour Chart of China in Determining Munsell Color of Soils – A case study of Central Sichuan Hilly Region. Acta Pedologica Sinica 1, 78–89. https://doi.org/10.11766/trxb201802250012

Czigány, S., Novák, T.J., Pirkhoffer, E., Nagy, G., Lóczy, D., Dezső, J., Fábián, S.Á, Świtoniak, M., Charzyński, P., 2020. Application of a topographic pedosequence in the Villány Hills for terroir characterization. Hungarian Geographical Bulletin 69(3), 245–261. https://doi.org/10.15201/hungeobull.69.3.2

Deumlich, D., Schmidt, R., Sommer, M., 2010. A multiscale soil–landform relationship in the glacial-drift area based on digital terrain analysis and soil attributes. Journal of Plant Nutrition and Soil Science 173, 843–851. https://doi.org/10.1002/jpln.200900094

Drewnik, M., Żyła, M., 2019. Properties and classification of heavily eroded post-chernozem soils in Proszowice Plateau (southern Poland). Soil Science Annual 70, 225–233. https://doi.org/10.2478/ssa-2019-0020

Durn, G., Perković, I., Razum, I., Ottner, F., Škapin, S.D., Faivre, S., Rubinić, V., 2023. A tropical soil (Lixisol) identified in the northernmost part of the Mediterranean (Istria, Croatia). Catena 228, 107144. https://doi.org/10.1016/j.catena.2023.107144

FAO, 2022. Global status of black soils. Rome. https://doi.org/10.4060/cc3124en

Galović, L., Husnjak, S., Šorša, A., Lazar, J.M., 2023. Evidence and mineralogical and physico-chemical properties of chernozem and chernozem-like soils in Croatia. Geologia Croatica 76(3), 113–129. https://doi.org/10.4154/gc.2023.08

Gholizadeh, A., Saberioon, M., Rossel, R.A.V., Boruvka, L., Klement, A., 2020. Spectroscopic measurements and imaging of soil colour for field scale estimation of soil organic carbon. Geoderma 357, 113972. https://doi.org/10.1016/j.geoderma.2019.113972

Gus-Stolarczyk, M., Drewnik, M., Michno, A., Szymański, W., 2023. The origin and transformation of soil lamellae in calcareous and non-calcareous loess soils in the Central European loess belt–A case study from southern Poland. Catena 232, 107399. https://doi.org/10.1016/j.catena.2023.107399

Ibáńez-Asensio, S., Marques-Mateu, A., Moreno-Ramón, H., Balasch, S., 2013. Statistical relationships between soil colour and soil attributes in semiarid areas. Biosystems Engineering 116(2), 120–129. https://doi.org/10.1016/j.biosystemseng.2013.07.013

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.

Jaint, N., Verma, P., Mittal, S., Mittal, S., Singh, A.K., Munjal, S., 2010. Gender based alteration in color perception. Indian Journal of Physiological Pharmacology 54(4), 366–70.

Jankowski, M., Bednarek, R., 2021. Rusty soil–gleba rdzawa–Soil of the Year 2021 in Poland. Concepts of genesis, classification and regularities of geographical distribution. Soil Science Annual 72(4), 145585. https://doi.org/10.37501/soilsa/145585

Jonczak, J., Parzych, A., Sztabkowski, K., 2022. Soil-forming processes and properties of soils developed from fluvic materials in the headwater river valleys of Middle Pomerania, north Poland: A case study of the Kamienna stream. Soil Science Annual 73, 156044. https://doi.org/10.37501/soilsa/156044

Kabała, C., Charzyński, P., Chodorowski, J., Drewnik, M., Glina, B., Greinert, A., Waroszewski, J., 2019. Polish soil classification: Principles, classification scheme and correlations. Soil Science Annual 70, 71–97. https://doi.org/10.2478/ssa-2019-0009

Kabała, C., Charzyński, P., Czigány, S., Novák, T.J., Saksa, M., Świtoniak, M., 2019. Suitability of World Reference Base for Soil Resources (WRB) to describe and classify chernozemic soils in Central Europe. Soil Science Annual 70, 244–257. https://doi.org/10.2478/ssa-2019-0022

Kabala, C., Musztyfaga, E., Jary, Z., Waroszewski, J., Gałka, B., Kobierski, M., 2022. Glossic Planosols in the postglacial landscape of Central Europe: Modern polygenetic soils or subaerial palaeosols?. Geoderma 426, 116101. https://doi.org/10.1016/j.geoderma.2022.116101

Karklins, A., 2005. Soil information in Latvia. Soil Resources of Europe, 2nd edition. [In:] Jones R.J.A., Houskova, B., Bullock, P., Montanarella, L. (Eds). European Soil Bureau Research Report (9), 201–209.

