# Point by point response - Referee #1

# Plastic film residues on cropland: monitoring soil contamination through optical remote sensing

Alessandro Fabrizi, Peter Fiener, Kristof Van Oost, Florian Wilken

We appreciate the time and effort the reviewer dedicated to providing constructive feedback. We are pleased that the reviewer acknowledged the study and provided us with detailed suggestions for improving the work.

Please find below our detailed answers (in italics). Line numbers refer to the marked-up manuscript version.

**Comments**

1. Fabrizi et al. should also highlight the benefits of using plastics in the Introduction section as more text is about the unwanted effects. It is equally important to acknowledge how plastic based farming has helped improve output in the agriculture sector.

*We agree that the advantages of plastic film use could be further acknowledged, and we add the following text to provide some examples (lines 44-48):*
*"Mulching films can reduce evaporation from the soil surface and hence reduces the demand for water in dry regions or increase soil temperature in cold regions to improve the control of harvesting time. Additionally, mulching films can reduce weed growth and can be used for soil disinfestation to reduce the use of agrochemicals. Greenhouse films typically create a controlled environment for the growth of fruits and vegetables outside of typical growing seasons."*

2. Objective 1-the supplied dataset should be provide in a more detailed structure with the more metadata for ease of reuse.

*We really appreciate the suggestions you provided, and the time invested in reviewing the research data. The dataset was shared as part of an open data repository, which collects all the research data used throughout SOPLAS, an interdisciplinary project that funded this research ([https://zenodo.org/communities/soplas/](https://zenodo.org/communities/soplas/)). The editorial line on the data repository* *was to homogenise the structure of the data and the metadata as much as possible to build a consistent database for the whole project.*

*Where possible, we revised the metadata. Please refer to the 'research_data.zip' file uploaded in the supplementary material, for reviewing purposes. The changes will be made permanent, if accepted, by updating the dataset on zenodo. However, some of the points raised in the review conflict with SOPLAS' goals, and we would prefer to maintain the current data structure. Please find below the reply to every individual comment:*

a. The excel sheet can be combined with the pdf instead of having to check five separate files.

*We would like to keep the pdf and csv files separated to ensure consistency with the rest of the data repository.*

b. The excel sheet was challenging to open in excel and required time to decipher the format […] Column-wise arrangement of the data with the headers well defined

*The use of non-formatted .csv files was thought to allow for using the data in csv file readers such as R. As the ESR02_21 data is a 142599x9 matrix of data, it might be slow to open it in excel. We add the following text to the metadata 'ESR02_21':*

*"The file contains a 142599 x 9 matrix of data and can be slow to open in excel."*

*We specified the location of the column-wise arrangement of the data and the location of their names in ESR02_02:*

*"The data in the csv files were arranged in columns separated by semicolons. The column names and units are specified in the above cited metadata."*

c. Check the spellings of the headers. see "Wavelenght"

*We changed 'Wavelenght' to Wavelength in all the headers. Thank you.*

d. Suggestion is to have the metadata + source information provided as a single structured Excel sheet so that users can easily open and format as they see fit? Examples format can be found on PANGAEA or 4TU

*We would like to keep the structure as is to be harmonised with the rest of SOPLAS dataset.*

e. Name of sensors, date time, location, geometric properties, experimental setting well explained

*We add to the metadata a reference to the preprint, where all the requested details are described.*

f. Pictures in the metadata can be used to better explain the binary options 3 + 4

*We add to the metadata a reference to the preprint, where the pictures of the experimental setup are shown.*

g. The justification of only sharing the descriptive data should be provided otherwise simply provide the raw data or provide at least the plots to better show how the raw data appeared

*We decided to share the pre-processed data in the repository to facilitate use for further analyses, especially for users outside the specific research field. Showing the plots of the raw data would imply showing almost 500 different spectra. Hence, we would provide justifications for the pre-processing in the following comments.*
*We add the following text to ESR02_21 and ESR02_22 to specify the availability of the raw data upon request:*
*"The raw data are available upon request."*

h. Was the mean and median similar?

