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Wydział Nauk o Ziemi i Gospodarki Przestrzennej

Katedra Gleboznawstwa i Kształtowania Krajobrazu

Rola edukacji gleboznawczej w kształtowaniu świadomości ekologicznej społeczeństw

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Dr hab. Przemysławowi Charzyńskiemu, prof. UMK,

za opiekę naukową, cenne uwagi, wyrozumiałość, cierpliwość i zaufanie,

a także

pracownikom Katedry Gleboznawstwa i Kształtowania Krajobrazu,

za wszechstronną pomoc i życzliwą atmosferę

serdecznie DZIĘKUJĘ

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1. *Urbańska M., Charzyński P., Kolejka J., Yilmaz D., Sahin S., Peter K., Gatsby H., 2022. Environmental Threats and Geographical Education: Students' Sustainability Awareness—Evaluation. Education Sciences 12 (1)*; (Cite Score - 2.9; SJR - 0.518; SNIP - 1.314; punktacja MNiSW: 70 punktów). *https://doi.org/10.3390/educsci12010001*
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4. *Urbańska, M., Świtoniak, M., Charzyński, P., 2021. Rusty soils—"Lost" in school education. Soil Science Annual 72(4)*; (Cite Score - 2.6; SJR - 0.363; SNIP - 0.799; punktacja MNiSW: 70 punktów; autor korespondencyjny). *https://doi.org/10.37501/soilsa/143466*
5. *Urbańska, M., Charzyński, P., Świtoniak, M., 2022. Alluvial soils - a stream into soil awareness. Soil Science Annual 73(4), 152484*; (Cite Score - 2.6; SJR - 0.363; SNIP - 0.799; punktacja MNiSW: 70 punktów; autor korespondencyjny). *https://doi.org/10.37501/soilsa/152484*

Popularyzacja gleboznawstwa

6. *Urbańska, M., Charzyński, P., 2021. SUITMAs as an archive of the human past: educational implications. Journal of Soils and Sediments 21, 928–1937;* (Impact Factor: 3.536; Cite Score - 6.0; SJR - 0.826; SNIP -1.092; punktacja MNiSW: 100 punktów). *https://doi.org/10.1007/s11368-021-02886-2*

Wstęp i cel badań

Gleby są istotnym komponentem lądowych ekosystemów Ziemi. Zrozumienie procesów glebotwórczych, jak również funkcji gleb oraz ich przestrzennego zróżnicowania umożliwia pełniejsze poznanie i wnikliwą obserwację relacji zachodzących między biotycznymi a abiotycznymi elementami środowiska przyrodniczego. Nauczanie treści gleboznawczych jest zatem przekazywaniem umiejętności pozwalających na całościowe rozumienie zjawisk przyrodniczych oraz przygotowaniem do świadomego i racjonalnego korzystania z zasobów środowiska w kontekście zrównoważonego rozwoju.

Nauka o środowisku oferuje możliwość rozwijania umiejętności rozumienia nie tylko procesu kształtowania się krajobrazów i interakcji między człowiekiem a przyrodą, ale także konsekwencji, które wynikają z codziennych decyzji podejmowanych zarówno przez decydentów, jak i ogół społeczeństwa. Znaczenie świadomości społecznej dotyczącej roli gleb zostało uwypuklone przez Komisję Europejską (EC, 2006, 2012), Departament Środowiska, Żywności i Spraw Wiejskich (Department for Environment, Food and Rural Affairs), (Defra, 2004) w Wielkiej Brytanii, amerykańską agencję rządową NRCS (Natural Resources Conservation Service; United States Department of Agriculture) oraz przez inne podmioty i organizacje w wielu krajach świata. Gleby powinny być uważane za zasoby nieodnawialne (Friend, 1992; Cruse et al., 2013), dlatego tak istotny jest proces właściwego nauczania podstaw gleboznawstwa.

Na funkcjonowanie współczesnych społeczeństw wpływają między innymi zagrożenia naturalne, zmiany klimatu, zaburzenia dostaw energii, migracje, użytkowanie gruntów, urbanizacja i konflikty. Wymienione czynniki można podzielić na naturalne i antropogeniczne. Geografia stanowi rodzaj pomostu łączącego nauki przyrodnicze i społeczne oraz zachęca do całościowych badań nad wieloma zagadnieniami. Edukacja gleboznawcza może być doskonałym narzędziem przekazywania informacji na temat stanu środowiska, ponieważ daje wyraźny obraz jego funkcjonowania, i, przy właściwym doborze metod i treści, pozwala na ukształtowanie prośrodowiskowej postawy i gotowości zmierzenia się nie tylko z aktualnymi problemami, ale także tymi, które trzeba będzie rozwiązywać w przyszłości. Gleby stanowią ukryty, zazwyczaj niewidoczny dla oka element środowiska. Często określane jako „ziemia" czy „grunt", kojarzone jedynie z działalnością rolniczą, bywają uważane za nieciekawe i mało ekscytujące. Niewystarczająca edukacja gleboznawcza może skutkować postrzeganiem pokrywy glebowej jako mniej ważnej niż powietrze, woda czy skały (Urbańska i. in., 2022).

W niniejszym zbiorze wskazano wybrane artykuły autorki, których tematyka związana jest z analizą edukacji gleboznawczej w ujęciu lokalnym, krajowym i globalnym. Celem badań była próba oceny poziomu edukacji gleboznawczej w wybranych krajach świata na podstawie badań ankietowych oraz analizy treści gleboznawczych zamieszczonych w szkolnych podręcznikach geograficznych, biologicznych, a także tych z zakresu nauk o środowisku.

We wstępnej hipotezie założono, że nauczanie podstaw gleboznawstwa odbywa się w sposób nieadekwatny do potrzeb odbiorcy, a przekazywane treści nie odpowiadają aktualnemu stanowi wiedzy i nie korespondują z kształceniem opartym na przekazywaniu zasad zrównoważonego rozwoju. Zrealizowano zadania badawcze dotyczące możliwości wypracowania metod i technik poprawiających transfer wiedzy gleboznawczej. Uzyskane rezultaty pozwoliły na podjęcie próby określenia roli edukacji gleboznawczej w kształtowaniu rozumienia funkcjonowania środowiska przyrodniczego w i opracowanie rozwiązań prowadzących do zwiększenia świadomości ekologicznej odbiorcy w zakresie gleboznawstwa. Metodyka badań została przedstawiona w poszczególnych pracach zbioru.

Charakterystyka zbioru publikacji

Ocena poziomu edukacji gleboznawczej

W zbiorze zgromadzono najważniejsze publikacje autorki poświęcone tematyce edukacji gleboznawczej. Zestawiono je w kolejności przyczynowo-skutkowej odpowiadającej etapom prowadzonych badań: a) ocena poziomu edukacji gleboznawczej i wskazanie uchybień oraz pozytywnych aspektów w nauczaniu podstaw gleboznawstwa; b) propozycje zmian w zakresie edukacji gleboznawczej; c) popularyzacja gleboznawstwa.

Właściwa edukacja należy do najskuteczniejszych metod zapobiegania lub przynajmniej minimalizowania wielu problemów środowiskowych. Jednym z celów edukacji przyrodniczej jest uświadomienie konieczności ochrony zasobów Ziemi i środowiska poprzez wprowadzenie pozytywnych zmian w zachowaniach społecznych oraz zapewnienie aktywnego udziału w poszukiwaniu rozwiązań pojawiających się, czy narastających problemów. Szczególną i ważną rolę w tym procesie odgrywa edukacja geograficzna. Niestety, proces kształcenia wraz z towarzyszącymi mu formalnymi ograniczeniami nie zawsze jest w stanie sprostać wyzwaniom stawianym przez promowanie zasad zrównoważonego rozwoju. Istnieje wiele przeszkód, które sprawiają, że nauczyciele nie są w stanie przekazać wystarczającej wiedzy i umiejętności (np. niewłaściwe metody kształcenia, niewystarczająca liczba godzin lekcyjnych przeznaczona na realizację treści, trudna terminologia, brak odpowiednich narzędzi edukacyjnych). Nie wszystkie zagadnienia dotyczące środowiska przyrodniczego omawiane są z należytą uwagą. W związku z tym próba oceny poziomu wiedzy gleboznawczej oferowanej w szkole ponadpodstawowej wydała się autorce szczególnie istotna i warta podjęcia. Wyniki analiz zamieszczono w pierwszym artykule niniejszego zbioru (Urbańska et al., 2022).

Celem publikacji pt. *Environmental Threats and Geographical Education: Students' Sustainability Awareness—Evaluation* jest analiza koncepcji zrównoważonego rozwoju w nauczaniu geografii, porównanie najpopularniejszych metod dydaktycznych pod kątem skuteczności, wskazanie trudności w kształceniu geograficznym, uwypuklenie mocnych i słabych stron edukacji geograficznej, a także zaproponowanie zmian prowadzących do zwiększenia świadomości stosowania zasad zrównoważonego rozwoju. Z przeprowadzonych badań wynika, że uczniowie otrzymują znacząco mniej informacji na temat zagadnień związanych z pokrywą glebową (degradacja i zanieczyszczenie gleb, erozja, zmniejszanie bioróżnorodności) niż z zakresu pozostałych sfer Ziemi. Ponadto, dział edukacyjny – *Gleby i biosfera* jest postrzegany jako najbardziej nieatrakcyjny zarówno przez uczniów, jak i nauczycieli. Uczniowie nie uzmysławiają sobie roli, jaką gleba odgrywa w życiu człowieka i funkcjonowaniu środowiska, a bez takiej świadomości nie będą w stanie w pełni zrozumieć zasad zrównoważonego rozwoju ani też właściwie rozwiązywać problemów środowiskowych. Uczelnie wyższe, media, a także politycy i naukowcy powinni być zaangażowani w skuteczniejszą promocję problematyki gleboznawstwa, aby poziom znajomości tych zagadnień zrównał się z poziomem wiedzy na temat innych problemów środowiska naturalnego. Współczesne pokolenie jest świadome wielu zagrożeń i problemów, takich jak globalne ocieplenie i zanieczyszczenie powietrza, ale nie jest dostatecznie poinformowane o zasobach glebowych i ich ochronie jako równie ważnych dla egzystencji człowieka. Problematyka gleboznawcza jest dla nich nieatrakcyjna. Takiego stanu rzeczy nie można akceptować. Gleby są zasobem Ziemi ukrytym przed ludzkimi oczami, ale nie oznacza to, że nie istnieją. Wręcz przeciwnie, odgrywają bardzo istotną rolę, jako ważny komponent ekosystemu, zapewniając ludzkości m.in. większość pożywienia.

W kolejnej publikacji: *A Global Perspective on Soil Science Education at Third Educational Level; Knowledge, Practice, Skills and Challenges* autorka podejmuje próbę wskazania nieprawidłowości i braków , jak również pozytywnych aspektów edukacji gleboznawczej. Dane zebrano z 43 krajów zamieszkałych łącznie przez 62% ludności świata. Proces gromadzenia informacji wymagał zaangażowania gleboznawców i nauczycieli, a także analizy podręczników szkolnych. Narzędzie pozwalające ocenić treści gleboznawcze dostępne w podręcznikach zostało skierowane do naukowców, którzy zostali poproszeni o ocenę i charakterystykę wiedzy gleboznawczej zawartej w podręcznikach szkolnych w ich krajach, a także o konsultacje z nauczycielami odpowiedzialnymi za edukację gleboznawczą. Celem było porównanie globalnego poziomu kształcenia w zakresie podstaw nauk o glebach na poziomie szkoły średniej. Zaproponowano ilościowy wskaźnik w celu oceny łącznego wpływu uzyskanych wyników oraz dostarczenia informacji dotyczących skuteczności treści podręczników w osiągnięciu trzech operacyjnych celów edukacyjnych: uczeń *zna*, *rozumie*, *potrafi*. Wykazano, że na świecie istnieje wiele problematycznych kwestii i rozbieżności z zakresu gleboznawstwa w podręcznikach na poziomie szkoły średniej. Obecne pokolenie uczniów w wielu krajach nie jest świadome znaczenia gleby. Istnieje potrzeba opracowania odpowiednich wytycznych metodologicznych i instruktażowych, aby uświadomić przyszłym pokoleniom istotność i funkcje pokrywy glebowej. Zagadnienia teoretyczne (cel operacyjny: uczeń *wie*) z zakresu znajomości faktów (profil glebowy, geneza gleby, pokrywa glebowa kraju i świata itp.) powinny być omawiane w powiązaniu z zagadnieniami opartymi na rozumieniu procesów (cel operacyjny: uczeń *rozumie*) i umiejętności zastosowania tej wiedzy w praktyce (cel operacyjny: uczeń *potrafi*). Znacznie większy nacisk należy położyć na kształcenie w zakresie funkcji i roli gleb w środowisku (jest to kluczowy aspekt ze względu na wielozadaniowość pokrywy glebowej). Uczniowie powinni umieć wyciągać wnioski i dostrzegać zależności pomiędzy typami gleb i ich zagospodarowaniem (zwiększenie świadomego zarządzania zasobami glebowymi). Porównując cele edukacyjne: uczeń *zna*, *rozumie*, *potrafi* oraz współzależności między ich realizacją, można stwierdzić, że Finlandia, Włochy, Rosja i Mongolia oferują w swoich podręcznikach to, co można określić jako *optymalną edukację gleboznawczą*. Wyważone proporcje pomiędzy poszczególnymi tematami z zakresu gleboznawstwa, nacisk na realizację najważniejszych celów oraz zwrócenie szczególnej uwagi na konieczność rozwijania u uczniów umiejętności dostrzegania faktów, zagrożeń i korzyści związanych z gospodarowaniem glebą stawiają te kraje w elitarnej pozycji w zakresie edukacji gleboznawczej.

Propozycje zmian w zakresie edukacji gleboznawczej

W kolejnych artykułach (*Digital media in soil education; Rusty soils—"Lost" in school education.; Alluvial soils - a stream into soil awareness*) celem jest przedstawienie propozycji zmian w zakresie edukacji gleboznawczej. Praca pt. *Digital media in soil education* koncentruje się na porównaniu narzędzi multimedialnych wykorzystywanych do wspierania nauczania gleboznawstwa oraz ocena tendencji ich wykorzystywania w procesie edukacyjnym. Należy podkreślić, że współczesny uczeń wymaga interakcji, rywalizacji i możliwości zaistnienia w wirtualnej rzeczywistości. Media społecznościowe i gry zmieniły sposób, w jaki młodzi ludzie postrzegają świat. Dotyczy to również procesu edukacji gleboznawczej, który powinien być wspierany przez odgrywanie ról i elementy grywalizacji. Ponieważ gracze dobrowolnie spędzają długie godziny grając w gry, to naturalne wydaje się wykorzystanie tej silnej motywacji, aby zwiększyć skuteczność edukacyjną zarówno w sali lekcyjnej, jak i podczas zajęć terenowych związanych geografią i gleboznawstwem.

W publikacji *Rusty soils—"Lost" in school education* autorka analizuje dostępność informacji na temat gleb rdzawych na poziomie kształcenia w szkołach ponadpodstawowych oraz diagnozuje stan wiedzy o tych glebach w szerokim środowisku pozaakademickim. Realizowane są następujące zadania badawcze: przegląd (kwerenda) i ocena informacji zawartych w podręcznikach szkolnych i na edukacyjnych stronach internetowych; sprawdzenie stanu wiedzy społeczeństwa na temat gleb rdzawych oraz ocena przydatności omawianych gleb w procesie edukacyjnym - zwłaszcza w kontekście zajęć terenowych dla uczniów szkół średnich. Gleby rdzawe zajmują duży procent powierzchni Polski, są one zatem łatwo dostępne, a ze względu na piaszczysty materiał, nie przysparzają trudności podczas prac związanych z wykopaniem odkrywki glebowej. Są intuicyjnie i łatwo rozpoznawalne, a ich geneza jest stosunkowo prosta do wyjaśnienia. Cieszą się dużym zainteresowaniem wśród społeczeństwa, co może być związane z nazwą tych gleb (rdzawe) nawiązującą do innych, dobrze znanych procesów. Niestety, rzadko stanowią element edukacji szkolnej (podobnie jak gleby płowe), a przecież mogłyby z powodzeniem przyczynić się do zwiększenia społecznej świadomości ekologiczno-glebowej.

Celem artykułu *Alluvial soils - a stream into soil awareness* jest diagnoza stanu wiedzy uczniów szkół średnich ogólnokształcących województwa kujawsko-pomorskiego na temat mad oraz ocena przydatności tych gleb w popularyzacji gleboznawstwa. Głównymi metodami badawczymi zastosowanymi w pracy była kwerenda podręczników geografii i źródeł internetowych oraz ankietowa ankieta wśród uczniów. Wyniki badań wskazują, że informacje o glebach aluwialnych są powszechnie dostępne. Świadomość wartości ekologicznej tych gleb na terenie województwa kujawsko-pomorskiego jest wysoka. Respondenci prawidłowo oceniają przydatność mad i potrafią wskazać sposoby zwiększenia społecznej świadomości gleboznawczej. Wśród ankietowanych panuje przekonanie o potrzebie zmian w edukacji gleboznawczej, zwłaszcza w zakresie zajęć pozalekcyjnych i pozaszkolnych. Propozycje takich działań zostały zawarte w niniejszej publikacji.

Popularyzacja gleboznawstwa

W publikacji *SUITMAs as an archive of the human past: educational implications* celem jest przedstawienie pokrywy glebowej poprzemysłowego terenu byłych zakładów chemicznych "Polchem" (Toruń) w ujęciu kulturowych funkcji gleb, 70-letniej historii technologii produkcji oraz infrastruktury przemysłowej i jej roli w życiu pracowników fabryki. Podjęto próbę odpowiedzi na pytanie, czy gleby poprzemysłowe mogą być interesującymi obiektami edukacyjnymi dla naukowców, uczniów i studentów oraz ciekawym uzupełnieniem oferty turystycznej miasta. Badany teren może być postrzegany jako świadectwo działalności przemysłowej wraz z historią zapisaną w tamtejszej pokrywie glebowej. Według Fielda (Field et al., 2017), miejsca tego typu mogłyby stanowić odpowiednią bazę dla nauczania gleboznawstwa w modelu który wykracza poza tradycyjne nauczanie. Publikacja *SUITMAs as an archive of the human past: educational implications* powstała w oparciu o analizę artefaktów glebowych, materiałów fotograficznych i studiów literaturowych, koncentrujących się na glebach technogenicznych, oraz historii fabryki "Polchem" w powiązaniu z zagadnieniami z zakresu turystyki i archeologii przemysłowej. Stwierdzono, że w pokrywie glebowej "Polchemu", w postaci artefaktów – śladów przemysłowej działalności, zapisana została historia zakładu. Takie miejsce mogłyby stać się żywym laboratorium edukacji gleboznawczej, ponieważ na tym terenie istnieje wiele możliwości dostarczenia informacji o procesie indukowanej antropopresją modyfikacji gleby, jej degradacji i ochrony. Ciekawym aspektem jest możliwość zaintrygowania odbiorcy artefaktami, które często postrzegane są jako zwykłe odpady. Kulturowe funkcje gleb mogłyby poszerzyć turystyczną i edukacyjną ofertę miasta, a także stać się miejscem badań naukowych skierowanych do różnych grup odbiorców.

Podsumowanie

Zagadnienie edukacji gleboznawczej jest tematem niezbyt chętnie podejmowanym przez badaczy i bardzo skromnie reprezentowanym w literaturze przedmiotu. Dotyczy to zwłaszcza poziomu szkoły średniej, a więc etapu, na którym kształtują się plany zawodowe uczniów i dokonywane są wybory w zakresie kierunku dalszego kształcenia, a także postawy wobec społeczeństwa i środowiska. W literaturze dostępnych jest kilka analiz i propozycji dotyczących edukacji przedszkolnej i wczesnoszkolnej w tym zakresie (Capra et al., 2017; Xylander and Zumkowski-Xylander, 2018; Xylander, 2020), trudno jednak o rzetelne analizy porównawcze dotyczące kształcenia na poziomie szkoły średniej. Powstało kilka projektów i badań charakteryzujących nauczanie gleboznawstwa na poziomie akademickim (Field et al., 2011; Hartemink et al., 2008, 2013; Smith et al., 2020;), ale są to nieliczne prace, dotyczące wybranych zagadnień. Propozycje zmian i aktywności w zakresie nauczania podstaw gleboznawstwa na poziomie szkoły średniej dotyczą raczej edukacji nieformalnej, a zasięg ich oddziaływania jest niewielki (Hirai and Mori, 2020; Fritz, 2020; Reyes-Sanches, 2020).

Problemy edukacji gleboznawczej dotyczą większości krajów świata. Społeczeństwo nie jest wystarczająco świadome zagrożeń wynikających z degradacji gleb, nie zna ich funkcji i, tym samym, może nie być w stanie właściwie i umiejętnie gospodarować zasobami glebowymi. Wiele przykładów w historii niewłaściwego użytkowania gleb przyczyniło się do wprowadzenia wytycznych dotyczących ochrony zasobów glebowych i rozpoczęcia programów szkoleniowych dla rolników. Okres „Dust Bowl" z lat 30-tych XX wieku, kiedy to dziewiętnaście stanów na obszarze Wielkich Równin w Stanach Zjednoczonych zostało dotkniętych katastrofą ekologiczną, będącą skutkiem suszy i silnej erozji wiatrowej gleb (za sprawą bezwodnych burz pyłowych zwanych „dusterami",) zaowocował wprowadzeniem zmian na szczeblu federalnym i stał się przyczynkiem do właściwej edukacji.

Wyniki analiz przedstawionych przez autorkę pozwalają na jednoznaczne stwierdzenie wyraźnych braków w zakresie kształcenia gleboznawczego. W porównaniu z innymi zagadnieniami omawianymi w ramach kształcenia przyrodniczego (hydrosfera, atmosfera), gleby traktowane są jako mniej istotny komponent środowiska. Przejawia się to w mniejszej liczbie godzin lekcyjnych przeznaczonych na wprowadzenie podstaw gleboznawstwa, fragmentarycznych i nieuporządkowanych treściach oraz braku uwypuklenia aplikacyjności omawianych zagadnień. Informacje z zakresu gleboznawstwa zawarte w podręcznikach geografii, biologii, czy przyrody, a więc przedmiotów związanych z edukacją gleboznawczą są przestarzałe i niezgodne z aktualnym stanem wiedzy. Metody pracy nie są dostosowane do potrzeb współczesnego odbiorcy. Przedstawiciel cyfrowego pokolenia jest niezwykle wymagający w zakresie formy przekazywania treści ze względu na rzeczywistość, która go otacza i do której jest przyzwyczajony. Można nazwać go „cyfrowym tubylcem" (ang. *digital native*), podczas gdy nauczyciel bywa zwykle „cyfrowym imigrantem" (ang. *digital immigrant*), (Prensky, 2001). Podział ten doskonale określa poziom umiejętności wykorzystania technologii i komunikacji multimedialnej u osób, które się nimi posługują.

Lekcje szkolne bazujące na tradycyjnych środkach dydaktycznych wydają się być dla takiego odbiorcy przestarzałe i nudne, a pamięciowy sposób przyswajania informacji budzi szczerą niechęć. Podstawowym narzędziem poszerzania wiedzy dla młodego człowieka są nowe technologie pozwalające na sprawne funkcjonowanie w wirtualnym świecie (Kulik, 2015). Wyniki ekspertyz dotyczących zmian w sposobach uczenia się osób urodzonych po 1990 r. sugerują, że pokolenie „cyfrowych tubylców" można nazwać również pokoleniem C albo 7C, od słów, które określają ich zachowania: *Connected*, *Communicating*, *Content-centric*, *Computerized*, *Celebritized*, *Community-oriented*, *Clicking* (połączone, komunikujące się, skomputeryzowane, mające silną potrzebę publicznego zaistnienia, samodzielnie wybierające i tworzące interesujące ich treści, zainteresowane internetowymi społecznościami, ciągle klikające), (Morbitzer, 2014). Uważa się, że dla pokolenia „cyfrowych tubylców" świat wirtualny jest naturalnym środowiskiem funkcjonowania i jest ono ukształtowane przez kulturę obrazu, podczas gdy dla „cyfrowych imigrantów", sprzed epoki internetowej, podstawą był tekst drukowany. Z uwagi na to, że tekst oddziałuje na intelekt a obraz na emocje, współcześni uczniowie są bardziej emocjonalni niż racjonalni (Morbitzer, 2014). Czy w takim układzie, mając do dyspozycji dwie do trzech godzin lekcyjnych przeznaczonych na edukację gleboznawczą, można spróbować ten czas uatrakcyjnić stosując dostępne środki multimedialne czy też elementy grywalizacji? Wydaje się to trudne, niemniej jednak, przy właściwym doborze środków, możliwe do realizacji. Jest to jeden ze sposobów wzbogacenia przekazywanych informacji i motywowania odbiorcy do czynnego udziału w zajęciach (Urbańska et al., 2019). Aktywizacja ucznia w zakresie edukacji gleboznawczej podniesie nie tylko jego zaangażowanie w proces edukacyjny, ale również przyczyni się do wzrostu poziomu jego wiedzy o roli, jaką w środowisku zajmuje właśnie pokrywa glebowa.

Niemniej jednak, wyrywkową wiedzę gleboznawczą, którą uzyskają uczniowie stanowią treści zawarte w podstawach programowych, rozkładach nauczania i wytycznych edukacyjnych. Należy zauważyć, że informacje zawarte w podręcznikach, stanowią bazę wiedzy nie tylko dla ucznia, ale także dla nauczyciela, poprzez którego odbywa się transfer wiedzy w procesie edukacyjnym. Omawiane badania wskazują na wyraźną lukę w edukacji gleboznawczej, a także na brak wystarczających, rzetelnych opracowań literaturowych dotyczących tej edukacji (Charzyński et al., 2022). Należy podkreślić, że przeprowadzone analizy koncentrują się zarówno na wiedzy uczniów, jak również na treści podręczników których wiedzę uczeń może potencjalnie zdobyć i mają charakter globalny.

Rezultaty badań nad edukacją gleboznawczą uzyskane przez autorkę przyczyniły się do poszerzenia dotychczasowej wiedzy na temat zróżnicowania i specyfiki tej edukacji. Rzetelne i wnikliwe analizy o międzynarodowym zasięgu charakteryzują się nowatorstwem i innowacyjnością zarówno w zakresie zastosowanych mierników, jak i propozycji rozwiązań dostrzeżonych problemów. Omawiane publikacje stanowią unikatowy zbiór wiedzy na temat kształcenia gleboznawczego i jego roli w kształtowaniu świadomości ekologicznej społeczeństw. Zebrane dane mogą wspomagać procesy decyzyjne w zakresie konstruowania ram programowych nauczania podstaw gleboznawstwa na szczeblach krajowych w oparciu o wspólne, międzynarodowe wytyczne oparte na zasadach zrównoważonego rozwoju.

Do zachowania zasobów Ziemi potrzebna jest zrównoważona edukacja geograficzna, a właściwe nauczanie podstaw gleboznawstwa powinno być jej bardzo ważnym elementem. Ochrona gleby jest niezbędna do prawidłowego funkcjonowania każdego społeczeństwa. Niewłaściwe zarządzanie zasobami pedosfery skutkowało już wielokrotnie upadkiem wielu społeczeństw (Spurr, 1986; Van Andel et al., 1990; Sandor and Eash, 1991; Zangger, 1992; Runnels, 1995). Zmiany zachodzące na przestrzeni czasu w naszym naturalnym otoczeniu są odciśnięte w pokrywie glebowej. Ten historyczny zapis daje pewność, że utrzymanie współczesnej cywilizacji będzie zależało w takim samym stopniu od ochrony gleby, jak od innowacji (Montgomery, 2007). Analiza i ocena stanu edukacji gleboznawczej w skali światowej, krajowej i lokalnej zawarta w pracach niniejszego zbioru przyczyniła się do zmiany kierunku kształcenia gleboznawczego. Pozwoliła także zaproponować zmiany w oferowanej edukacji gleboznawczej mające kluczowe znaczenie dla rozwoju świadomych ekologicznie i odpowiedzialnych środowiskowo obywateli świata.

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Streszczenie

Gleby są istotnym komponentem lądowych ekosystemów Ziemi. Zrozumienie procesów glebotwórczych, jak również funkcji gleb oraz ich przestrzennego zróżnicowania umożliwia pełniejsze poznanie i wnikliwą obserwację relacji zachodzących między biotycznymi a abiotycznymi elementami środowiska przyrodniczego. Nauczanie treści gleboznawczych jest zatem przekazywaniem umiejętności pozwalających na całościowe rozumienie zjawisk przyrodniczych oraz przygotowaniem do świadomego i racjonalnego korzystania z zasobów środowiska w kontekście zrównoważonego rozwoju.

Prezentowany zbiór zawiera wybrane artykuły autorki, których tematyka związana jest z analizą edukacji gleboznawczej w ujęciu lokalnym, krajowym i globalnym. Celem badań była próba oceny poziomu edukacji gleboznawczej w wybranych krajach świata na podstawie badań ankietowych i analizy treści z zakresu gleboznawstwa zawartych w podręcznikach szkolnych. We wstępnej hipotezie założono, że nauczanie podstaw gleboznawstwa na poziomie szkoły średniej odbywa się w sposób nieadekwatny do potrzeb odbiorców, a przekazywane treści nie odpowiadają aktualnemu stanowi wiedzy i nie odpowiadają edukacji opartej na przekazywaniu zasad zrównoważonego rozwoju. Zrealizowano zadania badawcze dotyczące możliwości wypracowania metod i technik poprawiających transfer wiedzy gleboznawczej. Uzyskane rezultaty pozwoliły na podjęcie próby określenia roli edukacji gleboznawczej w kształtowaniu rozumienia funkcjonowania środowiska przyrodniczego w i opracowanie rozwiązań prowadzących do zwiększenia świadomości ekologicznej odbiorcy w zakresie gleboznawstwa. Metodyka badań została przedstawiona w poszczególnych pracach zbioru.

Rezultaty badań nad edukacją gleboznawczą uzyskane przez autorkę przyczyniły się do poszerzenia dotychczasowej wiedzy na temat zróżnicowania i specyfiki tej edukacji. Rzetelne i wnikliwe analizy o międzynarodowym zasięgu charakteryzują się nowatorstwem i innowacyjnością zarówno w zakresie zastosowanych mierników, jak i propozycji rozwiązań dostrzeżonych problemów. Omawiane publikacje stanowią unikatowy zbiór wiedzy na temat kształcenia gleboznawczego i jego roli w kształtowaniu świadomości ekologicznej społeczeństw. Zebrane dane mogą wspomagać procesy decyzyjne w zakresie konstruowania ram programowych nauczania podstaw gleboznawstwa na szczeblach krajowych w oparciu o wspólne, międzynarodowe wytyczne oparte na zasadach zrównoważonego rozwoju.

Analiza i ocena stanu edukacji gleboznawczej w skali globalnej, krajowej i lokalnej zawarta w publikacjach niniejszego zbioru wskazała kierunek niezbędnych zmian w zakresie kształcenia gleboznawczego. Umożliwiła także zaproponowanie rozwiązań kluczowych dla rozwoju świadomych ekologicznie i odpowiedzialnych środowiskowo obywateli świata.

Summary

Soils are an important component of the Earth's terrestrial ecosystems. Understanding the soil-forming processes, as well as the function of soils and their spatial variation, enables a more complete understanding and insight into the relationship between biotic and abiotic elements of the natural environment. Teaching soil science content is therefore the transfer of skills that allow a holistic understanding of natural phenomena and preparation for the conscious and rational use of environmental resources in the context of sustainable development.

Environmental science offers the opportunity to develop the ability to understand not only the process of landscape formation and the interaction between humans and nature, but also the consequences that result from everyday decisions made by both decision-makers and the general public. The importance of public awareness of the role of soils has been highlighted by the European Commission (EC, 2006, 2012), the Department for Environment, Food and Rural Affairs, (Defra, 2004) in the UK, the US government agency NRCS (Natural Resources Conservation Service; United States Department of Agriculture) and by other entities and organizations in many countries around the world. Soils should be considered a non-renewable resource (Friend, 1992; Cruse et al., 2013), which is why the process of properly teaching the basics of soil science is so important.

The functioning of modern societies is affected by natural hazards, climate change, energy supply disruptions, migration, land use, urbanization and conflict, among other factors. The aforementioned factors can be divided into natural and anthropogenic. Geography is a kind of bridge between the natural and social sciences and encourages holistic study of many issues. Soil science education can be an excellent tool for conveying information on the state of the environment, as it provides a clear picture of how it functions, and, with the right choice of methods and content, allows the formation of a pro-environmental attitude and a willingness to face not only current problems, but also those that need to be solved in the future.

Soils are a hidden, usually invisible element of the environment. Often referred to as "dirt" or "ground," and associated only with agricultural activities, they are sometimes considered uninteresting and unexciting. Insufficient soil science education can result in the perception that soil cover is less important than air, water or rocks (Urbanska et al., 2022).

This collection identifies selected articles by the author, the topics of which are related to the analysis of soil science education in local, national and global terms. The purpose of the research was to try to assess the level of soil science education in selected countries of the world on the basis of surveys and analysis of soil science content included in school textbooks on geography, biology, as well as those on environmental science. In the preliminary hypothesis, it was assumed that the teaching of soil science basics is done in a way that is inadequate to the needs of the audience, and the content provided does not correspond to the current state of knowledge and does not correspond to education based on the transmission of sustainable development principles. Research tasks were carried out

on the possibility of developing methods and techniques to improve the transfer of soil science knowledge. The results made it possible to try to determine the role of soil science education in shaping the understanding of the functioning of the natural environment in and to develop solutions leading to increased environmental awareness of the recipient in the field of soil science. The research methodology is presented in the individual papers of the collection.

The issue of soil science education is a topic that is not very readily taken up by researchers and is very modestly represented in the literature on the subject. This is especially true at the secondary school level, that is, the stage at which students' career plans are formed and choices are made regarding the direction of further education, as well as attitudes toward society and the environment. There are several analyses and proposals available in the literature on preschool and early childhood education in this regard (Capra et al., 2017; Xylander and Zumkowski-Xylander, 2018; Xylander, 2020), but it is difficult to find reliable comparative analyses on secondary education. There have been a few projects and studies characterizing the teaching of soil science at the university level (Field et al., 2011; Hartemink et al., 2008, 2013; Smith et al., 2020;), but these are a small number of works, dealing with selected issues. Proposals for change and activity in teaching the basics of soil science at the high school level are more about informal education, and their reach is small (Hirai and Mori, 2020; Fritz, 2020; Reyes-Sanches, 2020).

Soil science education problems affect most countries of the world. The public is not sufficiently aware of the dangers of soil degradation, does not know its functions and, thus, may not be able to properly and skillfully manage soil resources. Many examples in the history of improper use of soils have contributed to the introduction of guidelines for the protection of soil resources and the start of training programs for farmers. The Dust Bowl period of the 1930s, when nineteen states in the Great Plains area of the United States were hit by an environmental disaster as a result of drought and severe wind erosion of soils (due to waterless dust storms known as "dusters,") resulted in the introduction of changes at the federal level and became a cause for proper education.

The results of the analyses presented by the author make it clear that there are clear deficiencies in soil science education. Compared to other issues discussed in natural science education (hydrosphere, atmosphere), soils are treated as a less important component of the environment. This manifests itself in the smaller number of lesson hours allocated to the introduction of the basics of soil science, fragmented and unstructured content, and a lack of emphasis on the applicability of the issues discussed. Soil science information contained in geography, biology, or nature textbooks, i.e. subjects related to soil science education, is outdated and inconsistent with the current state of knowledge. The working methods are not adapted to the needs of a modern audience. The representative of the digital generation is extremely demanding in terms of the form of content transfer due to the reality that surrounds him and to which he is accustomed. He can be called a "digital native", while the teacher tends to be a "digital immigrant" (Prensky, 2001).This division perfectly determines the level of skill in the use of technology and multimedia communication in those who use them. School lessons based on traditional didactic means seem outdated and boring to such an audience, and the memory-based way of assimilating information arouses sincere resentment. The primary tool for expanding knowledge for a young person are new technologies that allow them to function efficiently in the virtual world (Kulik, 2015). The results of expert studies on changes in the ways of learning of people born after 1990 suggest that the generation of ‘digital natives’ can also be called Generation C or 7C, from the words that describe their behavior: Connected, Communicating, Content-centric, Computerized, Celebritized, Community-oriented, Clicking (Morbitzer, 2014). It is believed that for the "digital natives" generation, the virtual world is the natural operating environment and is shaped by image culture, while for the "digital immigrants", before the Internet age, the basis was printed text. Because text affects the intellect and image affects the emotions, modern students are more emotional than rational (Morbitzer, 2014). In such a set-up, with two to three classroom hours allocated to soil science education, is it possible to try to make this time more attractive by using available multimedia or gamification elements? It seems difficult, but nevertheless, with the right choice of means, possible to implement. This is one way to enrich the information provided and motivate the recipient to actively participate in the class (Urbanska et al., 2019). Activating the student in the field of soil science education will not only increase his involvement in the educational process, but also contribute to the level of his knowledge of the role that soil cover plays in the environment.