Kawalko, D., Jezierski, P., Kabala, C., 2021. Morphology and physicochemical properties of alluvial soils in riparian forests after river regulation. Forests 12(3), 329. https://doi.org/10.3390/f12030329

Khitrov, N., Smirnova, M., Lozbenev, N., Levchenko, E., Gribov, V., Kozlov, D., Koroleva, P., 2019. Soil cover patterns in the forest-steppe and steppe zones of the East European Plain. Soil Science Annual 70(3), 198–210. https://doi.org/10.2478/ssa-2019-0018

Kirillova, N.P., Grauer-Gray, J., Hartemink, A.E., Sileova, T. M., Artemyeva, Z.S., Burova, E.K., 2018. New perspectives to use Munsell color charts with electronic devices. Computers and Electronics in Agriculture 155, 378–385. https://doi.org/10.1016/j.compag.2018.10.028

Kobza, J., 2022. Mollic soils situated in non-Chernozem regions in Slovakia. Agriculture 68, 25–33. https://doi.org/10.2478/agri-2022-0003

Koné, B., Bongoua-Devisme, A.J., Kouadio, K.H., Kouadio, K.F., Traoré, M.J., 2014. Potassium supplying capacity as indicated by soil colour in Ferralsol environment. Basic Research Journal of Soil and Environmental Science 2(4), 46–55.

Krupski, M., Kabala, C., Sady, A., Gliński, R., Wojcieszak, J., 2017. Double-and triple-depth digging and Anthrosol formation in a medieval and modern-era city (Wrocław, SW Poland). Geoarchaeological research on past horticultural practices. Catena 153, 9–20. https://doi.org/10.1016/j.catena.2017.01.028

Łabaz, B., Kabała, C., 2014. Origin, properties and classification of’ black earths in Poland. Soil Science Annual 65, 80–90. https://doi.org/10.2478/ssa-2014-0012

Łabaz, B., Kabała, C., 2016. Human-induced development of mollic and umbric horizons in drained and farmed swampy alluvial soils. Catena 139, 117–126. https://doi.org/10.1016/j.catena.2015.12.013

Łabaz, B., Kabała, C., Dudek, M., Waroszewski, J., 2019. Morphological diversity of chernozemic soils in south-western Poland. Soil Science Annual 70(3), 211–224. https://doi.org/10.2478/ssa-2019-0019

Łabaz, B., Waroszewski, J., Dudek, M., Bogacz, A., Kabala, C., 2022. Persistence of arable Chernozems and Chernic Rendzic Phaeozems in the eroded undulating loess plateau in Central Europe. Catena 216, 106417. https://doi.org/10.1016/j.catena.2022.106417

Łachacz, A., Załuski, D., 2023. The usefulness of the Munsell colour indices for identification of drained soils with various content of organic matter. Journal of Soils and Sediments 23:4017–4031. https://doi.org/10.1007/s11368-023-03604-w

Linné C. V., 1748. Systema Naturae Sistens Regna Tria Naturae, in Classes et Ordines Genera et Species Redacta Tabulisque Aeneis Illustrata. Kiesewetterus, Lipsiae (Leipzig), 257 pp.Loaiza-Usuga, J.C., Toro-Quijano, M.I., Weber-Scharff, M., 2022. Alluvial soils as paleoenvironmental indicator in fluvial environments: A case study from Colombia. Soil Science Annual 73(3), 157400. https://doi.org/10.37501/soilsa/157400

Marqués-Mateu, Á., Moreno-Ramón, H., Balasch, S., Ibáńez-Asensio, S., 2018. Quantifying the uncertainty of soil colour measurements with Munsell charts using a modified attribute agreement analysis. Catena 171, 44–53. https://doi.org/10.1016/j.catena.2018.06.027