*We report here an example of median values for pristine films only (Figure R1):*

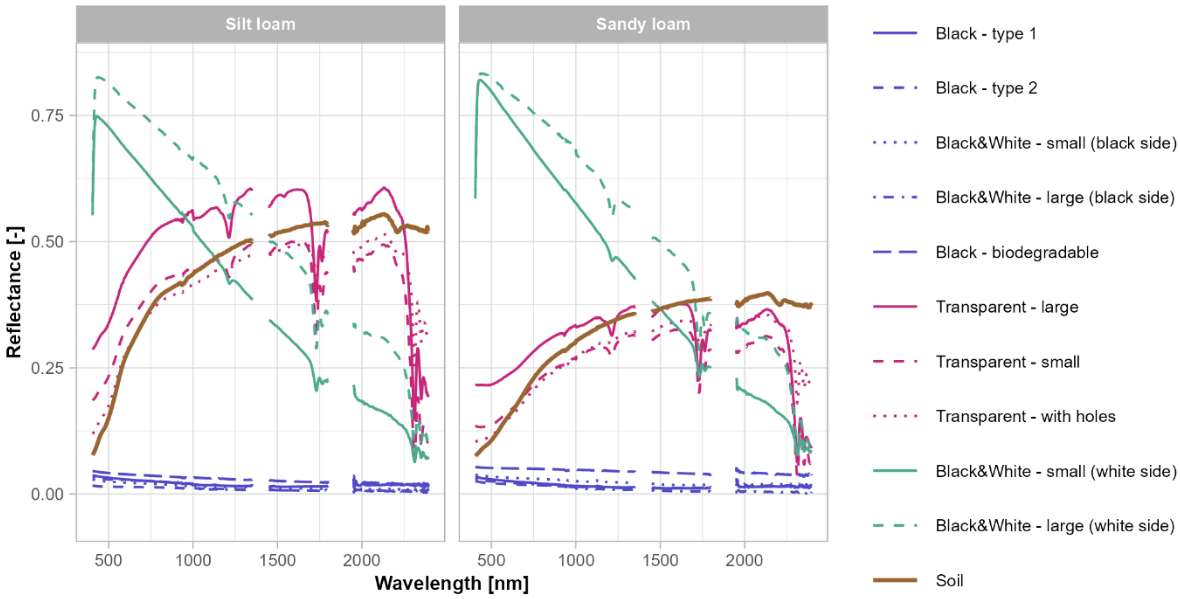



*Figure R1 - Spectra of pristine plastic films and of soils used as background. On the left side, spectra acquired on silt loam; on the right side, spectra acquired on sandy loam. Film colours are represented by different colours, and variation within film colours are represented by line shapes.*

*Spectra mainly keep the shapes presented in Fig. 3 of the manuscript, but reflectance of plastic films is influenced by light conditions, as outlined in section 4.1. The decision of using the mean was taken in reason of the high variability of plastic film reflectance with changing light conditions, which could not be considered by using median values. We add the following text to the manuscript at line 173-174:*

*“Mean values and standard deviation of the five replicates were calculated for each sample (i) and for each wavelength (λ) to account for variability in plastic film reflectance under changing light conditions.”*

i. ‘Reflectance measurements have been pre-processed with a Savitzky-Golay smoothing of second order and 11 nm of window size’ why was this applied can the before-after be presented to assess the usefulness of the step

*Savitzky-Golay smoothing was applied to remove random noise. In our case, the pre-processing did not affect the data visualization in a substantial way. However, ASD fieldspec has very high spectral resolution and results in random noise, and we applied a smoothing algorithm as a good practice to reduce possible noise. We add this in the manuscript (lines 161-163) and in the shared research data:*
*“Then, a Savitzky-Golay smoothing (Savitzky and Golay, 1964) was applied with a second order polynomial fit and a window size of 11 nm to remove random noise that can arise from outdoor measurements.”*

j. The wavelength ordering seems strange with the first value in column 2 being 1000?