Nevertheless, the random soil science knowledge that students will obtain is the content contained in the core curriculum, teaching schedules and educational guidelines. It should be noted that the information contained in textbooks, is the knowledge base not only for the student, but also for the teacher, through whom the transfer of knowledge in the educational process takes place. The discussed studies indicate a clear gap in soil science education, as well as the lack of sufficient, reliable literature on this education (Charzynski et al., 2022). It should be emphasized that the analyses carried out focus both on the knowledge of students, as well as on the content of textbooks whose knowledge students can potentially acquire, and are global in nature.

Sustainable geographic education is needed to conserve the earth's resources, and proper teaching of soil science basics should be a very important part of it. Soil conservation is essential to the proper functioning of any society. Mismanagement of pedosphere resources has already resulted in the collapse of many societies on several occasions (Spurr, 1986; Van Andel et al., 1990; Sandor and Eash, 1991; Zangger, 1992; Runnels, 1995). Changes over time in our natural environment are imprinted in the soil cover. This historical record provides reassurance that the sustenance of modern civilization will depend as much on soil conservation as on innovation (Montgomery, 2007).

The results of the research on soil science education obtained by the author have contributed to expanding the existing knowledge of the diversity and specificity of this education. Insightful analyses and assessment of soil education on a global, national and local scale presented in this collection are characterized by novelty both in terms of the metrics used and proposals for solutions to the problems noticed. The publications in question constitute a unique body of knowledge about soil science education and its role in shaping the environmental awareness of societies. The collected data can support decision-making processes in constructing a curriculum framework for teaching soil science at the national level based on common international guidelines in line with sustainable development principles.

education sciences

MDPI

Article

Environmental Threats and Geographical Education: Students' Sustainability Awareness—Evaluation

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Abstract: Teaching geography creates an opportunity for the transfer of knowledge about environmental problems and ways of solving them. Teachers from the Czech Republic, Hungary, Poland, Romania, Turkey, and the United Kingdom indicated strengths and weaknesses of physical geography as well as the selected geographical concepts of: Maps/Cartography, Astronomy/The Earth in the Universe, Atmosphere, Hydrosphere, Endogenic processes, Exogenic processes, and Soils and biosphere. There was a variety in how confident students were around these topic areas. The main types of difficulties identified by the study were: too little time for implementation, difficult terminology, and lack of tools for the proper transfer of knowledge. Moreover, the attractiveness of individual issues for students also varies. The research clearly shows that students lack an awareness of problems related to the environment. There are considerable differences between the level of students' knowledge about climate change or air and water pollution (relatively high awareness of global warming) and issues related to soil and vegetation cover (low awareness of soil depletion, soil pollution, changing the boundaries of the occurrence of plant zones, etc.). To make people aware of the importance of environment, we should take care of education in relation to global challenge and sustainable development.

Keywords: sustainable education; pedosphere; geography; soil science education; environmental threats

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1. Introduction

The main purpose of education is to help people become ready for today and tomorrow [1]. According to the International Charter on Geographical Education, environmental science offers the opportunity to develop skills to understand and appreciate not only how landscapes are formed and how people and environments interact but also the consequences that arise from everyday spatial decisions made by both decision makers and laymen. Geography is concerned with human–environment interactions with crucial issues influencing societies such as natural hazards, impact of climate change, energy supplies, migration, land use, urbanization, etc. This is a kind of bridge connecting natural and social sciences and encourages the 'holistic' study of such issues [2–4]. There are many areas of geographic interest from physical to human geography. Most school subjects are included in the curricula in different levels of formal education. They are perceived by policy makers to be relevant to the goals of the particular education systems. Traditionally geography has been included in school curricula of formal education and has an important relationship with other subjects such as history (geography helps to explain historical events and political processes) or sociology (cultural developments and spatial relationships) [5]. Appropriate geographical education should ensure a more careful use of natural resources by people and increase environmental awareness by making positive changes in their knowledge, attitudes, and behaviors in relation to the environment [6–8].

The prevention of environmental problems before they appear seems to be the most effective solution. However, proper instruction is needed in this case. Moreover, there is a need for sustainable education encompassing all forms of learning about sustainable development [9]. The aim of this teaching is to benefit individuals, society, and all factors that make up the environment [10], as well as to protect nature by making positive changes in the behavior of individuals and by ensuring that they actively participate in finding solutions to problems. Geography education should play an important role in this process.

Teachers are important transmitters of knowledge also in the context of sustainability. A young student shapes his view of environmental problems on the base of information from various sources, but geography education should influence students' deep understanding of sustainability thinking on a local and global scale. Teaching methods and educational tools used in schools should meet the needs of the recipient. Teachers' self-efficacy is equally important. The ability of teachers to interpret the education program policy is widely recognized in the literature and is influenced by their cognitive skills [11–15]. These skills may be reinforcing or distracting with the ability to interpret and implement the education program policy. James P. Spillane [16] developed a framework that can help curriculum researchers understand these abilities which interact with contextual factors, obstructing processes development and the implementation of the curriculum. Teachers have an important responsibility to raise the environmental awareness of students through geographical education. From this point of view, the level of teachers' self-efficacy is significant [17].

This study aims at:

- Analyzing the sustainability concepts in teaching geography;
- Comparing the most common teaching methods regarding the effectiveness;
- Indicating the difficulties in learning geography for a high school student;
- Making education policy makers as well as teachers and scientists aware of strong and weak aspects of geographical education under the aspect of sustainability;
- Proposing changes in school curricula in order to increase the awareness of sustainable development.

2. Materials and Methods

2.1. Procedure and Participation

2.1.1. Survey among Teachers

The data collected from the survey aims to evaluate high school geography education related to environmental issues. It consisted of a random selection of participants based on non-probability sampling. One hundred and ninety-eight (198) teachers living in the Czech Republic, Hungary, Poland, Romania, Turkey, and the United Kingdom participated in the study.

The survey consisted of 7 questions relating to the geography issues: Maps/Cartography, Astronomy/The Earth in the Universe, Atmosphere, Hydrosphere, Endogenic processes, Exogenic processes, and Soils and biosphere.

Questions:

- Select the tools/methods you use in geography teaching (lecture, multimedia presentation, educational movie, educational game).
- Which of the units of physical geography discussed in geography lessons are (according to your observations) difficult and which are easy for a student? The answer should be based on the results of tests checking the scope of the student's knowledge.
- Indicate the causes of difficulties in the effective implementation of educational units (difficult content, difficult terminology, too little time for implementation, lack of tools for the proper transfer of information, inadequate methods, no difficulties).
- What results do students get from tests covering the content of each unit?

- How many lessons do you spend on the implementation of each educational unit?
- How students perceive the attractiveness of each educational unit?
- The list below shows threats/problems in the natural environment. Which of them are the student aware of before implementing/discussing at school? (Floods, global warming, soil depletion, wildfires, water pollution, air pollution, soil pollution, desertification, ozone hole, melting of glaciers, reduction of biodiversity, intensification of extreme weather phenomena, changing the boundaries of the occurrence of plant zones, change of flora and fauna species, bad waste disposal).

Moreover, the questionnaire included information about the respondents (age, sex, seniority at school, type of school, and self-assessment of the ability to use ICT—information and communication technologies in geography lessons). A total of 198 respondents—teachers—participated in the study to answer the questions (Table 1).

Table 1. Information on the teachers.

Sex	%
Female	45
Male	55
Age	
24–35	35
35–45	32
45–55	28
55–65	4
>65	1
Seniority at school	
0–5 years	19
5–10 years	16
10–15 years	15
15–20 years	25
20–25 years	16
25–30 years	5
30–35 years	2
35–40 years	2
Type of school	
High school	74
Vocational high school	8
Artistic (vocal) high school	1
Other	17
Self-assessment of the ability to use ICT in geography lessons (1—poor, 5—high)	
1	1
2	4
3	20
4	48
5	27

The survey was conducted via the Internet and then collated for data analysis. The study was based on the results of a survey addressed to a group of teachers. The questionnaire was constructed as a "Google Form" and sent to recipients via e-mail or distributed through social media. The authors of this publication invited people involved in teacher education, preparation of external exams, and geographic competitions to cooperate. Facebook social groups associating geography teachers ("Nauczyciele Geografii"—Poland; "Cool Geography Teachers Group"—United Kingdom; "Učitelé humanitních oborů"—Czech Republic; "Földrajztanárok Klubja"—Hungary) were also involved in distributing the survey.

2.1.2. Survey among Students

A total of 204 students from High School No. 10 in Toruń (Poland) participated in the study. The students indicated (by marking) the issues/problems in the natural environment: floods, global warming, soil depletion, wildfires, water pollution, air pollution, soil pollution, desertification, ozone hole, melting of glaciers, reduction of biodiversity, intensification of extreme weather phenomena, changing the boundaries of the occurrence of plant zones, change in flora and fauna species, and bad waste disposal that they were aware of before starting high school. Information on the respondents is presented in Table 2.

Table 2. Information on the surveyed students.

Sex	Number of Indications	%
Female	125	61
Male	79	39
Sum	204	100
Age		
15–16	158	77
17–18	46	23
Sum	204	100

The research was conducted between 7 and 13 June 2021 during geography lessons. Responses were counted and analyzed using a quantitative approach to test knowledge of sustainability issues.

2.1.3. Analysis

Respondents' answers were analyzed using a quantitative approach to investigate the knowledge about geography education related to sustainability issues. To indicate the difficulty level of particular issues of MapsCartography, Astronomy/The Earth in the Universe, Atmosphere, Hydrosphere, Endogenic processes, Exogenic processes, and Soils and biosphere, the Difficulty Index (DI) has been introduced. The frequency of three difficulty levels (easy, medium, hard) for the issues above was the basis for assigning "difficulty scores" within each type of level: (a) easy—multiplied by 1 point; (b) medium—×2 points; and(c) hard—×3 points. The Difficulty Index (DI) providing information about the difficulty level of each geographical issue was calculated according to the formula below:

DI = (e1 + m2 + h3)/N (DI—Difficulty Index, e1—sum of "easy" indications multiplied by 1, m2—sum of "medium" indications multiplied by 2, h3—sum of "hard" indications multiplied by [3].

Kruskal–Wallis's one-way analysis of variance was used to determine the level of differentiation of environmental threats indicated by respondents. The threats were divided into three groups corresponding to individual spheres of the Earth: Atmosphere, Hydrosphere, and Soils and biosphere. A significant Kruskal–Wallis test indicates that at least one sample (group) stochastically dominates one other sample (group). Due to the fact that this test does not identify where the stochastic dominance occurs Dunn's test was used for analyzing the specific sample pairs for stochastic dominance.

3. Results and Discussion

The types and use of educational methods and tools were analyzed obtaining the results presented in Figure 1. During geography lessons, lectures and multimedia presentations are most often used, whereas educational games are not used at all or are rarely used. Lectures are often perceived by the students as the least effective method used but the lecture time involving students is usually regarded as a more effective learning tool [18–20]. During the lecture, the teacher is able to share information with a large number of students, and it can be effective in transmitting factual information [21,22], but the implementation of didactic goals is accomplished by various methods which are selected by the teacher. Properly used digital media can contribute to more effective education. Some of them will help to activate students and involve them in the teaching–learning process. The multiplicity of information allows teachers to individualize the learning process and achieve better results in geography education [23]. However, it requires a certain level of skill in using different educational tools. Teachers from analyzed countries assessed their ICT skills at a "good" level, and they use different methods (lectures, multimedia presentations, and educational movies).

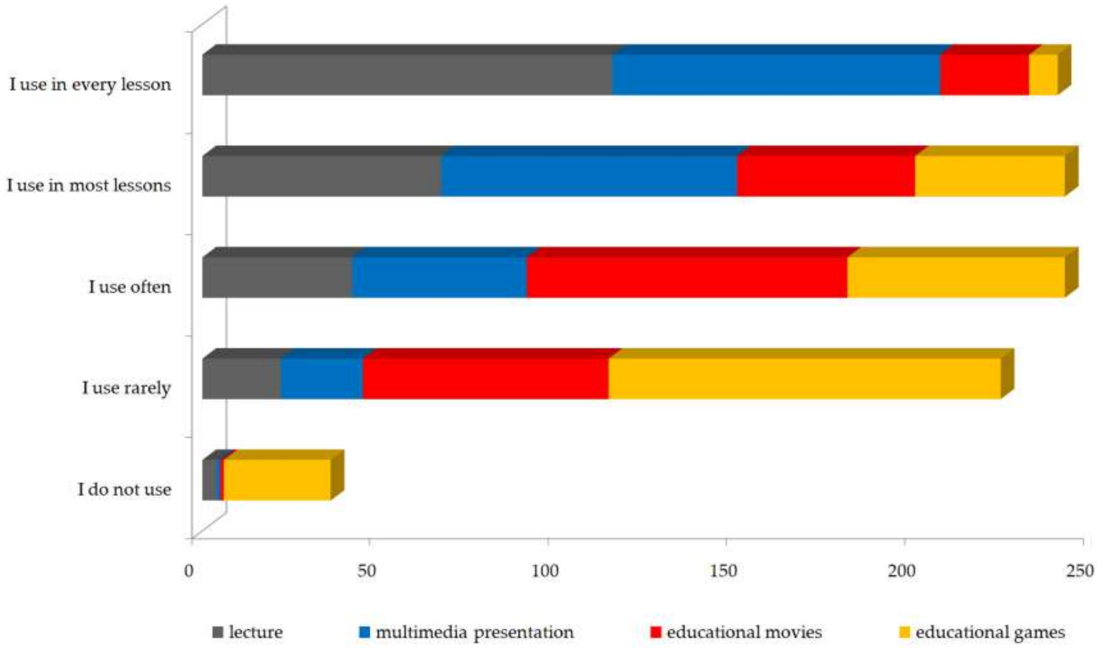

Figure 1. Educational methods using in geography teaching.

According to teachers' observations and the results of tests checking the students' knowledge, the most difficult parts of physical geography discussed during school lessons are Astronomy (DI = 2344) and Endogenic processes (DI = 2292) (Figure 2). The Hydrosphere is the least difficult for students (DI = 1656). On the horizontal axis of Figure 2, there is the average number of lessons provided for the implementation of individual issues estimated on the basis of the average number of lessons indicated by teachers for implementation of a given part. For the implementation of the most difficult, as well as the least difficult parts of physical geography a similar number of lessons are noticed. This lack of differentiation can cause low test scores and difficulties in discussing issues.

The types of difficulties in the implementation of individual parts are presented by Figure 3. The most common problem (the largest number of indications) were having too little time for the implementation the geographical concepts (Maps/Cartography, Exogenic processes, Astronomy, Soils and biosphere), difficult content and terminology (Endogenic processes, Exogenic processes, Astronomy, Soils and biosphere), and a lack of tools for the proper transfer of information (Soils and biosphere, Maps/Cartography). The teachers indicated the Hydrosphere as the geographical section with the least difficulties in implementation. One of the most problematic areas (many different difficulties) is Soils and biosphere. Teachers indicated that almost every educational inconvenience, including inadequate methods, e.g., lack of activating methods.

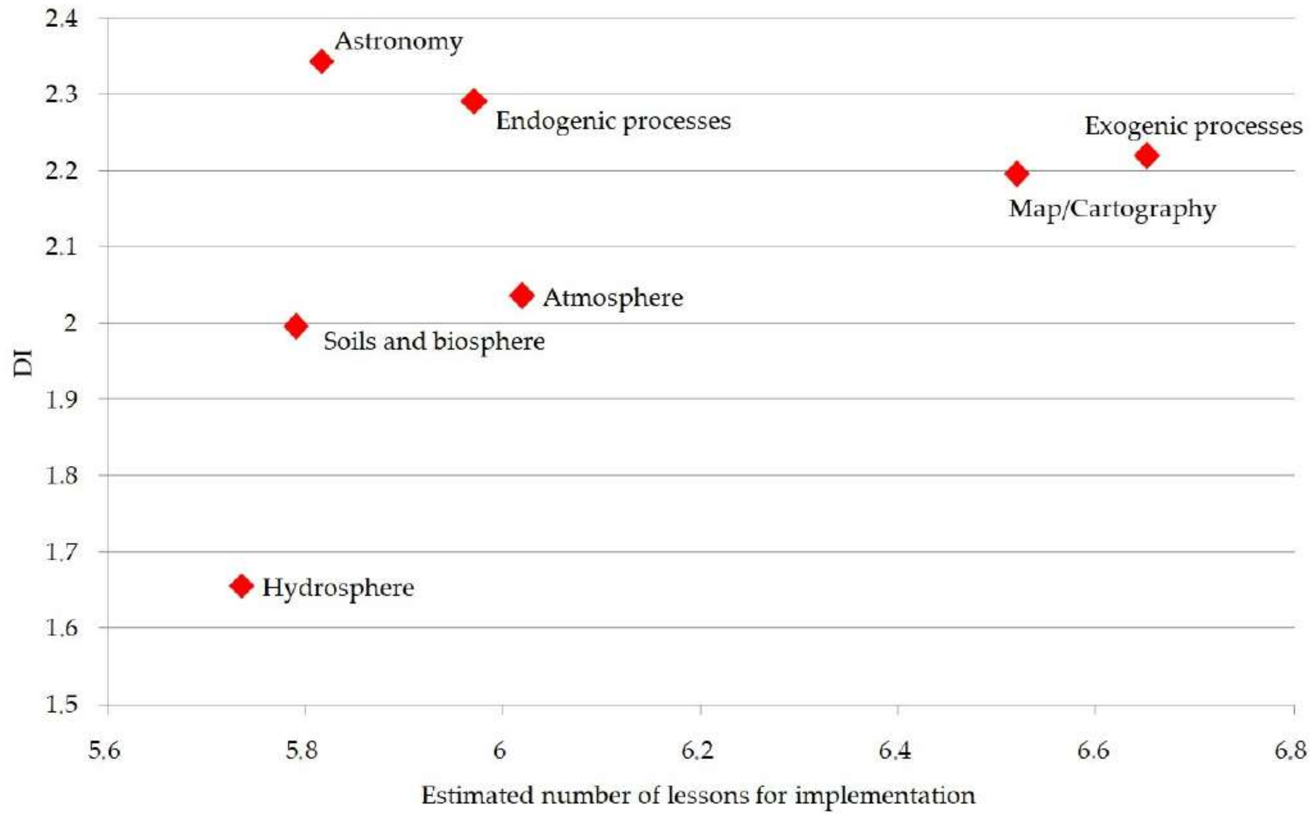

Figure 2. Difficulty Index of individual geographical issues and estimated number of lessons for implementation.

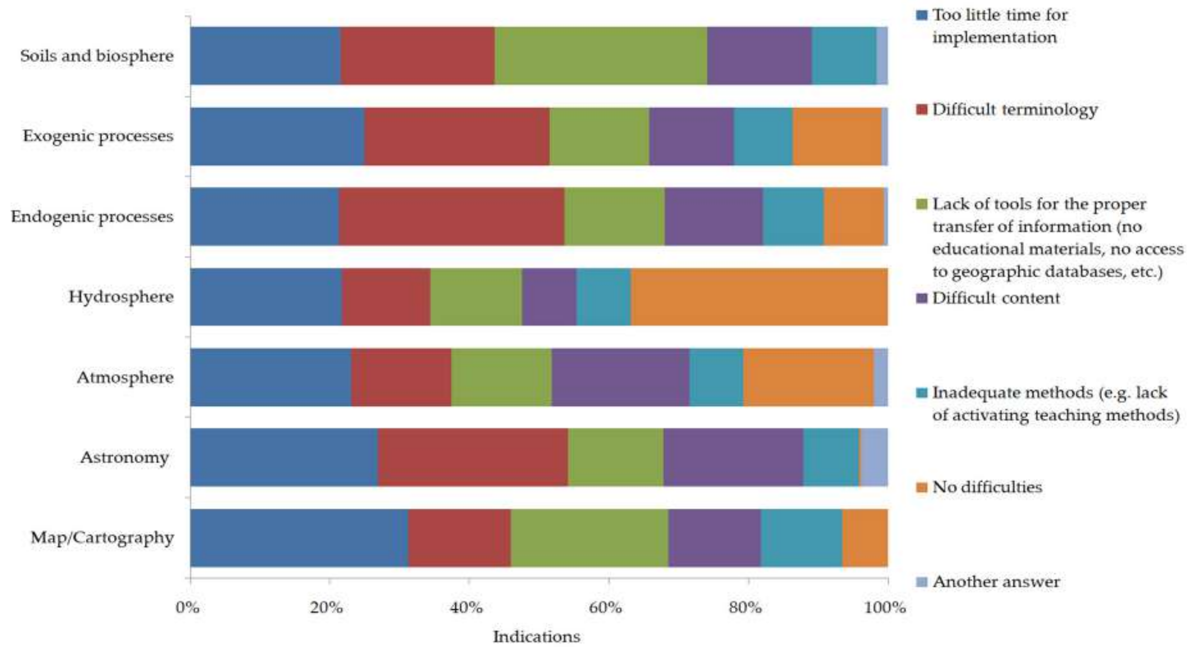

Figure 3. The types of difficulties indicated by teachers in the implementation of individual parts of geographical education by number of indications.

The results which students usually obtain from the assessment tests covering the content of each part were on the medium level (50–80%). The higher results (above 80%) were scored in Hydrosphere tests, whereas the lowest scores were in Astronomy tests (Figure 4), and this analysis correlates with previous results concerning the level of difficulty of particular issues.

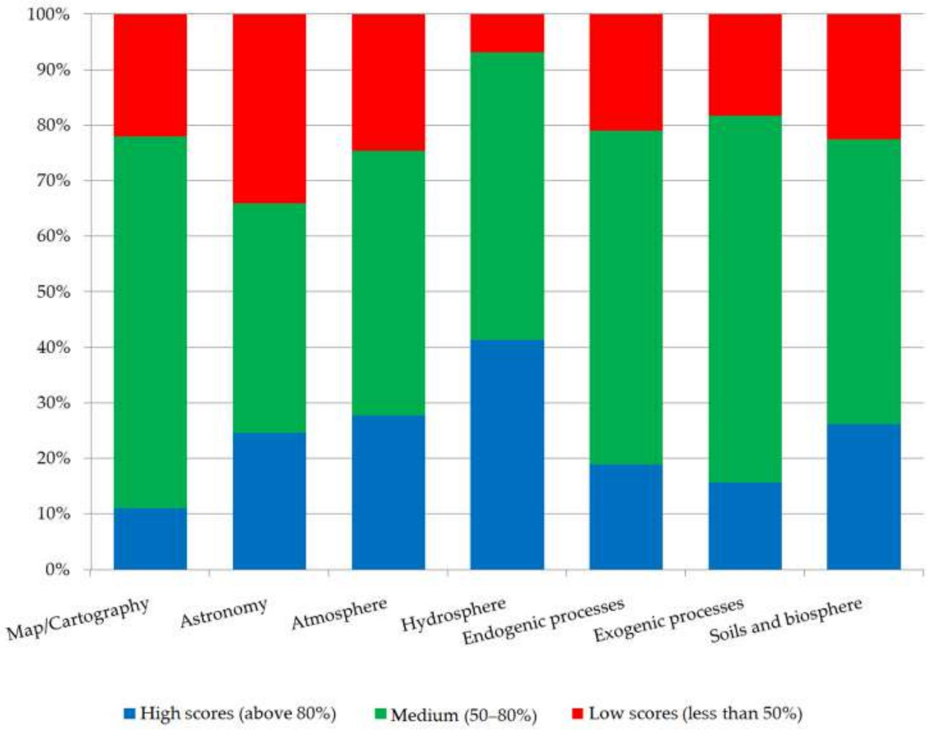

Figure 4. Knowledge test results (in teachers' opinion).

The number of lessons allocated to the implementation of a given issue is not without significance. Due to the fact that in the analyzed countries the total number of hours devoted to geography lessons is different, it is difficult to indicate the share of particular issues. However, it can be concluded that some issues are given more time than others. Teachers usually spend from two to five lessons on the implementation of each part of the identified geographical concepts (Figure 5). Despite the fact that the Hydrosphere tests were higher than all the other concepts few teachers discuss these issues in more than 15 lessons. Cartographic topics are usually taught the longest (above 15 lessons), and yet, as mentioned above, teachers lack the time to sufficiently explain these issues.

The next important matter especially with regard to sustainability is to understand what environmental problems the student is aware of before discussing them in school. It turned out that some problems were sufficiently known to students (from the media or early education), while many other problems did not become known to students until high school (Figure 6). According to teachers' opinions, the best-known issues are related to air pollution and global warming. Students are also quite aware of floods and water pollution. Unfortunately, only a few of them are aware of problems related to soils. Students are generally unaware of the effects of deforestation leading to landslides, loss of biodiversity, and ecological soil functions. They probably do not know the examples of Haiti or Mexico, where the human impact on the topsoil led to the collapse of the economy in these places [24,25]. It is difficult to imagine a proper approach to the issues of sustainable development without an equal knowledge of the underlying threats. Therefore, more emphasis should be placed on those issues that the student is the least aware of.

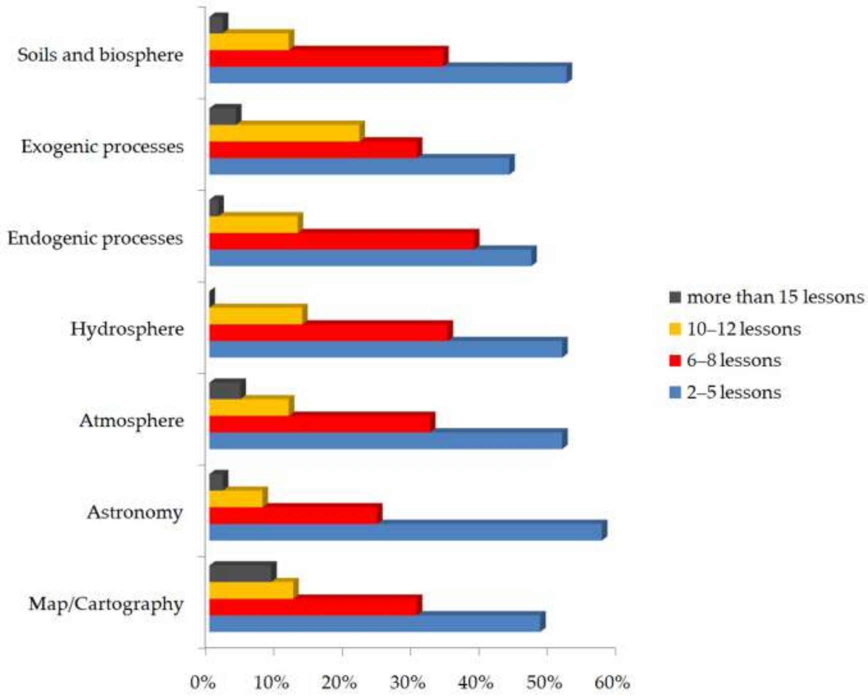

Figure 5. The number of lessons devoted to the implementation of specific issues.

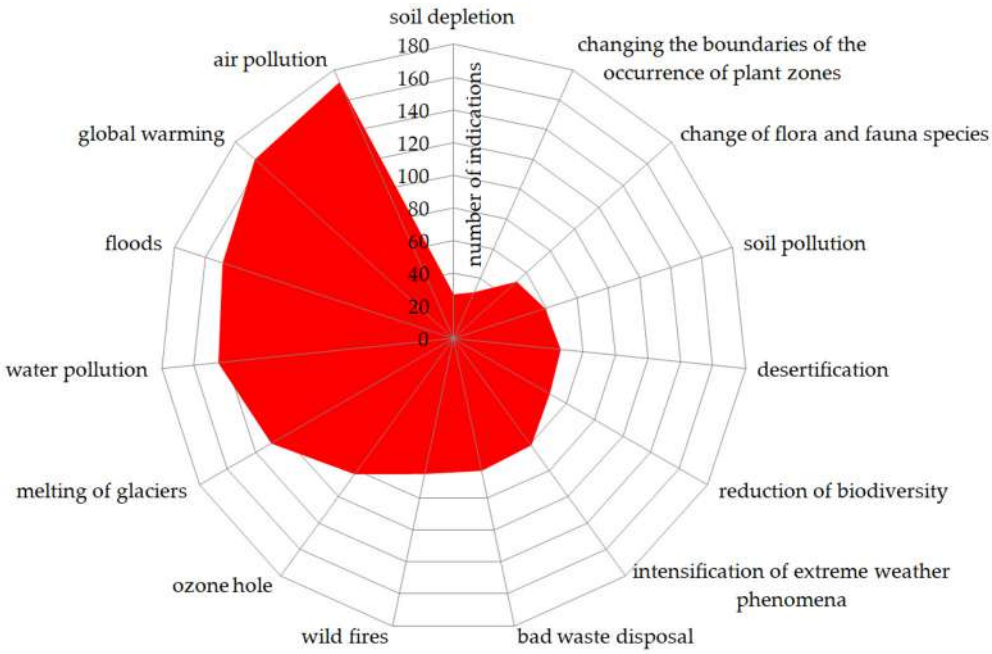

Figure 6. Students' awareness of environmental problems in teacher's opinion (N = 198).

All analyzed issues are discussed in the corresponding parts of geographical education. The list of environmental problems included the issues discussed in the implementation of the part: Atmosphere, Hydrosphere, and Soils and biosphere. For this reason, neither the Astronomy nor Cartography section was included in the analyzes below. By far the worst are the problems discussed during the introduction of the Soil and biosphere part (379 indications). It means that students' knowledge is poorest in the soil topic. Within the discussed fields of geography, ecological awareness is also diversified (Table 3). In the topic of the Atmosphere, the problems of air pollution and global warming are best known by students (27–28%), whereas extreme weather phenomena are the worst known (13%). In the topic of the Hydrosphere, floods and water pollution have the best results (29%).

The reduction of biodiversity and desertification issues are the best known by students within the topic of Soils and biosphere (17–18%). In contrast, changing the boundaries of the occurrence of plant zones and soil depletion are the most poorly understood.

Table 3. Problems in the natural environment corresponding with proper parts of geographical education (teachers indications N = 198).

Atmosphere	**% of Indications**
air pollution	28
global warming	27
ozone hole	17
wildfires	14
intensification of extreme weather phenomena	13
Hydrosphere	
floods	29
water pollution	29
melting of glaciers	25
bad waste disposal	16
Soils and biosphere	
reduction of biodiversity	18
desertification	17
soil pollution	14
change of flora and fauna species	14
changing the boundaries of the occurrence of plant zones	8
soil depletion	7

As indicated, the result of Kruskal–Wallis test the differences between some of the groups of problems discussed above are statistically significant (Table 4).

Table 4. Results of Kruskal–Wallis test for the groups of environmental threats (N = 15; based on [26]).

Kruskal–Wallis Test Components	**Scores**
H (chi2)	10.08
Hc (tie corrected)	10.11
p (same)	0.006364

Statistically significant differences are noted between the problems from the Soil and biosphere group and the problems from the Atmosphere and Hydrosphere groups. However, there are no statistically significant differences between the issues related to the Atmosphere and Hydrosphere groups (Table 5).

Table 5. Dunn's post hoc test results for groups of environmental threats (N = 15; p = 0.05; based on [26]).

	Atmosphere	**Hydrosphere**	**Soils and Biosphere**
Atmosphere	x	0.9812	0.006428
Hydrosphere	0.9812	x	0.01014
Soils and biosphere	0.006428	0.01014	x

As mentioned before, this part of geographical education is one of the most problematic for implementation: too little time for presenting the geographical concepts, difficult content and terminology, lack of tools for the proper transfer of information, and the lack of adequate activating methods. It takes a long time to understand the relationships between the components of the environment and to become aware of the interdependence between them. Students should discover these cause–effect relationships for themselves and think about and predict the consequences of their own actions. The above-mentioned difficulties probably contribute to the low attractiveness of these concepts for students in the teachers' opinion (Figure 7).

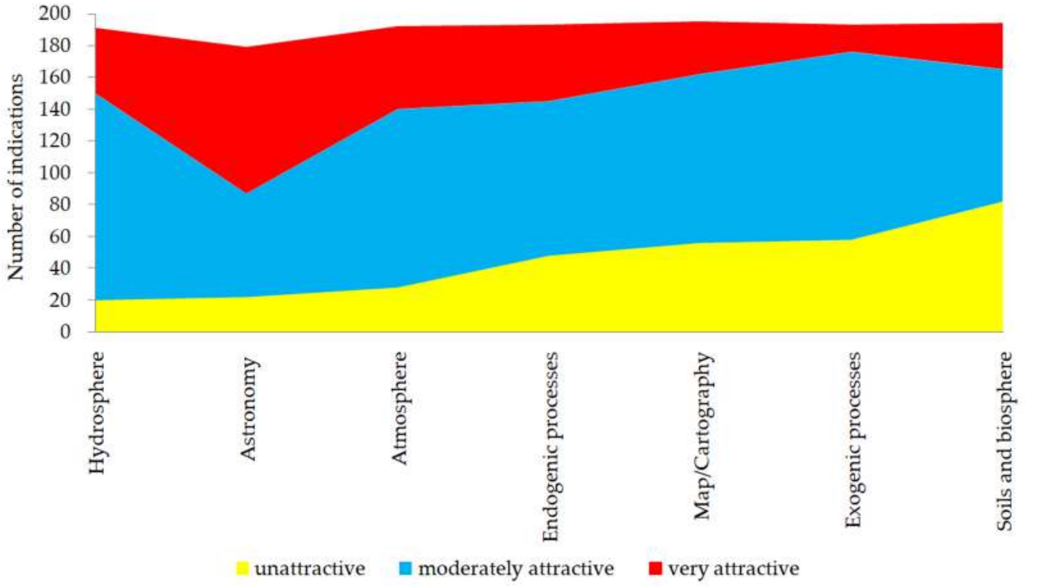

Figure 7. Attractiveness of individual geographical parts for students in teachers' opinion (*N* = 198).

Students' indications on environmental problems known before their school education confirm previous conclusions (Figure 8). A a total of 100% of the respondents indicated knowledge of the issues discussed in the sections: Atmosphere and Hydrosphere (floods, water pollution, air pollution, bad waste disposal). The least known threats concern the topic Soils and biosphere: changing the boundaries of the occurrence of plant zones (9%, 19 indications), reduction of biodiversity (11%, 22 indications), soil depletion (11%, 23 indications), soil pollution (19%, 38 indications), change in flora and fauna species in relation to extreme events (26%, 53 indications), and desertification (50%, 101 indications). Altogether, this is 256 out of 1974 indications. This fact is very disturbing because soils have a very important role in our life and in the management of the human environment. They are one of the most valuable elements of terrestrial ecosystems and perform many ecological functions [27–29], that is why they can be a testimony of human activity.

They also are a reservoir of artefacts—a historical trace of human existence and management [30]—so people should realize that soil problems (e.g., pollution and depletion) are equally important for humankind as global warming and the ozone hole. Despite the importance of soil cover, there is still a limited understanding of the role of soils in human life among the general public [31–33]. Unfortunately, people frequently overlook soils as components of the physical and biological landscape and do not perceive soil management as essential for sustainability. According to The International Union of Soil Sciences [34] the key to achieve the Sustainable Development Goals (SDGs) is to protect soil resources and educate for its conservation [35]. Geography, as a school subject, is defined as the study of the landforms, features, inhabitants, as well as soils and phenomena of the Earth and touches all aspects of sustainability thinking [36–39]. In physical geography, sustainability-related concepts should include an understanding of geomorphological processes, resource distribution, landforms, weather, and soil cover, as well as the close interdependencies between them. The impact of thoughtless behavior (inconsistent with the principles of sustainable development) on human beings should be particularly emphasized. Nevertheless, geography lessons have much unused potential when it comes to sustainability [37,40]. According to Agenda 21 [41] and the 2030 Agenda for Sustainable Development [42], the following environmental issues can be identified: soil/land degradation, desertification, biodiversity loss, climate change, water, health and food, etc. It can be stated that suitable teaching topics for education in geography include issues relevant to Earth sciences. However, it should be noticed that sustainable development concerns not only natural elements but also socio-economic ones. The knowledge and understanding of the major natural Earth' s systems (landforms, soils, water climate, vegetation), and the interactions within and between ecosystems and the major socio-economic systems (agriculture, settlement, transport, industry, trade, energy, population) should be considered as a cooperating one [43]. Geographical education could be a key strategy for sustainability development. The environmental problems identify the need for the proper education and promotion of citizens' commitment to the environment and 'ecological literacy' [44–46]. This is essential for understanding the natural systems that make life on Earth possible. There are many examples of how the overexploitation of the Earth's resources has changed the direction of development of societies, often forcing people to leave inhabited areas. People whose homes and communities have been destroyed by environmental disasters are called environmental refugees. Scattered throughout the developing world are 135 million people threatened by severe desertification and 550 million people subject to chronic water shortages [47–50]. Soil loss contributed to the demise of societies from the ancient Greeks and Romans to European colonialists and the American pioneers [51]. Due to the imprecision of the concept of environmental migration, it is difficult to estimate the scale of the problem. According to statistics from the United Nations Development Program as a result of natural disasters an average of 21 million people are displaced every year [52]. In 2019, the number of displacements due to natural disasters (disaster displacement) totaled 24.9 million on all continents, of which 96% was the result of weather events such as storms, floods, droughts, extreme temperatures, and fires [53]. The World Bank experts predict that 143 million migrants will be forced to escape their countries by 2050 from Latin America and Sub-Saharan Africa and Southeast Asia [54]. A significant increase in the total number of migrants in the last two decades (from 173 million in 2000 to 258 million in 2017) was noticed [55].

