Supplementary Material

Overview

This supplementary material includes the proposed field guide for the description of visible plastic residues, which can be applied during soil related field work like soil description and mapping, with a focus on profile and excavation description. The structure of the field guide is based on the "Guidelines for soil description" (FAO, 2006) to enable a uniform and comparable description of soil profiles. Explanations on the requirement for a description of plastic residues during the soil description as well as the theoretical background are given in the related publication. The description process is explained in Figure 2 of the publication.

Content

References

Food and Agricultural Organization of the United Nations (FAO) (2006): Guidelines for soil description. FAO, 4th edition. Rome

frontiers

Field guide

for plastics detection and soil description

1 Plastic artefacts

With the ongoing global plastic crisis and evidence of plastic residues within soils, it becomes important to describe those residues found in soils. Plastics, as human-made materials can therefore be handled like human-made materials (e.g., artefacts) but need a more precise and harmonized description for accurate documentation.

In general, plastics can be described as human-made, polymeric or co-polymeric, solid and insoluble materials, without a natural equivalent or geogenic background contents, which occur in the environment as particles of different sizes, shapes and properties.

Plastics are therefore created by humans, part of an anthropogenic manufacturing and life-cycle process. Furthermore, plastics are manufactured and used only since the 1950s, with an exponential production increase until 2022 and therefore also an important stratigraphic and temporal indicator.

Examples of plastic artefacts:

- Consumer-products or fragments of them, such as PET-bottles (polyethylene terephthalate), single-use plastic (SUP) bags and general plastic waste made from common polymers such as polyethylene (PE), polypropylene (PP), polystyrene (PS), polyamides (PA) entering the environment through littering.
- Plastic films, often made of (PVC) or (HDPE) used in agriculture or as geomembranes in the construction sector.
- Power cables and other wires sheathed with plastic or rubber
- Plastic waste and residues from landfills
- Used tires or tire wear from synthetic rubbers

2 Detection and description of plastics

Detection and description of plastic in soils can only be done in the field for visible plastic residues and is therefore size-dependent. In general, an in-situ detection is possible mainly for macroplastics (MAP, >25 mm), mesoplastics (MEP, 25–5 mm) and possibly also for coarse microplastics (CMP, 5–2 mm). For valuable descriptions and investigation of microplastics (MP, common definition: 5–0.001 mm), sampling and laboratory analysis are necessary (section 2.3 sampling).

The description of plastic can be done in the soil profile or excavation as well as in detail after the removal of plastic pieces from the soil matrix. Documentation can be given in addition to the general soil description or separately (see section 3: plastic documentation table).

2.1 Abundance and distribution

The abundance of plastics within the soil can be described for visible plastic pieces within the investigated soil profile. However, the heterogeneous distribution of plastics in soils must be particularly considered here. Following the FAO (2006) guidelines, the abundance of artefacts and therefore plastics can be described by volume (Table S1)

Table S1: Abundance of plastics, by volume

Abbr.	Class	Volume (%)
N	None	0
V	Very few	0–2
F	Few	2–5
C	Common	5–15
M	Many	15–40
A	Abundant	40–80
D	Dominant	>80

According FAO (2006)

In addition, it is necessary to describe the storage and distribution of the plastic pieces in the soil, by horizon:

Table S2: Distribution of plastics

Abbr.	Class	Description
I	Isolated	Single and isolated plastic pieces within soil horizon
S	Sporadic	Sporadic occurrence of single plastic pieces (>1) within soil horizon
A	Accumulated	Accumulation of various plastic pieces (>5) within soil horizon
L	Layer	Occurrence of a single layer filled with plastic pieces or built up from a layer (e.g., membrane, cable tie)

2.2 Plastic characteristics

Characteristics of plastics within the environment and in soils are strongly dependent on each individual piece and its origin. In order to be able to describe the variety of possible character types, classifications are proposed, which can also be combined in the case of several applicable classes. However, the focus should always be on the dominant class for generalization purposes.

2.2.1 Expose plastic pieces

For a detailed description of plastic pieces within the soil, it becomes necessary to expose individual plastic pieces from the investigated soil profile. Plastic pieces should be collected according to soil horizons and placed next to the profile, organized by depth and location

In the field, plastic pieces can be removed with the help of spatulas or hand shovels. In the case of layers, it may be necessary to cut off parts of the layer using a knife. Since plastic pieces are often strongly coated with soil material, a short cleaning may be necessary. This can be done using water from a spray bottle and cotton towels.