Matecka, P., Świtoniak, M., 2020. Delineation, characteristic and classification of soils containing carbonates in plow horizons within young moraine areas. Soil Science Annual 71, 23–36. https://doi.org/10.37501/soilsa/121489

Moritsuka, N., Kawamura, K., Tsujimoto, Y., Rabenarivo, M., Andriamananjara, A., Rakotoson, T., Razafimbelo, T., 2019. Comparison of visual and instrumental measurements of soil color with different low-cost colorimeters. Soil Science and Plant Nutrition 65(6), 605–615. https://doi.org/10.1080/00380768.2019.1676624

Melville, M.D., Atkinson, G., 1985. Soil colour: its measurement and its designation in models of uniform colour space. Journal of Soil Science 36(4), 495–512.

Mendyk, Ł., Hulisz, P., Świtoniak, M., Kalisz, B., Spychalski, W., 2020. Human activity in the surroundings of a former mill pond (Turznice, N Poland): implications for soil classification and environmental hazard assessment. Soil Science Annual 71, 371–381. https://doi.org/10.37501/soilsa/131617

Miechówka, A., Zadrożny, P., Mazurek, R., Ciarkowska, K., 2021. Classification of mountain non-forest soils with umbric horizon–a case study from the Tatra Mountains (Poland). Soil Science Annual 72(1), 134619. https://doi.org/10.37501/soilsa/134619

Munsell Soil Color Charts, 2009. Munsell Soil Color Charts with genuine Munsell color chips. 2009 Year Revised, 2013 Production. Produced by Munsell Color X-Rite, Grand Rapids, Mi, USA.

Polish Soil Classification, 2019. Polskie Towarzystwo Gleboznawcze, Komisja Genezy Klasyfikacji i Kartografii Gleb. Wydawnictwo Uniwersytetu Przyrodniczego we Wrocławiu, Wrocław–Warszawa.

Przewoźna, B., 2012. Transformations of soils as an effect of anthropogenic denudation interpreted on the base of agricultural map of soils, ortophotomaps and terrain research. Prace Komisji Krajobrazu Kulturowego, Polskie Towarzystwo Geograficzne 16, 148–156

Repe, B., 2020. Classification of soils in Slovenia. Soil Science Annual 71, 158–164. https://doi.org/10.37501/soilsa/122411

Repe, B., Pristovsek, A., 2022. Marine tidal /subaqueous soil sequence at the coast of Slovenia. [In:] Świtoniak, M., Charzyński, P. (Eds.), Soil Sequences Atlas V. Uniwersytet Mikołaja Kopernika, Toruń, Poland, 135–154.

Rossel, R.V., Minasny, B., Roudier, P., McBratney, A.B., 2006. Colour space models for soil science. Geoderma 133(3-4), 320–337. https://doi.org/10.1016/j.geoderma.2005.07.017

Sánchez-Marañón, M., Huertas, R., Melgosa, M., 2005. Colour variation in standard soil-colour charts. Soil Research 43(7), 827-837. https://doi.org/10.1071/SR04169

dos Santos, H.D., Jacomine, P.T., Dos Anjos, L.H.C., De Oliveira, V.Á., Lumbreras, J.F., Coelho, M.R., Cunha, T.J.F., 2018. Brazilian Soil Classification System. EMBRAPA, Brasilia, Brazil.

Satoh, C., 1998. Change in color perception with aging. Journal of Light and Visual Environment 22(2), 50.

Schad, P., 2023. World Reference Base for Soil Resources–Its fourth edition and its history. Journal of Plant Nutrition and Soil Science 186, 151–163. https://doi.org/10.1002/jpln.202200417

Simonson, R.W., 1993. Soil color standards and terms for field use—history of their development. [In:] Bigham, J. M., Ciolkosz, E.J., (Eds.), Soil Color, SSSA Spec. Publ., vol. 31, SSSA, Madison, WI, 1–20

Soil Survey Staff, 2022. Keys to Soil Taxonomy, 13th edition. USDA Natural Resources Conservation Service.

Świtoniak, M., 2014. Use of soil profile truncation to estimate influence of accelerated erosion on soil cover transformation in young morainic landscapes, North-Eastern Poland. Catena 116, 173–184. https://doi.org/10.1016/j.catena.2013.12.015

Świtoniak, M., Kabała, C., Charzyński, P., Capra, G.F., Czigány, S., Pulido-Fernández, M., Vircava, I., 2022. Illustrated Handbook of WRB Soil Classification. Wroclaw, Poland.