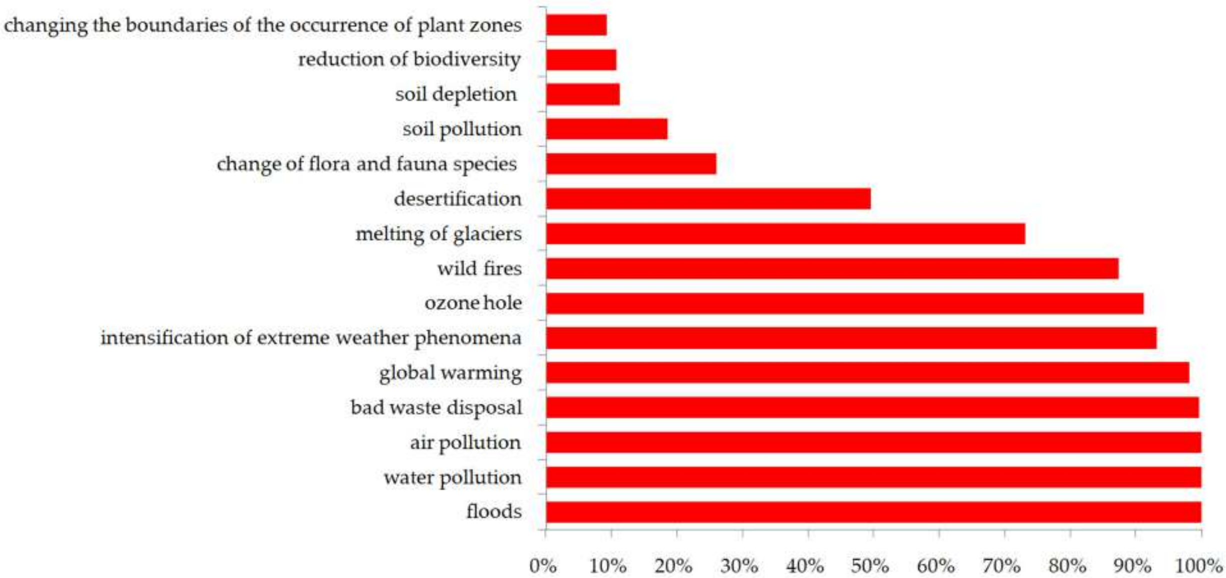

Figure 8. Students' indications on environmental problems they were aware of prior to school education(N = 204).

4. Summary and Conclusions

There are two types of environmental driving factors influencing migration of people: sudden onset events, i.e., various types of natural disasters, and long-term, slow onset events, such as droughts, desertification, increasing the salinity level, ocean acidification, and the lifting the level of the seas and oceans. Sub-Saharan Africa, South Asia, and Latin

America together represent 55 percent of the developing world's population. Current research finds that climate change will force millions of people to migrate by 2050 [54]. These people could be pushed to move their countries to escape the slow-onset impacts of climate change. Soil depletion, soil erosion or desertification are definitely less spectacular processes than floods or typhoons, but they are equally dangerous for human beings. Threats that change the nature of the soil develop insidiously because they are invisible to the eyes, buried under the surface of the Earth [56]. People will migrate from places with lower water availability and crop productivity, but there will be less and less areas with good and healthy soil conditions. Despite the currently dominant socio-economic nature of migration [57], it should be noted that this process is also directly influenced by soil depletion, water availability, and the quality of the ecosystem.

Education is the most effective method to prevent or at least minimalize many environmental problems before they appear. One of the aims of education is to make people aware of necessity of protecting the Earth and our environment by making positive changes in human behavior and by ensuring that people actively participate in finding solutions to emerging problems. Geographical education plays a special and important role in this process. Unfortunately, geographical education is not always able to meet the demands of sustainability. There are many obstacles to teachers being unable to implement sufficient knowledge and skills (e.g., improper educational methods, too little time for implementation, difficult terminology, lack of proper educational tools). However, not all parts of physical geography are equally familiar to students before they enter high school.

The conducted research allows for the following conclusions:

- Students have the least information about issues related to the pedosphere (soil depletion and pollution, reduction of biodiversity). This topic—Soils and biosphere—is perceived as the most unattractive for them to study, even during and after implementation.
- Students are not aware of the role that soil plays in human life and in the functioning of the environment. Without such awareness, they will not be able to fully understand the principles of sustainable development and properly solve environmental problems.
- Universities and media, as well as authorities and scientists, should be involved in the better promotion of soil science issues so that the level of their awareness is equal to other problems of the natural and anthropogenic environments.
- Active questioning of social and environmental decisions should be promoted.
- Teachers should make students aware of how problems over space or sustainability can be resolved.

Only such a balance can shape a young world citizen who will be able to stop the existing threats being caused by careless exploitation of the Earth's resources and face emerging environmental problems.

To save the world, we should take care of sustainable geographical education, and soil science ought to be a highly important component. How much soil it takes to support a human society depends on the size of the population, but people should realize that soil conservation is essential for the longevity of any civilization as history shows civilizations failed due to improper management of pedosphere resources [58–62].

"Many factors may contribute to ending a civilization, but an adequate supply of fertile soil is necessary to sustain one" [51]. However, not every part of sustainable development measures addresses the particular problem of environment and environmental refugees. Especially important, for example, would be the Anti-Desertification Action Plan as applied to the Sahel and arid sectors of Africa, as well as the Indian subcontinent.

Soils provide us with an insight into changes over time in our natural surroundings from ancient civilizations to the modern digital world. This history makes it certain that sustaining an industrialized civilization will rely as much on soil conservation as on technological innovation [51].

Students are aware of many risks and problems such as global warming and air pollution, but they are not sufficiently informed about soil resources and soil protection as being equally important for their existence. Soil science issues are unattractive for them. This is unacceptable. Soil is a treasure of the Earth deeply hidden from human eyes. It does not mean that soils do not exist. On the contrary, they accompany us from the first days of our existence. It would be worth treating it with due respect. School education based on the principles of sustainable development including soils concepts can help people to make their life as well the Earth's life better.

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A global perspective on soil science education at third educational level; knowledge, practice, skills and challenges

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ABSTRACT

The pivotal role of soil as a resource is not fully appreciated by the general public. Improving education in soil science represents a challenge in a world where soil resources are under serious threat. Today's high school students, the world's future landowners, agriculturalists, and decision makers, have the potential to change society's apathy towards soils issues. This research aimed to compare the level of soil education in high and/or secondary schools in forty-three countries worldwide, together comprising 62% of the world's population. Comparisons were made between soil science content discussed in educationally appropriate textbooks via a newly proposed soil information coefficient (SIC). Interviews with teachers were undertaken to better understand how soil science education is implemented in the classroom. Statistical analyses were investigated using clustering. Results showed that gaps in soil science education were most commonly observed in countries where soil science is a non-compulsory or optional subject. Soil science concepts are predominantly a part of geography or environmental science *curricula*. Consequently, considerable variability in soil science education systems among investigated countries exists. Soil information coefficient's outcomes demonstrated that a methodological approach combining textbooks and the use of modern digitally based strategies in the educational process significantly improved soil education performances. Overall, soil science education is under-represented in schools worldwide. Dynamic new approaches are needed to improve pivotal issues such as: *i*) promoting collaborations and agreements between high school and universities; *ii*) encouraging workshops and practical exercises such as field activities; and, *iii*) implementing technology tools. This, in turn, will prepare the next generation to contribute meaningfully towards solving present and future soil problems.

1. Introduction

Soils are an invisible, buried, hidden element of the environment. Soils, frequently referred to as earth, ground or dirt, might even be considered as dull and unexciting. Most people associate soils only with agricultural activities. In part, this may be because soil education is deficient in many countries. This may result in students perceiving the pedosphere as being less important than, for example, the hydrosphere or lithosphere (Urbańska et al., 2022). However, such an essential element of the terrestrial system cannot simply be ignored. Appropriate soil education at the school level serves to increase a general awareness of soil and the important, but often overlooked role it plays in sustaining human existence.

Over the past twenty years, significant advances and a better scientific understanding have been achieved in soil science and its subdisciplines (Brevik and Hartemink, 2010). In addition to a better scientific understanding, there have been major developments in the perception of both the ecological and non-ecological functions of soils in providing fundamental ecosystem goods and services (e.g., Blum, 2005; Brevik, 2009; Jones et al., 2012; Crossman et al., 2013; Cruse et al., 2013; Lal and Stewart, 2013; Pritchard et al., 2014; Baveye et al., 2016; Urbańska and Charzyński, 2021). Despite the importance of soils, an understanding of the role they play in supporting and sustaining human existence is still limited among the general public (Brevik et al., 2020). In attempting to explain why this is so, other questions arise: Is soil science education at the secondary school level appropriate? Is soil knowledge being promoted adequately? Is information regarding the need to protect soil resources communicated effectively?

Soil science education is important for understanding terrestrial environmental systems and the value of protecting them. Improving the way that soil concepts are taught will facilitate a realisation that unpolluted and productive soil is just as important as clean water or fresh air. Today's high school students, who are our future landowners, agriculturalists, and decision-makers, require a deeper appreciation of the basic functions of all environmental systems, including soils, and the interrelations between human activities and the natural world, thus being able to make appropriate decisions about contemporary environmental problems when and where they arise.

The importance of public awareness regarding the role of soils in sustaining life has been raised in several policy reports by the European Commission (EC, 2006, European Commission (EC, 2012), the Department for Environment, Food and Rural Affairs (Defra, 2004) in the United Kingdom, and by other role players. Over the span of a human lifetime, soils should be considered a nonrenewable resource (Friend, 1992; Cruse et al., 2013). However, people frequently overlook soils as components of the biophysical landscape which have developed over thousands of years yet can be destroyed in an instant. The Food and Agriculture Organization (FAO, 2011) estimated that 33 % of the global land area has been degraded. Currently, the world is faced with numerous ecological problems. High school students are aware of global warming, floods, and water and air pollution, but they are not necessarily sufficiently informed that soil resources and soil protection are equally important for humankind (Urbańska et al., 2022). Healthy soils are essential for plant growth, water filtration, and human nutrition.

They are fundamental to our survival and the best gift we can bequeath to our descendants (Defra, 2004; EC, 2006, EC, 2012; Hallett, 2008; Jones et al., 2012). Many countries have been supporting activities promoting soil science for some time. Since 2004, Germany, Austria and Switzerland have been selecting a "Soil of the Year" and have published information in social and traditional media via press releases, folders, flyers, workshops, conferences and other activities (https://de.wikipedia.org/wiki/Boden_des_Jahres). The International Union of Soil Sciences (IUSS) sees the need to make young people aware of the importance of soils in the environment. During the conference, "Celebration of International Year of Soils 2015 – Achievements and Future Challenges," the International Decade of Soils 2015–2024 was proclaimed by the IUSS President (https://www.iuss.org/international-decade-of-soils/). Since then, there have been many events at both national and international level: posters, image and book contests (such as the Poster Contest "Soilutions", and a book contest on soil biodiversity with the motto "Keep soil alive, protect soil biodiversity"), activities of soil science societies and institutions (such as the Soils in Landscapes of the World – 2018 Calendar designed by the Department of Soil Science and Landscape Management, Faculty of Earth Sciences, Nicolaus Copernicus University in Torun and the program, "Thus are Soils of my Nation", an educational project of the Latin-American Soil Science Society). Events have been held in various locations around the world, including Japan ("Where and how does your food grow?"), Spain ("Soil Art: Painting with Soils''), Argentina (''These are the soils of my country!"), México (''Thus are the Soils of my Nation"; (Spanish Society of Soil Science. International Decade of Soils, 2021); Hirai and Mori, 2020; Fritz, 2020; Reyes-Sanches, 2020a), Germany ("Life in the soil", „Beneath our feet - Soil as a habitat", "The Thin Skin of the Earth - our Soils") – exhibitions prepared by The Senckenberg Museum of Natural History in Goerlitz (https://www.senckenberg.de/de/museen-und-events/) and the US ("Dig It! The Secrets of Soil" which was a travelling exhibit from the Smithsonian Museum; (https://forces.si.edu/soils/02_00_00.html) . However, these infrequent events are insufficient to ensure an in-depth understanding of the role of soils in humanity's future. First and foremost, students should have access to appropriate educational content in the field of soil science. In order to achieve this, soil science education at school level, as well as the soil science educational content of many school-level textbooks, needs to undergo change so as to improve learning outcomes. The extra-curricular soil science activities and events related to soil science that universities offer may filter down to local school students but, by and large, their participation is negligible. It can be stated without doubt that these extra activities are not enough to reach the entire student population. In addition to university centers offering additional soil science classes designed for school students, there are many soil museums around the world (39 museums and 34 permanent exhibitions), but these facilities only have between 1000 and 10,000 visitors per year (Richer-de-Forges et al., 2020; muzeumgleb.pl/baza-wiedzy-o-glebie/ksiazki-o-glebach/). This number is, in view of the fact that almost eight billion people in the world are beneficiaries of soil resources, extremely low. Soil science societies, national ministries and departments of education should establish closer collaborations to develop appropriate methodological and didactic guidelines to make future generations aware of the importance of soils and risks threatening it. This process should not involve only a specific country but should become an international goal for all countries that care about Earth systems and human life.

Against the backdrop outlined above, this paper aimed to compare the level of high school soil education in forty-three countries around the world. It should be noted that the differences in the structures of educational systems throughout the world makes the very naming and differentiation of high school and secondary school levels problematic. According to the international standard classification of education (ISCED), the high school level corresponds to level 3 (upper secondary education). This level is typically designed to complete secondary education in preparation for tertiary education or provide skills relevant to employment, or both. Note that secondary education is divided into upper secondary education (described above) and lower secondary education; typically designed to build on the learning outcomes from ISCED level 1 (primary education). Usually, the aim is to lay the foundation for lifelong learning and some education systems may offer vocational education programmes (UNESCO Institute for Statistics, 2012). Thus, in this paper, the terms high school level and secondary school level are used interchangeably. It is important to emphasise that the analysis focuses on the content of the textbooks, not the testing of students' knowledge. The goal is to show what knowledge a student can *potentially* gain from a textbook. The review of information focused only on formal and compulsory education and did not include informal or extracurricular activities. Information related to the soil science content provided to students in secondary (high) schools was gathered from 43 countries. According to Field's concept of "knowing" soil, students can (Field, 2019): *i*) "be aware of" soil; *ii*) "know of soil"; and *iii*) "know soil". These concepts can be interpreted as the realisation of the operational goals of the lesson, i.e., the student *knows*, *understands,* and *is able to* - according to the Taxonomy of Educational Objectives: *Knowledge, Comprehension, Application* (Bloom et al., 1956). The following questions therefore arise: Which soil issues presented in the relevant school textbooks educate with regard to the above-mentioned skills? Are they equally important? Is the situation the same in every country? This research attempted to answer these questions and to review the soil science knowledge offered to students in selected countries of the world. It should be noted that education systems in countries are diverse and difficult to compare. The examples of Russia and Italy clearly show that soil science is taught in different ways and at different educational levels. Traditionally, compulsory general education in Russia includes primary (the 1st to 4th grades) and secondary school (the 5th to 11th grades). At the end of the 9th grade, students take semi-final exams, after which they can choose to either stay at school for two more years, or enroll in a technical college, where they can learn a trade. In the Russian Federation, students acquire elementary knowledge about soils from the 'World Around Us' course. They gain this through studying general geographic principles in the 6th year of school. The 'Geography of Earth' (grades 5 to 7) course is designed to teach students about geographical integrity and heterogeneity of the Earth as a planet populated by people, general principles of development of relief, hydrological networks and climatic processes, the distribution of plants and animals and the influence of the environment on people's lives and occupations. The "Geography of Russia" (grades 8 and 9) course aims to give students a general understanding of the geography of their country in all its diversity and integrity based on a holistic approach and knowledge about the interaction and interdependence of three main components, i.e., nature, people, and the economy. In Italy, education is compulsory between the ages of 6 and 16. Soil science topics are mainly taught in "Science" and "Techniques" curricula. In the former, soil science is explained through concepts of soil genesis, soil-forming processes (primary schools), soil horizons (lower secondary schools), and soil classification systems. In both curricula, according to the teacher's autonomous decision, further concepts such as soil erosion and degradation, and soil importance in the view of climate change can be discussed. Descriptions of educational systems in forty-three countries were analyzed in terms of similarities and differences through a newly proposed Soil Information Coefficient (SIC), and the results thus obtained were used to propose some initial guidelines to improve soil science education on a worldwide level.

2. Materials and methods

2.1. Research general background.

Information regarding soil knowledge and soil education was gathered from 43 countries worldwide, which countries together are home to 62 % of the world's population (Fig. 1). Data collection required the involvement of soil scientists in contact with teachers, as well as the

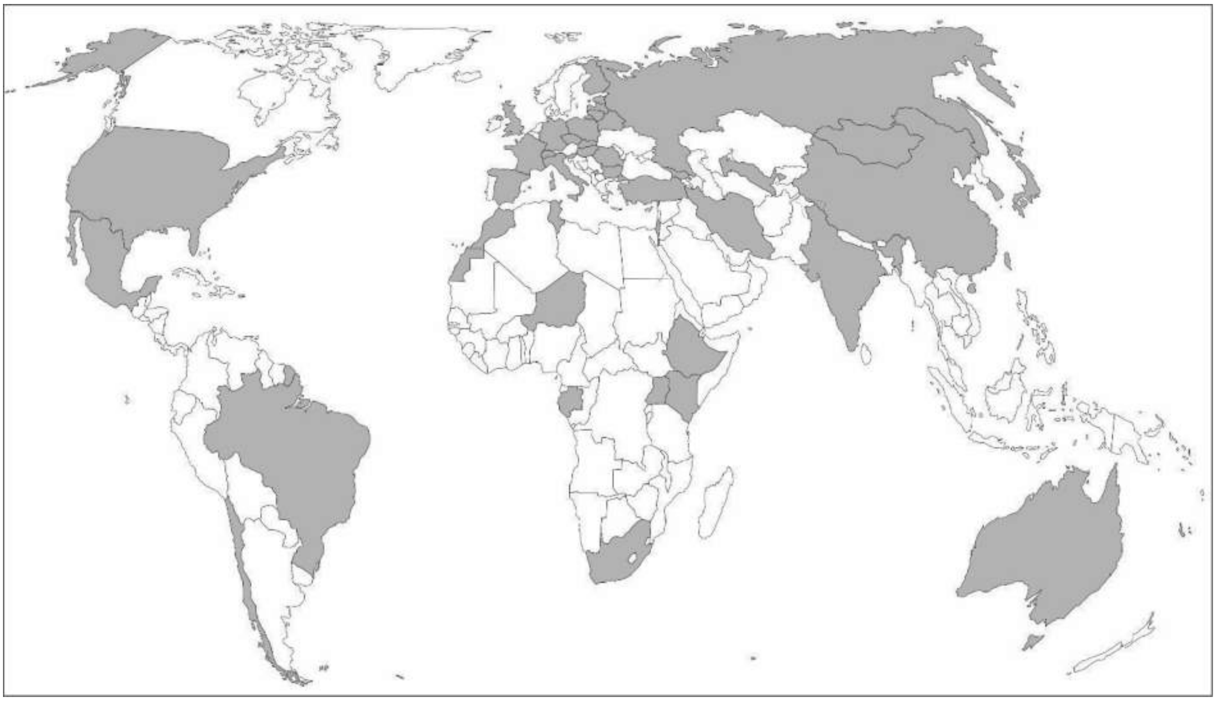

Fig. 1. Participating countries from which data was collected (see also Table 2).

analysis of school textbooks (ISCED 3rd level). Due to the Covid-19 pandemic, there were a number of challenges, including school and library closures as well as limited contacts with relevant contributors. Similarly, it was not possible to include a number of countries where political, ideological or language factors presented insurmountable logistical problems. Potential participants in more than 50 countries were invited to cooperate, and 43 of these were able to obtain and contribute information. A tool that evaluates textbook content (a list of analyzed textbooks from all countries with an indication of the educational level is available in the Supplementary Material 1) was addressed to soil scientists who were asked to assess and characterise the soil science knowledge contained in their country's school textbooks, as well as to consult with teachers responsible for soil science education. The tool for evaluating textbook content was designed so that any soil scientist could complete it, given the appropriate information. Due to the necessity of obtaining the opinion of experts in soil science from around the world, a purposive sampling method was used to select the respondents.

The evaluation tool (Table 1) was compiled regarding the implementation of soil education. It comprised 25 questions covering general information pertaining to textbooks, schools, and students. The most important information related to the detailed characteristics of individual soil concepts discussed in the country's often-used textbooks. In most countries, several available textbooks at different levels within secondary/high education were analyzed. The data were averaged in order to obtain complete information about the soil science knowledge provided over the entire cycle of teaching at a given level, regardless of the textbook. Soil concepts referred in particular to soil genesis, soil profiles, soil processes, soils of the country, world soils, soils management, soil degradation and protection, soil functions, agricultural usefulness, and climatic-soil-vegetation zones. The content of the textbooks was analyzed in terms of the above-mentioned concepts: Are they present? If yes, what level of detail does the content provide? Are there appropriate graphics, maps, and charts? Is any relevant or important information omitted?

Information with regard to whether soil knowledge in the analyzed textbook was up-to-date was also considered. In addition, the soil scientist from each participating country provided a description of their particular education system (Table 1). In some countries, for example

Table 1
Evaluating tool regarding soil science education and education systems.

No.	Textbook information
1.	*Country*
2.	*Is soil knowledge present?*
3.	*School level*
4.	*Grade*
5.	*Student age*
6.	*Textbook authors*
7.	*Textbook title*
8.	*Pages concern soil knowledge from … to …*
9.	*How many pages?*
Topics	
10.	*Soil genesis*
11.	*Soil profile*
12.	*Soil processes*
13.	*Soils of country*
14.	*World soils*
15.	*Soil management*
16.	*Soil degradation and protection*
17.	*Agricultural usefulness*
18.	*Soil functions*
19.	*Climatic-soil-vegetation zones*
20.	*Other*
Additional information	
21.	*Is the information up-to-date?*
22.	*Comments*
23.	*What soil classification was used to describe world soils?*
24.	*Is soil classification up-to-date?*
25.	*Additional remarks*
Description of the education system - questions	
1.	*What is the geographic education based on?*
2.	*What does this document include? Is it compulsory for each school?*
3.	*How many stages of geographic education are available?*
4.	*Is geographic education compulsory?*
5.	*What is the most popular publishing house offering textbooks?*
6.	*Who chooses the textbook?*
7.	*Additional information*

the USA, Germany and Switzerland, national education systems relate to a federal structure. There are no national requirements or science education standards officially endorsed by the United States government, but guidelines and recommendations are periodically written and recommended. In 2013, the National Research Council (NRC), the National Science Teachers Association (NSTA), the American Association for the Advancement of Science (AAAS), and other nongovernmental organizations worked with state-level education departments to develop the Next Generation Science Standards (NGSS). Twenty states and the District of Columbia now use the NGSS for their schools. Twenty-four other states have adapted the NGSS for use in their schools, often with minimal changes. Currently about 71 % of US students are in schools with syllabi based on these standards and recommendations. The American textbooks analyzed were based on the requirements specified in the standards, and the results were averaged. In the case of Switzerland, topics and learning targets are stipulated for every school-level separately in a curriculum. Since 2016 the German speaking cantons (21) have developed a common document. The exact number of years in every school level, school books, curricula and specific requirements for qualifications vary between cantons. Therefore, instead of an overview of soil education in Switzerland, the canton of Bern was used in this study as representative of the Swiss system. In Germany education is not centrally regulated by the national government. Education is the official responsibility of each of the sixteen individual federal states. Hence, education affairs are diversely administered, although the basic structure and most standards are aligned across the states. In this research, we focused on the federal state of Lower Saxony and, specifically, lower, and upper secondary schools (high school level) which qualify for university admission. In other countries, educational programs and core curricula are standardised and centralised based on government guidelines, so the soil science content in textbooks is the same for the whole country.

2.1. Data analysis and statistics

Data and statistical analyses were conducted using the Paleontological Statistics Software Package for Education and Data Analysis - PAST (Hammer et al., 2001). The descriptive data were analyzed, compared, and contrasted. In particular, soil knowledge concepts (vide supra) were analyzed, and the descriptive data converted into a quantitative form: 0 points - no information, 1 - scanty information, 2 - some information, 3 - complete information. Each country could potentially receive a maximum of 30 points. The correlation between the figures was tested, and an attempt was made to cluster individual components ($p = 0, 05$). This was carried out using the k-means, the classical, and the neighbor-joining methods. Average scores on specific soil science concepts in all countries were grouped using the classical clustering method (hierarchical). Unweighted pair-group average (UPGMA) was applied where clusters were joined based on the average distance between all members in the two groups (Euclidean similarity index). The hierarchical clustering routine produces a 'dendrogram' showing how data points can be clustered. The same data were grouped using the k-means method representing the group of non-hierarchical algorithms. It was necessary to specify the number of clusters in advance. Based on previous results of classical clustering, three clusters were determined for this method. Neighbor joining clustering was an alternative method for hierarchical cluster analysis of the average scores on specific soil science concepts. Bray-Curtis similarity index and bootstrap replicate of 1000 were used for this clustering analysis.

The data provided for the listed soil concepts were converted into quantitative values: 1 - no information, 2 - scanty information, 3 - some information, 4 - complete information. The relationships between particular concepts were calculated by dividing the sum of points into individual categories (group of analyzed soil concepts). In relation to the educational operational goals: *knowledge* (*the student knows), comprehension (student understands), application (student is able to)*, (Krathwohl, 2002), the soil concepts presented in the textbooks were divided into groups corresponding to the implementation of individual goals: knowledge (*soil genesis, soil profile, soils of the country, world soils* and *climatic-soil vegetation zones*), understanding (*soil processes, soil functions* and *agricultural usefulness*), and ability (*soil management, protection, and degradation*), (Fig. 2). Objectives that describe intended learning outcomes as the result of instruction are usually framed in terms of a description of what is to be done with that content. Thus, statements of objectives typically consist of a noun - the subject matter content - and a verb - the cognitive process (Krathwohl, 2002). Therefore: the student *knows* - the student was expected to be able to recall or recognise soil science *knowledge*, the student *understands* - the student was expected to interpret, classify, compare, and explain soil science processes, the student is able to - the student is expected to execute and implement previously acquired soil science knowledge.

The student *knows* represents a basic educational goal. Soil concepts such as *soil genesis, soil profile, soils of the country, world soils*, and *climatic-soil vegetation zones* available in the textbook provide the student with elementary knowledge about soils. However, the factual knowledge (theoretical soil concepts) is likely to be quickly forgotten by students if they do not *understand* the relationships and processes occurring in the soil. *Understanding* (another educational goal) allows the combining of known facts into a complex context. Showing *understanding* is the role of the following concepts: *soil processes, soil functions,* and *agricultural usefulness*. Following on from this, if students do not understand, they will not *be able to* put the relevant knowledge and skills into practice. In short, they will be unlikely to appreciate the applicability of soil education. To achieve this, students need to be familiar with the following concepts: *soil management*, *protection*, and *degradation*. The values of these three educational goals were the basis for assigning "scores" within each type of goal: a) knowledge – multiplied by 1 point, b)

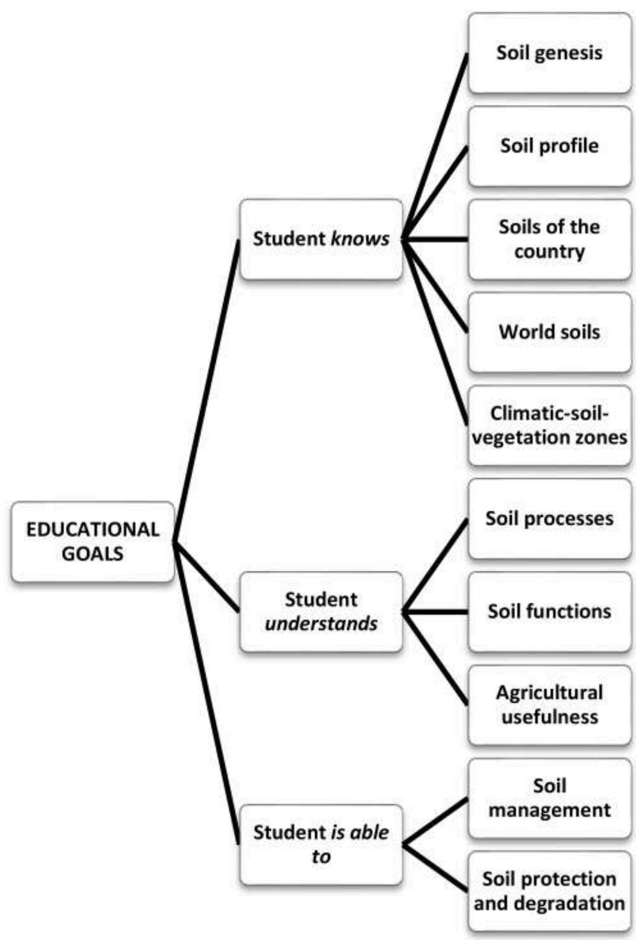

Fig. 2. Soil concepts presented in textbooks in relation to the three groups of individual educational goals.

understanding - multiplied by 2 points, c) ability - multiplied by 3 points.

2.2. Soil information coefficient (SIC)

A soil information coefficient (SIC) was created to further evaluate the combined effect of the calculated scores. This was undertaken with the aim of providing quantitative information regarding the effectiveness of textbooks in contributing to the achievement of the three, primary educational goals (Fig. 2).

The SIC was calculated according to this formula:

$$SIC = \sqrt{\frac{S_w}{S_{w^{max}}}} \times S_w \times S_{w^{max}}$$

Where:

S_w is the weighted sum of scores related to particular goals;

$S_w max$ is the maximum weighted sum of scores related to particular goals.

3. Results and discussion

3.1. Review of textbook analysis and statistics

Fig. 3 reflects soil science topics analyzed in textbooks from the investigated 43 countries worldwide. The mean value for overall content score was 16.1. The highest scores were achieved by Mongolia (28 out of 30), Turkey (26), Niger (25), and Uganda (25). Unfortunately, soil education in these countries is often presented as an optional subject. General analyses of individual topics discussed in the textbooks (given numerical values) are presented in Table 2. Issues related to *soil genesis* and *soil profile* were discussed in the most detail in textbooks (scores of 2.2 and 2.0 respectively), whereas *world soils* (1.2) and *agricultural usefulness* (1.2) received the lowest coverage. The remaining issues received scores ranging from 1.3 to 1.9.

The ten soil science concepts were clustered into three groups for further analysis (k-means). Specifically, cluster 1 included the topics which received the most attention; cluster 2 included topics receiving a moderate amount of attention; and cluster 3 included the least discussed topics (Table 3). *Soil genesis, soil profile, world soils, soil degradation and protection and climatic-soil-vegetation zones* (cluster 1) are the most discussed topics, whereas *soil processes* and *soil of country* (cluster 3) are the least discussed, with *soil management, agricultural usefulness and soil functions* (cluster 2) falling between the most and least discussed. These results agree with the sum of points obtained from the individual concepts (Table 1).

A further analysis concerned the grouping of countries in relation to the soil science concepts taught in schools. As is evident from clustering results (Supplementary Material 2), the groups of countries demarcated by the classical and k-means method clustering are similar with regard to their approach to soil science concepts taught in schools. Few differences in the results of the neighbor joining method were observed. Further analyses were performed based on clusters obtained from classical and k-means methods. Cluster 1 included countries where numerous clearly visible gaps in soil science education from textbooks and core curricula were observed. Countries with some gaps in soil science education are included in cluster 2**,** whereas cluster 3 included countries where soil topics were best represented. It should be noted that the group of higher scoring countries included countries where soil science education at the secondary/high school level is non-compulsory or optional and may involve a relatively small number of students (e.g., Ethiopia, Uganda, Kenya, Niger, and the USA).

In the overall analysis, the knowledge concepts (listed above) were the most commonly represented (mean 68 %). This percentage represents the sum of individual soil issues included in category: the student *knows* (Fig. 4).

While Turkey, Niger, and Uganda rate relatively highly according to all three educational goals, the student audience reached is not necessarily a broad one, because soil science education is not compulsory in these countries (Fig. 4). Interestingly, Poland, Belarus, and Latvia are European countries showing, in terms of soil science education, similarities in their attainment of the three goals. The three countries share similar historical and political backgrounds (long-term socialist systems). In these countries, education is compulsory up to the age of 18 and is provided to all citizens. In terms of its overall achievement against all three goals (Fig. 4), special mention can be made of Mongolia - a country where compulsory education lasts 11 years. Ninety-eight percent of young Mongolians are enrolled in primary schools, and eighty-five percent continue education in secondary schools (lower and higher). High school (high secondary) education is interrupted almost halfway through by means of an exam, and compulsory schooling ends at this stage (https://www.scholaro.com/pro/Countries/Mongolia/Education-System). Despite this challenging situation, Mongolia scored highly on the above list (90 %). On the other hand, the lowest result in the category student *knows* were observed for Australia, Iran, and India (30–40 %). Nevertheless, in this case, the lowest is *not the*

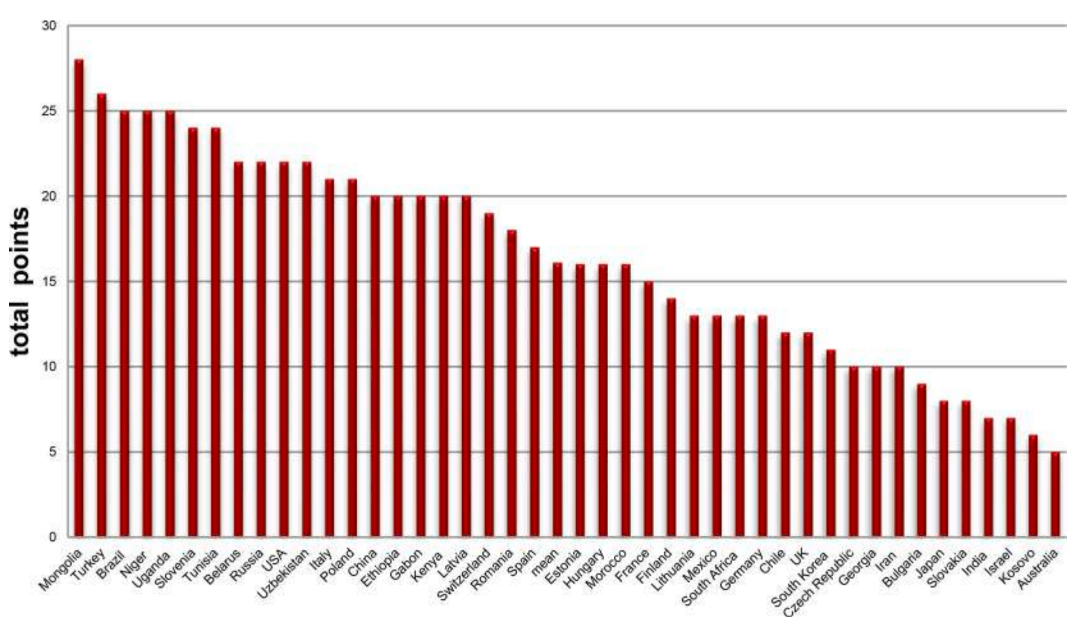

Fig. 3. Soil science concepts: total points for individual countries regarding the presence and depth of the listed soil science concepts.

Table 2
Analysis of individual soil science concepts discussed in textbooks, scored from 0 (no information) to 3 (complete information).