2.2.2 Fixation

Depending on the residence time of plastic in soils, plastic can be integrated and fixed in macro- and microaggregates (depending on their size). Therefore plastics can be fixed within soil structure (pedogenic ped formations). While the soil structure can be described according to FAO 2006 or national specifications, the fixation of the plastic pieces can be documented during extraction.

Table S3: Fixation within soil structure

Abbr.	Class	Description
NF	None fixed	Plastic pieces are not included in soil aggregates (no soil aggregates or loose plastic)
SF	Solely fixed	Single plastic pieces are in cooperated into soil aggregates, but others are loose
MF	Moderate fixed	The majority of plastic pieces is in cooperated into soil aggregates, but single are loose
CF	Complete fixed	All plastic pieces are in cooperated into soil aggregates

2.2.3 Form and shape

The description of plastics form and shape is one of the most important properties, as plastic can be found in the environment in a wide variety of forms. A plastic specific classification can be made as follows:

Table S4: Classification of plastics forms and shapes

Plastic forms		Plastic shapes	
Abbr.	**Class**	**Abbr.**	**Class**
COM	Complete piece	P	Preserved
FRA	Fragment	B	Broken
FIL	Film	F	Flat
MEM	Membrane	A	Angular
CAB	Cable tie	R	Rounded
STY	Styrofoam	S	Spherical

In case of several shapes and forms within one soil horizon, combinations can be generated. The dominant shape and form should be placed at the end.

Example for combination of form and shapes:

COM(P)+FRA(B) → Broken fragments with preserved complete pieces

2.2.4 Size

In addition to shape and form, the size of the plastic pieces and the size composition is an important basis for documentation. Sizes can be measured in the field with the help of a folding rule or tape measure, with fine divisions (mm-scale). Since common plastic size classifications and classifications of soil textures and rock fragments are different, the following classification is recommended:

Table S5: Plastics size classification

Abbr.	Class	Size (mm)
CMP	Coarse microplastics	2.0–5.0
MEP	Mesoplastics	5.0–25.0
MAP	Macroplastics	25.0–100.0
L-MAP	Large-macroplastics, *often complete products*	>100.0

In the case of several plastic size classes, combinations can be generated. The dominant size should be placed at the end.

Example for combination of size classes:

CMP+MAP → Macroplastics with coarse microplastics

2.2.5 Degradation

The state of degradation (or weathering) is important to estimate the residence time of the particles in the environment or in the soil. The classification of the degradation status is based on the classification for coarse fragments (FAO 2006), but contains additions:

Table S6: Classification of plastic degradation

Abbr.	Class	Description
N	Not verifiable	Designation not possible / uncertain
F	Fresh	Fresh plastic pieces with bride colours, unaffected shape, without signs of deterioration (cracks, broken edges, rough surfaces)
IA	Incipient alteration	Plastic pieces with incipient deterioration surface such as first cracks, broken edges or roughened/grooved surfaces
D	Degraded	Plastic pieces with clear indications of ageing such as pale colours or yellowing (UV light), strong fragmentation, frayed edges
S	Strongly degraded	Plastic pieces with strong degraded surfaces, faded colours, soft surface, frayed areas or edges

In the case of several degradation classes, combinations can be generated. The dominant degradation class should be placed at the end.

Example for combination of degradation classes:

F+D → Degraded plastics with fresh plastics

2.2.6 Colour

Unlike naturally occurring colours in soil, plastic pieces can appear in very diverse colours. However, inconspicuous colours such as white, black and grey are also common, which can hinder identification in the soil matrix.

The documentation of the colours should be uniform and traceable. It is therefore recommended to document the main colour of each plastic piece (main percentage, area percentage) by simple abbreviations. Furthermore, colour combinations are possible (in case of equal area shares). Examples for classification can be found in Table 7 as well as colour examples in Figure 1.