*The issue may arise from the use of non-formatted .csv files. As the fields are not formatted as numbers, the data may be automatically ordered in alphabetical order.*

k. Why only share the data 405 to 2395 nm? see line 91-93 range of the ASD

*Data below 400 nm and above 2400 nm were removed because of excessive noise, according to the procedure followed by Crucil et al. (2019); (Crucil and Van Oost, 2021). We add the references to the manuscript as follows (lines 160-161):*
*“First, data at wavelengths below 400 nm and above 2400 nm were removed because of excessive noise in the outdoor measurements (Crucil et al., 2019; Crucil and Van Oost, 2021)”*
*The statement was added to the shared research data as well.*

l. What are the specs of the ‘corrected with reflectance panels.’

*We add a text in the metadata “ESR02_22” to provide the specifications of the panel used, with reference to the camera model used:*
*“The reflectance panel used had the following reflectance values for RedEdge-MX cameras with serial numbers RX02: blue = 47.49 %; green = 47.73 %; red = 47.81 %; red edge = 47.82 %; near infrared = 47.72 %.”*

m. Revised à The measurements have 1 nm ‘resampled’ of bandwidth

*We are not sure if the reviewer is referring to the Savitzky-Golay smoothing. In this case, the smoothing does not resample the data but only changes their values. We apologise for the confusion, and we specified this with the following text in the metadata "ESR02_21":*
*"Before and after the pre-processing, the measurements have 1 nm of bandwidth […]"*

3. Objective 2-the spectral properties should be well explained and relevant plots to support the text should be presented

*Thank you for providing us with detailed feedback to improve the presentation of objective 2. We address all relative comments later in this document.*

4. Objective 3-the use of UAVs should be better explained with regards to spatial resolution depends on the camera system used and height of flight,

*We agree that the spatial resolution of the UAV sensors used should be further described and we add the specifications in the text as follows (lines 214-216):*
*"The flight height was set to 7 m. The camera used had 1280 x 960 pixels of image resolution, 4.8 cm of sensor width, and 5.4 cm of focal length, thus providing images with a spatial resolution of around 0.5 cm/pixel at 7 m of flight height."*

5. the goals of using UAV for knowing about plastic also rely on several aspects hence the need for spectral information for example can the team explain or confirm how easy it would be to differentiate a green cloth from a green plastic and green leaf if partly covered by soil would RGB be sufficient? Assuming the piece is of same size and imaged at same resolution and same surface texture. Spectra can be used to evaluate the above question.

*Green plastic is rarely used for agricultural films, which are the focus of our case study, and we do not have available spectra of green plastic film. Even without the spectra of a green plastic film, we could speculate that green plastic can be generally distinguished from vegetation (e.g., a green leaf) due to the high reflectance of vegetation in the near-infrared region. As for a green cloth, the reflectance will depend on the specific textile used, which can also be a synthetic textile; in this case, the specific polymer and additives used would alter the spectral properties. In general, we believe that the discussion of this example confirms one of our core messages: the spectral properties of plastic and its spectral separability from other targets require a case-by-case assessment, outside of the short-wave infrared absorption features. However, the proposed example may be outside the scope of the study, as it involves a type of plastic film that is rarely found in the catalogues of plastic film manufacturers and may still represent an experimental use of plastic films. Similarly, the presence of a coloured non-plastic object in an agricultural field will represent a very specific case that we would not include in one of the first studies on the topic.*

6. In general the references are ok, additional literature review is need to better position the current study with prior studies

Suggest literature review

a. For examples of a relevant papers see some commercial materials and ASD used in farming associated experiments
https://doi.org/10.1016/j.solener.2020.11.058
The authors can compare the measurements in the provided study or at least provide more details about the materials as explained in the above paper. The methods also on the ASD should be improved in terms of details provided.