Country	Soil genesis	Soil profile	Soil processes	Soils of country	World soils	Soil management	Soil degradation and protection	Agricultural usefulness	Soil functions	Climatic-soil-vegetation zones	Sum
Australia	1	0	1	0	0	1	0	1	1	0	5
Belarus	3	3	3	3	2	1	3	0	1	3	22
Brazil	1	3	2	2	3	3	3	2	3	3	25
Bulgaria	2	2	0	3	1	0	0	1	0	0	9
Chile	0	0	0	3	0	0	3	3	3	0	12
China	2	3	3	3	0	3	2	2	2	0	20
Czech Republic	2	1	2	3	0	0	1	0	1	0	10
Estonia	3	3	3	3	1	0	1	0	1	1	16
Ethiopia	3	0	2	3	1	2	2	1	3	3	20
Finland	3	1	3	3	0	3	1	0	0	0	14
France	3	1	2	0	0	2	2	2	3	0	15
Gabon	3	3	3	3	3	0	2	2	1	0	20
Georgia	1	2	1	2	0	0	1	1	1	1	10
Germany	1	1	1	2	1	1	3	1	1	1	13
Hungary	3	3	0	1	2	1	3	1	0	2	16
India	0	3	2	0	0	0	0	1	1	0	7
Iran	3	0	0	0	0	2	3	0	2	0	10
Israel	1	1	1	1	1	0	1	1	0	0	7
Italy	3	3	1	1	0	3	3	3	3	1	21
Japan	1	0	0	0	2	0	1	1	0	3	8
Kenya	2	2	2	2	2	2	2	2	2	2	20
Kosovo	2	0	0	1	0	0	2	0	0	1	6
Latvia	3	3	2	3	3	0	3	1	0	2	20
Lithuania	3	1	2	2	0	3	1	0	1	0	13
Mexico	3	2	1	0	1	0	2	0	1	3	13
Mongolia	3	2	3	3	3	3	3	3	3	2	28
Morocco	2	2	3	0	2	2	3	0	1	1	16
Niger	3	3	3	3	2	2	3	1	2	3	25
Poland	3	3	3	3	3	1	1	1	1	2	21
Romania	3	3	0	0	3	0	3	1	2	3	18
Russia	3	3	2	2	0	3	3	1	2	3	22
Slovakia	0	0	0	2	0	0	2	1	1	2	8
Slovenia	3	3	3	1	3	1	2	2	3	3	24
South Africa	3	3	0	1	2	1	3	0	0	0	13
South Korea	1	2	2	0	0	0	2	1	2	1	11
Spain	2	3	2	3	2	1	0	1	0	3	17
Switzerland	2	2	3	1	0	3	2	2	1	3	19
Tunisia	3	3	3	3	0	3	2	3	2	2	24
Turkey	3	3	3	3	3	3	2	1	2	3	26
Uganda	3	3	3	3	2	2	2	2	2	3	25
UK	0	1	2	0	1	2	2	1	0	3	12
USA	2	3	2	2	3	2	2	3	2	1	22
Uzbekistan	2	2	3	1	2	3	2	3	2	2	22
Statistics											
N	43	43	43	43	43	43	43	43	43	43	
Min	0	0	0	0	0	0	0	0	0	0	
Max	3	3	3	3	3	3	3	3	3	3	
Sum	92	84	76	74	53	58	81	52	58	65	
Mean	2,2	2	1,8	1,7	1,2	1,3	1,9	1,2	1,3	1,5	
Median	3	2	2	2	1	1	2	1	1	2	

Table 3
K-means clustering (average scores on specific soil science concepts in all countries).

Item	Cluster
Soil genesis	1
Soil profile	1
World soils	1
Soil degradation and protection	1
Climatic – soil – vegetation zones	1
Soil processes	2
Soil of country	2
Soil management	3
Agricultural usefulness	3
Soil functions	3

worst. The same countries scored higher in the category *understanding* (India, Australia) and *ability* (Iran). The previously discussed comparison relates to knowledge-based concepts. Finland, a model of education in many respects, is below the average (60 %) but, as shown by the subsequent results, this does not have much of an impact on the acquisition of skills by Finnish students. Over the years, Finland has initiated a number of simple changes that have completely revolutionised their educational system. Finland outranks the United States and Eastern Asian countries because of common-sense practices and a holistic teaching environment.

The student *understands* - the achievement of this educational goal is responsible for the degree of implementation of the following topics: *soil processes, soil functions,* and *agricultural usefulness*. These concepts help to clarify the functioning of soils and their role in the environment. This

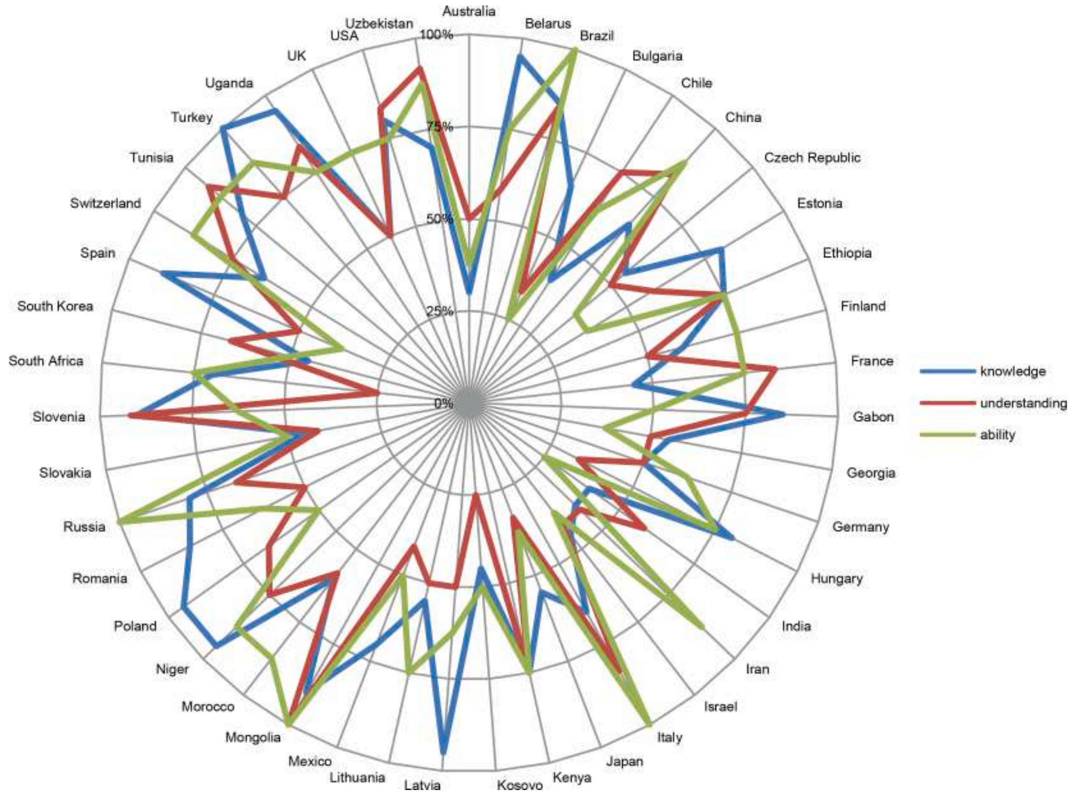

Fig. 4. Achievement of three educational goals (student *knows*, *understands* and *is able to*) in soil science education in 43 countries.

category was the most poorly represented (Fig. 4). The best results were achieved by Mongolia, Slovenia, Tunisia, and Uzbekistan. In Uzbekistan soil education is, as with Mongolia, not compulsory at the high school level. The other countries with high scores are Tunisia, Uganda, and the USA (where, as mentioned, soil education is optional, and policy-dependent in each state). In Brazil, geography is a compulsory curricular component in elementary school (1st to 9th grade). Currently, it is a mandatory subject in high school (1st to 3rd year), however, Brazil is in a process of curricular reorganization, and, with the implementation of the "New High School," geography will no longer be mandatory at this stage. In Slovenia, China, Italy, and France this education is compulsory and, the goal of *understanding* was best achieved (80–90 %). In the group of countries where the results of *understanding* were the lowest (South Africa and Kosovo) or below the average (61 %), there were also countries in which the category student *knows* was the highest rated (Latvia, Estonia, Romania, and Hungary).

Two topics are undoubtedly of an applied nature: *soil management* and *soil protection and degradation.* These concepts were used to determine the achievement of the educational goal: the student *is able to.* Among the countries that achieved the best results were Brazil, Italy, Mongolia, and Russia (Fig. 4).

The average score in the category student *is able to* was 65 %. Higher

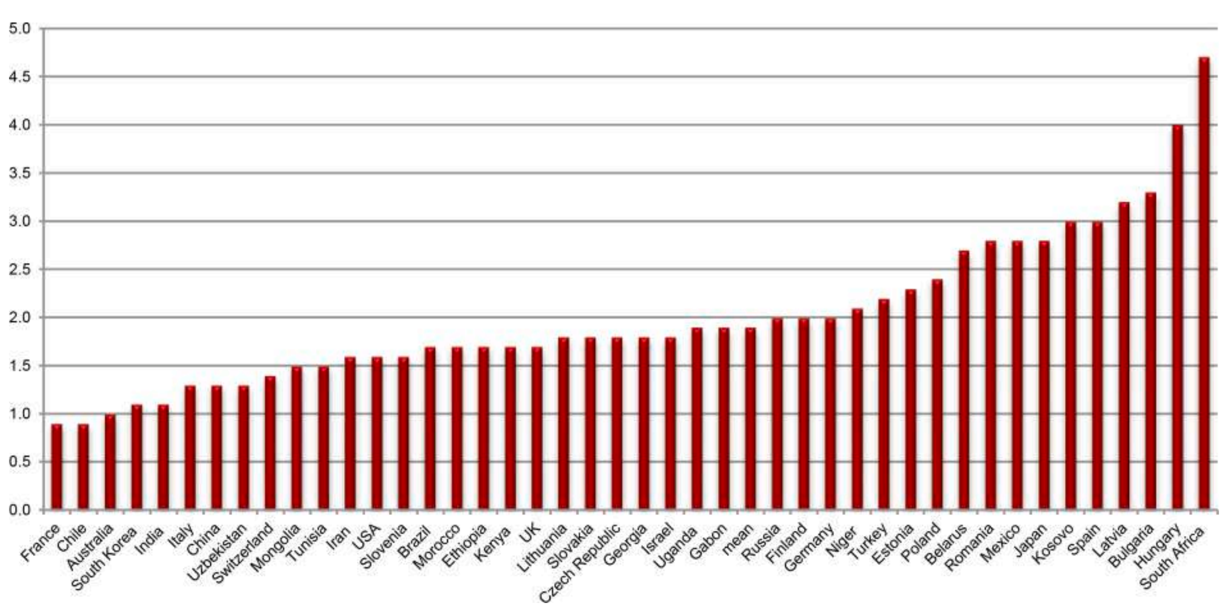

Fig. 5. Knowledge-understanding balance.

results in this category were achieved by countries which, in the previous combination of educational goals were at a medium or low level (Belarus, Finland, Hungary, and Lithuania).

By comparing the categories, the student *knows* and the student *understands*, a knowledge-understanding balance can be calculated by dividing the summed points of the respective categories. A higher number mean that the student *knows* more than *understands* (Fig. 5). Students *know* a lot in Bulgaria, Latvia, Hungary, and South Africa but do *not necessarily understand* as much, so they may forget quickly (Bui and McDaniel, 2015; Kang, 2016; Sekeres et al., 2016). In France, Chile, Australia, and South Korea, the emphasis is on concepts that shape the process of understanding the environment. Poland, Estonia, Turkey, Niger, Germany, Finland, Russia, Gabon, Uganda, Israel, Georgia, Czech Republic, Slovakia, and Lithuania were near the average score (1.9) which implies a knowledge-understanding balance.

The next indicator assessed whether students see the practical application of the knowledge they have already acquired. For this purpose, the topic soils *of the country* was compared with the topic *soil management;* a mean value of 1.2 (Fig. 6) was observed. Theoretically, the higher the index, the more questionable the knowledge-understanding balance in soils education because, while students know which soils occur in their surroundings, this knowledge is simply abstract, with no practical dimension (Latvia, Gabon, Chile, Czech Republic, and Estonia). In the UK, Morocco (optional education), Iran (optional education), and France students know little about their country's soils, but they know how to manage various soil resources. These countries do not take advantage of teaching on familiar examples. Therefore, a ratio below 1.0 was unfavorable. The group of countries with an index oscillating around 1.0 indicates correctly balanced proportions between knowledge, understanding and skills: India, Slovenia, Turkey, Kenya, USA, Tunisia, Mongolia, China, South Korea, Romania, México, Japan, Finland, South Africa, and Hungary. Soil education in high/secondary school is mandatory in Slovenia, China, South Korea, Romania, Japan, Finland, and Hungary.

Another indicator determining the ability to apply knowledge may be an understanding of *soil functions* and the concepts of *degradation and protection of soil resources*. A low mean value (0.9) was observed (Fig. 7). Countries with lower rates were characterised by a greater emphasis on degradation and protection issues than familiarity with soil functions. In Hungary, Latvia, South Africa, Finland, Switzerland, and Russia (all scored < 0.9), the student knows that soil should be protected and they are aware of soil degradation, but they do not know why and to what purpose because their understanding of soil functions is inadequate (Fig. 7). In Australia, India, France, and Slovenia, understanding soil functions seems to be a more important goal than understanding soil degradation and conservation. It can be argued here that the student is aware of how important soil is but is not necessarily aware of soil problems and what can be done to protect soil resources. Ideally, this emphasis on soil functions and soil protection and degradation should be in equilibrium. In the case of Italy, Russia, Romania, Uzbekistan, Brazil, Lithuania, South Korea, China, Mongolia, Tunisia, USA, Turkey, and Uganda (result 0.8–1.0) this indicator appears well balanced, however, it should be noted how poorly the concept: *soil functions* scored in each country. Typically, one or two soil functions were mentioned in textbooks: "providing food" and "habitat for animals". In the case of soil protection, there was usually little information on soil degradation and even fewer details regarding its protection, a significant issue that requires addressing in the near future.

3.2. Soil information coefficient (SIC) and teaching forms of soil science

General access in textbooks to educational implementation of three goals were assessed by SIC (vide supra). Textbooks from Mongolia, Brazil, Turkey, Tunisia, Niger, Uganda, Uzbekistan, and Italy achieved the highest scores, achieving 50 points for their SIC score (Fig. 8). Conversely, Japanese, Israeli, Indian, Bulgarian, Kosovarian, and Australian textbooks proved to be inadequate, with a SIC below 20.

Comparing the educational goals the student *knows*, *understands*, *is able to*, and the interdependencies between their implementation, it can be argued that Finland, Italy, Russia, and Mongolia offered what might best be described as *optimal* soil education. Balanced proportions between individual soil science topics, equal emphasis on achieving the most important goals and paying special attention to the need to develop students' ability to perceive facts, threats, and benefits related to soil management put these countries in an elite position regarding soil science education. Additionally, the attractive graphic design of textbooks, as well as encouraging students to use modern, digital approaches to the educational process, further improved the performances of these countries in SIC terms (Fig. 9).

It should be noted that although the extent to which textbooks are

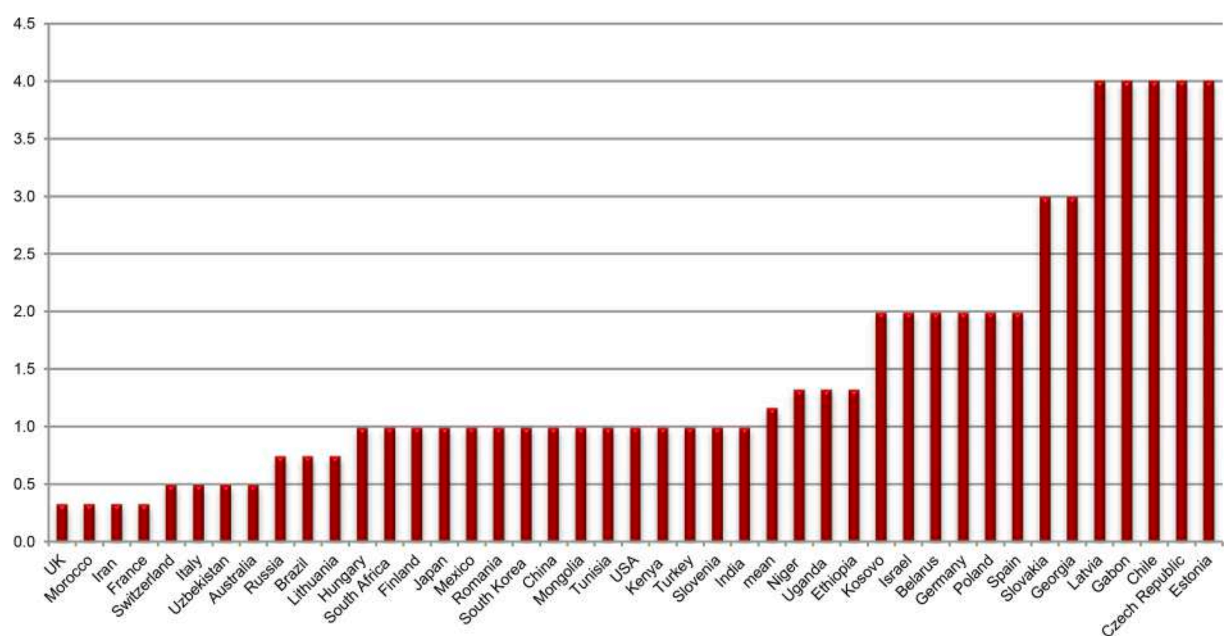

Fig. 6. Knowledge-practice balance: soil of country/soil management.

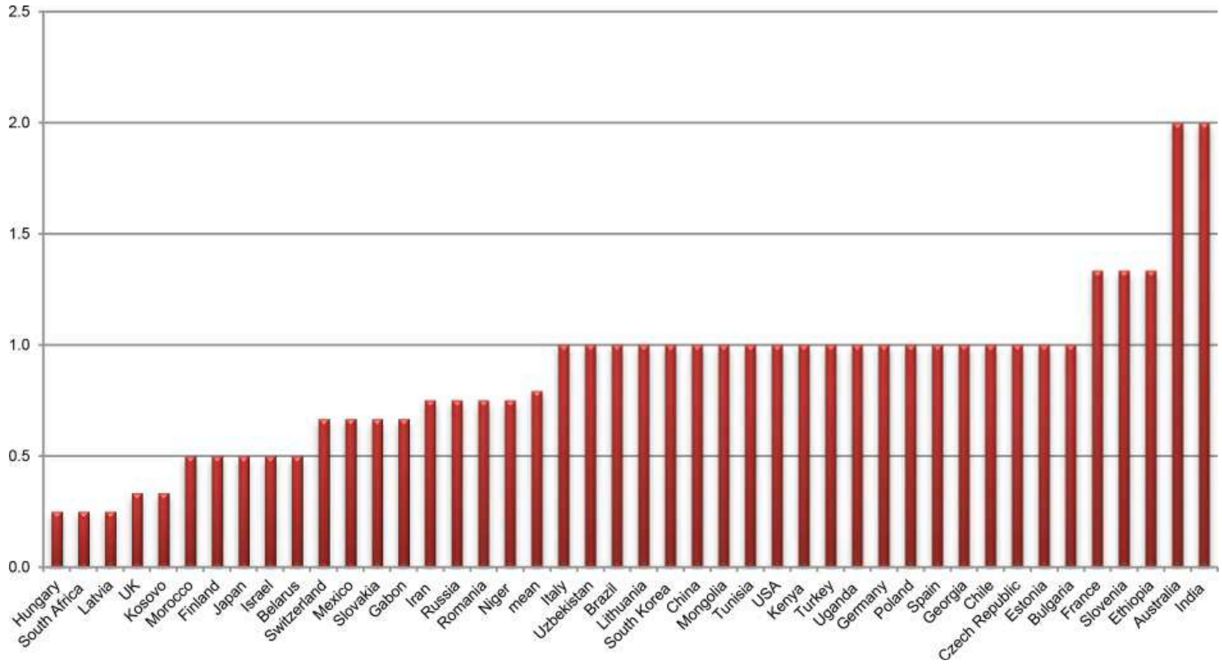

Fig. 7. Knowledge-practice balance: soil functions/soil degradation and protection.

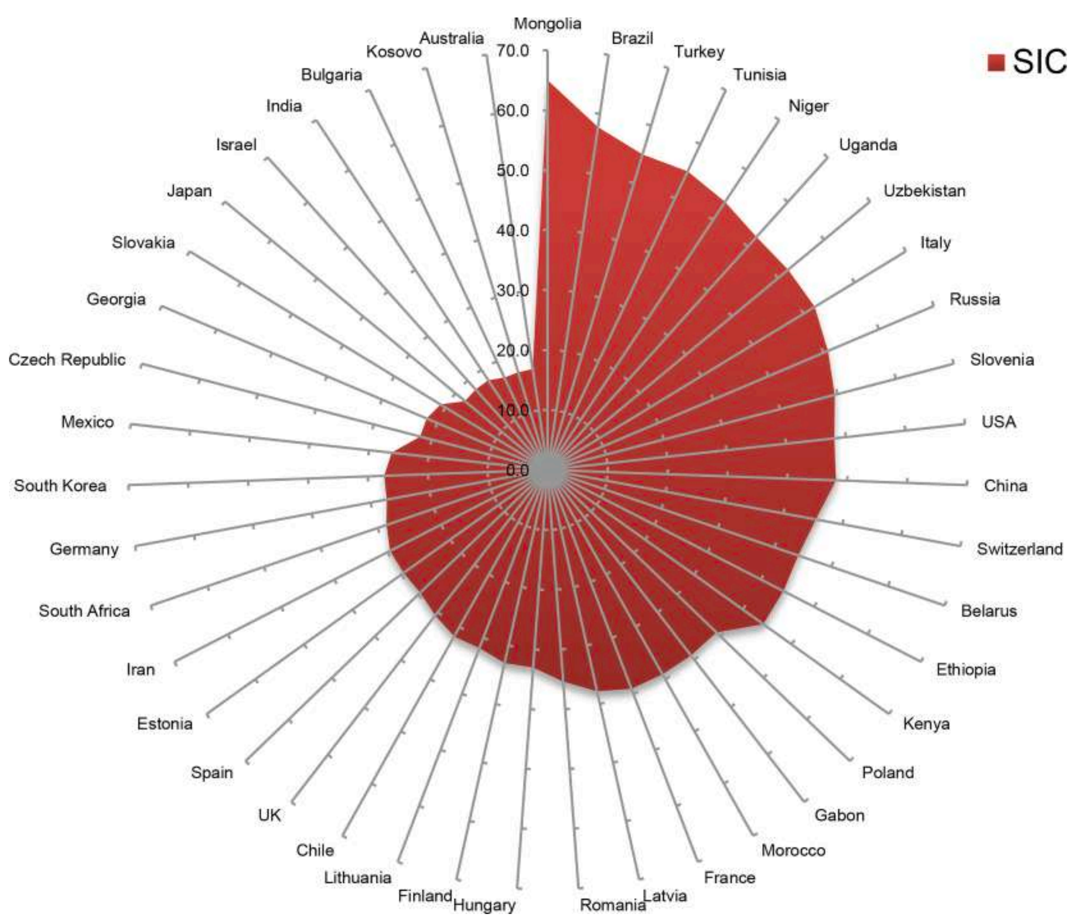

Fig. 8. Soil Information Coefficient (SIC) in investigated textbooks.

used varies (depending on the teacher and subject and class), there is little doubt that textbooks are an extremely important instruction medium utilised by teachers. Care should therefore be taken to make them attractive and tailored to the needs of the student/recipient.

Not only do indicators differ from country to country, but also between educational systems. In most countries, geographic education is

Fig. 9. Soil-related graphics included in: 1 – Finnish, 2 – Italian, 3 – Mongolian, 4 –Russian textbooks (note that these are simply included as examples of soil-related graphics and have not been assessed or evaluated *per se)*.

based on the core curriculum compiled and structured by experts in their ministry or department of education and which stipulates a compulsory set of teaching goals, content, and skills. These are prescribed in the form of general and specific requirements for knowledge and skills that a student should have after successfully completing an appropriate educational stage. In some countries (USA, Germany, Switzerland) there are no national requirements or science education standards officially endorsed by the government. However, guidelines are periodically written and recommended. Topics and learning targets (as well as competences of students) are often stipulated for every school-level separately.

Soil science education is not always combined with geographic education. Soil education elements are written into the core curricula or educational guidelines of various subjects. In South Korea, for example, soil science education is part of geological education, and in Uzbekistan, the USA and Germany, soil science education is incorporated within various subjects (from geography and biology to earth science). The geography curriculum and education in Italy is based on the "annual plan of activities" (APA). This must be approved by the School Director, based on proposals coming from the "collegial bodies" represented by all the teachers (regardless of their curriculum) belonging to the school. The approved curriculum must be based on both basic (mandatory) and additional activities. The latter are not mandatory but, frequently, teachers decide to include them because they focus on more applicative aspects. The APA can be modified at any time, even during the course of a scholastic year, but this must be done only after following the same previously reported procedure.

Generally, governments have exclusive legislative responsibility for the "general rules on education" and for the determination of the essential levels of services that must be guaranteed throughout the national territory. In most countries there are two to three stages of geographic education (primary, middle/secondary, and high school) but sometimes geography is available as an optional one-year course in high school (for example, in Brazil). Often geography content is incorporated into social studies classes and is not physical science-based.

Geography and environmental science are included as compulsory subjects in most countries with some significant exceptions, such as in the USA. Textbooks are most often chosen by teachers or a school district from several options offered by various publishing houses (Watt, 2004, 2009). In most countries there is plenty of supplementary material; examples include experiment sheets, activity kits, videos, lesson plans, and accompanying websites. In Finland, field trips into the natural and built environment, as well as the use of digital learning and spatial information are an integral part of geography teaching.

The mean years of schooling also has an impact on educational results. Countries with the highest SIC do not always top the list of this mean (Fig. 10). The annual Best Countries Report, conducted by US News and World Report, BAV Group, and the Wharton School of the University of Pennsylvania, reserves an entire section for education. This report surveys people across 78 countries, and ranks those countries based upon the surveyees' responses. It compiles scores from three equally-weighted attributes: a) a well-developed public education system, b) would consider attending university there, and c) provides top-quality education. Therefore, it can be concluded that some countries with lower SIC (Australia, Germany, the United Kingdom, and the USA) and excellent educational outcomes, "catch up" at the tertiary stage. However, the focus of the analysis was not on education systems but on the soil science content of level 3 textbooks that apply to the majority of the population (not only to those who decide to continue their education). The number of persons at a given age who are enrolled in education is also differentiated. Percentage of 15- to 29-year-olds enrolled in school, by selected levels of education, age, and country as well as percentage of children of a given age who are enrolled at an education level compatible with their age or enrolled at a higher education level are presented in Table 4. Data for individual countries come from different sources and refer to different indicators, as it was not possible

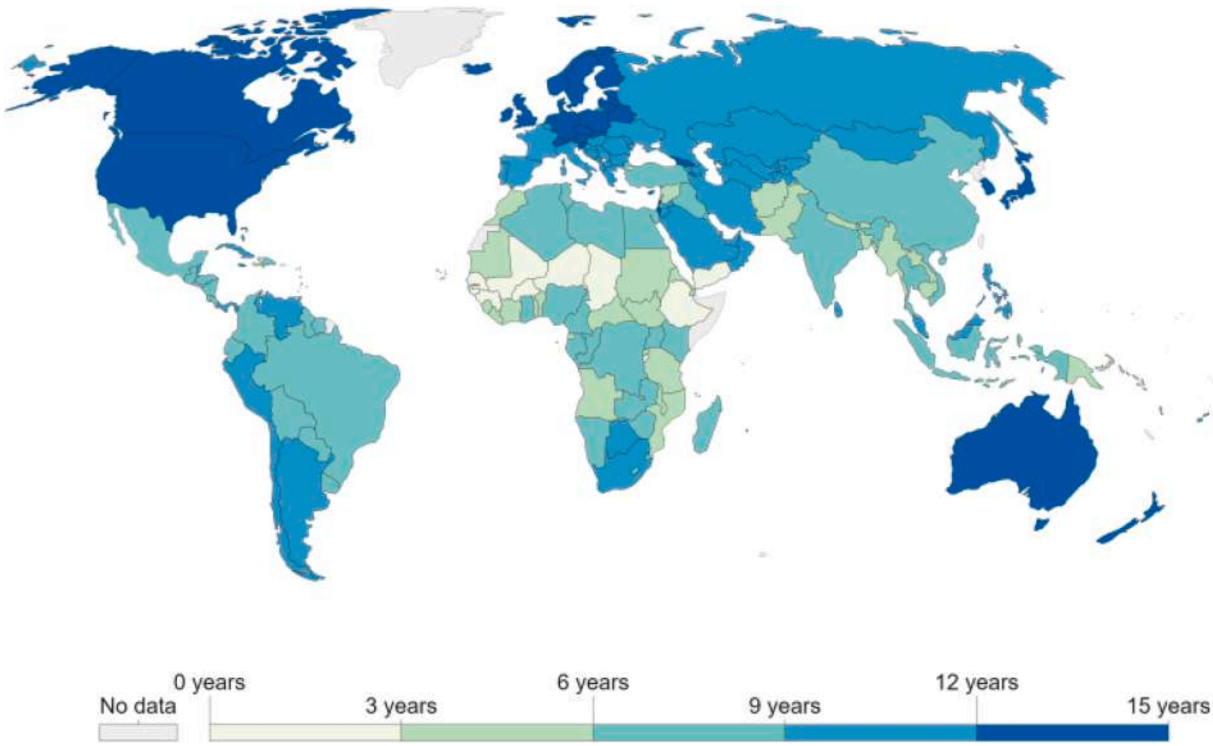

Fig. 10. Average number of years of total schooling across all education levels for the population aged 25 + in 2017 (https://ourworldindata.org/global-education).

to find corresponding data for all countries. The data in the table indicate the importance of education (including soil science education) at level 3. In most of the OECD (Organization for Economic Cooperation and Development) countries analyzed, 70 % of students attend secondary school and only 27 % go on to further education. Except for some African countries (Niger, Uganda, Ethiopia, Gabon) the percentage of children of a given age that are enrolled at an education level compatible with their age is also high (above 75 %). Therefore, the 3rd educational level should present the type of information which will facilitate the development of an environmentally conscious graduate.

One more issue raised major concerns. Most countries declared that no soil classification was mentioned in their textbooks (Fig. 11) and the soil science information was, in 38 counties, not up-to-date. The implication is that the names of soils, their types and locations do not correspond to the current state of knowledge (often these are classifications from 20 to 30 years ago - valid at the time of initial publication of a particular textbook, and then simply repeated in the following editions). The transfer of current, cutting-edge soil science knowledge is slow and, typically, reaches the intended recipients (students at secondary school level) after a considerable delay. This is understandable due to the procedures accompanying the preparation of textbooks. However, the question must be raised as to whether this should really take a decade or even longer. Admittedly nowadays the option of releasing textbooks via open-source content management systems is possible, and that process takes much less time, but it is still problematic because of the need to get ministry (or local government in the case of some countries) approval. Similarly, many developing countries do not have the resources to produce quick-release, online, open-source material. In many, if not most countries, the printed textbook still comprises the backbone of resource material in soil science education. All too frequently, soil science knowledge in textbooks is out of date, with little or nothing being done to bring it up to date.

In spite of the concerns flagged above, a number of positive aspects were identified in the core curriculum in many countries. In Chile, for example, the curriculum included deeper concepts such as the relevance of soil for human health development, the negative effects of intensive/mono-biotic agriculture in biodiversity preservation and soil functionality, causes and consequences of soil pollution, soil degradation, erosion and desertification as universal threats, soils as principal reservoirs of nutrients and organisms, and the influence of soil in social transformations. At this time, many countries are considering or implementing educational reforms and changing their core curricula as well as recommended teaching methods. Contemporary teaching methods consider the life experiences of the students, internationality, and cooperation with out-of-school bodies.

3.3. *Learning from mistakes: Challenging proposals for improving future soil science teaching.*

As previously noted, problems with inadequate soil science knowledge topics result from incomplete information on soils available to students. In addition to concerns about a decline in student participation in learning science, in particular soil science programs and courses (Baveye et al., 2006; Hartemink et al., 2008), the key challenge as to how best to effectively engage and address student deficiencies in soil education remains.

Although the content of soil science is situated between the natural sciences and professional practice (Philip, 1991), and a unique aspect of soil science is the interaction between basic research and its application (Hartemink et al. 2014), this aspect is neglected in most countries. Soil degradation has become a global problem whereas among the soil concepts worst taught are “soil functions”, “soil management”, and “agricultural usefulness”. The concept “soil degradation and protection” usually covers only the degradation part without addressing its protection. Emphasizing the importance of providing examples of improvements to degraded soils because of their pivotal role in sustainable development is necessary. Similarly, the limited examples of solutions to soil degradation issues leads young people to believe, incorrectly, that little or nothing can be done to resolve such issues. Textbooks lack examples of specific actions taken to address soil conservation and degradation. No mention is made of reports produced by international expert teams, such as the unprecedented report of the

Table 4
Percentage of students enrolled in schools and attending an education level compatible with their age (based on OECD Online Education Database and UNICEF Global Database, (https://data.unicef.org/topic/education/overview/), (Organization for Economic Cooperation and Development OECD, 2022), (https://ourworldindata.org/global-education).

Percentage of 15- to 29-year-olds enrolled in school, by selected levels of education, age, and country: 2018			
	All levels of education[1]		Secondary education[2]
Country	15 to 19 years old	20 to 29 years old	Total
Australia	83.7	36.3	64.7
Chile	81.5	28.9	64.4
Czech Republic	90.3	23.7	85.1
Estonia	88.2	24.4	82.4
Finland	86.7	40.1	83.8
France	87	22.6	66.2
Germany	86.4	34.1	75.1
Hungary	83.3	22.5	73
Israel	66.2	20.3	61.4
Italy	85.3	24.6	76.4
Japan	no data	no data	57.9
Korea	84.3	28.9	55
Latvia	93	28.3	84.2
Lithuania	93.7	28.4	80.4
Mexico	62.5	18.6	51.5
Poland	92.6	28.4	83.7
Portugal	88.9	23.2	73.2
Russian Federation	87.3	18.7	46.9
Slovak Republic	83.8	17.6	77.4
Slovenia	94.3	33.5	82.5
Spain	87.2	31.5	69.4
Switzerland	84.9	27.7	81
Turkey	70.9	42.2	59.9
United Kingdom	83.3	20.1	66.1
United States	83.7	24.4	64.2
Percentage of children of a given age that are attending an education level compatible with their age or attending a higher education level: 2021[3]			
Belarus			88
Brazil			65
Bulgaria			86
China			60
Ethiopia			8
Gabon			16
Georgia			85
India			64
Kenya			36
Mongolia			87
Niger			4
Romania			90
South Africa n/c			85
South Korea			95
Tunisia			59
Uganda			8
Iran			no data
Morocco			no data
Uzbekistan			no data

[1] In addition to secondary and postsecondary education, may include enrollment in International Standard Classification of Education (ISCED) 2011 level 1 (primary or elementary education).

[2] Refers to ISCED 2011 level 2 (lower secondary education) and level 3 (upper secondary education). Secondary education generally corresponds to grades 7–12 in the United States.

[3] Household survey data from the past 10 years are used for the calculation of completion rate. For countries with multiple years of data, the most recent dataset is used.

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (Scholes et al., 2018).

There are many functions of soil which could and should be presented in greater detail. Understanding of all relevant functions may be difficult for students but brief mentions of such functions can be included in textbooks as a foundation for higher education (Mori et al., 2020). In turn, soil management is essential for sustainability. According to The International Union of Soil Sciences (IUSS, 2016) the key to achieving the Sustainable Development Goals (SDGs) is the protection of soil resources and education for its conservation (Reyes-Sanches, 2020b).

Agricultural usefulness is one such feature that emphasises the basic function of the soil: supplying food, fiber, and fuel. Insufficient or inadequate knowledge in this area may have serious consequences for the future. Many educational programs lack the ability to demonstrate to students that the food which sustains their lives depends on soil, as well as making them aware of the daily efforts of farmers and other agricultural practitioners (Hirai and Mori, 2020). In many countries there is a lack of soil science content and the lack of enquiry teaching materials for schools (Moebius-Clune et al., 2018). Equally, there are insufficient field activities to present students with appropriate practical skills.

According to Field (Field et al., 2013; Field et al., 2017) students will benefit from the interplay of teaching and research, and field-school (practical abilities) is much more effective than traditional lecturing. Field lessons are one of the most effective techniques in teaching soil science (Kasimov et al., 2013; Hartemink et al., 2014; Al-Maktoumi et al., 2016, Urbańska et al., 2019; Smith et al., 2020). Siebe et al. (2017), site three aspects which should be considered in order to increase awareness about soils. In the human psyche, there should be a desire for "soil care", the participation of the body should be provided by experiences ("learning by doing") and spiritual connections to soils create emotional links to them. All three aspects can be perfectly fulfilled with field lessons (Urbańska and Charzyński, 2021).

A separate problem is inadequate soil training for those teachers who have often not taken any soil science courses at university level (Huang et al., 2014; Huang et al., 2015; Huang and Hseu, 2020). The teachers in the countries which formed the focus of this research held qualifications on many different levels. In Tunisia teachers have a license or bachelor's degree in natural sciences. Teaching licensure requirements differ in each state in the USA. The board of education in each state determines the necessary requirements for obtaining a teaching license. Typically, at high school level, teachers must have an undergraduate degree in a related subject (a few states require a graduate degree), complete a teacher preparation program, and pass several standardised exams. In Italy as well as in many other countries (for example, Russia and Poland) teachers typically possess inadequate skills for soil science teaching. Many schools (for example, Estonia, Mexico, Brazil, Argentina, Germany, and Poland) have resolved this issue with the help of different projects in collaboration with universities. Teachers actively use workshops, worksheets, practical exercises in real life, as well as utilizing using modern IT tools. Capra et al. (2017) proposed the use of soil songs in teaching activities as a powerful means of communication; several teachers coming from different disciplines (for example ecology and climate science) already use songs, and music in general, in their activities (Turner and Freedman, 2004; Bucchi and Lorenzet, 2008; Huang and Allgaier, 2015). Recognizing the intrinsic ability of music to share emotions, intentions, and meanings, even among people with different backgrounds, can prove to be advantageous (Miell et al., 2012). Xylander (2020) suggested that soil science education should be experienced with all the senses (for example, in school gardens). Stirring the viewer's imagination can also be done through storytelling, which is what happens during soil exhibitions at the Senckenberg Museum für Naturkunde Görlitz (Xylander, 2020). During the summits in Tbilisi (1987), Rio de Janeiro (2000) and Johannesburg (2002), both the UN and UNESCO emphasised the importance of building teacher capacity so as to enable teachers to teach and support the education of children and young people (Reyes-Sanches, 2020b). This in turn will prepare the next generation to contribute meaningfully towards the solving of present and future environmental problems.