Volungevicius, J., Jukna, L., Veteikis, D., Vaisvalavicius, R., Amaleviciute, K., Slepetiene, A., Jankauskaite, M., 2016. The problem of soil interpretation according to the WRB 2014 classification system in the context of anthropogenic transformations. Acta Agriculturae Scandinavica, Section B–Soil & Plant Science 66(5), 452–460. https://doi.org/10.1080/09064710.2016.1164231

Wakwoya, M.B., Woldeyohannis, W.H., Yimamu, F.K., 2023. Characterization and classification of soils of upper Hoha sub-watershed in Assosa District, Western Ethiopia. Heliyon 9, e14866. https://doi.org/10.1016/j.heliyon.2023.e14866

Woronko, B., Zagórski, Z., Cyglicki, M., 2022. Soil-development differentiation across a glacial–interglacial cycle, Saalian upland, E Poland. Catena 211, 105968. https://doi.org/10.1016/j.catena.2021.105968

Zádorová, T., Žížala, D., Penížek, V., Vaněk, A., 2020. Harmonisation of a large-scale historical database with the actual Czech soil classification system. Soil and Water Research 15(2), 101–115.

Zhang, Y., Hartemink, A. E., 2019. Digital mapping of a soil profile. European Journal of Soil Science 70(1), 27–41.

Žížala, D., Juřicová, A., Zádorová, T., Zelenková, K., Minařík, R., 2019. Mapping soil degradation using remote sensing data and ancillary data: South-East Moravia, Czech Republic. European Journal of Remote Sensing 52, S1: 108–122. https://doi.org/10.1080/22797254.2018.1482524

Zastosowanie przenośnego kolorymetru w identyfikacji poziomu mollic i typów gleb z diagnostycznym poziomem mollic

Słowa kluczowe

Barwa gleby
Kolorymetr
Atlas barw Munsella
Poziom mollic
Klasyfikacja gleb

Streszczenie

Identyfikacja kolorów gleb, mająca kluczowe znaczenie jako jedno z kryteriów diagnostycznych dla poziomu mollic i jednostek typologicznych opartych na obecności tego poziomu, zależy w pewnym stopniu od indywidualnej percepcji i doświadczenia badawcza. Przeprowadzono eksperyment porównujący identyfikację barwy 30 gleb wytworzonych z lessu i utworów aluwialnych, obejmujący rozpoznanie barwy w terenie przez doświadczonego eksperta z użyciem standardowego atlasu barw Munsella, rozpoznanie barw tych samych gleb w laboratorium przez cztery grupy ekspertów, a także z wykorzystaniem elektronicznego przenośnego kolorymetru. Terenowa identyfikacja poziomu mollic przez pojedynczego gleboznawcę, bazująca na rozpoznaniu jasności i nasycenia barwy (na podstawie atlasu Munsella), może być zawyżona do 17% w porównaniu do średniej z identyfikacji wykonanej przez grupę gleboznawców w warunkach laboratoryjnych. Różnice między podgrupami ekspertów były statystycznie nieistotne; jednakże zaobserwowano słabą tendencję do zaniżania jasności (na sucho) oraz zawyżania nasycenia (na wilgotno) wraz z wiekiem lub doświadczeniem badaczy (w kolejności: magistranci – doktoranci – doktorzy – profesorowie). Nie stwierdzono statystycznie istotnych różnic w identyfikacji kolorów w zależności od płci eksperta. Elektroniczny pomiar barwy gleby wykonany z użyciem przenośnego kolorymetru potwierdził zawyżenie terenowej identyfikacji poziomu mollic o 17% i 7%, odpowiednio w stosunku do rozpoznania indywidualnego oraz średniej z rozpoznania przez grupę ekspertów. Przeprowadzony eksperyment potwierdził wysoką przydatność standardowego przenośnego kolorymetru do weryfikacji barw wymaganych dla poziomu mollic, w szczególności w sytuacji, gdy barwa gleby (głównie jasność barwy) jest zbliżona do wartości granicznej, a jej poprawne rozpoznanie w dużym stopniu zależy od doświadczenia badacza.