*We add the recommended reference when discussing the limitations of our experimental setup at line 387-389:*
*"An experimental setup such as the one used by (Jones et al., 2021) would allow a complete characterization of spectral radiative properties — reflectivity, transmissivity, and absorptivity — and provide insights into spectral changes of transparent films with different backgrounds."*
*And at line 294-295:*
*"Transmittance measurements could further elucidate how plastic film transmittance changes across the spectral region, and could be a relevant topic for crop production (Jones et al., 2021)."*

b. Recommended papers for the authors to review include in the introduction and discussion to better put the current manuscript into context

Case studies - including use of hyperspectral tools, proximal measurements of LDPE materials, use of satellite and airborne sensors, algorithms development, data for comparisons

- https://doi.org/10.1016/j.rsase.2025.101802

*Thank you for the suggestion, but as the study focuses on the use of hyperspectral satellite data to map plastic greenhouses, we do not think that it fits to the discussion of our work done with UAVs.*

- https://doi.org/10.1016/j.envc.2025.101398

*This publication perfectly fits into our discussion and we add the following at line 479-482:*
*"However, plastics films do not share any absorption feature in the visible and near infrared (Fig. 3), and their identification with currently available multispectral broadband sensors is mostly colour-driven and influenced by spectral shape ambiguities (Garaba, 2025)."*

c. State-of-the-art reviews

- https://doi.org/10.1002/ldr.4497
- https://doi.org/10.34133/remotesensing.0395

*We would not include these reviews in the literature because they focus on the use of remote sensing, especially satellite data, for monitoring plastic covered crops, and not plastic residues resulting from agricultural film use.*

d. The data in the above studies should also be used to better demonstrate how the Fabrizi et al. open-access library is benefitting the community

- How does it bring diversity to what is already available?

*We made explicit that this work is the first to provide open access to a spectra library for plastic films and to discuss the use of the non-visible part of the spectrum for detecting plastic films as residues in soils (lines 382-383):*
*"This work introduces an open-access spectral library for agricultural plastic films and explores non-visible regions of the electromagnetic spectrum for identifying plastic films as residues in agricultural soils."*

- Can this be used for developing algorithms? How?see statement line 19-21

*It has already been shown how spectral libraries encourage developing spectral indexes and detection algorithms. We specified this and add references in the discussion (lines 485-487):*
*"We showcased the use of plastic indexes available in the literature, but we provided open-access to the spectral library used in this study to promote the development of new spectral indexes and detection algorithms (Garaba, 2025)."*

7. Given the sample size used the title should reflect this is a 'case study' with a subset of materials used.

*We agree with the reviewer that we are only investigating a subset of all possible soil–plastic film combinations and that the study is exploratory in nature, demonstrating the potential of UAV-based remote sensing for the detection of macroplastic fragments. However, in our view, this study design is not a classic "case study" in which, for example, the contamination of specific areas with macroplastic fragments is investigated. Moreover, the plastic films used in this study nearly cover 'all plastic film colours used in agriculture' (lines 381-382).*
*Therefore, we would avoid referring to case study in the title. Instead, we would further acknowledge that the ability to detect plastic films may change based on the soil type and topography, and that other possible combinations of soil–plastic film need further research. We add the following line to the manuscript to make this clearer (lines 477-479):*

*“Our study investigated a fraction of all possible soil–plastic film combinations, and further research is needed to comprehensively assess the capabilities of UAV-based detection with current technologies.”*

8. The quantitative aspects are missing in the abstract especially how many samples were done to build the open-access library.

*Thank you for the suggestion. We add the number of films used in the abstract, as follows (line 19-21):*
*“Through proximal acquisitions of hyperspectral data on 8 different agricultural plastic films, we built spectral libraries and located absorption features at wavelengths that are not commonly available on off-the-shelf multispectral cameras.”*

9. Line 11-the sentence should be revised as remote sensing has been used extensively in agricultural plastic-based mapping see the suggested references in point 12 including the cited works in the references above.