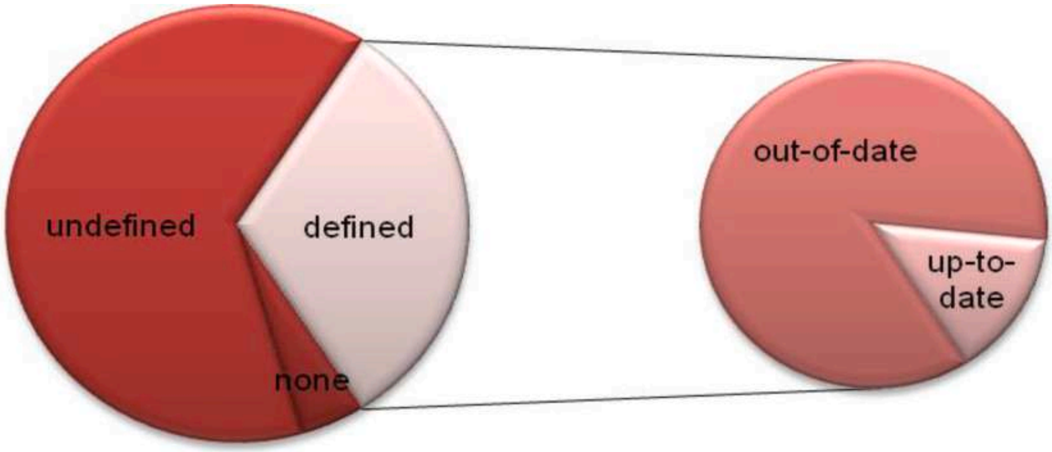

Fig. 11. Type of soil classification used in textbooks.

4. Summary and conclusions

Globally, there are many problematic issues and disparities in textbooks at the high school level. Soil scientists need to be aware that the current generation of students in many countries are unaware of the importance of soil. Universities offering soil science courses should appreciate that it might well be extremely difficult to recruit students to soil science as most are unaware that the discipline even exists (Brevik et al., 2020). There is a need to develop appropriate methodological and instructional guidelines to make future generations aware of the study of soil science at more than just a superficial level. This process should not only concern a particular country but should become an international goal for everyone with an interest in soils. Soil science societies could develop common guidelines for global soil science education and even create educational platforms with soil science content delivered in a form that caters to the needs of young audiences. It should also be remembered that young people respond favorably to modern, digital teaching methods. Role playing and spatial data applications may well increase students' motivation, interest in learning, and improve digital literacy (Urbańska et al., 2019). Teachers should provide students with the opportunity and time to develop their own thinking, creativity, and action; only the combination of such methods with appropriate soil science content in textbooks, supported by field lessons, can shape a "new" citizen of the world who is ready to face the future challenges facing our planet. From this perspective, the German concept of "from idea to action" (Xylander and Zumkowski-Xylander, 2018) should be applied in more countries worldwide. Some educational solutions will help to achieve this goal. For instance, theoretical issues in the field of *knowledge of facts* (soil profile, soil genesis, country, and world soils, etc.) should be discussed in connection with the issues based on the *understanding* of processes and the ability to *apply* this knowledge in practice (minimizing the forgetting of factual data). Much greater emphasis needs to be placed on educating students about the functions of soils and the role that soils play in the environment (a key aspect due to the multitasking nature of the soil cover). Students should be able to draw conclusions and notice the relationship between soil types and their management (increasing the conscious management of soil resources). Field lessons (with the participation of soil science specialists) should be an integral part of high school soil education ("learning by doing"). Much work has yet to be done, but this should not be seen as a deterrent but, rather, as a fresh challenge for soil science academics and scholars worldwide. Without an improvement in the main issues around soil science teaching highlighted in this paper, soil scientists will be unlikely to solve all the outstanding issues affecting the fragile, non-renewable soil resource on their own. It must be emphasised that several positive examples have been identified globally, thus presenting a fundamental foundation for further improvements. Educating young people, starting at the compulsory school level, and bridging the gap in terms of knowledge between higher and lower educational levels, can be seen as one of the most effective solutions. It is often said, but now truer than ever, that future generations will be faced with, and will be required to solve significant challenges in terms of soil resource protection and management. Can soil science have a future without facing the *educational* aspects surrounding these issues?

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

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Digital media in soil education

Abstract: Teaching soil science as a part of geography subject is crucial, because students learn not only about soil properties, but also about conscious and rational use of the soil resources. Nowadays digital media play increasingly important role in education and can be employed both in geography classes and soil science. The article aims at comparing various multimedia tools used as a support in teaching on soil science and evaluation of trends concerning the use of these methods in education. The use of ICT during lessons should be purposeful, therefore a need arises to develop strategies on effective use of multimedia and methodological guidance in specific teaching situations. Social media and virtual reality games have changed the way young people perceive the real world, and this includes education. Thus, it is of value to attempt employing role-playing and elements of gamification in teaching soil science and geography lessons.

Keywords: soil science, geography, education, multimedia tools

1. Introduction

The soil cover is one of the most important environmental elements. Soil has many functions, from satisfying the elementary nutritional needs of a human to landscape protection. The knowledge of soil genesis, processes, its spatial diversity provides an opportunity to better understand the relation between biotic and abiotic components of the environment. Teaching basics of soil science as a part of geography subject is essential, because students learn not only about the properties of soil, but also about conscious and rational use of the earth resources. The digital media play increasingly crucial role in education, and there are many opportunities to use this form of support when teaching on soil. Getting to know the digital media tools allows us to enhance the use of the information and communication technologies (ICT) in teaching. Possibilities offered by interactive devices, multimedia software, e-books and internet resources can aid the development of teaching methods.

The aim of the article is to compare various multimedia tools used to support teaching of soil science and to evaluate trends in the use of these methods in education.

2. Principles, aims and objectives of multimedia methods in geography and soil education

Using multimedia in schools depends on both external and internal factors. The former involve the legislation, education curricula and teacher's promotion paths, whereas the latter comprise willingness to increase the attractiveness and effectiveness of lessons. The multimedia effect is understood as an increase in the effectiveness of the learning and teaching process achieved by means of incorporating multisensory stimuli. It is related to the intersensory transfer, which leads to transferring sensory sensitivity from one group of receptors to another (Żuk, 1996).

Psychologists who conduct studies on multimedia in education point to numerous advantages of their use in teaching. Information transfer via many channels enables their parallel processing. Thus, students can save the time otherwise required for reprocessing the information (Żuk, 1996). Information coming to the student through multiple sensory channels can be immediately verified and compared. In addition, the message stimulating the visual cortex of the *brain* leads to the activation of attention. Multimedia-based learning takes advantage of the brain's capability to make connections between visual and verbal representations of content, and improves understanding, This supports the transfer of acquired knlowledge to other situations.

Interactive multimedia are a natural environment for the entertainment of "digital natives"– contemporary students –thus using them wisely in the form of edutainment could be an efficient motivation for learning. The use of ICT in education is also changing the role of the teacher from the "sage" to the "guide" in the world of knowledge (Kida and Neczaj-Świderska, 2007). With smartphones and the constant internet connection, students today have unlimited access to the information they need.

To enable adequate teaching-learning process within the scope of geography using multimedia, certain conditions must be met (Pliszka, 2005).The teacher and students must be aware of the purpose of digital media-assisted education, which is often omitted in various teaching materials. Unfortunately, excessively much attention is focused on the teaching materials, and not enough on preparing people to use them. The issue of teachers' qualifications should be considered in two interdependent areas. The teacher should have knowledge and skills to use computer, and also be familiar with at last basic applications and educational software. It is particularly important to know how to use the computer in educational work (Pliszka, 2005). The implementation of didactic goals is accomplished by various methods selected by the teacher. Properly selected and used digital media can contribute to more effective education. Some of them, in particular the interactive ones, will help activate students and engage them in the didactic process. The multiplicity of information allows the teachers to individualize the learning process and achieve better education results.

The aims of geography teaching presented by Zając (1997) are a detailed and subject-focused version of the general taxonomy by Niemierko (1975). The analysis performed by the authors made it possible to assign functions that multimedia software can perform in the teaching-learning process pertaining to geography of soils. The use of digital media in geography classes helps better accomplish the aims of teaching on the subject in all taxonomic categories. Presenting information in a multicoded form improves students' remembrance. Interactive animations, videos and maps present difficult spatial and time processes in a way that is simplified and easier to understand.

Due to their diversity, attractiveness and interactivity, multimedia tend to engage the student more closely in the learning process. They allow for the implementation of basic activities, such as: exploring the world, experiencing, evaluating and, sometimes, performing simulations that involve changing and transforming the reality. As in the case of chemistry teaching (Strykowski, 1996 after Gulińska, 1997), multimedia in geographical education can include cognitive, emotional and motivational functions (Cornish, 2012).There are essentially two approaches to comparing the aims of geographical education and the concepts of computer-aided learning. The first one refers to the computer as a device designed to transmit information, facilitating its passive reception and assimilation. The second approach treats it as an educational tool for supporting mental processes and improving skills through various types of activities and exercises.

In the commentary to the core curriculum for the third education stage, as well as in the core curriculum of general education in geography from 2017 (Dz.U. 2012, item 977; Dz.U 2017 item 356), the attention is drawn to the use of ICT as an important source of geographical information. Their use facilitates collecting, processing and presenting information.

Methodological recommendations include suggestions to use modern media in teaching regional geography –aerial photographs, 3D images, multimedia presentations, internet resources etc. It should support the analysis of landscapes also in the context of the relationship between natural environment and human activity.

At the time of changes in schools related to the reform of Polish education, there is a need to establish a core curriculum for (terminated but still existing) secondary schools with core curriculum for eight-year primary schools.

Current legal documents written in the form of a core curriculum directly determine geographical education. It is the basis for creation of geography textbooks. The possibility of using multimedia with reference to general geography classes is aims at the third stage of education and primary school classes as part of the current core curriculum of general education for both secondary and primary schools (Table 1).

Table 1. Possibilities of supporting the implementation of geography teaching aims for the third educational stage (as well as 8-Year primary school classes) with the use of multimedia (Authors' own study based on the core curriculum of general education: Dz.U. 2012, item 977; Dz.U. 2017, item 356)

Educational purpose	General requirements	Achievement of a specific aim using the multimedia
I. Using different sources of geographical information.	The student observes and makes field measurements; can use plans, maps, photographs, drawings, charts, statistical data, source texts, as well as information and communication technologies to collect, process and present geographical information.	Visualization of information in a different form that is attractive to the student by means of using various combinations of transmission codes; The ability to present and create digital tables, charts, maps, diagrams and drawings; Development of the ability to acquire, use and evaluate information from various sources.
II. Identifying relationships and dependencies; explaining phenomena and processes.	The student uses the basic geographical vocabulary to describe and explain phenomena and processes taking place in the natural environment, economy and social life in various spatial scales (local, regional, national, global); student understands the nature-human relationship; explains the spatial diversity of the natural environment conditions and human activities on Earth.	Processing of the reality by simulating natural and socio-economic phenomena occurring at different time and greater scales; Improving the understanding of relationships between the natural environment and human activity, and presenting them with the use of interactive tools.
III. Using knowledge and geographical skills in practice.	The student uses knowledge and geographical skills to better understand the contemporary world, and applies the acquired skills in life, among others, to rationally use the environmental resources.	Activation of perceptional processes, observation, comparison, deduction and reduction reasoning using interactive materials; Developing the ability to use information technologies as a key-competence in self-education and lifelong learning.
IV. Development of social skills and competences.	The student develops: Curiosity by getting interested in his or her own region, Poland, Europe and the world; Awareness and a sense of responsibility for the natural and cultural environment of the region and Poland; Patriotism and a sense of identity (local, regional, national), while retaining respect for other nations and communities – their systems of values and ways of life.	Shaping emotional attitude towards the surrounding reality manifested on a global scale, as well as towards local natural and socio-economic phenomena and processes; The use of various tools to stimulate the curiosity of the world and to familiarize students with its diversity, developing respect for other religions, ways of life and culture.

3. Soil education as part of geography teaching

Issues pertaining to soil education, outside geography classes, are also touched upon on other school subjects, such as biology and chemistry. However, the detailed requirements for the third and fourth educational stage as well as for primary school classes (according to the new core curriculum) indicate only six of them as directly related to soil education. The core curriculum for the grammar school contains similar soil issues to those included in the new core curriculum for primary school and for secondary school (high school). As a general rule, the implementation of these topics involves issues related to the biosphere and usually is scheduled near the end of as chool year. It is important to ensure that the didactic tools and methods employed are as effective as possible. The use of multimedia in soil education can contribute to an increase in the educational effectiveness of the discussed issues (Table 2).

Table 2. Teaching on soil science and possible application of ICT evaluation (Authors' own study based on the core curriculum of general education: Dz.U. 2012, item 977; Dz.U.2017, poz. 356)

Teaching content	Specific requirements	Use of multimedia
Junior high and primary school (according to the core curriculum of 2017)		
Selected issues of physical geography/ climate, soil and vegetation zones in Africa.	Using thematic maps the student presents the relationship between Earth's axial tilt and climatic zones, and shows the climate impact on the diversity of vegetation and soils on Earth; Using thematic maps the student explains the climate, soil and vegetation zonality in Africa.	Access to digital maps, satellite images from different parts of the world; Use of GIS software to display individual thematic layers, and to facilitate the analysis of the diversity of vegetation and soils on Earth.
Location and natural environment of Poland/ The main soil types of Poland.	The student: Lists the main types of natural resources in Poland and his own region: forests, waters, soils, mineral resources; Using the map, describes distribution of resources and determines their economic importance; Distinguishes the most important features of Brown soils, Podzolic soils, Chernozems, Ordinary alluvial soils and rendzinas[1], indicates their location on the map of Poland and assesses their agricultural suitability.	Access to digital maps at various scales allows the student to describe the distribution of soils in Poland and his or her region.
Secondary school (high school) – basic level		
Human-environment relation and sustainable development.	The student presents examples of excessively intensive agricultural use of soils and incompetent agronomical techniques causing soil degradation in different parts of the world, which in consequence leads to decline in food production and, in some regions of the world, to starvation and poverty.	Analysis of various digital materials (maps, charts, statistical data) obtained from the Internet also on different time scales; Enables quick access to a large number of materials from various sources(e.g., organizations, offices).
Secondary school (high school) – extended level		
Earth's spheres –biosphere and pedosphere.	The student describes soil-forming processes and discusses the characteristics of the main types of zonal and azonal soils, as well as assesses their agricultural suitability.	Animations and interactive digital schemes that facilitate the understanding of soil-forming processes. Extended access to photos and drawings of soil profiles, access to free-of-charge soil databases.

Earth's spheres –biosphere and pedosphere.	The student digs a soil pit and observes the soil profile near the place of his or her residence.	Facilitating collection and preparation of data with regard to the place of observation. Use of an application on mobile devices (smartphones, tablets) to immediately collect information, document, process and publish it on the web.
Geography of Poland –natural environment.	The student explains the occurrence of zonal and azonal soils in Poland.	Analysis of various digital materials (maps, charts, statistical data) and GIS tools to explain the occurrence of zonal and azonal soils.

[1] Official translations of Polish names (Kabała et al. 2019)

At the level of lower secondary and current primary schools, students – using maps – learn about the relationship between the climate and vegetation and soil zones.

Multimedia offer a possibility to quickly access up-to-date digital maps that allow the students to describe the distribution of soil resources and determine their economic importance. In secondary schools, at the basic level, information on soils is discussed in the context of agriculture geography. First of all, attention is paid to the causes and effects of soil degradation due to improper management. Multimedia educational tools expand the resources available to the teacher who presents the issues, as he or she can explain the changes through the analysis of digital data and maps on different time scales. At the extended level, students broaden their knowledge about soil-forming processes, which are very frequently hard to understand for them (authors' own data, unpublished). Animations, digital diagrams and drawings – supplemented with teacher's comments and notes as necessary – can contribute to a better understanding of soil processes. Digital multimedia can help students plan their field activities and observe the soil profile. Mobile devices and dedicated applications that can be used directly during a field trip can improve the effectiveness of fieldworks.

Juxtaposition of the detailed requirements with the possibilities offered by the implementation of multimedia in education shows that their use significantly expands the resources available to the teacher. One should also note that multimedia materials, unlike the traditional ones, can be easily updated, which constitutes a crucial advantage. An example is a map of soil types prepared for the Internet atlas of the Kuyavia-Pomerania Province (Bednarek et al., 2015; http://atlas.kujawsko-pomorskie.pl/). Digital maps, spatial data, aerial and satellite photos allow us to analyze matters related to soil in various spatial scales. The available software enables easy collection and comparison of data.

An important element of soil education are field trips. Mobile devices, such as smartphones or tablets with installed applications allow the students to collect data directly in the field. Thanks to the built-in cameras, the data can documented, saved, shared and instantly exchanged with other users via the Internet. Such an approach to field trips not only broadens the range of possibilities as far as collecting and recording information is concerned, but also, above all, introduces edutainment elements into the activity. Edutainment combines valuable educational content with elements of entertainment, and it is considered one of the most effective strategies for transferring knowledge and shaping social attitudes among the digital natives (Brooks, 2010). This is largely due to the less formal nature of the teaching-learning process and an attractive formula for (but not limited to)young recipients. Student at times forget that they are in fact learning thanks to game elements (Aksakal, 2015), which is perhaps the most notable advantage of this approach. The educational content is usually provided in a formula that is attractive to the recipient, which means that the student is not always aware that, while being entertained, he or she acquires knowledge or develops new skills. Multimedia used in this way can support the implementation of tasks in a group, stimulate cooperation and develop social skills.

4. Digital textbooks in soil education

On the Polish educational market there is a number of different digital textbooks that contain issues related to soil education. Most of them are prepared by publishers who specialize in traditional textbooks. They are often exact copies of analogue textbooks with only minor additional options, such as enlargement of selected graphic elements, inclusion of hyperlinks to movie clips, animations or slide shows displayed as side notes.

In order to determine the position of multimedia textbooks on physical geography that are on the market, we examined the features and structure of the available materials and performed a critical assessment of their educational value. Digital textbooks intended for geography classes are predominantly traditional textbooks supplemented with some multimedia features (Czerski and Wawer, 2014). There are still no fully interactive and intelligent textbooks on the Polish market that would answer students' questions, engage their interest, and improve their understanding.

Multimedia textbooks can also come with numerous multimedia supplements, including, among others, multimedia atlases, interactive boards, e-maps and interactive tourist maps, multibooks, multitecs, portals with educational content intended to be used by teachers, diagnostic portals and e-exercises. All the aforementioned elements can be successfully employed in geography education, thus also soil geography. Those that are applicable in class improve the teaching of the subject and make the teaching-learning process more attractive, thus bolstering students' interest in soil-related information.

Some of the first multimedia textbooks that appeared on the Polish education market were EduROMs. They contain all the required material for teaching school subjects at the level of primary, secondary and high schools (http://www.2.ydp.com.pl). EduROMs are ready-to-use presentations with boards demonstrating lessons contents enriched with numerous video clips, voice recordings, animated presentations and maps that facilitate understanding of a particular issues, including the field of soil education. EduROM can be used in various forms both individually (on computers in a computer lab) or collectively (on an interactive board).

The creators of the program supplemented it with numerous interactive exercises and quizzes, which can be used on an interactive whiteboard during the lesson.

There are special elements integrated in the program that can be used to work with EduROM, which can be helpful during geography learning:

- Photo browser – about 2,000 photos (each picture can be enlarged);
- Solar System – a multimedia presentation enabling observation of planetary motion from different perspectives, reflecting spatial relationships between planets and their orbits, and providing basic information about the planets in the Solar System;
- Tables – dozens of essential geographical tables, contents of which can be sorted alphabetically and by keywords, and which present all the important numerical data;
- Dictionary – contains several hundred geographical terms explained in a way that is easy to understand;
- Maps –the collection contains several hundred maps falling into a multimedia atlas that comes with an index, legend and an options to zoom in on maps;
- Biographies – a set of 40 unconventional richly-illustrated biographies of famous geographers and travelers, including facts related to their lives that are usually omitted in encyclopedic descriptions.

Other options of the above mentioned software package aimed at achieving even better results include:

- Remember – a list of most important information;
- Notes – an electronic notebook that allows students to make own notes;
- Search – a tool for finding information by category and keywords;
- Bookmarks – a tool that allows for storing the most important or the most interesting pages of the e-book in the computer memory.

A major disadvantage of this product is that some multimedia resources are not adapted to the age of students. The level of knowledge presented on slides is definitely too high for an average student. There are also terminological errors. For example, instead of providing a proper definition of "genetic horizons", it is simplified to "soil layers". The e-textbooks from Nowa Era are an electronic version of the paper-back editions with built-in multimedia materials. Teacher and students can work with them in many environments, including the web browsers on iOS devices. E-books are available on the publisher's website (http://www2.ydp.com.pl). It can also be installed along with an e-book application for Android devices. this solution provides access to textbooks even if the device is disconnected from the Internet.

Using e-books is possible after activating a code obtained from the publisher. The structure of the textbooks is clear and the interface user-friendly. A considerable disadvantage of this particular digital textbook is that it comprises small quantity of multimedia materials. In the case of the analyzed soil science topics there were only two pictures and a zoomable map, which could hardly be called a multimedia feature. The lessons do not contain any movie clips or animations.

Another example of a multimedia tool is a series of e-textbooks entitled Świat *pod lupą (https://epodreczniki.pl/b/swiat-pod-lupa/PwgzmmYwR)*. It is available online and every Internet user has free access to it. It was developed as a part of a government project co-financed from the European Social Fund. It is a component of the government program for developing students' and teachers' competences involving the use of information and communication technologies – *Digital School*. The program was implemented by the Center for Education Development. The e-textbook of geography was created as one of the 64 dedicated to various general subjects on all levels of teaching.

The technological partner was the Supercomputing and Networking Center from Poznan (http://www.man.poznan.pl). Developed as a result of team work, these e-textbooks constitute a comprehensive collection of modern educational resources dedicated to teachers and students. Each user has access to them via a range of devices (computer, laptop, tablet, smartphone, e-book reader). They can be used either online or offline, and are compatible with various operating systems (Android, IOS, Windows). They are suitable for users with dysfunctions, e.g. the visually impaired, who can print out contents in the Braille alphabet. The resulting e-textbooks can be integrated with other environments: e-journals, e-learning platforms, blogs, websites. Thus, they can be used in a creative way, and maybe a valuable support in any forms and methods related to work with students (http://www.epodreczniki.pl). It is also possible to generate a textbook in the form of PDF files in two versions – for the student or the teacher. QR codes (QR - Quick Response two-dimensional barcode developed to quickly read and write URL data) provide quicker access to their contents.

Issues in the field of soil education can be found under the following topics:

1. "The impact of climate on biodiversity and soils" (junior high school) (https://epodreczniki.pl/a/jak-klimat-wplywa-na-bioroznorodnosc-i-zroznicowanie-gleb/DV4EXUBAh) (Fig. 3). The multimedia supplement in this textbook is very limited. In addition to the photo gallery, illustrations, diagrams, tables and map, there are no movie clips or animations.
2. "The diversity of soils and vegetation on the territory of Poland" (junior high school) (https://epodreczniki.pl/a/zroznicowanie-gleb-i-roslinnosci-na-obszarze-polski/DSM0RxNIH) –two hyperlinks to definitions (on soil and soil-forming process)and five quizzes, two of which lack photographs.

On High School level the only topic related to soils is "Degradation of soils in the world and its consequences"(https://epodreczniki.pl/a/degradacja-gleb-na-swiecie-i-jej-skutki/DuguSPvVG). There are two movie clips: *Let's talk about soil* and *Soil degradation and its prevention in the Philippines* and 3 quizzes.

Soils are also discussed in topic "Problems resulting from the exploitation of renewable and non-renewable resources of the Earth". The major advantage of this e-textbooks is free access both online and offline. A rich methodical supplement (https://epodreczniki.pl/search?query=geografia&format=e-materialy) paired with a substantial number of interactive exercises further increase the attractiveness of this particular e-textbook.

Teachers using textbooks of Nowa Era have access to a tool called *multiteka* (*Multiteka – Oblicza geografii 1* [Nowa Era https://www.

dlanauczyciela.pl/zasoby/szkoly-ponadgimnazjalne/geografia/oblicza-geografii-zr/czesc-1/?f:11[0]=469]). It is a form of database containing multimedia materials, which can be used in two modes. The first is the *resource* mode, where the user searches for the desired content arranged thematically. Multiteka includes: animations, movies, didactic games, graphics, maps, slide shows and tables. Appropriate materials can be found using the search filter and then added to *my lessons* mode. From there they can be displayed using a multimedia projector. The analysis of the resources included in the multiteka proved that they are not always adapted to the educational level.

A big practical problem of the media published by Nowa Era (e-textbooks and materials in the multiteka) is the lack of possibilities to integrate them. Switching between the two programs takes time and makes it difficult to work during the lesson. The resources contained in both are often duplicated. It seems that the ideal solution, at least from a practical point of view, would be to combine both programs. The ability to freely choose ready resources, to put them in the place chosen by the teacher on the margin of the digital version of the textbook would allow for more efficient use of the collected materials. A good solution on the part of geographical education is also to provide a geographical multimedia textbook with simple GIS functions. Displaying individual layers of digital maps and making simple measurements would facilitate a lot of comparisons and analyzes. The option of zooming in and out the map content and displaying the legend by clicking an appropriate icon does not make it an interactive map, but only provides a few simple digital elements.

5. The use of educational portals

With development of the Internet and social media in particular, popularization of geographical science and soil knowledge has become easier, and an increasing number of institutions engaged in this kind of activities. This typically involves posting various educational resources on websites and in social media, as well as organizing various actions to promote knowledge. Educational portals could be also an important tool for distance learning (Świtoniak et al., 2018).

While pedology knowledge is frequently promoted abroad (e.g. in Scotland: http://www.hutton.ac.uk/learning/dirt-doctor), in Poland similar endeavors have only started in recent years. The efforts include the website of the Soil Education Committee of the Polish Society of Soil Science (https://sites.google.com/site/edukacjaglebawawstwa/) as well as Facebook site of the Center for Soil Education – Soil Museum (https://www.facebook.com/Centrum.Edukacji.Gleboznawczej.Muzeum.Gleb/), which contains didactic ideas and links to documentary films. An example of a campaign aimed at popularizing and educating in soil knowledge is "The Soil of the Year" initiated in 2018 by the Polish Society of Soil Science. Rendzina was selected the soil of 2018 and Chernozem of 2019 (Fig. 1).

Figure 1. Logos of "The Soil of the Year 2018 and 2019"

However, not all educational web portals have guidelines for teachers in the form of methodical materials. Interesting multimedia materials that can be potentially used during a geography lesson are also developed as part of international projects carried out at universities. One example that can be used in soil education is the portal created in relation to the FACES Erasmus+ project (http://www.sites.google.com/site/centraleuropesoils). Its effect is, among others, soil database (http://www.soils.umk.pl/database) that can be used in geography lessons at the extended level of high school. It could also be a valuable material for students in schools where geography is taught bilingually. The portal structure offers an option to search for any type of soil from the available list, or by clicking on a symbol on the map. A photo of soil pits appears in the window that opens along with physical and chemical data presented in tables (Fig. 2).

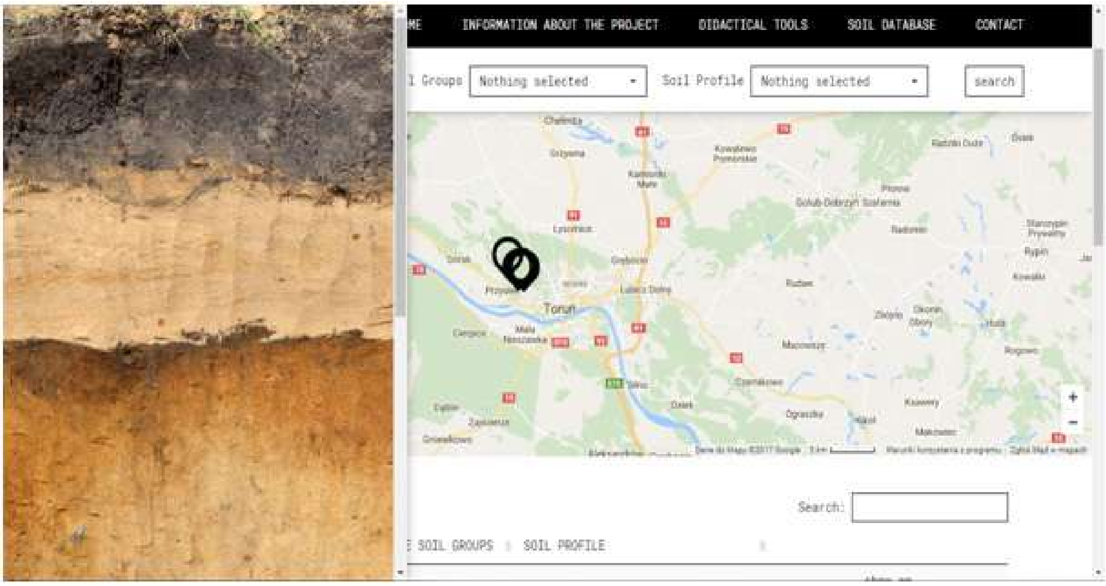

Figure 2. Example of a soil profile along with its location retrieved from the soil base developed as part of the FACES project (Source: http://www.soils.umk.pl/database, access: May 2019)

Figure 3. Example of a spherical panorama taken from the soil base – developed as part ofthe FACES project (Gleyic Umbrisol from Brodnica Lake District) (Source: http://www.soils.umk.pl/database, access: May 2019)

Spherical panoramas are a considerably valuable element of the portal. These are photographs depicting the landscape (surroundings), within which the soil profile was made. They give the opportunity to view the area in a 360 degree perspective. This provides a direct reference of the soil profile to the natural environment, in which it is located, and enables the analysis of a given soil in the context of soil-forming factors: terrain, water conditions and vegetation (Fig. 3). The database is still expanding. Portal creators increase the number of places, countries and regions where soil profiles were made and various soil types were documented. Using the educational resources available on this portal it is possible to successfully implement the provisions included in the core curriculum with reference to the analysis of spatial distribution of soils and the impact of vegetation, climate or anthropopressure on their development and degradation. Educational websites constitute an extensive source of knowledge and facts, and the amount of information stored in various forms is overwhelming (Świtoniak et al., 2018).

6. Conclusions

The issues presented above by no means exhaust topics related to multimedia supporting soil education. Creation of educational multimedia is undoubtedly a great chance to modernize teaching and learning process, and make it more attractive for students of the "digital natives" generation. Perhaps, in time's perspective, they should incorporate a number of technologies from the field of artificial intelligence. Such materials should include a formal representation of knowledge contained in the textbook, reasoning methods for answering questions and natural language processing that would be capable of understanding user's questions paired with natural language generation system to produce answers (Chaudhri et al., 2013).

Modern and attractive didactic tools are created within the framework of various educational projects. The use of ICT during classes should be purposeful, therefore a need arises to develop strategies on effective use of multimedia and methodological guidance in specific teaching situations. National and regional Centers dedicated to support training and professional development of active teachers should diagnose their needs in this regard and provide appropriate courses.

The multimedia materials are typically created by the publishers of textbooks. They are usually an integral part of said material, or are meant to complement it. The analysis shows that they are not always useful in the teaching and learning process. Sometimes they are not adapted to the age of students or cannot be used to accomplish the objectives indicated in the core curriculum. Practitioners and geography educators who deal with the theory of geographical education (including soil education) should be ready to express their opinions on published multimedia teaching materials. Therefore, the society should be stimulated and encouraged to review the multimedia tools on offer in terms of the educational value to provide feedback to their creators.

The changes taking place in the education system and the elimination of junior high schools provide an opportunity to review the existing educational solutions. Thus, elements that have a positive impact on the efficiency of education should be retained, while the least effective ones should be eliminated.

It should be stressed that even modern, web-based digital teaching and learning materials may be not exciting enough to captivate the digital natives. Majority of them require interaction, competition and opportunities to impress one another in virtual reality. Social media and virtual reality games have changed the way young people perceive the real world, and that also includes the education process, which has to be supported by role-playing and elements of gamification. Gamification is the process of introducing game-related principles in education – especially those related to user experience and engagement. Since gamers voluntarily spend long hours playing games, it seems only natural to make use of this strong motivation to enhance the experience in the classroom and during field activities related to geography and soil science.

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Rusty soils – "lost" in school education

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Abstract

Rusty soils cover about 15% of Poland's territory and they are the most important type of soil used in the forest management. Polish soil scientists know these soils very well but, unfortunately it seems, that students who come to environmental studies know very little about them–less than about other soil units. Does electing rusty soil as the Polish Soil of the Year 2021 present an opportunity to change that? The aim of this paper is to diagnose what is the availability of information on rusty soils at the level of education in secondary schools and what is the state of knowledge about these soils in the broad non-academic community. Three main research methods were used: querying geography textbooks, querying internet sources and survey method. Information on rusty soils is rather not presented in textbooks. Of the 17 analysed websites – 8 lack any information on those soils. Coefficient of Information Availability (CIA) for rusty soils is one of two lowest among all studied units. Respondents assessed the knowledge of rusty soils lower than most of other Polish soils but they would like to learn more about them. Additionally, the low level of knowledge about it does not reduce its recognition: respondents had no problem to recognize rusty soil on the base of photograph and to distinguish the correct number of genetic horizons. The Year of Rusty Soil is a great opportunity to introduce young people to these soils. Field lessons can combine soil education with ecological issues. Rusty soils can be seen as optimal choice for these activities. These soils could be an perfect type to increase public awareness of soils at all but especially with regard to common soils important to our local environment.

1. Introduction

Soil is one of the most important component of terrestrial ecosystems but at the same time it is relatively poorly known to a wide community. One of the challenges of the modern world is to increase social awareness of the environment, including soil cover. People should know that soils are important in the production of biomass, food, fiber, and fuel (Cruse et al., 2013), in the hydrological cycle (Brevik, 2009), a support for ecological habitats and biodiversity (Blum, 2005), in a struggle against many forms of pollution (Jones et al., 2012) and their contribution to carbon sequestration (Jones et al., 2012; Crossman et al., 2013; Lal and Stewart, 2013). They are a source of materials for building and infrastructures (Jones et al., 2012; Pritchard et al., 2014) and provide a preservation for past cultural landscapes and artifacts (Kibblewhite et al., 2015; Urbańska and Charzyński, 2021). The Polish Soil Science Society is, among other things, a promoter of soil science knowledge in Poland. The organization try to draw the public's attention to soils by promoting them (creating an appropriate logos, banners and posters) as well as encouraging scientists to further research on many types of soils and publishing their results. These activities are aimed not only at soil scientists but also at a wider audience (teachers, pupils and students). In previous years the Polish Soil of the Year was chosen to spread knowledge about the selected type to a larger audience. The Soils of the Year were: Rendzinas (2018), Chernozems (2019) and Technosol (2020). These activities did not attract the attention of the non-academic community. Only rusty soil – Soil of the Year 2021 aroused enormous media attention. Information appeared in the TV news programs ("Contact Mirror" on the TVN 24 station, TVP 1, Polsat News) it was also widely commented on Facebook (265 comments and 400 shares, as of 12th February 2021), Twitter and Instagram. These sandy soils are typical for post-glacial areas of the temperate climate zone. Rusty soils cover about 15% of Poland's territory and they are the most important type of soil used in the forest management. Usually they are formed from loose and slightly loamy sandy deposits of various origins. Rusty soils are formed under the vegetation of poorer variants of deciduous forests as well as mixed forests. However, in many places they are planted with monoculture pine crops, causing change on their properties and their degradation. Rusty soils are one of the most important, basic components of soil cover, which has long been studied by many soil scientists (Bednarek, 1991, Jankowski, 2003, 2014; Rosa et al., 2019; Kobierski et al., 2020). Polish soil scientists know these soils very well but, unfortunately it seems, that students who come to environmental studies know very little about them–less than about other soil units. Is it just the lecturers' impression? Are rusty soils not mentioned in currently used school textbooks? Does identifying rusty soil as the Soil of the Year present an opportunity to change that? The aim of this paper is to diagnose what is the availability of information on rusty soils at the level of education in secondary schools and what is the state of knowledge about these soils in the broad non-academic community. The authors set the following research tasks:

– review (querying) and evaluation of information contained in school textbooks and educational websites;
– checking the state of non-academic society's knowledge of rusty soils;
– assessment of the suitability of the discussed soils in the educational process- especially in the context of field works for high school students.