Table S7: Examples of plastic colours

Abbr.	Colour
W	White
BK	Black
BL	Blue
GR	Green
GR+W	White with green

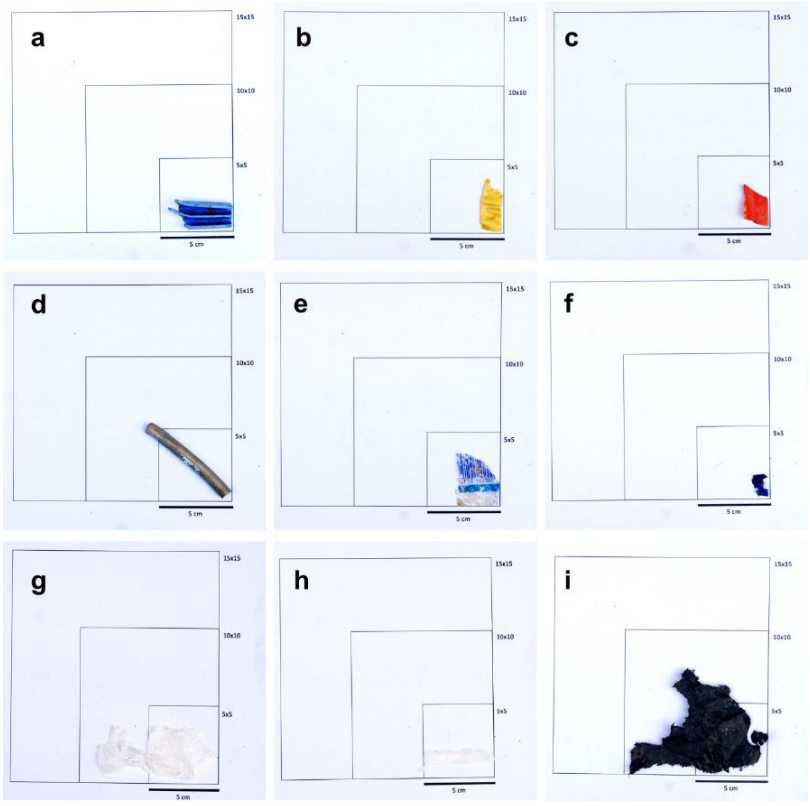

Figure S1: Examples of macroplastic colours collected from agricultural fields (C.J. Weber, 2022) with a) blue plastic fragment; b) yellow plastic film; c) red plastic fragment; d) brown-grey cable tie; e) white-blue packaging film; f) dark blue film; g) white film; h) white film; i) black film.

2.2.7 Origin

In case of completely preserved consumer-products or less degraded fragments as well as film residues, the original use of the plastic residues can be assigned. For example, the shape of the pieces provides information about the original use or imprints provide information about origin and function.

Table S8: Classification of plastics origin

Abbr.	Class	Description
N	Not verifiable	Designation not possible / uncertain due to missing indications
CP	Consumer products	Consumer-products (everyday-products) like PET-bottles, SUP bags, packages, signs etc.
AP	Agricultural products	Agricultural products like mulch film, silage film, straw bale nets, tire wear etc.
IP	Industrial products	Industrial products like broken pieces of industrial equipment, industrial waste
CM	Construction materials	All plastic materials which were placed in soil for construction and supply purposes (e.g., power cables, geomembranes)

In the case of several origins, combinations can be generated. The dominant origin class should be placed at the end.

Example for combination of origin classes:

AP+CP → Consumer products with agricultural products

2.3 Sampling

In general, the recommendations for sampling plastic residues follow those of artefacts according to FAO (2006) descriptions. Their recommendation thereby comprises of the following, among others:

a) Sample-ID combined from profile number + additional capital letter (A, B, C, etc.) + depth range at which each sample was collected (top to bottom)
b) Samples should never be taken across horizon boundaries or in boundary areas
c) Samples can be taken in equal proportions over the whole horizon or in equal proportions within a depth of 20 cm around the centre of each horizon

Important against the background of a plastic oriented examination and possible laboratory analysis is the strict avoidance and control of possible sample contaminations. This is particularly important for further investigations of smaller plastic residues such as micro- and nanoplastics, which cannot be carried out in-situ.

Plastic pieces as well as soil samples should therefore be handled in a plastic-free working environment. This means that all plastic equipment is avoided during sampling. Samples can therefore be taken with the help of stainless-steel spatulas or shovels, are temporarily stored in metal or glass buckets and also be transported in metal or glass containers. Another possibility is to transport the samples in bioplastic bags (e.g., made of corn starch).

In order to control possible contaminations (e.g., from workwear, outdoor clothing mostly made of synthetic fibers), the parallel implementation of blank samples already in the field is strongly recommended. Alternatively, cotton suits can also be worn during sampling.

3 Plastic documentation table

Table S9: Plastic documentation table

Plastics in soil description														
Profile number		Date of description		Authors				Location						
FID	**Pedogenetic subdivision***		**Plastic abundance and distribution**		**Plastic characteristics**									**Samples**
	Soil horizon	Depth	Abundance (vol%)	Distribution	Fixation	Form	Shape	Size	Degradation	Colour	Origin			Sample-ID

** Pedogenetic subdivision of soil profile into soil horizons and their depth (lower limit) to connect Plastic data to FAO (2006) Guidelines for soil description.*