*In line 11, we strictly refer to the use of UAV for monitoring macroplastic residues, and not for plastic films mapping. We apologise for the confusion, and we add the word ‘residues’ to the abstract, as follows (line 11):*
*“Remote sensing has been qualified as a valuable tool for monitoring macroplastic residues mainly on waters […]”*

10. Line 16-it must be discussed more and presented in the results to support the statement. How is the efficacy shown? See question raised in point 5 objective 3 comment.

*We believe that the statement is supported by the accuracy of plastic detection and the factor of plastic overestimation shown with the different datasets in Fig. 7. The results show that datasets without near-infrared and red-edge bands have similar or better performance compared to datasets including these bands. Even considering similar performances, the advantage of having a higher resolution on a standard RGB camera supports the statement. Increased spatial resolution implies either a better ground sampling distance or an increase in flight height to acquire data with the same ground sampling distance, resulting in shorter flight times.*
*We moderated the statement in the abstract as follows (lines 17-19):*
*“Our findings highlight a greater, or at least similar, efficacy of spatial resolution compared to spectral resolution, encouraging the use of high-resolution RGB cameras over multispectral cameras.”*

11. Line 18-the data report is based on reflectance and yet the Fabrizi et al. call this absorption peaks? Is this not commonly termed ‘absorption feature’? revise throughout the text as suggested

*We replaced all occurrences in the revised manuscript.*

12. Line 19-this is absorption features are relevant in hyperspectral data make it clear because with the camera system is this evident with the five-bands?it is not evident in the Figure 6

*We modified the text in the abstract as follows (lines 19-21):*
*"Through proximal acquisitions of hyperspectral data on 8 different agricultural plastic films, we built spectral libraries and located absorption features at wavelengths that are not commonly available on off-the-shelf multispectral cameras."*

13. If automated proofing tools were used it must be declared?

*We specified the use of Grammarly in the acknowledgments as follows:*
*"Grammarly was used for automated grammar and language proofreading only."*

14. Line 21-the cited works report on microplastics right?out of curiosity are these figures accounting for the ocean that cover 70% of the Earth surface and the amounts being reported at sea?

*The estimates account for the ocean's surface cover. However, typical estimates of microplastic for oceans refer to surface microplastic. We modified the text as follows to avoid confusion:*
*"Soils are estimated to be a greater plastic sink than the ocean surface […]"*

15. Line 29- 'Despite….monitoring plans' provide references and rephrase as the main message is unclear

*We agree that the statement was somewhat unclear and we rephrased as follows (lines 32-35):*
*"The knowledge about the effects of current plastic contamination is still limited (Landrigan et al., 2023), while the ubiquitous presence, persistence, bioaccumulation, and possible unknown effects of plastic threaten soil health and call for plastic contamination monitoring plans."*

16. Line 33- are the agricultural soils a source or is it the activity?

*Agricultural activities can be an additional source of plastic However, sources of plastic for agricultural soils are not limited to agricultural activities, and can also be identified in major plastic sources such as tyre wears, littering, or atmospheric deposition (Kawecki and Nowack, 2019), meaning that soils used for agriculture tend to have higher plastic contamination levels than soils that are not used for agriculture.*

17. Line 38-the references style should be revised check the formatting.

*We followed the formatting guidelines of the journal for references, We are not sure whether the reviewer referred to the position of the references. In this case, we moved the references as follows (lines 40-42):*
*"While plastic films have been associated with the generation of macro- and microplastic residues (Steinmetz et al., 2022) (> 5 mm and < 5 mm, respectively (Thompson et al., 2004; Frias and Nash, 2019)) […]"*

18. Line 43-define LDPE at first use.

*We defined the acronym at first use (line 51):*
*"Plastic covers used in agriculture are mainly LDPE (low-density polyethylene) […]"*