2. Materials and methods

Three main research methods were used: querying geography textbooks, querying internet sources and survey method.

2.1. Querying geography textbooks/websites

The content of high school geography textbooks was analyzed in terms of the knowledge offered in the field of rusty soils. Currently, only two publishing houses in Poland offer textbooks intended for teaching geography in high school at the extended level: Operon and Nowa Era. However, the content of 14 textbooks and 3 geographical repertories were analyzed (Table 1).

As well as the textbooks the Internet resources were analyzed in the light of available information of rusty soils (Table 1). 17 websites were analyzed (first 17 results; search date: 18th April 2021) after the entry: "soils of Poland" (gleby Polski) in the *google* search engine). However, it should be noted that the results depend on the history of previous searches so they can vary from user to user. Nevertheless, in all sources (textbooks and websites) information was analyzed for 9 main soil types in Poland: clay-illuvial, brown, podzolic and rusty soils as well as chernozems, black earths, alluvial soils, rendzinas and peat soils. The frequency of four kinds of information (categories) was the basis for assigning "information scores" within each type of soil: a) names of these soils – multiplied by 1 point, b) their properties x 2 points, c) profiles–photo or scheme x 3 points and d) description of soil sequences x 3 points. **Coefficient of Information Availability (CIA)** providing general access in textbooks/websites to educational information on each nine types of soils is the sum of the **Partial Coefficient of Information Availability** (CIA_p) values calculated for every of four information categories (a, b, c, d).The CIA_p was calculated according to elaborated formula: $CIA_p = \sqrt{\frac{Ti}{Tt}} \times ip$ (CIA_p – the Partial **Coefficient of Information Availability**; Ti – the number of textbooks/websites with soil information; Tt – the total number of textbooks/websites; ip – sum of "information points" in particular categories.

2.2. The survey method

The data collected from survey aims to evaluate soil awareness level. It consisted random selection of participants based on non-probability sampling who were not related to soil science (non-academic society). The survey consisted of 4 questions relating to the mentioned above 9 types of soils:

– How do you estimate your knowledge of each of the mentioned soils (on a scale from 1 to 5)? (Self-Assessment of Knowledge index)
– Are the following soil names intriguing / interesting for you and would you like to learn more about them?
– The photos show 4 different soils. How many distinct soil horizons (layers) do you see in each of them?
– Try to match the soil name (all 9 main types were possible to choose from) with the photo.

The last two questions are accompanied by photos of the soils – podzolic, brown, rusty and clay-illuvial profiles.

Moreover, the questionnaire included information about the respondents (age, sex, place of residence). A total of 420 respondents participated in the study to answer questions about their soil awareness in the context of rusty soils. The participants included 40,4% males and 59,6% females. 70,1% of respondents were urban and 29,9% rural residents.

Survey was conducted via Internet and then collected for data analysis. The study was based on the results of a survey addressed to a diverse group of recipients (employment, students, schoolchildren) who are not professionally involved in soil science. The questionnaire was constructed as a "Google Form" and sent to recipients via e-mail or distributed through social media. Answers were analyzed using a quantitative approach to investigate the knowledge about rusty soils.

3. Results and discussion

Rusty soils are common in Poland, and they were recognized many years ago-they were officially distinguished in Polish Soils Classification as soil type almost 50 years ago (PSC, 1974). Nevertheless, the textbooks as well as websites have little information about them (Fig. 1). They are the only ones in the group of common (occupy more than 10% of country area) , zonal soils with low CIA. Moreover, information on rusty soils is totally not presented in six out of 17 textbooks. There is no difference between information in the older and most recent ones. Only two textbooks (from 1999 and 2013) have a soil profile with a description of rusty soil morphology. Of the 17 analyzed websites – 8 lack any information on rusty soils. Only one website (geografia24.eu) gives relatively detailed knowledge of rusty soil characteristics and profile. Moreover, the name "rusty soil" occurs there six times. This is an excellent result because, according to a website query, information on rusty soils available on the Internet for

Table 1
Textbooks, geographical repertories list and Internet sources

Title	Author	Year of publication	Publishing House
Geography of Poland. Textbook for X class,	Barbag J., Janiszewski M.	1964	Państwowe Zakłady Wydawnictw Szkolnych. Warsaw (in Polish)
Geography of Poland. Textbook for II class of high school and economic school.	Batorowicz Z., Górecka Ł., Prokopek B.	1970	Państwowe Zakłady Wydawnictw Szkolnych. Warsaw (in Polish)
Physical geography with geology. Textbook for high school.	Stankowski W.	1987	Wydawnictwa Szkolne i Pedagogiczne. Warsaw (in Polish)
Geography. Textbook for bascic vocational school.	Domachowski R., Makowska D.	1987	Wydawnictwa Szkolne i Pedagogiczne. Warsaw (in Polish)
Poland i Europe. Geography textbook for high school.	Batorowicz Z., Nalewajko J., Suliborski A.	1990	Wydawnictwa Szkolne i Pedagogiczne. Warsaw (in Polish)
The Earth and people. Physical geography textbook for high school.	Makowska D.	1998	Wydawnictwa Szkolne i Pedagogiczne. Warsaw (in Polish)
Geography of Poland.	Świtalski E., Preisner Z.	1999	Oficyna Wydawnicza Turpress" Torun [In [Polish]
Outline of knowledge about the Earth. Textbook for high school.	Podgórski Z., Marszelewski W., Becmer K.	2002	Wydawnictwa Szkolne i Pedagogiczne. Warsaw (in Polish)
Physical geography 1. Extended level. Textbook for high school.	Czubla P., Papińska E.	2003	PWN WydawnictwoSzkolne. Warsaw (in Polish)
Geography of Poland. Textbook for high school.	Krynicka-Tarnacka T., Wnuk G.	2005	SOP. Torun (in Polish)
Geography 1. Basic level.	Kop J., Kucharska M., Szkurłat E.	2006	PWN Wydawnictwo Szkolne. Warsaw (in Polish)
Geography. Vademecum.	Stasiak J., Zaniewicz Z.	2013	Wydawnictwo Pedagogiczne Operon. Gdynia (in Polish)
Faces of geography 3. Textbook for high school and technical school. Extended level.	Więckowski M., Malarz R.	2014	Nowa Era. Warsaw (in Polish)
Geography. Repertory for high school graduates.	Biłgoras J., Głowacz A., Koperska-Puskarz D., Mazur M., Mozolewska-Adamczyk M., Srokosz W., Zieliński K.	2014	Wydawnictwa Szkolne I Pedagogiczne. Warsaw (in Polish)
Geography. Repertory for high school graduates.	Łękawa A.	2015	Greg. Cracow (in Polish)
Faces of geography 1. Textbook for high school and technical school. Extended level.	Malarz R., Więckowski R., Kroh P.	2019	Nowa Era. Warsaw (in Polish)
Geography-extended level. Textbook for high school.	Kurek S.	2019	Wydawnictwo Pedagogiczne Operon. Gdynia (in Polish)

Internet sources

https://epodreczniki.pl/a/zroznicowanie-gleb-i-roslinnosci-na-obszarze-polski/DSM0RxNIH (website 1)
https://www.ekologia.pl/wiedza/slowniki/leksykon-ekologii-i-ochrony-srodowiska/ (website 2)
https://pracownik.kul.pl/files/32723/public/pdf/gleba.pdf (website 3)
https://eszkola.pl/geografia/rozmieszczenie-gleb-w-polsce-6778.html https://www.edukator.pl/resources/page/gleby/11165 (website 4)
https://matura100procent.pl/rozmieszczenie-gleb-na-swiecie/ https://geografia.gozych.edu.pl/gleby-w-polsce/ (website 5)
https://opracowania.pl/opracowania/geografia/gleby-w-polsce,oid,1729 https://www.naukowiec.org/wiedza/geografia/gleby-w-polsce-rodzaje_3403.html (website 6)
https://www.bryk.pl/wypracowania/geografia/geografia-fizyczna/8387-gleby-polski.html http://geografia24.pl/gleby-w-polsce/ (website 7)
https://swiatrolnika.info/gleby-w-polsce-rolnictwo (website 8)
https://www.geografia24.eu/geo_prezentacje_rozsz_3/383_1_srodowisko_przyrodnicze/r3_1_08a.pdf (website 9)
https://geografia.na6.pl/warstwa-glebowa (website 10)
https://sciaga.pl/tekst/39463-40-gleby_w_polsce (website 11)
http://geomorawa.ucoz.pl/publ/gleby_i_roslinnosc_polski/1-1-0-228 (website 12)
http://www.pcez-bytow.pl/download/plk/gleby-w-polsce.pdf (website 13)
https://www.edukator.pl/resources/page/gleby/11165 (website 14)
https://geografia.gozych.edu.pl/gleby-w-polsce/ (website 15)
https://www.naukowiec.org/wiedza/geografia/gleby-w-polsce-rodzaje_3403.html (website 16)
http://geografia24.pl/gleby-w-polsce/ (website 17)

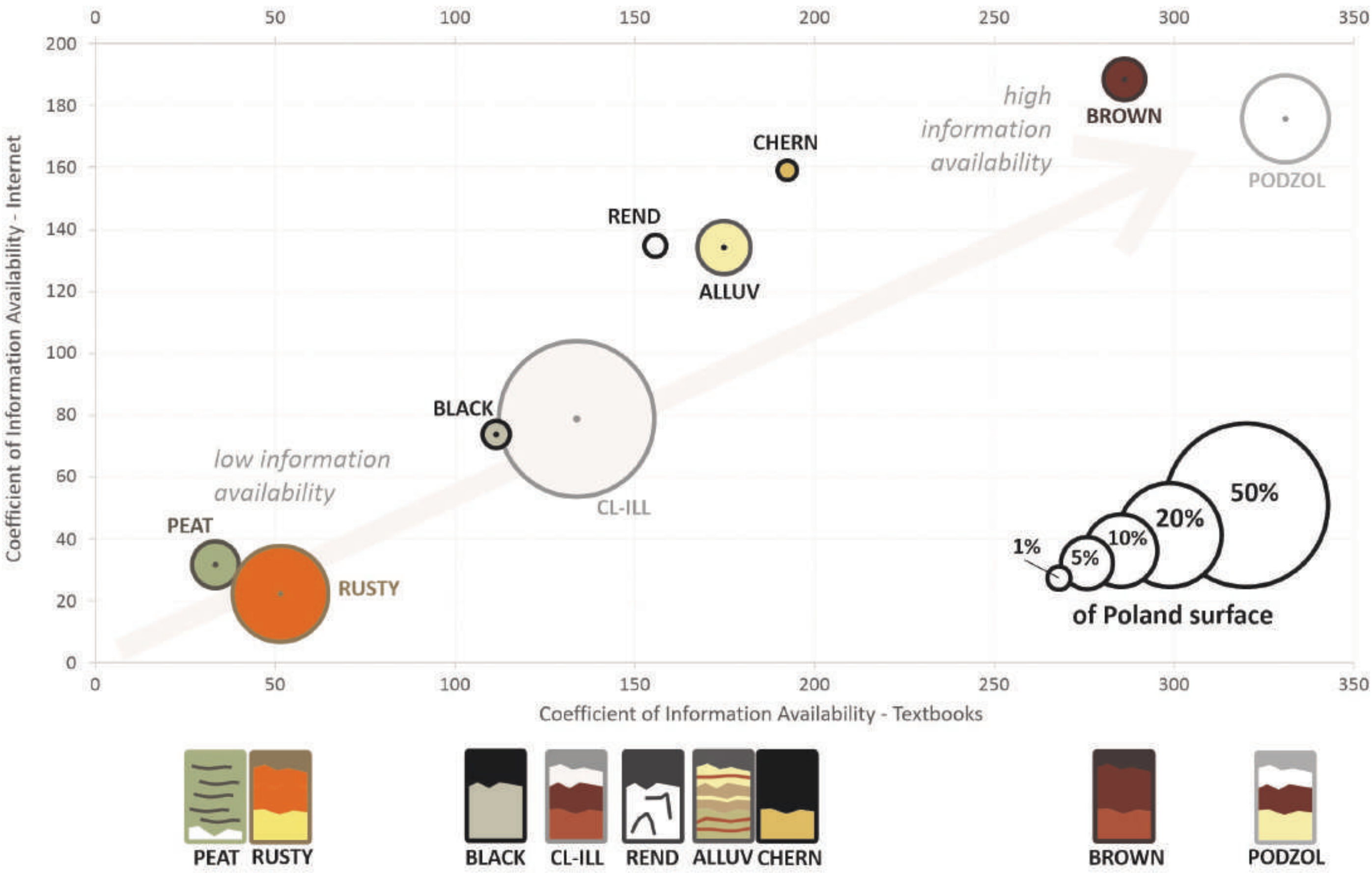

Fig. 1. Comparison of the Coefficient of Information Availability (CIA) of main soil types (CLay-ILLuvial, BROWN, PODZOLic, RUSTY soils, CHERNozems, BLACK earths, ALLUVial soils, RENDzinas and PEAT soils) in textbooks and Internet

the average finder is even more scarce than in textbooks. While websites are often created by anonymous authors and are characterized by numerous mistakes and omissions about soils of Poland (Świtoniak et al., 2018), the textbooks should contain correct, professional information in accordance with the current state of knowledge. The only one textbook providing up-to-date information about share of particular soil types is book written for children for Polish emigrants in Norway (Mazurek-Daves, 2019) as it doesn't have to follow Polish School Curriculum. The lack of educational information on rusty soils is probably inherited from the period before 1970s when rusty soils were treated as sandy brown soils (Świtoniak et al., 2019) and educational 'inertia' – the lack of updating the school curricula and thus content of the textbooks in line with the progress of knowledge. It should be noted that research conducted in the Polish Lowlands has shown that the so-called "brown soils" developed from morainic, loamy deposits are in fact eroded clay-illuvial soils (Kobierski, 2013; Podlasiński, 2013; Świtoniak, 2014; Świtoniak et al., 2016, 2019). Similar phenomena were also noticed in south part of the country (Rodzik et al., 2014; Loba et al., 2021). For these two reasons there are almost no such type of soils in the Poland. However, in textbooks and websites, information about the brown soils (together with podzolic soils) still dominate. It is present in all textbooks and websites and as many as 13 textbooks and 7 websites have its soil profile. 16 from 17 websites describe brown soil in detail. It is necessary to introduce an amendment stating that the soils are not brown but eroded clay-illuvial soils (Świtoniak, 2006, 2007, 2011). This is the key ecological and functional information and should be communicated to a wider audience.

How, then, did the respondents describe their knowledge (Self-Assessment of Knowledge index) of rusty soils? Does it reflect the low level of availability of information about them? The analysis of the respondents' answers showed that rusty soil is almost the worst in this comparison (Table 2). Respondents assessed lower only the knowledge of rendzinas (which are local soils with an average CIA. Interestingly, the highest values of the Self-Assessment of Knowledge index have soils with the highest CIA (brown and podzolic soils). Chernozems and peat soils with a low CIA achieved also high Self-Assessment of Knowledge index but their names are well known from everyday life – they are associated with the urban agriculture, e.g. cultivation of gardens and the care of plants.

It is interesting to know if respondents would like to learn more about rusty soils despite the low level of knowledge. Figure 2 answers this question. Rusty soil was not among the leaders (alluvial soils and chernozems are) but it is in the group of soils of considerable interest (+59 – together with rendzinas and peat soils) and stands out among all zonal soils in Poland – 1st place in zonal, ahead of brown, podzolic and clay-illuvial soils.

Table 2
Self-assessment of knowledge about specific soil types

Respondents / Soil type			Chernozem	Black soil	Brown soil	Clay-illuvial	Rusty soil	Podzol	Alluvial soil	Rendzina	Peaty soil
Age	number of respondents										
0–15	40		2.08	1.73	1.83	1.45	1.30	1.53	1.43	1.10	1.68
16–20	131		2.42	1.87	2.16	1.79	1.54	2.09	2.00	1.63	2.11
21–25	73		2.22	1.85	2.07	1.67	1.74	1.93	1.74	1.40	2.05
26–40	96		2.00	1.55	1.64	1.27	1.29	1.45	1.38	1.09	2.00
>41 years	79		2.10	1.46	1.65	1.41	1.23	1.48	1.47	1.18	2.20
	Total 420	Mean:	**2.20**	**1.70**	**1.89**	**1.55**	**1.44**	**1.75**	**1.66**	**1.33**	**2.05**

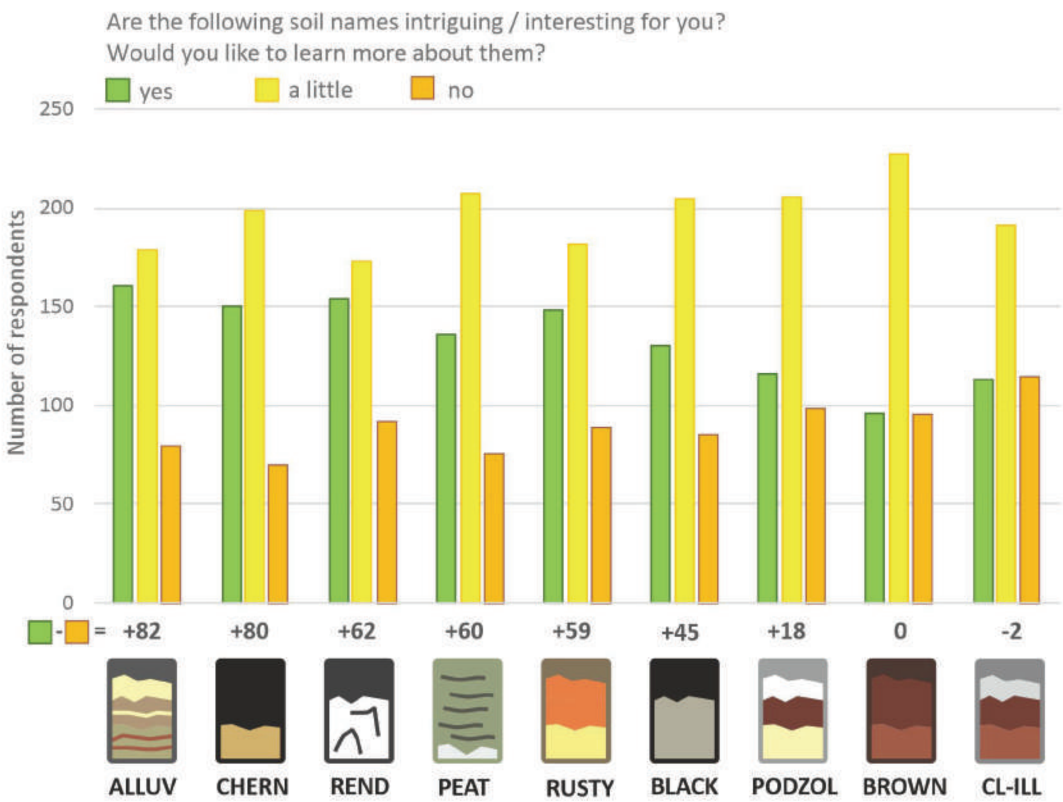

Fig. 2. The respondents' curiosity about the studied soils (CLay-ILLuvial, BROWN, PODZOLic, RUSTY soils, CHERNozems, BLACK earths, ALLUVial soils, RENDzinas and PEAT soils)

An attempt was made to indicate whether the rusty soil is easily recognizable based on their morphology. Despite the very poor transfer of information at the level of school education, the interest in these soils is significant. Additionally, the low level of knowledge about it does not reduce its recognition (Fig. 3). The characteristic orange-brown color is undoubtedly a great asset. As many as 34% of respondents recognized rusty soil which puts it on a par with the recognition of soils most often described in textbooks – podzolic and brown soils (Fig. 3). Interestingly, rusty soils are most often confused with clay-illuvial and podzolic soil – which is difficult to explain. Except that as many as 17% of respondents confused brown soil (eroded clay-illuvial soil in fact) with rusty soil–probably due to the similar colors of these soils. The worst situation (7% of correct indications) concerns fully developed clay-illuvial soils and it is the limit of statistical randomness. This is an unfavorable and dangerous situation from the point of view of education. These soils are the basis of the Polish agricultural economy and near 50% of the country and they should be much better recognizable (Sykuła et al., 2019).

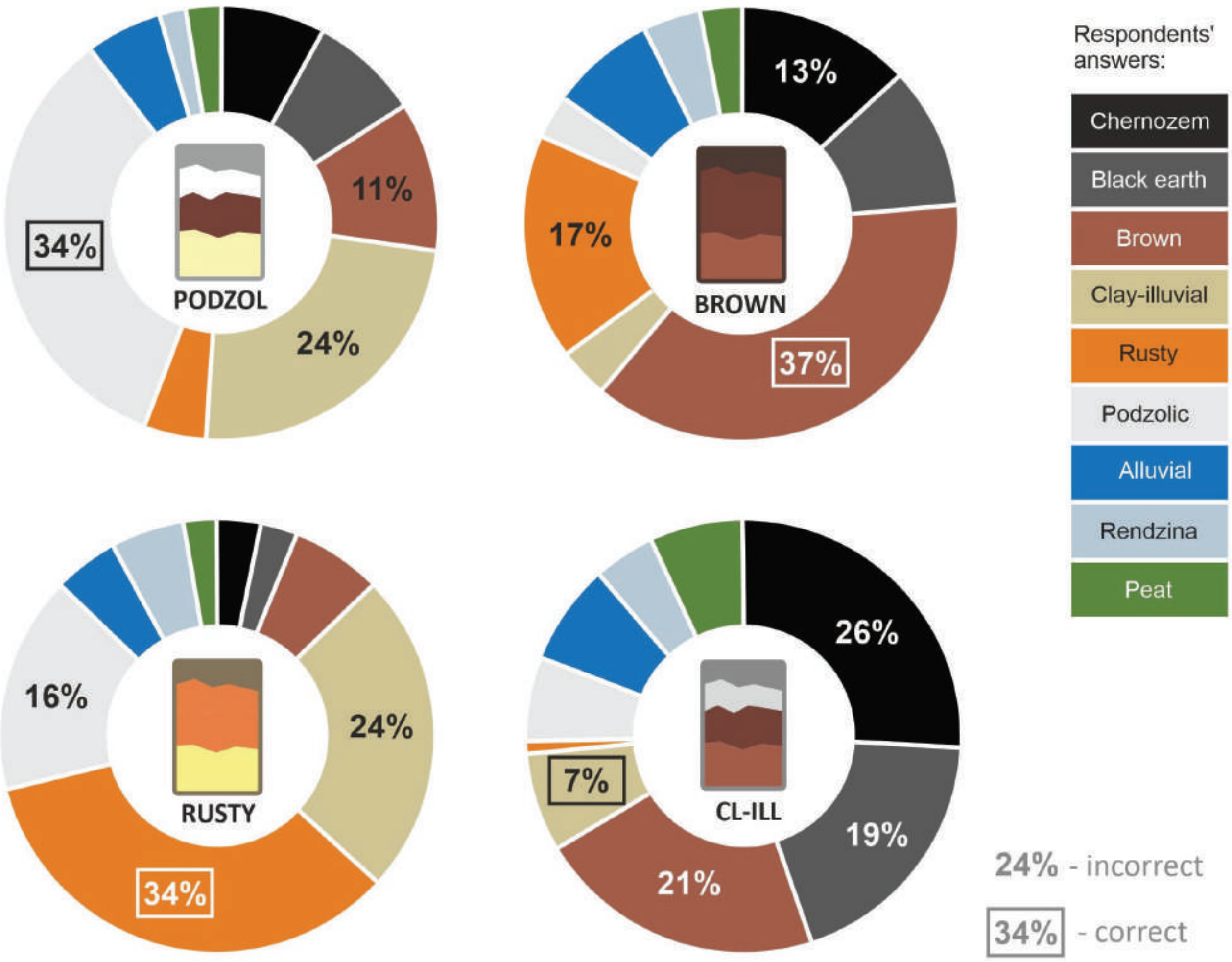

Fig. 3. Recognition of soil types (CLay-ILLuvial, BROWN, PODZOLic, RUSTY soils)

The relatively high recognizability of rusty soils is certainly due to its characteristic (even intuitive) morphology. This is confirmed not only by the correct naming of the soil type, but also by the highest percentage of respondents who indicated the proper number of soil horizons (Fig. 4). The A-B-C morphology is easy to identify even for people not related to soil science. Over 50% of the respondents had no problem pointing to the correct number of horizons. However, in rusty soil, as in brown soil, there is a tendency to omit (underestimate) certain horizons. Quite the opposite as in the case of soils with the morphology A-E-B-C where the respondents overestimated the number of horizons.

Various factors may have contributed to the increased curiosity about rusty soils. The campaign Soil of the Year had a great impact on the media (TV, FB analysis) which resulted in an increase in the search for the phrase "rusty soil" at the beginning of February 2021 (Fig. 5). This fact is confirmed by the analysis of google trends. They do not have such statistics as chernozems or peat soils but the interest in rusty soils in the network has definitely increased in recent times.

It is important to state if the rusty soils have high value for the educational process, e.g. in the context of the possibility of conducting field works with pupils? In authors opinion, among the analyzed soils, rusty ones are the most favorable (Table 3). They are quite common – easy to find for teachers in almost all parts of Poland and also easily recognizable. Moreover, due to its sandy nature it is relatively easy to dig a soil pit. Their genesis can be clearly explained and understood–they have a simple and very expressive morphology, intuitively recognizable by people not related to soil science (Fig. 3, 4). Only the podzolic soils have a similar usefulness but unfortunately in most of them the podzolization is not enough clear and easy to explain for pupils because is superimposed on the rust-forming process as a pinetization effect (due to the pine reforestation). Changes in the nature of vegetation caused changes in the soil profile. Despite the fact that rusty soils have been "forgotten" in textbooks a lot of information about them can be found on the website of the Polish Soil Science Society. Interesting multimedia materials that can be used in rusty soil education is the portal created in relation to the FACES Erasmus+ project (website 18) as well as soil database (website 19). Using the educational resources is possible to successfully implement the provisions included in the core curriculum with reference to the analysis of spatial distribution of soils and the impact of vegetation, climate or anthropopressure on their development and degradation (Urbańska et al., 2019).

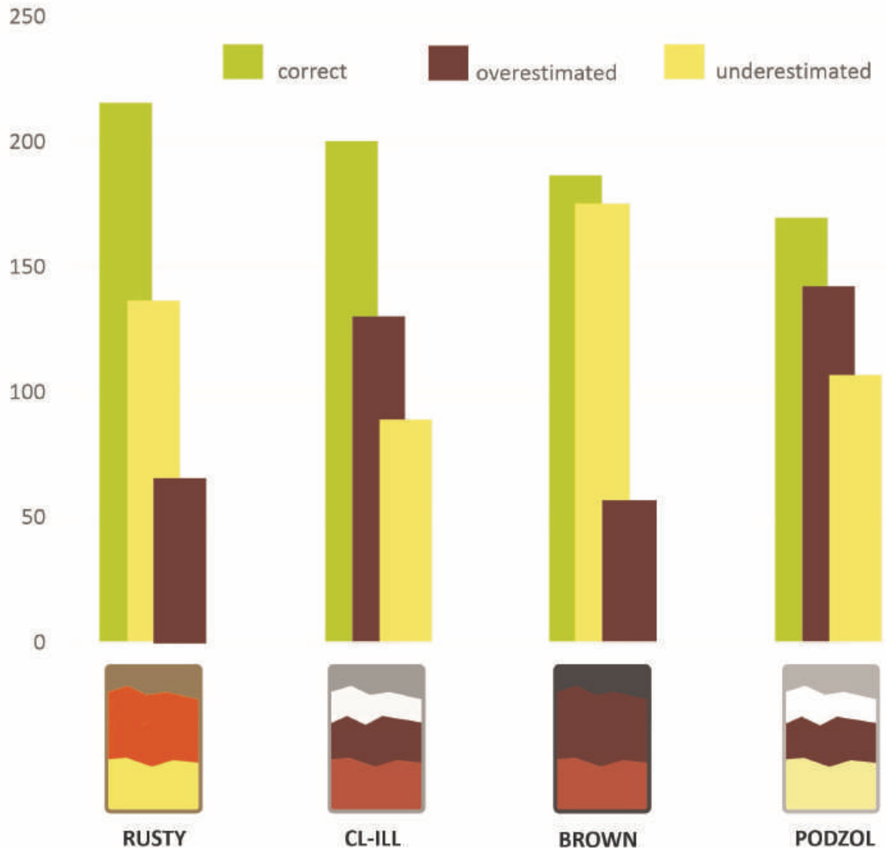

Fig. 4. Recognition of the number of genetic horizons (CLay-ILLuvial, BROWN, PODZOLic, RUSTY soils)

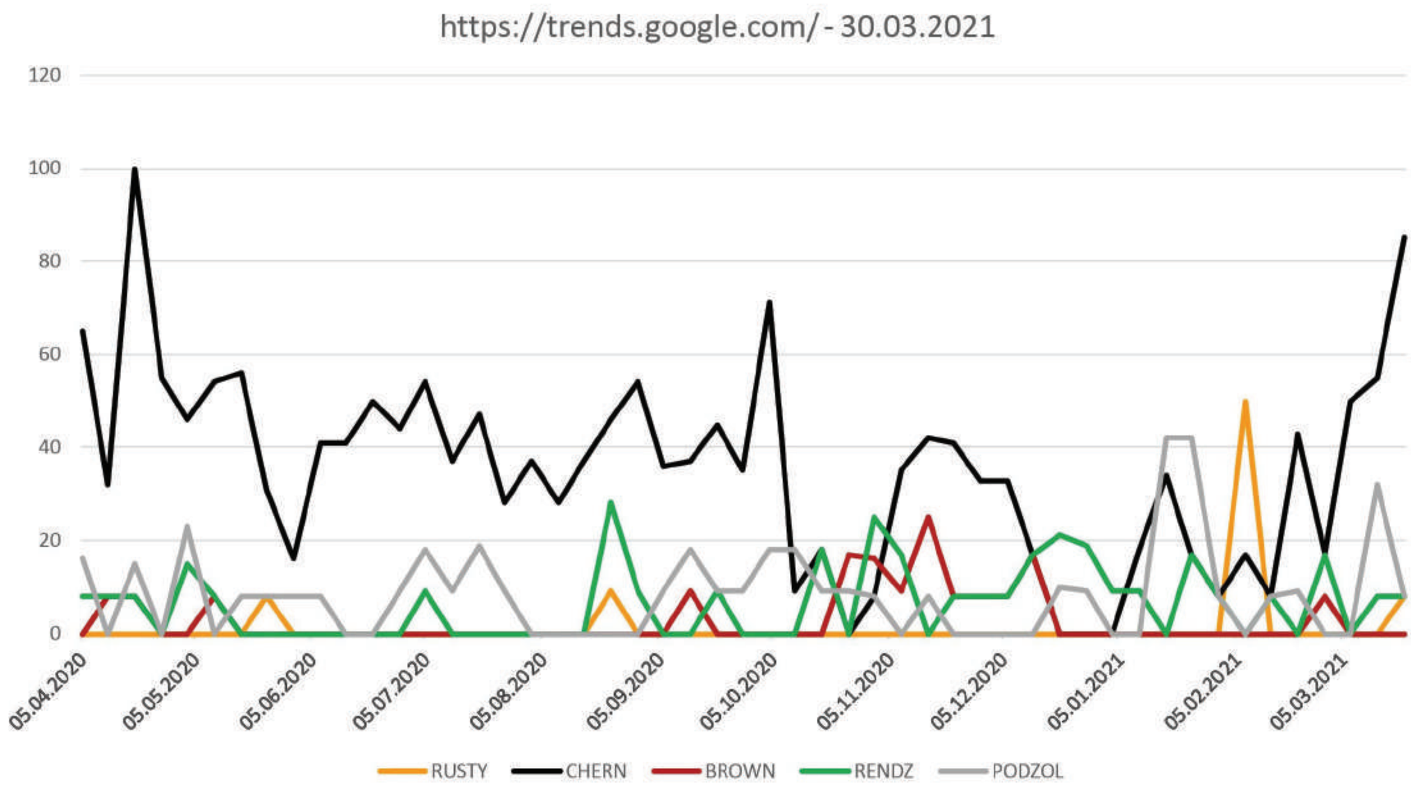

Fig. 5. The viral impact of rusty soils (FB post) on internet interest

Table 3
The utility of soil types in education

Utility in education \ Soil type	Chernozem	Black soil	Brown soil	Clay-illuvial	Rusty soil	Podzol	Alluvial soil	Rendzina	Peaty soil
Frequency of occurrence	–	–	–	+	+	+	–	–	–
Recognizability	+	+	–	–	+	+	+	+	+
Soil pit preparing	–	–	–	+	+	+	–	–	–
Understanding of pedogenesis	+	+	–	–	+	+	+	+	+

4. Conclusions

The Year of Rusty Soil is a great opportunity to introduce young people to these soils. It shall start with update of National Curricula and, according to the latest scientific knowledge, information on brown soils should be also updated. Brown soils should "give way" to more common soils (clay-illuvial and rusty soils). Soils should not only achieve better scientific understand but also they should be treated as natural element of human being. There are significant developments in the perception of both the ecological and non-ecological functions of soils in providing fundamental ecosystem services (Blum, 2005; Jones et al., 2012; Crossman et al., 2013; Lal and Stewart, 2013; Morel et al., 2015; Baveye et al., 2016). Students are aware of many risks and problems like global warming and air pollution but they are not sufficiently informed that soil resources and soil protection are equally important for their existence. Field lessons can combine soil education with ecological education and at the same time constitute a kind of excursion. Rusty soils can be seen as optimal choice for these activities. To sum up, rusty soils:

1. Cover a large percentage of Poland's territory. They are therefore easily accessible and, moreover, easy to mechanically dig out the soil pits due to the sandy material.
2. Are intuitively and easily recognizable and their genesis is easy to explain.
3. Are of great interest among the public which may be related to the name of these soils (rusty) referring to other, well-known processes (iron /steel/car rusting).
4. Are hardly ever present in school education (as well as clay-illuvial soils).

Rusty soils could be an ideal choice to increase public awareness of soils at all but especially with regard to common soils important to our local environment.

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website 2: https://www.ekologia.pl/wiedza/slowniki/leksykon-ekologii-i-ochrony-srodowiska/gleba
website 3: https://pracownik.kul.pl/files/32723/public/pdf/gleba.pdf
website 4: https://eszkola.pl/geografia/rozmieszczenie-gleb-w-polsce-6778.html
website 5: https://matura100procent.pl/rozmieszczenie-gleb-na-swiecie
website 6: https://opracowania.pl/opracowania/geografia/gleby-w-polsce,oid,1729
website 7: https://www.bryk.pl/wypracowania/geografia/geografia-fizyczna/8387-gleby-polski.html
website 8: https://swiatrolnika.info/gleby-w-polsce-rolnictwo
website 9: https://www.geografia24.eu/geo_prezentacje_rozsz_3/383_1_srodowisko_przyrodnicze/r3_1_08a.pdf
website 10: https://geografia.na6.pl/warstwa-glebowa
website 11: https://sciaga.pl/tekst/39463-40-gleby_w_polsce
website 12: http://geomorawa.ucoz.pl/publ/gleby_i_roslinnosc_polski/1-1-0-228
website 13: http://www.pcez-bytow.pl/download/plk/gleby-w-polsce.pdf
website 14: https://www.edukator.pl/resources/page/gleby/11165
website 15: https://geografia.gozych.edu.pl/gleby-w-polsce/
website 16: https://www.naukowiec.org/wiedza/geografia/gleby-w-polsce-rodzaje_3403.html
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website 18: http://www.sites.google.com/site/centraleuropesoils
website 19: http://www.soils.umk.pl/database

Gleby rdzawe – przeoczone w edukacji szkolnej

Słowa kluczowe

Brunic Arenosols
Wskaźnik Dostępności Edukacyjnej
Analiza podręczników
Edukacja gleboznawcza
Świadomość gleboznawcza w społeczeństwie

Streszczenie

Gleby rdzawe zajmują około 15% terytorium Polski i są jednym z najważniejszych typów gleb wykorzystywanych w gospodarce leśnej. Są one powszechnie znane w środowisku gleboznawców, jednakże poziom wiedzy na ich temat wśród społeczeństwa (uczniów, studentów i osób nie związanych z naukami o glebie) jest zdecydowanie niewystarczający. Czy wybór gleby rdzawej na Glebę Roku 2021 jest szansą na zmianę w tym obszarze? Celem niniejszego opracowania jest zdiagnozowanie poziomu dostępności informacji o glebach rdzawych na etapie edukacji w szkołach średnich oraz określenie stanu wiedzy o tych glebach w społeczeństwie. Zastosowano trzy główne metody badawcze: analizę podręczników geografii, analizę źródeł internetowych oraz metodę ankietową. Wyniki analiz wskazały, że informacje o glebach rdzawych w niewielkim stopniu są prezentowane w podręcznikach szkolnych. Spośród 17 analizowanych stron internetowych na 8 nie ma żadnych informacji o tych glebach. Opracowany na potrzeby prezentowanych badań Wskaźnik Dostępności Edukacyjnej informacji na temat gleb rdzawych jest jednym z dwóch najniższych spośród wszystkich analizowanych jednostek glebowych. Respondenci nisko oceniali swoją znajomość gleb rdzawych, ale wyrażali chęć poszerzenia swojej wiedzy w tym zakresie. Niewystarczający poziom informacji na temat gleb rdzawych nie ogranicza ich rozpoznawalności. Respondenci nie mieli problemu ze wskazaniem gleby rdzawej na podstawie zdjęcia, ani też z określeniem właściwej liczby poziomów genetycznych. Rok Gleby Rdzawej stwarza doskonałą okazję do zaoferowania szerszej wiedzy o tych glebach młodym odbiorcom poprzez akcje promocyjne i zajęcia terenowe. Lekcje terenowe mogą łączyć edukację gleboznawczą z zagadnieniami ekologicznymi. Wiedza dotycząca gleb rdzawych, jako element edukacji formalnej i nieformalnej, może przyczynić się do wzrostu świadomości ekologicznej, szczególnie w odniesieniu do gleb powszechnie występujących i ważnych dla lokalnego środowiska.