19. Line 44-can the multiple years be enumerated

*The years of use can be very different depending on the film and on the location. We reported an indicative value of 4 years as a reference in the text (line 51-53):*
*"Plastic covers used in agriculture are mainly LDPE (low-density polyethylene) films with thickness ranging from 15 to 200 microns and lifetime ranging from a single cropping season to multiple years (e.g., 4 years) (Scarascia-Mugnozza et al., 2011)."*

20. Line 48-49 reference to the term 'earlier studies' are missing provide citations

*The term 'earlier studies' referred to the studies cited above. We apologise for the confusion, and we rephrased as follows (line 56-58):*
*"Overall, earlier studies, such as the ones cited above, improved our understanding of plastic residue generation and concentration in soils but quantitative analyses are still hampered by the methodologies used for mapping plastic residues."*

21. Line 49- missing source for the sentence

*The sentence is based on the authors' comprehensive review of current literature. Even currently available literature reviews on plastic quantification methodologies in soil focus on the use of laboratory techniques. To the best of our knowledge, we cannot provide a reference for this statement.*

22. Line 53-the term broad also include satellite remote sensing?

*The term 'broad' can indeed refer to satellite remote sensing as well. However, UAVs offer a much higher spatial resolution that can't be achieved with satellite data. Thus, the statement refers to the combination of area coverage and spatial resolution offered by UAVs. We apologise for the confusion and rephrased as follows (line 61-62):*
*"The broad area coverage combined with very high spatial resolution offered by UAVs (Unmanned Aerial Vehicles) (Colomina and Molina, 2014) […]"*

23. Line 55-plastics in marine have received much interest but not necessary started the topic or efforts to use UAVs see the suggested literature in point 12

*We are not quite sure whether the reviewer refers to the cause-effect link we used. In this case, we would delete the first part of the sentence (lines 64-65) :*
*"UAV use has been explored to detect macroplastic on waters and coastal areas first and foremost (Veenstra and Churnside, 2012; Martin et al., 2018), while applications on land are still limited."*

24. Line 60 also see the case studies provided in point 12

*We add (Garaba, 2025; Despini et al., 2025) at line 70.*

25. Line 72-is it about the RGB camera or other aspects such as flight altitude, size of the samples, environmental conditions?

*Environmental conditions can influence data collection, which can be more challenging with multispectral cameras in situations such as partial cloud cover and variable light conditions. The size of the samples can be related to spatial resolution, as smaller samples typically need higher spatial resolution. Flight altitude is also related to spatial resolution, as RGB cameras can fly higher, and cover larger areas, to acquire data with the same ground sampling distance as a multispectral camera. We add the following text to further discuss the comparison of RGB and multispectral camera (lines 81-85):*
*"RGB cameras further decrease the complexity of data collection and analysis, as additional data processing such as radiometric calibration, which can be more or less challenging depending on light conditions, are not required. Moreover, RGB cameras increase spatial resolution at the cost of spectral resolution. This allows to acquire data with higher ground sampling distance at the same flight height, or to fly higher and cover larger areas in shorter times to acquire data with the same ground sampling distance."*

26. how does RGB camera increase the spatial resolution? Is this also accounting for the sensor capability in terms of megapixels or lenses used? Same question would be applicable to the Micasense camera used

*Increase in spatial resolution refer to the possibility of having higher ground sampling distance at the same flight height. Having set the flight height, this solely depends on sensor specifications (i.e., sensor width of the camera, focal length of the camera, image width and height in pixels). We explicate this relationship by adding the following text (lines 84-85, same as comment 25):*
*"This allows to acquire data with higher ground sampling distance at the same flight height, or to fly higher and cover larger areas in shorter times to acquire data with the same ground sampling distance."*