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Alluvial soils – a stream into soil awareness

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Abstract

Alluvial soils cover about 5% territory of Poland and they are an important part of the environment of floodplains and river valleys. These soils have long been studied by soil scientists around the world. The high school students also have a relatively high knowledge of them in comparison with other soil types. Information about them is readily available in textbooks and on the internet. Is this enough to make alluvial soils the driving force behind efforts to popularize soil science? The aim of this paper is to diagnose the state of knowledge about these soils among high school students of Kuyavian-Pomeranian region as well as the assessment of their suitability in the soil awareness raising. Querying geography textbooks and internet sources as well as a survey method were used as the main research methods. Information on alluvial soils is commonly found in geography textbooks and websites. The awareness of soil distribution within Kuyavian-Pomeranian voivodship is the highest for alluvial soils among all studied types of soils. Respondents correctly assess the value of these soils and can identify ways to increase soil awareness among the public. Among the respondents there is a conviction that there is a need for changes in soil science education, especially in the field of extracurricular activities. Suggestions for such activities are included in this publication. The Year of Alluvial Soils is a good opportunity to introduce new solutions in the popularization of soil science on a regional and national scale.

1. Introduction

Soil is one of the most important environmental components but its importance and threats resulting from human activities are undoubtedly poorly known to a large number of people (Charzyński et al., 2022; Urbańska et al., 2022). One of the challenges of the soil scientists should be to increase social awareness of the soil cover. The soil science knowledge promoter in Poland is the Polish Soil Science Society encouraging public audience to get familiar with soils. One of the most important events under the patronage of this organization since 2018 is the election of the Polish Soil of the Year. In 2022 Alluvial Soil was chosen in this plebiscite. Genesis of these soils is related to the sedimentary action of flowing water. Therefore alluvial soils occur in majority on flooded plains as an result of accumulation of river sediments (e.g. Bednarek and Prusinkiewicz, 1980; Driessen et al., 2001; Paz et al., 2008). Most often, alluvial soils are formed near river beds, on the inside of meanders or at the mouths of larger rivers. Due to their fertility, these soils were the basis for the development of the greatest ancient cultures around the world (Montgomery, 2008). Alluvial soils cover about 5% Poland's territory and they are the most important part of soil cover in Vistula Valley (Prusinkiewicz and Bednarek, 1991). Mentioned soils are also an important component of the environment of the Kuyavian-Pomeranian voivodship, where the "queen of Polish rivers" formed the central axis of the region (Michalski, 2013; Bednarek and Świtoniak, 2017). In case of Toruń – a medieval city founded on the Vistula bank river played a key role (Wroniecki et al., 2021). The location factor was the proximity to the river and the related strengthening of the defensive function as well as economic benefits (e.g. transport route, fees, spatial development of the town). Contemporary the river boulevards closed to the UNESCO-listed old town are an attraction for tourists and local people. Within the floodplain there is also a reserve "Kępa Bazarowa" protecting natural riparian forests located in the immediate vicinity of the old gothic town. It should be considered whether the inhabitants are sufficiently (or at least equally) aware of the fact that the occurrence of typical soils is connected with the river. Is the awareness of their existence, properties and possibilities of their use sufficient among the inhabitants? Since the dawn of agriculture, the high productivity of alluvial soils lining has been known and appreciated. The alluvial soils belong to the youngest soils due to the contemporarily deposition (or recently deposition). River sediments are spatially and vertically very differentiated and the most typical feature of alluvial soils (changes in color, grain size and humus content) is stratification . In young, still forming soils the stratification is visible in their whole profile or starts directly under the well-formed humus horizon. Alluvial soils are commonly used for agriculture, and often, with proper reclamation and drainage, become highly productive soils. Those that are not used for agriculture form valuable natural and semi-natural habitats of scrub and meadow vegetation, as well as fertile and very varied riparian forest habitats. Due to their diversity and potential use, they are well and widely known to foreign and Polish scientists who have repeatedly studied the properties and occurrence of these soils (Valentin, 1995; Iqbal et al., 2005; Chojnicki, 2002; Sokołowska et al., 2002; Łabaz and Kabała, 2016; Michalski et al., 2018; Kawalko et al., 2018). Floodplains are dynamic spatial mosaics, characterized by multidimensional ecological systems and they are forming a kind of 'bridge' between aquatic and terrestrial environments. They are always connected in some way to an active riverbed and this connection is essential for the floodplains functioning (Thoms, 2003). The integrity of this system depends on the interaction between hydrological, geomorphological, and biological processes (Thoms, 2003; Petts and Amoros, 1996; McAuliffe, 2004; Daniels, 2003; Bullinger-Weber and Gobat, 2006). Because human has inhabited river valleys since the dawn of time, it would seem obvious that alluvial soils would be most familiar to him. However, it should be noted that in the 20th century, nature-dominated environments were changed to human-dominated environments (Messerli et al., 2000; Naveh, 2000). This includes the soil cover, which for residents of urban areas, is often hidden and unknown. Is this really the case? Do the young inhabitants of the Vistula Valley really have enough knowledge about the soil cover they walk on?

The aim of this paper is to diagnose the state of knowledge about alluvial soils among high school students of Toruń and surroundings.

Moreover, the authors set the following research tasks:

- review and evaluation of school textbooks and educational websites in terms of the availability of information on alluvial soils ;
- checking the state of knowledge of alluvial soils among high school students;
- assessment of the suitability of alluvial soils in the soil awareness raising.

2. Materials and methods

2.1. The survey method

A cross-sectional, cohort study was conducted with consecutive sampling using a self-administrated questionnaire through a Google online survey form. Data were collected among high school students in the Kuyavian-Pomeranian province (Toruń and surroundings). The participants were recruited for the study online through a form sent to schools and teachers. The survey covered schools whose students participate in the Geographic Olympiad every year. Procedurally representative (random) sample – respondents were selected using a random sampling scheme. The procedure was based on creating an appropriate list of units belonging to the population under study (high schools in the Kuyavian-Pomeranian region) and drawing an appropriate number of units for the survey. It should be noted that regardless of the level of teaching in secondary school, a student has the same basic knowledge of alluvial soils (acquired in primary school). At this (basic) level of education a student acquires knowledge and skills to distinguish the most important characteristics of alluvial soils, indicate their distribution on a map of Poland and assess their agricultural usefulness (Dz.U. 2017, poz. 356). A total of 305 students completed online Google form shared via email. Data collection began in January 2022 and ended in mid-March 2022. The survey (form) consisted of 6 questions relating to the alluvial soils:

- Match the name of the soil (students could use names of soil types: podzols, alluvial soils, clay-illuvial soils, urbisols, chernozems, rendzinas, black earths) to the mark on the map (the numbers from 1 to 5 indicate areas dominated by urban soils (cities), alluvial soils (flooded plains), podzols (dunes), clay-illuvial soils (undulating morainic plateau) and black earths (flat morainic plateau with poor drainage).
- Which of the following profiles represents alluvial soil? (three profiles to choose from).
- Provide the correct answer (Alluvial soils belong to the 1) azonal/ 2) zonal/ 3) intrazonal soils because: a) they are typical of the warm temperate climate zone, but can also occur in the subtropical climate zone/ b) they have a weakly developed soil profile and their distribution does not show any geographical regularities/ c) they occur in different climate zones and their distribution is related to specific local conditions).
- Select the correct answer (The ecological value of alluvial soils is manifested in: 1) increased biodiversity, due to the low fertility of these soils/ 2) increased biodiversity, due to the high fertility of these soils/ 3) decreased biodiversity, due to the low fertility of these soils/ 4) decreased biodiversity, due to the high fertility of these soils).
- Select the correct answer (Alluvial soil cover: 5%, 10%, 30% of Poland's area).
- Justify the statement that alluvial soils can have an educational value for the inhabitants of the Kuyavian-Pomeranian province. Suggest solutions to popularize soil science by studying local soil cover (open question).

The answers to the first question have been taken for analysis for providing general information on the awareness of distribution soils listed above within Kuyavian-Pomeranian voivodship. The proportion of correct answers was calculated for urbisols, alluvial soils, podzols, clay-illuvial soils and black earths along with the characteristic landscape of their occurrence.

Moreover, the questionnaire included information about the respondents (gender, place of residence). The participants (high school students aged 15–19 years) included 42% males and 58% female. They came from: Toruń 61.3%; Bydgoszcz 6.6%; Inowrocław 3.3%; Włocławek 3%; Grudziądz 2.3%. Nearly one quarter (23.5%) of respondents came from other places. Answers were also analyzed using a quantitative approach to investigate the knowledge about alluvial soils.

2.2. Querying geography textbooks and websites

The content of 17 high school geography textbooks as well as 17 websites were analyzed (first 17 results; search date: 18th April 2021, re-search date: 20th March 2022) after the entry:

"soils of Poland" (in Polish: gleby Polski) in the google search engine). However, it should be noted that the results depend on the history of previous searches so they can vary from user to user. It should be noted that currently only three publishers: "Operon", "Nowa Era", and "Viking" (no alluvial soils topic) offer geography textbooks approved for implementation by the authorities in Poland. Thus, it can be concluded that all possible Polish geography textbooks that schools can use have been analyzed (according to the list of textbooks approved for school use in general education). In all sources (Table 1) information was analyzed for

Table 1
Geography textbooks and internet sources overview

Title	Author	Year of publication	Publishing House
Geography of Poland. Textbook for X class.	Barbag J., Janiszewski M.	1964	Państwowe Zakłady Wydawnictw Szkolnych. Warsaw (in Polish)
Geography of Poland. Textbook for II class of high school and economic school.	Batorowicz Z., Górecka Ł., Prokopek B.	1970	
Physical geography with geology. Textbook for high school.	Stankowski W.	1987	Wydawnictwa Szkolne i Pedagogiczne. Warsaw (in Polish)
Geography. Textbook for bascic vocational school.	Domachowski R., Makowska D.	1987	
Poland i Europe. Geography textbook for high school.	Batorowicz Z., Nalewajko J., Suliborski A.	1990	
The Earth and people. Physical geography textbook for high school.	Makowska D.	1998	
Geography of Poland.	Świtalski E., Preisner Z.	1999	Oficyna Wydawnicza Turpress" Torun [In [Polish]
Outline of knowledge about the Earth. Textbook for high school.	Podgórski Z., Marszelewski W., Becmer K.	2002	Wydawnictwa Szkolne i Pedagogiczne. Warsaw (in Polish)
Physical geography 1. Extended level. Textbook for high school.	Czubla P., Papińska E.	2003	PWN WydawnictwoSzkolne. Warsaw (in Polish)
Geography of Poland. Textbook for high school.	Krynicka-Tarnacka T., Wnuk G.	2005	SOP. Torun (in Polish)
Geography 1. Basic level.	Kop J., Kucharska M., Szkurłat E.	2006	PWN Wydawnictwo Szkolne. Warsaw (in Polish)
Geography. Vademecum.	Stasiak J., Zaniewicz Z.	2013	Wydawnictwo Pedagogiczne Operon. Gdynia (in Polish)
Faces of geography 3. Textbook for high school and technical school. Extended level.	Więckowski M., Malarz R.	2014	Nowa Era. Warsaw (in Polish)
Geography. Repertory for high school graduates.	Biłgoras J., Głowacz A., Koperska-Puskarz D., Mazur M., Mozolewska-Adamczyk M., Srokosz W., Zieliński K.	2014	Wydawnictwa Szkolne i Pedagogiczne. Warsaw (in Polish)
Geography. Repertory for high school graduates.	Łękawa A.	2015	Greg. Cracow (in Polish)
Faces of geography 1. Textbook for high school and technical school. Extended level.	Malarz R., Więckowski R., Kroh P.	2019	Nowa Era. Warsaw (in Polish)
Geography-extended level. Textbook for high school.	Kurek S.	2019	Wydawnictwo Pedagogiczne Operon. Gdynia (in Polish)

Internet sources

https://epodreczniki.pl/a/zroznicowanie-gleb-i-roslinnosci-na-obszarze-polski/DSM0RxNIH (website 1)
https://www.ekologia.pl/wiedza/slowniki/leksykon-ekologii-i-ochrony-srodowiska/ (website 2)
https://pracownik.kul.pl/files/32723/public/pdf/gleba.pdf (website 3)
https://eszkola.pl/geografia/rozmieszczenie-gleb-w-polsce-6778.html https://www.edukator.pl/resources/page/gleby/11165 (website 4)
https://matura100procent.pl/rozmieszczenie-gleb-na-swiecie/ https://geografia.gozych.edu.pl/gleby-w-polsce/ (website 5)
https://opracowania.pl/opracowania/geografia/gleby-w-polsce,oid,1729 https://www.naukowiec.org/wiedza/geografia/gleby-w-polsce-rodzaje_3403.html (website 6)
https://www.bryk.pl/wypracowania/geografia/geografia-fizyczna/8387-gleby-polski.html http://geografia24.pl/gleby-w-polsce/ (website 7)
https://swiatrolnika.info/gleby-w-polsce-rolnictwo (website 8)
https://www.geografia24.eu/geo_prezentacje_rozsz_3/383_1_srodowisko_przyrodnicze/r3_1_08a.pdf (website 9)
https://geografia.na6.pl/warstwa-glebowa (website 10)
https://sciaga.pl/tekst/39463-40-gleby_w_polsce (website 11)
http://geomorawa.ucoz.pl/publ/gleby_i_roslinnosc_polski/1-1-0-228 (website 12)
http://www.pcez-bytow.pl/download/plk/gleby-w-polsce.pdf (website 13)
https://www.edukator.pl/resources/page/gleby/11165 (website 14)
https://geografia.gozych.edu.pl/gleby-w-polsce/ (website 15)
https://www.naukowiec.org/wiedza/geografia/gleby-w-polsce-rodzaje_3403.html (website 16)
http://geografia24.pl/gleby-w-polsce/ (website 17)

the frequency of four kinds of information concerning urban soils, alluvial soils, podzols, clay-illuvial soils and black earths: a) names, b) properties, c) profiles, d) description of soil horizons sequences. The frequency of these information was the basis for assigning "information scores" within each type of soil: a) names x 1 point, b) properties x 2 points, c) profiles – photo or scheme x 3 points, d) description of soil horizons sequences x 3 points. Coefficient of Information Availability (CIA) is the sum of the Partial Coefficient of Information Availability (CIAp) values calculated for every of four information categories (a, b, c, d). The CIAp was calculated according to elaborated formula: CIAp = $\sqrt{(Ti/Tt)} \times ip$ (CIAp – the Partial Coefficient of Information Availability; Ti – the number of textbooks/websites with soil information; Tt – the total number of textbooks/websites; ip – sum of "information points" in particular categories (Urbańska et al., 2021).

An attempt was made to compare and indicate the relationship between the survey results and the analysis of textbooks and online resources.

3. Results and discussion

In spite of their complexity, alluvial soils were the easiest to identify on the map by students (214 correct indications) and were far ahead of the other soil types. As many as 70% of students correctly associate floodplains with the presence of alluvial soils. Even in the case of podzols, which are very extensively described in textbooks, this share was only slightly over 50 percent. It is surprising, however, that only about 30% of students indicated urbisols as typical of cities and built-up areas. After all, it seems that the term "urbanization" is frequently used in geography teaching, and the widespread English proficiency among the younger generation should make the association of the Latin "urbium" with the adjective "urban" obvious (Fig. 1).

Despite not the greatest amount of information on these soils in textbooks, identifying them on the basis of a schematic profile structure did not pose a problem to most students. They were correctly recognized by 69% of the respondents while in the case of other soils, recognizing them did not exceed 30% of correct answers. The specific and easily recognizable layering

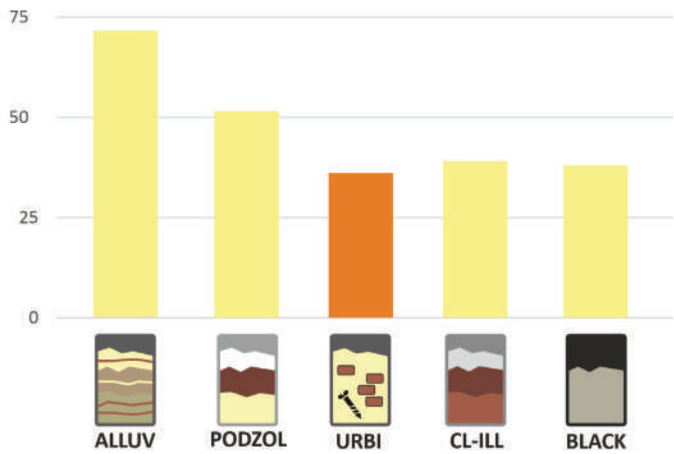

Fig. 1. Proportion of correct answers for selected soil types and their characteristic occurrence landscape

of alluvial soils (Kabała et al., 2013; Macklin and Klimek, 1992; Walker and Coventry, 1976) probably became the most significant factor influencing this result.

55% of respondents are aware that alluvial soils are intrazonal, they occur in different climate zones and their distribution is related to specific local conditions. As many as 69% of school students are convinced that the ecological value of alluvial soils is manifested in increased biodiversity due to the high fertility of these soils. Moreover, 56% of respondents indicated the correct answer concerning the area covered by alluvial soils in Poland. Therefore, it can be assumed that the majority of the respondents have basic (sufficient) knowledge about the discussed soils. Can this knowledge come from school textbooks? Probably yes, because in the analyzed geography textbooks, as well as in the queried websites, one can find a substantial amount of information about these soils (Table 2, 3). Information scores for geography textbooks are high (198) as well as for websites (158) which puts these soils in the second position in both cases. CIA values for these soils for textbooks and websites (respectively 175 and 134) which places them also on second position among the discussed soils (Fig. 2). This indicates a relatively high access in textbooks/websites to educational information on alluvial soils.

An important element was the assessment of the educational value of alluvial soils for the inhabitants of the Kuyavian-Pomeranian voivodship and the suggestion of solutions ways to popularize soil science by studying local soil cover. 67% of respondents point to educational value in alluvial soils and identify various solutions that can help increase local soil awareness (Fig. 3).

Certainly, soil science tours and workshops can provide a wealth of information and are one of the most effective educational method (Malina et. al, 2011; Urbańska et al., 2019; Urbańska and Charzyński, 2021; Urbańska et al., 2021). However, due to organizational problems (no time, no skills, no desire) these types of activities are not always possible. Soil posters that could be placed in various locations within the voivodship would be interesting. In the case of alluvial soils, such posters could be located along the Vistula River. During geography lessons school students of High School No 10 in Toruń prepared (in groups and individually) proposals of such information posters which could make the Philadelphia Boulevard in Toruń (a place along the Vistula River) more attractive for strollers and thus be a certain incentive to explore the knowledge, as well as become a source of soil science information (Fig. 4).

Alluvial soil arouses interest not only in soil scientists (Iqbal et al., 2005; Neal and Sposito, 1989; Valentin, 1991; Cubrinovski and McCahon, 2011) but also in school students as evidenced by the answers concerning the educational and ecological usefulness of these soils. Respondents believe that alluvial soils have great educational value. Due to the location of Kuyavian-Pomeranian province, they are especially important for the inhabitants (in the opinion of school students). The opinions collected testify not only to the knowledge of alluvial soils, but also to the existence of very limited soil awareness among the public. The following three responses show the dominant trend among respondents as well as their proposals for popularization of soil science.

Table 2
Information scores and CIA within urban soils, alluvial soils, podzols, clay-illuvial soils and black earths (geography textbooks)

Geography textbooks (the numbers of textbooks correspond to Table 1)

Soil type	Information type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Sum	Information scores	Sum of information scores	CIAp	CIA
Urban soils	name	0	0	0	0	0	1	0	0	0	0	1	0	0	2	0	0	1	5	5	9	2.4	3.8
	properties	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	2	4		1.4	
	profile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	
	description	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	
Alluvial soils	name	5	5	1	2	1	3	4	3	3	3	5	11	3	10	7	10	4	80	80	198	80.0	175
	properties	1	1	0	0	0	1	1	1	2	2	4	2	5	2	2	2	3	29	58		52.6	
	profile	0	0	1	0	0	0	1	0	0	0	1	1	1	1	0	3	1	10	30		20.6	
	description	1	1	0	0	0	1	1	0	0	0	1	1	1	1	0	2	0	10	30		21.8	
Podzols	name	9	10	9	2	3	6	6	7	5	5	9	15	5	9	10	7	7	124	124	345	124.0	331.1
	properties	2	2	1	1	1	2	7	3	1	3	7	2	10	4	2	4	3	55	110		110.0	
	profile	0	1	1	1	0	1	1	1	0	1	2	1	1	3	0	3	4	21	63		55.1	
	description	1	1	1	1	0	1	1	0	0	1	2	1	1	1	0	2	2	16	48		42.0	
Clay-illu-vial soils	name	0	0	6	1	0	4	4	6	3	3	2	14	3	9	8	6	1	70	70	162	63.5	134
	properties	0	0	1	0	0	1	4	2	1	2	2	2	6	2	2	3	3	31	62		54.2	
	profile	0	0	1	0	0	0	1	0	0	0	0	1	0	0	0	1	1	5	15		8.1	
	description	0	0	1	0	0	1	1	0	0	0	0	1	0	1	0	0	0	5	15		8.1	
Black earths	name	6	6	1	0	1	2	4	2	3	2	2	9	3	6	3	4	3	57	57	132	55.3	111.4
	properties	1	1	0	0	0	1	2	2	1	2	2	2	3	2	2	1	2	24	48		43.6	
	profile	0	0	0	0	0	0	1	0	0	0	0	2	0	1	0	0	2	6	18		8.7	
	description	0	0	0	0	0	0	1	0	0	0	0	1	0	1	0	0	0	3	9		3.8	

Table 3
Information scores and CIA within urban soils, alluvial soils, podzols, clay-illuvial soils and black earths (internet sources)

Internet sources (the numbers of websites correspond to Table 1)

Soil type	Information type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Sum	Information scores	Sum of information scores	CIAp	CIA
Urban soils	name	1	0	0	0	0	0	1	0	0	1	0	0	1	0	0	4	0	8	8	18	4.8	10.2
	properties	1	0	0	0	0	0	1	0	0	1	0	0	1	0	0	1	0	5	10		5.4	
	profile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	
	description	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	
Alluvial soils	name	5	3	2	1	3	2	4	1	1	3	2	0	14	4	10	4	8	67	67	158	65	134
	properties	1	0	1	1	1	1	1	1	1	3	1	0	2	2	2	1	1	20	40		37.6	
	profile	1	0	1	0	0	0	1	0	0	0	1	0	4	0	0	1	0	9	27		16	
	description	1	0	0	0	0	0	1	0	0	0	1	0	2	0	1	1	1	8	24		15.4	
Podzols	name	5	2	3	2	4	2	4	2	2	4	3	2	16	7	15	4	12	89	89	199	89	175.5
	properties	0	0	1	1	1	1	1	1	1	3	1	1	3	2	2	1	2	22	44		41.3	
	profile	1	0	1	0	0	0	1	0	0	0	1	0	4	0	0	1	2	11	33		21.2	
	description	1	0	1	0	0	0	1	0	0	1	1	0	3	1	0	1	1	11	33		24	
Clay-illuvial soils	name	4	3	1	2	3	1	4	2	2	2	1	2	9	1	8	4	11	60	60	99	60	78.2
	properties	0	0	0	0	1	0	1	1	1	1	0	0	1	1	0	1	1	9	18		13.1	
	profile	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	6	18		4.4	
	description	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	3		0.7	
Black earths	name	4	1	3	1	3	1	4	1	1	3	1	0	5	2	5	4	6	45	45	91	43.7	73.7
	properties	0	0	1	0	1	0	1	1	1	3	0	0	1	1	1	1	2	14	28		22.5	
	profile	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	3	9		3.8	
	description	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	3	9		3.8	

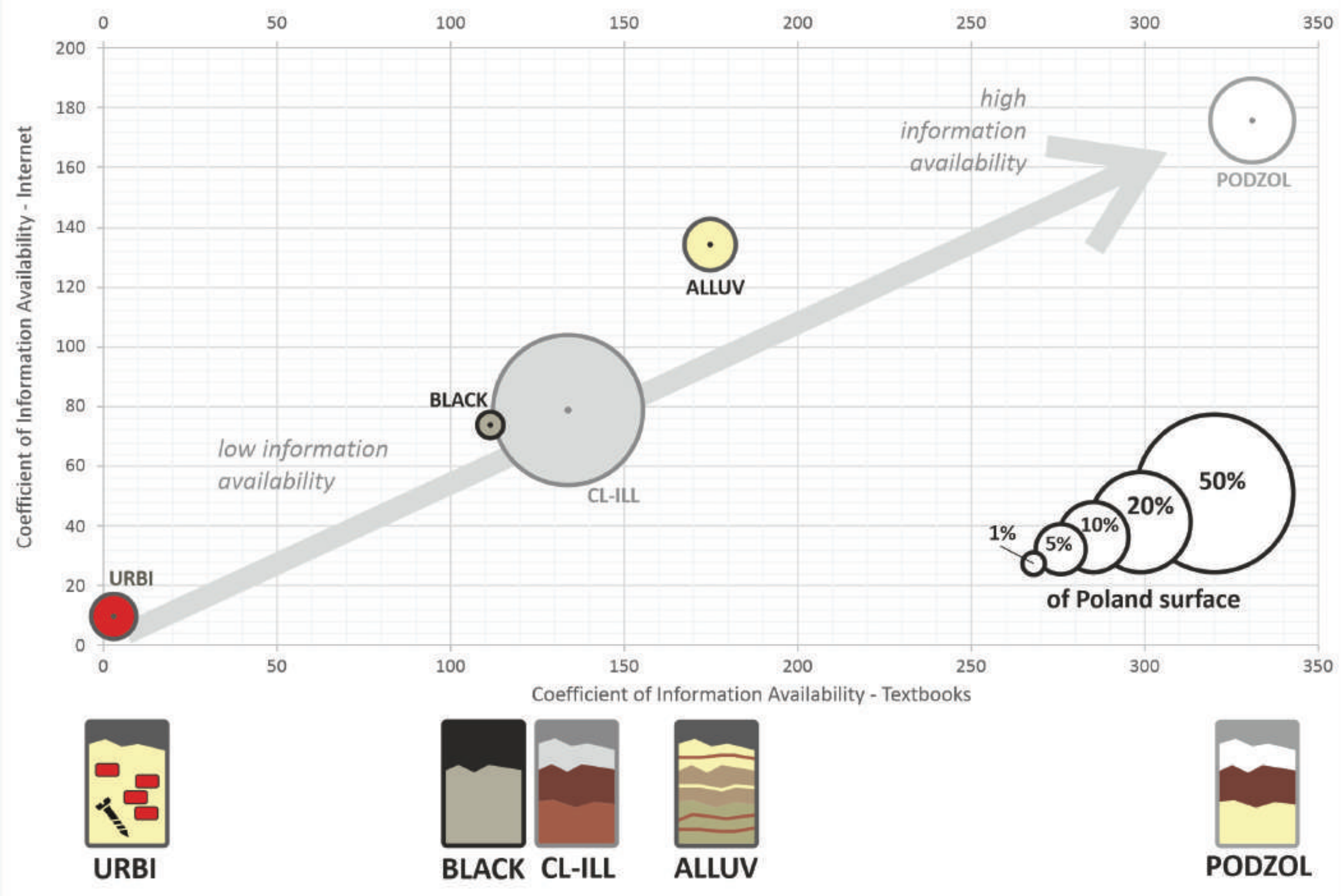

Fig. 2. Comparison of the Coefficient of Information Availability (CIA) of selected soil types (CLay-ILLuvial, PODZOLic, BLACK earths, ALLUVial soils, URBIzems) in textbooks and internet

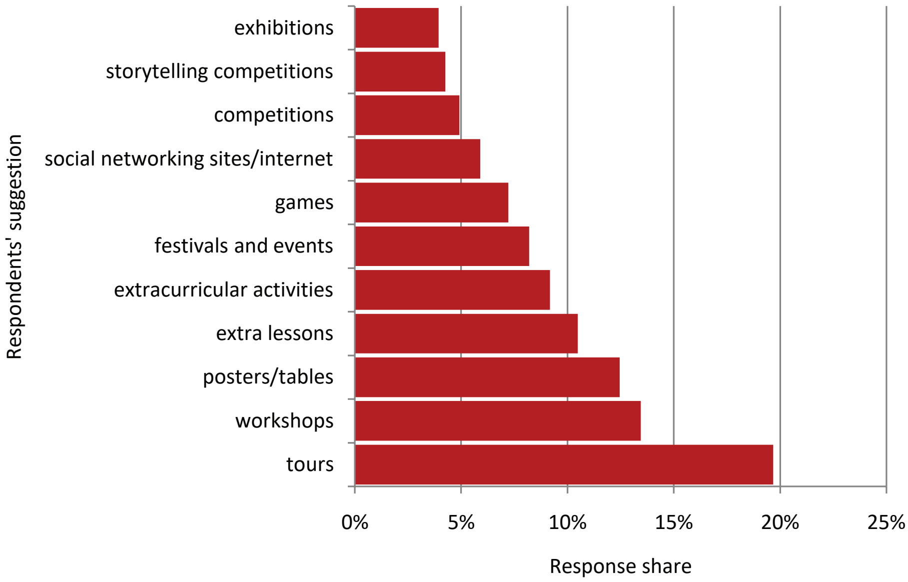

Fig. 3. Solution proposals to increase local soil awareness (school students opinions)

"People should be informed in some way about the importance of soil in our lives, for example by organizing activities or giving lectures on the subject, so that others become aware of how to take care of the soil we walk on".

Alluvial soils can definitely have an educational value, for inhabitants of all areas, as Poles generally have very little knowledge about soils – also about these soils, therefore any form of getting to know them is already a form of education. The solution for the popularization of soil science can be the workshops for children. Children absorb the most through stimuli from the environment. The option of "touching" soils, performing experiments is very appropriate and educational for them. Parents who watch over the children come with them, and whether they like it or not, they learn something from these meetings by "eavesdropping".

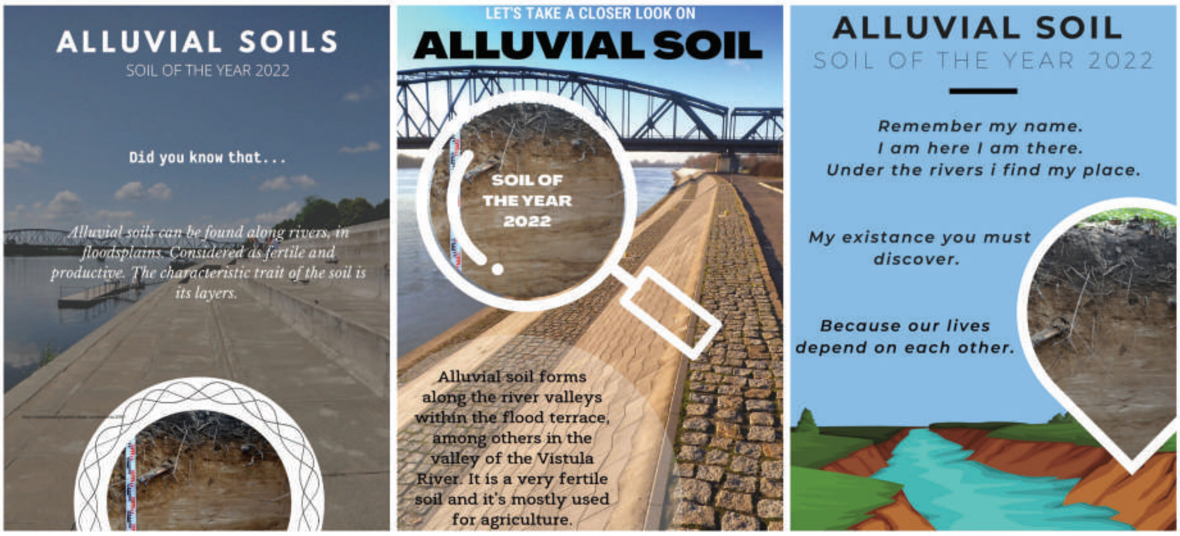

Fig. 4. Soils posters – students' proposals (authors: S. Bień, W. Hasiec, O. Stępniewska, W. Sadowska, A. Żurowska)

Alluvial soil is one of the most fertile soils in Poland, so it is worth talking about and learning more about this important factor in our country, because without good soils there is no life. A solution could be workshops with soil scientists, which would be combined in some way with games and not strictly connected with science itself.

Despite such an optimistic attitude of young people to alluvial soils and the proposal of relatively simple solutions, soil science still remains one of the most "unattractive" sections of geography teaching (Urbańska et al., 2022). Environmental problems the student is aware of before discussing them in school show clear deficiencies in soil science education (also non-formal). It turned out that some problems were sufficiently known to students (from the media or social network), while many other problems did not become known to students until high school (Fig. 5). The best-known issues are related to air pollution and global warming. Students are also quite aware of water pollution and floods. Unfortunately, only a few of them

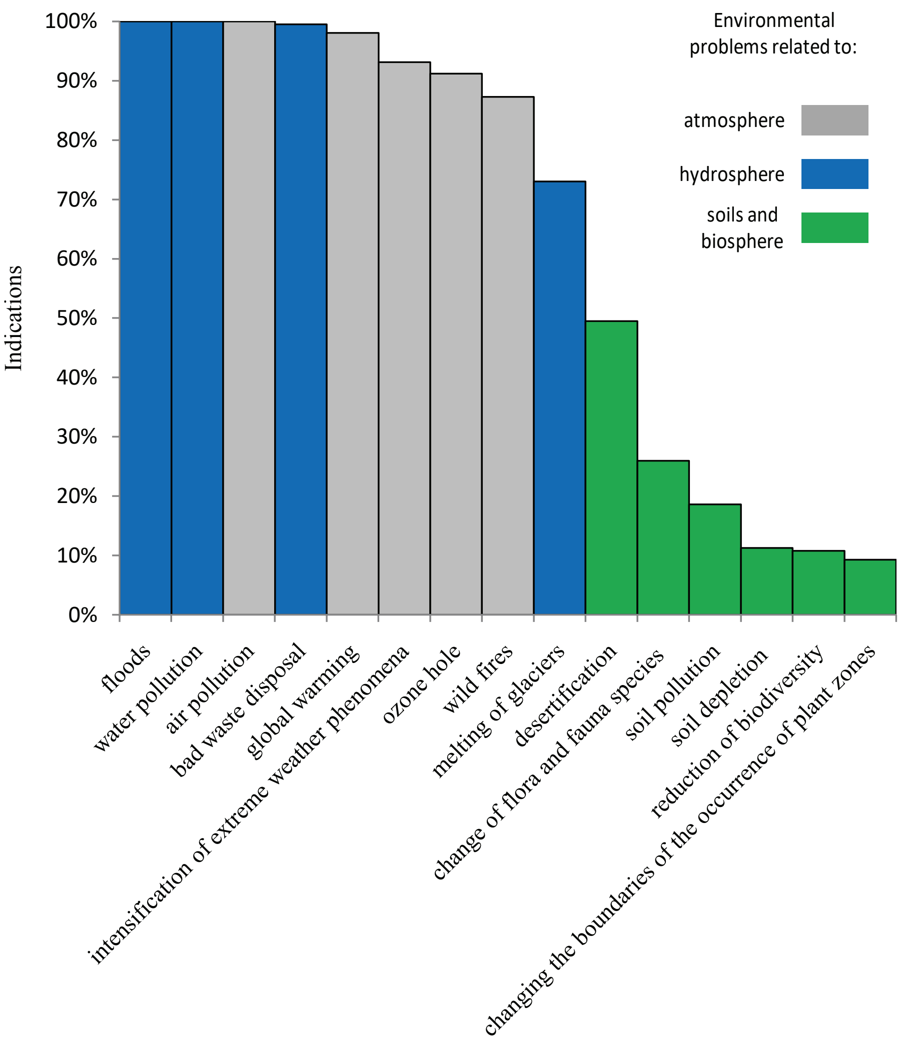

Fig. 5. Students' awareness of environmental problems (based on: Urbańska et al., 2022, modified)

are aware of problems related directly to soils. Students are generally unaware of the effects of deforestation leading to landslides, loss of biodiversity, and ecological soil functions as well as soil pollution and soil depletion. Nevertheless, young people's interest in problems related to floods or water pollution can (and should) be turned into an interest in soil. Alluvial soils seem to be an ideal link between these environmental threats.