27. Line 81-objective (ii) is repeated, is the goal to define or to propose workflows?

*Thank you for pointing at this. Objective (ii) was repeated but it was a typo. We apologise for the confusion, and we changed objective (ii) to objective (iii) (line 93).*

28. Paragraph starting Line 91-was the ASD run in reflectance or digital number mode?

*The ASD was run in reflectance mode. We specified this in the revised manuscript as follows (line 99-101):*
*"The measurements were performed through the parallel use of a spectroradiometer (ASD fieldspec 3; Fig. 1a; Malvern Panalytical, Ltd.), operated via an acquisition software in reflectance mode […]"*

a. Is the 75 number referring to scans for each individual spectral measurements and how was that consistent considering a fixed integration time of 34 ms was use?

*Each of the 75 scans was obtained with an integration time of 34 ms. Hence, the overall time to acquire a spectrum was around 2.5 s. We specified this in the revised manuscript (line 110): "Thus, around 2.5 seconds were needed to perform each measurement."*

b. How and when was optimization done?

*Instrument optimization was done about every 4 minutes. We specified this at line 107-109:*
*"A Spectralon panel with 12.7x12.7 cm2 of reflective area (Fig. 1a), provided by the same company manufacturing the spectroradiometer, was used as a white reference to optimize and calibrate the instrument about every 4 minutes"*

c. What type of Spectralon was used for reflectance any specs? Was the calibration file of the white reflectance applied in the determination of the relative reflectance?

*A standard white Spectralon panel provided by the company manufacturing the ASD was used to calibrate the instrument. We specified this at lines 107-109:*
*"A Spectralon panel with 12.7x12.7 $cm^2$ of reflective area (Fig. 1a), provided by the same company manufacturing the spectroradiometer, was used as a white reference to optimize and calibrate the instrument […]"*

d. How big was the white target and distance from ASD foreoptic tip at the 4 minute cycle?

*"The fiberoptic tip was placed 11 cm above the targets at the nadir position, providing a shadow-free conical field of view with a diameter of 4.9 cm." (line 110-112)*
*The area of the white target was specified in the previous comment.*

e. Did the measurements include a background measurement to account for light from the bottom material

*No, we did not include any measurement of the background. We specified this in the revised manuscript (146-147):*
*“However, background measurements were not performed.”*

f. How was shadow effect avoided in the experiment?

*The presence of shadows was avoided by setting the distance of the fiberoptic tip at 11 cm. In this way, no shadows were present in the field of view. We specified the choice in the revised manuscript (line 110-112):*
*“The fiberoptic tip was placed 11 cm above the targets at the nadir position, providing a shadow-free conical field of view with a diameter of 4.9 cm.”*

g. The step in the data was not corrected for in the ASD at around 1000nm and correction steps are reported in the cited works check for this

*We apologise but we cannot find the correction steps in the cited works. We are not aware of corrections needed for the step at 1000 nm, especially considering that absolute values of reflectance are not used in this study in that spectral region.*

29. Line 110-what does it mean ‘in case of ….’ Rephrase

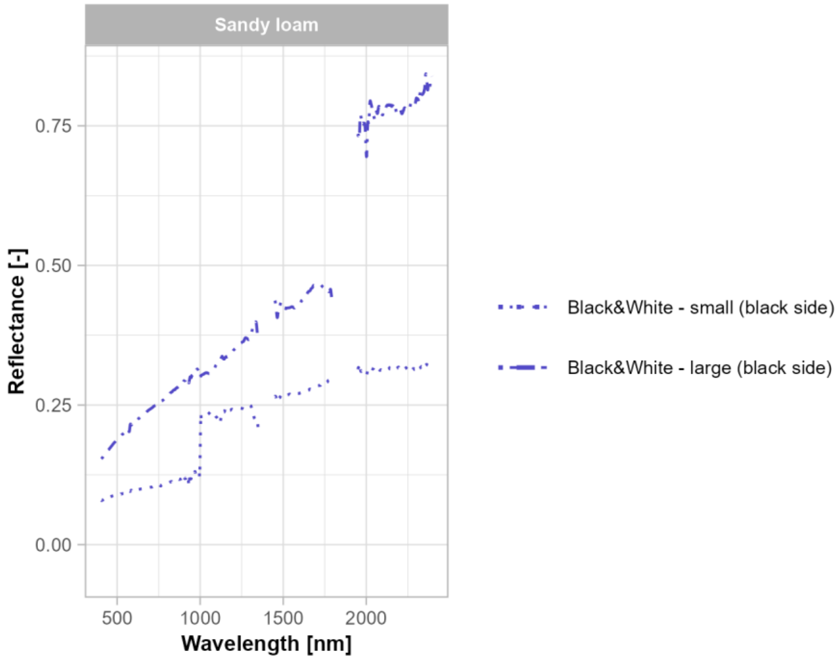
*We rephrased as follows (line 130):*
*“The measurements were performed on eight different LDPE films […]”*