This low state of soil science knowledge is also noticed by the respondents of the present study. Among the respondents there were the following answers: *Soils could have educational value because they are a very important part of the environment. People could popularize soil science by publicizing soil pollution and the effects of soil pollution.* This demonstrates the need to deepen the soil science knowledge not only of the school student, but of every inhabitant of our planet. Such a change is crucial not only for a healthy ecosystem, but also for the development of sustainable societies.

4. Conclusions

Alluvial soils are among the most recognizable soils of the soil cover in the Kuyavian-Pomeranian province. The availability of information about them both in geography textbooks and internet sources is also high. High school students are aware of their ecological value and the associated high biodiversity. Taking advantage of the fact that the Kuyavian-Pomeranian region is located in the Vistula Valley, the soil science awareness among the inhabitants may be increased. The soil science community, as well as local governments, should take advantage of the school students' suggestions to promote soil science knowledge. The most effective as well as interesting educational methods are soil science tours and workshops so the number of such events available to the public should increase. Soil posters that could be placed in various locations within the voivodship would be interesting. In the case of alluvial soils, such posters could be located along the Vistula River in commonly visited by locals and tourists recreational areas, e.g. Philadelphia Boulevard in Toruń. Alluvial soils, in their "inflow" nature, could initiate a stream of soil science knowledge in a way that would best reach today's generation – through image and applicability. Soil of the Year 2022 could be a great opportunity for development new and better soil awareness – based on public involvement in educational activities. Only such a proceedings can shape a young world citizen who will be able to face emerging environmental problems. Alluvial soil is a treasure of deeply hidden from human eyes. Soil educators should try to "dig them out" and make them visible to the public. Moreover, just as a river changes its character and course during its journey, societies should also begin to treat the soil with due respect. Taking the right action is crucial. The best way is proper soil science educational activity.

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website 9: https://www.geografia24.eu/geo_prezentacje_rozsz_3/383_1_srodowisko_przyrodnicze/r3_1_08a.pdf

website 10: https://geografia.na6.pl/warstwa-glebowa

website 11: https://sciaga.pl/tekst/39463-40-gleby_w_polsce

website 12: http://geomorawa.ucoz.pl/publ/gleby_i_roslinnosc_polski/1-1-0-228

website 13: http://www.pcez-bytow.pl/download/plk/gleby-w-polsce.pdf

website 14: https://www.edukator.pl/resources/page/gleby/11165

website 15: https://geografia.gozych.edu.pl/gleby-w-polsce/

website 16: https://www.naukowiec.org/wiedza/geografia/gleby-w-polsce-rodzaje_3403.html

website 17: http://geografia24.pl/gleby-w-polsce/

Gleby aluwialne – strumieniem wiedzy gleboznawczej

Słowa kluczowe

Gleby aluwialne
Gleby dolin rzecznych
Podręczniki geograficzne
Promocja gleboznawstwa
Edukacja gleboznawcza
Polska Gleba Roku 2022

Streszczenie

Gleby aluwialne (mady) zajmują około 5% powierzchni Polski i stanowią ważny element środowiska równin zalewowych i dolin rzecznych. Gleby te od dawna stanowią przedmiot badań gleboznawczych na całym świecie. Wiedza uczniów szkół średnich na temat mad jest szersza niż w przypadku innych typów gleb. Informacje na temat gleb aluwialnych są stosunkowo łatwo dostępne w podręcznikach i wśród zasobów internetowych. Czy to wystarczy, aby gleby aluwialne stały się przyczynkiem do działań popularyzujących gleboznawstwo? Celem niniejszego opracowania jest diagnoza stanu wiedzy uczniów szkół średnich ogólnokształcących województwa kujawsko-pomorskiego na temat mad oraz ocena przydatności tych gleb w popularyzacji gleboznawstwa. Głównymi metodami badawczymi zastosowanymi w opracowaniu była kwerenda podręczników geografii i źródeł internetowych oraz metoda ankietowa. Wyniki badań wskazują, że informacje o glebach aluwialnych są powszechnie dostępne zarówno w książkach, jak i mediach internetowych. Świadomość wartości ekologicznej tych gleb na terenie województwa kujawsko-pomorskiego jest wysoka. Respondenci prawidłowo oceniają przydatność mad i potrafią wskazać sposoby zwiększenia społecznej świadomości gleboznawczej. Wśród respondentów panuje przekonanie o potrzebie zmian w edukacji gleboznawczej, zwłaszcza w zakresie zajęć pozalekcyjnych i pozaszkolnych. Propozycje takich działań zostały zawarte w niniejszej publikacji. Rok Gleb Aluwialnych jest dobrą okazją do zaproponowania nowych rozwiązań w zakresie popularyzacji gleboznawstwa zarówno w skali regionalnej, jak i krajowej.

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SUITMA+20

SUITMAs as an archive of the human past: educational implications

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Abstract

Purpose The relics of the industry are widely used for educational and touristic purposes. There are many examples of brownfield sites turned into tourist attractions. Interest in post-industrial areas concerns not only an infrastructure and ruins but also the soil cover. Soils in such areas should be also considered as important element of this type of landscape due to the artefacts' stored. This article aim is to present educational potential of post-industrial soils and artefacts to be found there on the example of the area of "Polchem".

Methods and materials This publication is based on the analysis of soils' artefacts in the non-reclaimed area of former chemical plant. Photographic material and literature studies focus on technogenic soils and its functions. The history of "Polchem", industrial tourism and industrial archaeology as well as verbal communication of people associated with the company were important components of this publication.

Results and discussion Soils play many ecological functions, one of them is archiving human history. In this approach, archaeology is combined with soil science serving as a tool in archaeological research. Such cooperation within two scientific fields leads often to valuable scientific achievements. Relatively young post-industrial areas are generally out of interest of archaeology. However, they can form the basis of soil education activities targeted at a larger number of recipients.

Conclusions Soils within cities are interesting due to recorded marks of human activity. Artefacts in soils can be used in various ways. One of them is an educational purpose. "Polchem" area is out of use now so it can be accessed by visitors (students and teachers). Artefact's diversity allows for quick finding and recognition of industrial history of the former plant. In this way, it could be present an important soil function—protecting cultural heritage.

Keywords Urban soils · Industrial soils · Technosols · Soil education · Artefacts · Ecosystem services

1 Introduction

Soils have a very important role in our life and in the management of the human environment because they are one of the most valuable elements of terrestrial ecosystems. Awareness of this role appeared in the 1970s when the first attempts were made to define the functions of soils, to classify them and to perform physicochemical tests on them. The European Soil Chapter, issued in 1972, was a prototype for documents confirming the important role of the soil environment. Contemporary research deals with the subject of soils and their significance for humans through the prism of the quality, functions and ecosystem services of soils, often using these different terms interchangeably. Soils perform many ecological functions (Morel et al. 2015; Foley et al. 2005; Vitousek et al. 1997). Soil cover can be a testimony of human activity in agricultural development, settlement or industry. Soils are a reservoir of artefacts—a historical trace of human existence and management. As such, they can function as a research material not only for naturalists but also for archaeologists, historians and anthropologists. Moreover, they can be successfully promoted and used as a feature of touristic and educational attraction.

Soil functions are understood to be the benefits that soils offer to organisms, including humans. There are many divisions of these functions, of which two can be distinguished as the most frequently quoted. The first is the concept of W.E.H. Blum (2005), modified many times by the author since 1988, and it is probably the most popular concept in the European environment. Soil functions, according to Blum (2005), can

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be divided into the ecological and the non-ecological. *Geological and cultural heritage* is one of them. In American publications, e.g. Doran and Parkin (1994), there is a scheme of soil functions corresponding to their quality. According to the American scientists, one of the most important functions is *to protect cultural heritage*. According to the FAO (http://www.fao.org), basic soil functions (among them *cultural heritage*) can be distinguished. Karczewska (2012) divides soil functions into three groups: one consists of the issues *cultural heritage*, *geological history* and *scientific and landscape values*.

The European Commission COM (2002) 179 adopted the basic assumptions of a soil protection strategy. Soil functions were divided into five groups, including *the cultural and material environment of human activity*.

According to Blum et al., soils represent and record a landscape's history using evidence of human activity as well as palaeontological evidence. It is essential of soils' *cultural function* (Blum et al. 2018).

Nowadays, there is a need to improve awareness of soil within cities as they are usually significantly altered by human activity. This can be achieved by a learning-by-doing strategy. Mobile Environmental Education Projects (MEEPs) are one example of promoting soil education (Siebe et al. 2017). Students can explore the soils of parks or schoolyards and its interaction with other environmental compartments using vehicles equipped with the materials they need. Using all their senses, such as touch, taste, smell, sight and hearing, young people can enhance their interest in soils (Siebe et al. 2017). In Europe, a number of soil awareness and education initiatives already exist from primary school education to informing decision makers and working with stakeholder groups (Towers et al. 2010). Soil science education is important for teaching knowledge and understanding of environmental systems and the value of environmental protection (Hallett and Caird 2017) but teaching ideas and practice are different around the world (Hartemink et al. 2014). A considerable part of this teaching is given to students from different disciplines (Hartemink et al. 2014) and from different stages of education (Prokof'eva 2018). Methods and forms of soil education should be adapted to the needs of recipients of a certain age and educational stage. According to Hartemink et al., these all require extra efforts to generate student interest and engagement in the subject and to find the educating soil scientists whose competence and creativity will also be balanced by a deep understanding of the applications of knowledge. This is a challenging task for all soil science educators (Hartemink et al. 2014).

The modern perspective on soil functions recognises the importance of understanding the soil environment as a food producer and gene reservoir, and as a record of the history of human activity via artefacts that can sometimes transform particular soils into a museum of sorts. Technogenic soils—those strongly transformed by human existence (other than agricultural activity)—are of just such formations (Charzyński and Hulisz 2013). Thus, these soils occur in urbanised and industrialised areas. Interest in technogenic soils has increased since the 1990s, when more studies of these soils began to appear. A soil research group was established for urban, industrial, transport, mining and military areas—SUITMA. In essence, understanding SUITMAs involves understanding the needs that cities express, and how soils can be designed to support ecosystem services (Morel et al. 2015).

The aim of this article is to present the soil cover of a post-industrial area of the former chemical plant "Polchem" in a snapshot of the factory's cultural soil functions, its 70-year history of production technologies, its industrial infrastructure and its role in factory workers' lives. In this context, the question arises whether the post-industrial soils can be interesting educational objects for scientists, students and tourists. The studied area does not look like a museum of industry. It could be seen, rather as a museum of industrial activity without buildings, technology lines, chimneys or railroad tracks, but full of traces of that activity. According to Field et al. (2017), places like that could be an appropriate basis for a future teaching–research–industry–learning soil science curriculum model that extends beyond traditional discipline-based teaching.

2 Methods and materials

This publication is based on the analysis of soil artefacts, photographic material and literature studies focusing on technogenic soils and their functions, history of the "Polchem" factory, industrial tourism and industrial archaeology, as well as the verbal communication of people associated with the company.

Soils within "Polchem" area have large number of human artefacts which play important role in analysing these soils and its further educational implications. The procedures consisted of several stages: selection of the study area, field study, interpretation soils and artefacts and creating a model of possible interpretations of artefacts within the former chemical plant area. Artefacts were collected during various fieldworks from 2013 to 2019. An initial selection of artefacts was made. During this process, artefacts in the best condition were selected as well as artefacts interesting in appearance and useful for potential interpretation. Artefacts were divided into specific groups according to FAO (2006) due to its diversity. Its potential interpretation in relation to the history of industrial plant was proposed.

The scope of this article covers post-industrial soils on premises of the "Polchem" the Toruń's "Company of Non-Organic Chemistry". The acronym "Polchem" is derived from the combination of the names Polish chemistry, defining the factory production profile. Toruń (53°01'N 18°36'E,) is a city in the Toruń Basin in Northern Poland, and covers an area of about 116 km^2. The main factor in terrain relief is the activity of the Vistula River, which is connected with the occurrence of many flood terraces with inland dunes. Human activity has continued uninterrupted since the founding of the city in the thirteenth century. The soil cover (Fig. 1) is typical of most cities.

"Polchem" is located on the western outskirts of the city (Fig. 1). Geologically, it is a fragment of the third terrace of the Vistula's ice-marginal valley. The surface layer consists of well-sorted river sands transformed by wind. Part of the area is covered by large numbers of dune fields. Brunic Arenosols were developed from those sands and loamy sands that are not very rich in clay fraction and with a high susceptibility to chemical degradation (Bednarek et al. 2015). Due to the development of the city and industry, the soils of this area are classified as SUITMAs, according to the WRB soil classification (IUSS Working Group WRB 2015) as Spolic Technosols (Fig. 1). After the demolition of "Polchem" (Fig. 2) in this area, a shopping mall, the "Motoarena" sports facility and a petrol station were built. These objects occupy only part of the site of the former plant. Other than these three examples, the area is not used and is unreclaimed, despite various investment attempts.

Technosols are common in urban areas. They have large number of human artefacts which play important role in analysis of technogenic soils. Artefacts were produced, modified or transported from their source, by human activity. Its importance in soils was noticed by many scientists. J. Howard (Howard 2017) presented common types of anthropogenic particles found in soils as well as description of artefacts and its diversity. Many examples of technogenic soils in Poland were presented by P. Charzyński, P. Hulisz and R. Bednarek (Charzyński et al. 2013). In this monograph, there are descriptions of various soils with artefacts related to human activities in urban, industrial, traffic, mining and military areas in Poland. Artefacts were described in Technosols of New York City (Shaw et al. 2010), Emilia Romagna Region in Italy (Antisari et al. 2014) as well as in mining areas of many countries (Echevarria and Morel 2015). In general, artefacts are described by many specialists according to their discipline. Nevertheless, the role of soils in storing and collecting traces of human activity is emphasised almost by every disciplines which are interested in humanly modified grounds (Edgeworth 2017).

Fig. 2 Aerial view of "Polchem" after demolition (http://archiwum.mpu-Torun.pl/index.php?m=gal&id=13)

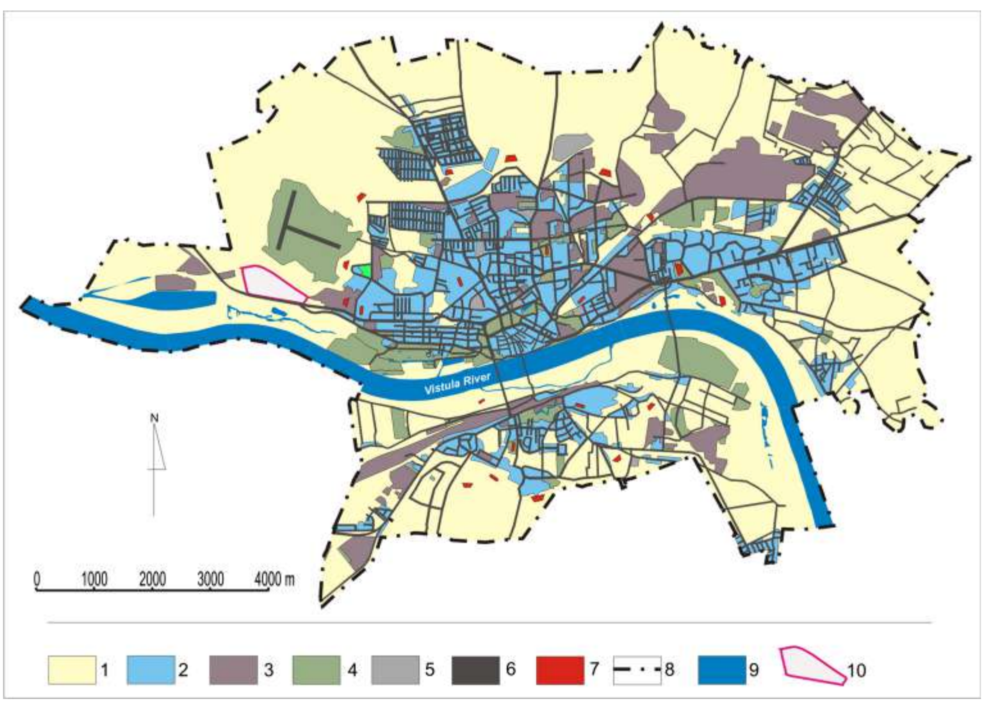

Fig. 1 The soil map of Toruń (Bednarek et al. 2003; Charzyński et al. 2018; Charzyński and Hulisz 2017). Explanations: 1 Brunic Arenols and Fluvic Gleysols (undisturbed and weakly transformed soils), 2 Urbic Technosols, Eutric Arenosols (Technic), 3 Spolic Technosols, Dystric Arenosols (Technic), 4 Fluvic Hortic Pheozems (Siltic or Loamic), Haplic Pheozems (Arenic or Siltic), 5 Ekranic Technosols, Relocatic Pheozems, 6 Ekranic Technosols, 7 Isolatic Technosols, 8 city boundaries, 9 surface waters, 10 area of former chemical plant 'Polchem'

2.1 Polchem: historical background

The sulphuric acid company "Polchem" in Toruń was the second of three such facilities built in Poland in the interwar period (Kruszka and Wartalski 1995). The Polish-Belgian joint-stock company was set up in 1929. In 1933, the company led to the construction and commission of "Polchem", a new chemical plant in Toruń covering 60 ha. Initially, production included sulphuric acid of various concentrations, oleum (sulphur oxide), sodium and potassium sulphate (IV) and bisulphate (IV). The years 1970–1980 were not only a period of modernisation but also the beginning of environmental awareness. The negative impact on the environment was noted, and many various actions were taken to reduce it.

Until 1990, "Polchem" specialised in the production of several substances, such as simple dust superphosphate, technical and battery sulphuric acid, hydrochloric acid, chlorosulphonic acid, sodium sulphate, hydrosulphite, rongalite, zinc sulphate and reagent chemicals based on the technical chemicals it produced (Majchrzak et al. 2012).

The plant's final bankruptcy was declared by the court on 18.03.2003 (http://www.krs-online), but today, the plant website is still listing the available products on offer at the time it closed business. These are sodium hydrosulphide, sodium hydrosulphide for food purposes, sodium sulphate anhydrous technical and sodium sulphate (IV) heptahydrate (http://www.polchem.com.pl/produkty.html). All products are non-toxic and non-flammable but emit sulphur dioxide (SO_2) on being heated, and in addition to sulphate derivatives, most of them contain the heavy metals lead and arsenic, and some contain selenium (non-metal), cadmium, zinc and mercury. After 2003, the buildings were abandoned, workers were dismissed, and the entire infrastructure became post-industrial ruins (http://urbanqatsi.pl/Poland/polchem/Toruń-polchem.htm). It was decided to demolish the buildings, and the demolition material (debris) was sold for construction purposes.

3 SUITMAs in education: results and discussion

According to Siebe et al. (2017), three aspects must be considered to increase awareness about soils. In the human **mind**, there must be the need for "soil care". The participation of the **body** should be provided by experiences ("learning by doing"). Spiritual connections to soils create emotional links to them (by the **soul**). All three aspects can be perfectly fulfilled within the research area: the picture of soil disturbances can evoke a need for soil protection, field experience (with all precautions needed in polluted areas) and emotional engagement as a former industrial plant can be considered part of little homeland of Toruń citizens. Nowadays, people are interested in the local environment. They are concerned about redeveloping lands and creating new open areas within cities. On the other hand, soil ecosystem services in cities are far more difficult to evaluate because they are not at the centre of political or economic interest (Levin et al. 2017). However, the fact is that brownfield investments are trendy, smart and popular. There are many examples of brownfields that have been reclaimed in recent decades (e.g. the Ruhr area in Germany, the Silesian area in Poland), but many of them are still out of use. The "Polchem" area is awaiting proper use. An educational function could be a practical possibility these days. According to Levin (Levin et al. 2017), there are many examples of places around the world for integrating soil scientific research and cultural reflection.

There are many different ways to present the importance of soils using various educational tools. The Senckenberg Museum of Natural History in Görlitz developed an international touring exhibition with the title "The Thin Skin of the Earth – Our Soils" (Xylander and Zumkowski-Xylander 2018) where many forms of educational approaches were presented. All forms were necessary to maintain the visitors' concentration and achieve maximum awareness, e.g. high-quality models of soil organisms, digital and analogue hands-on-media, movies and VR. The exhibition was developed for a variety of target groups but has a special focus on families and school classes to change the visitor's attitude towards environmental issues following the concept of "from idea to action" (Xylander and Zumkowski-Xylander 2018).

To promote environmental awareness, environmental perception was utilised as the main tool to analyse public understanding of local environment (Santos et al. 2000). In São Paulo, a non-formal environmental education (EE) programme has been implemented in the natural conservation area through EE paradigms, which consider the objectives of education *about*, *in* and *for* the environment within cultural and natural perspectives. Various pedagogical tools were produced (Santos et al. 2000).

It should be noted that different groups of people are potential recipients so there is a need to introduce various educational methods. Bruce C. Ball shows the outcomes of selected methods of improved connections to soil issues for different groups (e.g. farmers, policy makers, scientists, children, adults (Ball et al. 2018). Both Prokof'eva (2018) and Świtoniak et al. (2018) present experiences of teaching soil science to students at different educational stages. It should be noted that this teaching requires special didactic materials, e.g. "Guidelines for soil description and classification" (Świtoniak et al. 2018).

"Digital natives"—students who are all "native speakers" of the digital language of computers, video games and the Internet (Prensky 2001)—need to adapt materials to their digital language. The Regional Environmental Center for Central and Eastern Europe (http://greenpack.rec.org/soil/index.

shtml) has an online soil lesson that goes into: why soil is important, basic soil functions, problems and threats to the soil, and impacts of war on soils, and finishes with "what people can do" to protect soil for the future (Harrison et al. 2010). The Field Museum (http://www.fieldmuseum.org) has lessons for children called "underground adventure" (Harrison et al. 2010) with exercises in soil texture, temperature, compaction and percolation, factors that affect soil use and soil biodiversity. In Russia (Buyvolova et al. 2018), it was proposed to introduce the student competition (soil judging contest) in describing soils, and the team wins whose description is closest to the description expert. This could be an interesting way for students who will take part in "Polchem" soils education.

Increasingly, students have a desire to learn about soils with an emphasis on environmentally oriented applications (Harrison et al. 2010) so "Polchem" soils, with their cultural functions, could be interesting enough for them.

The Tea Bag Experiment—an interesting example of international project—shows that students willingly take part in such of undertakings. TeaTime4Schools was funded by Sparkling Science, a research programme of the Federal Ministry of Science, Research and Economy. The Tea Bag Experiment (http://www.teatime4science.org) was associated with the Tea Bag Index—a simple method to study decomposition of plant materials in soil. Students buried tea and investigated the relation between decomposition and microbial activity of the soil. The objective of the TeaTime4Schools project was to achieve a better understanding the role of microorganism in the decomposition process.

There are many examples of soil campaigns that make the target group aware of the importance of soil. The campaigns are part of the "soilution"—solution for soil degradation (Bramel 2012).

Table 1 lists a selection of artefacts found within the "Polchem" area, and possible interpretations by visitors (students or other recipients) in light of the industrial history of this former plant. This is a way to involve all the senses (mind, body and soul) to learn the history of the place through the area's soil cover. "Polchem" was turned into a site of poorly cleared rubble, but it is full of traces of its former activity that can be called "post-industrial artefacts". "Post-Polchem" soils, like many other soils of post-industrial areas, are characterised by the clear dominance of the function they perform at the moment—cultural functions. They are a treasury of knowledge hidden in artefacts that are important to the learning of the history of the place and human activity in this area.

The artefacts might be fragments of concrete, bricks and reinforcement elements that are the direct result of demolition work, but also production waste, used containers, and, finally, sulphur accumulated in the soil. In the area of the plant not only can traces of industrial activity be found but also fragments of transport infrastructure. The quantity of these materials indicates the important role that "Polchem" played in history. Post-industrial soils are a kind of record of events connected not only with production but with all industrial activity (fragments of reinforcements, debris from buildings, elements of railway tracks) (Fig. 4).

According to Howard (2017), artefacts are objects of > 2.0 mm (whereas microartefacts are 0.25–2.0 mm) that were produced, modified or transported from their source by human activity. Howard (2017) classified them into five types on the basis of composition: (1) carbonaceous, (2) calcareous, (3) siliceous, (4) ferruginous and (5) other. Due to its diversity, artefacts are divided into groups according to FAO (2006): (1) artisanal natural material; (2) industrial dust; (3) slag; (4) concrete fragments; (5) pavements and paving stones; (6) bricks, pottery fragments, and tiles; (7) metal fragments; (8) mixed materials; (9) organic garbage; (10) synthetic liquids; (11) synthetic solids; (12) waste liquids; (13) charcoals; and (14) other.

Most of these types can be found in the discussed area; moreover, they are common there (Table 1, Fig. 3, Fig. 4). This area can be seen as a living SUITMA laboratory that has been influenced for many years by the production of sulphuric acid and artificial fertilisers. In the new Polish soil classification (Kabała et al. 2019, 2020), two types of soil artefacts have been distinguished—"normal" (e.g. concrete, stones) and "reactive" (e.g. ash, slag, tailings), to reflect their different reactivity and toxicity in soil environments. There is an abundance of reactive artefacts (sulphur) in the study area, and its toxic properties can be observed (extreme pH, spots completely devoid of vegetation) and shown to visitors (Fig. 5).

In view of the fact that the framework of cultural ecosystem services provides the opportunity to cooperate with other disciplines (Levin et al. 2017),"Polchem" can be considered also in the context of industrial archaeology—a field that has been developing since the mid-twentieth century and combining many disciplines (history of technology, archaeology, history of architecture, conservation of monuments, etc.). Soils can be an important storehouse of information and soil analysis can help archaeologists to date sites and get to know the major human activities (Vranova et al. 2015).

Industrial archaeology has become a basic tool for interpreting industrial heritage and technology (Labadi 2001; Januszewski 2010). The interest in industrial archaeology has led to the creation of museums in abandoned industrial facilities, as well as new forms of technical museums—ecomuseums, which can be museums of time, space and humanity, showing the relation between man, nature and technology. Soil scientists are encouraged to discover new links between ecosystem functions and the unique cultural histories in which cities have evolved (Levin et al. 2017). It is the way that the area of "Polchem" can be seen.

The technological revolution, together with increasing ecology awareness, caused the liquidation of companies that had the potential to continue production but that were replaced by others that used more efficient and environmentally

Table 1 Possible interpretations of artefacts within the "Polchem" area, for educational purposes

No.	Artefact	Example	Artefact group (by division)	What the visitor should/could deduce?	Reference to "Polchem"
1.	Slag	Fig. 4a, 4i	Slag	It is an anthropogenic material; slag can be related to industry; slag changes the water and air characteristics of soil	Slag is a product of coal combustion in boiler rooms. *Boiler plant* rooms provided heating and hot water for "Polchem". It can also be a building material—"slag brick"
2.	Sulphur	Fig. 4d, 4f, 4g, 4i	Industrial dust	It is a chemical and anthropogenic product; sulphur affects the chemical properties of soils; toxic to plants	"Polchem" produced sulphur acid, so sulphur was a raw material in production process
3.	Synthetic solid	Fig. 4a	Synthetic solid	It is an anthropogenic material; synthetic solid can come from human activity other than industry	In the plant, there were many possible uses of synthetic solids (e.g. floor covering, insulation material, synthetic worktops)
4.	Brick fragments	Figs. 3, 4h	Bricks, pottery fragments, tiles	Brick fragments could come from demolished buildings; they might be elements of industrial infrastructure	Bricks were a popular building material. "Polchem" was built from, among things, bricks, which are now a product of plant demolition
5.	Chemical label	Fig. 4e, 4b	Mixed material	It is evidence of industrial activity related to the use of materials hazardous to people and the environment	Fluorosilicic acid (H_2SiF_6) was used in production of Sodium fluoride, Ammonium fluoride (acid), hydrofluoric acid and sodium fluorosilicate—important substances in the "Polchem" production structure. Many products were toxic, corrosive or irritant chemicals.
6.	Plastic	Fig. 4a	Synthetic solid	It is an anthropogenic material; plastic could come from various sources	Plastic is a very common material. It was used in many different situations (as a building material; in office or lab equipment)
7.	Metal fragments	Fig. 4b	Metal fragments	It is evidence of human activity; it could come from industry as well as from other sources	In the "Polchem" plant there were many metal constructions (sulphur furnaces, installation, railway infrastructure, etc.)
8.	Concrete fragments with sulphur	Fig. 4d	Concrete fragments/industrial dust	Concrete fragments could come from demolished buildings, and sulphur demonstrates the chemical processes performed as the human activity.	Sulphur as sulphur acid—the main product of "Polchem"—is corrosive. Sulphur efflorescence is very common not only on the surface but also inside concrete fragments
9.	Concrete fragments	Fig. 3	Concrete fragments	Concrete fragments are evidence of demolished buildings and human activity	Concrete fragments come from the demolition of "Polchem". Concrete was used as a building material
10.	Glass fragments	Fig. 4b, 4c, 4g	Other (glass)	This anthropogenic material could come from various human origins; it could be a type of rubbish	Glass is a fragment of the plant's windows and other constructions made of this material. Glass bottles were used for storing acid
11.	Cable fragments	Fig. 4h	Synthetic solid/metal fragments	This anthropogenic material comes from various human activities; it is evidence of human and industrial waste	Metal elements were part of various industrial constructions (e.g. electrical cables)

Fig. 3 Soil profile with abundance of artefacts within the former "Polchem" area

friendly modern technologies. This process was often a cause of discontent among local communities (e.g. due to jobs losses). Nowadays, nostalgia for a plant where local people worked for decades could be another driving force in stimulating interest in the area and its SUITMAs and leading to growth of public awareness of soil degradation issues.

In 1978, the International Committee for the Preservation of Industrial Heritage (TICCIH) was established. In its name, the term "monuments" was replaced with "heritage", which was a stimulus for the development of industrial archaeology.

The premises of Toruń's plant is now a feature of the city's landscape and part of local memory. The soil cover is a 70-year-old record of the industrial activities. There are important links between industrial archaeology and contemporary

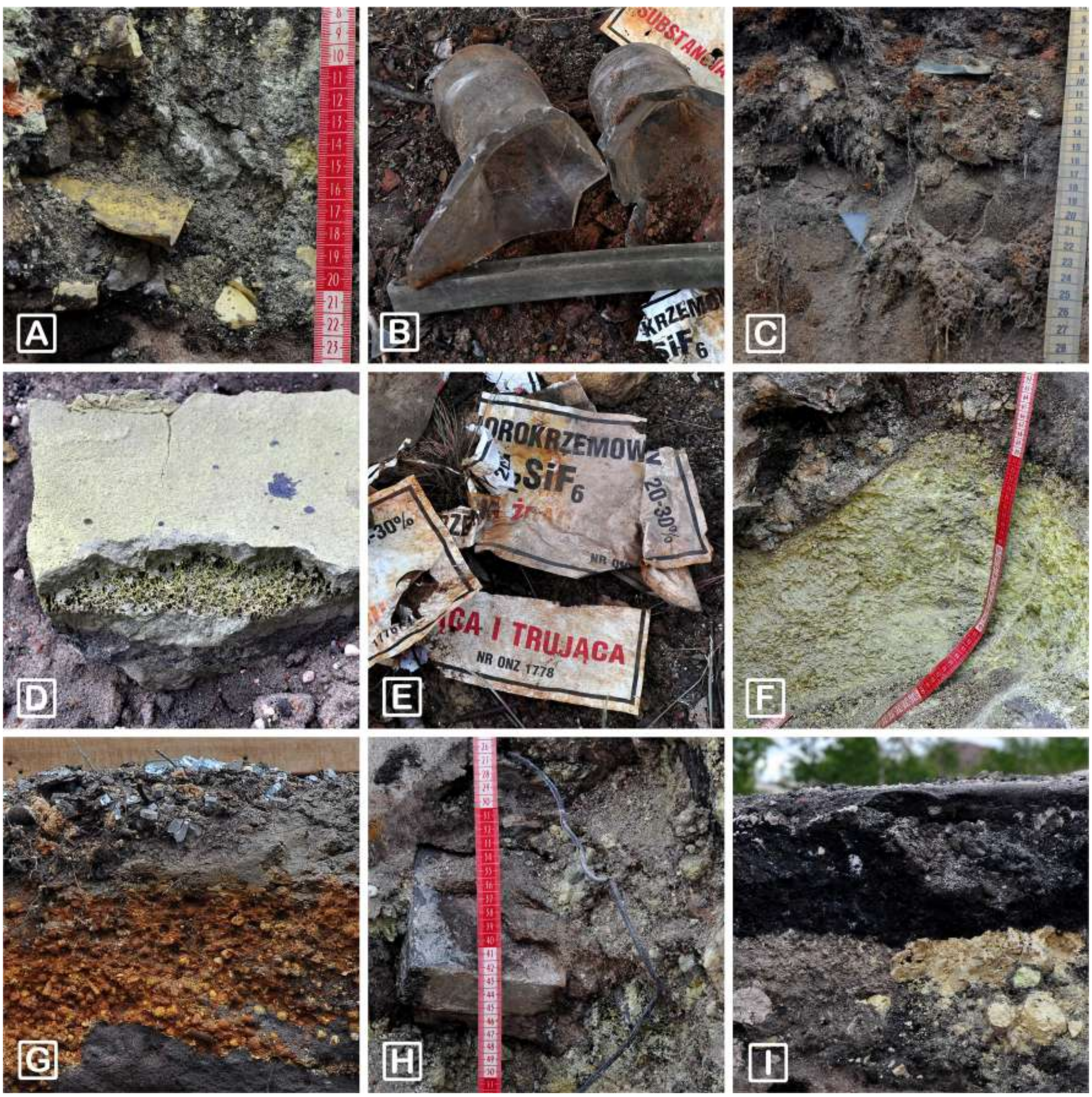

Fig. 4 Artefacts found in soils within the former "Polchem" area: A Synthethic solid and slag; B Metal and glass fragments; C Glass fragments; D Concrete fragments with sulphur, industrial dust; E Chemicals labels; F Sulphur; G glass fragments and sulphur; H Cable fragments, bricks, pottery fragments, tiles; I Slag, Industrial dust

Fig. 5 Extreme soil pH measured within the former "Polchem" area

society with its ideas, needs and plans for the development of post-industrial areas.

Industrial archaeology is an initiator and coordinator of research in the humanities and the technical, natural and economic sciences, and is seen as an interdisciplinary field in which specialist knowledge from many scientific fields is treated as a potential background for research. It certainly has a place for cultural studies into soil functions, as well as other branches of soil science. The soil cover of the "Polchem" site, and the artefacts and the history of this place, should be not only a subject of scientific research but could also be defined as cultural tourism with educational implications for post-industrial facilities. Industrial tourism and educational activities aim to provide knowledge about various elements of the industrial landscape. This kind of spaces includes not only buildings, installations and infrastructure but also the human factor—curiosity about the living conditions of the people who were "inside" the industrial centre in the past or are there in the present. Despite the fact that "Polchem" does not exist today, its history is written in the natural environment. The soils are features that perfectly preserve evidence of human activity. In connection with artefacts occurring in the soil, this could be a perfect reflection of the processes going on during industrial production. In such an environment, an educational and touristic approach can use the principles of *gamification* (Urbańska et al. 2019) to encourage engagement. Most modern students require interaction and competition because social media and virtual reality games have changed the way young people perceive the real world, and that also includes the education process, which should be supported by elements of gamification. It seems only natural to make use of such strong motivation in order to enhance the experience of field activities related to urban soil science.

According to Harrison et al. (2010) "education, whether formal or informal, is key to developing an understanding of any subject."

4 Conclusions

The "Polchem" soil cover has recorded the history of the plant. Nowadays, the world is being forced to solve many ecological problems. People are aware of the dangers of global warming and air pollution but they do not fully realise that soil resources and soil protection are equally important for humankind. The soil scientist community should paid much more attention to soil education to make people aware of the importance of soil, both in their surroundings and on a global scale. Soils are everywhere. Around the cities, there are unused brownfields, and these places could become a living laboratory for soil education. There are many possibilities in these areas to provide information about the process of soil evolution, destruction and protection, and other issues. The possibility to interest the recipient in artefacts that are often seen as ordinary waste is one of the options hidden in SUITMAs. The cultural functions of soils could, in combination with the artefacts found in former industrial areas, extend the tourist and educational offer of the city, in addition to being a place of scientific research addressed to different recipients.

Declarations

Informed consent Informed consent was obtained from all individual participants included in the study.

Conflict of interest The authors declare that they have no conflict of interest.

Human and animal rights Research did not involve human participants and/or animals.

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