30. Line 115-what is a field soil? Is this about a sample or..

*A field soil is a soil collected directly from a field. The term is used to make a distinction with the standard soil used for the experiment. We add the following text to specify the meaning of field soil (line 135):*
*“A field soil (i.e., directly collected from a site) […]”*

31. Section 2.1.3 -examples should be given to further demonstrate what is written it can be in the supplementary section or here. How effective were the steps done, was it really noise or something? A flowchart might also be useful

*We add the spectra of the noisy measurements in the Supplements and add a reference to the manuscript (line* 164-167):
*“Two spectra, corresponding to one replicate of pristine Black&White - small (black side) on sandy loam and one replicate of pristine Black&White - large (black side) on sandy loam (Table 1), were removed by visual assessment because of excessive noise (Supplement 1), probably due to rapidly changing light conditions.”*




*Supplement 1 - Spectra of noisy measurements*

32. Line 147-why only the mean is presented?

*As outlined in section 4.1, the high coefficient of variation between measurements is an important characteristic of plastic films, that we would like to account for by using mean values instead of median. We add the following text to specify the reason of the choice (line 173-174): "Mean values and standard deviation of the five replicates were calculated for each sample (i) and for each wavelength (λ) to account for variability in plastic film reflectance under changing light conditions."*

33. Line 162-with absorption features this is typically the convex and hull locations

*Thank you for pointing this out. However, we would like to avoid referencing to convex hull locations, as we used the original equations of the indexes to assume convex hull locations, and we did not calculate their position.*

34. Equations used are they from the original publications or other values were applied in the current manuscript?

*The equations for the original publications were used. We add the following in the text (line 186-187):*
*"Lastly, the following three plastic indexes were calculated for hyperspectral data only, according to their original equations:"*

35. Line 182-replace calibration with 'referencing', provide details about the panel used name and properties

*Calibration was replaced with referencing in all the occurrences, and details of the panel used were added as follows (lines 116-118 and 212-214):*

*"The reflectance panel used had the following reflectance values for RedEdge-MX cameras with serial numbers RX02: blue = 47.49 %; green = 47.73 %; red = 47.81 %; red edge = 47.82 %; near infrared = 47.72 %."*

36. Line 184-does placing mean the same as geo-referencing?

*It is not the same, but it implies geo-referencing, in this case. Plastic films were placed by hammering "metal spikes that were used to fix the plastic films into the soil" (line 230), and then they were geo-referenced by "acquiring their coordinates" (line 218).*

37. Line 195 define GNSS and GIS at first use,

*Thank you for the comment. We defined GNSS at first use. However, GIS was replaced with the name of the software used (QGIS).*

38. Line 195 provide the images of the samples to support and visualize the text, how many recievers were used?

*Thank you for the suggestion. "[…] two Reach RS2 RTK GNSS (global navigation satellite system) receivers (Emlid Tech Kft.) were used […]" (lines 216-217).*

*Images of the samples were added to Fig. 2.*

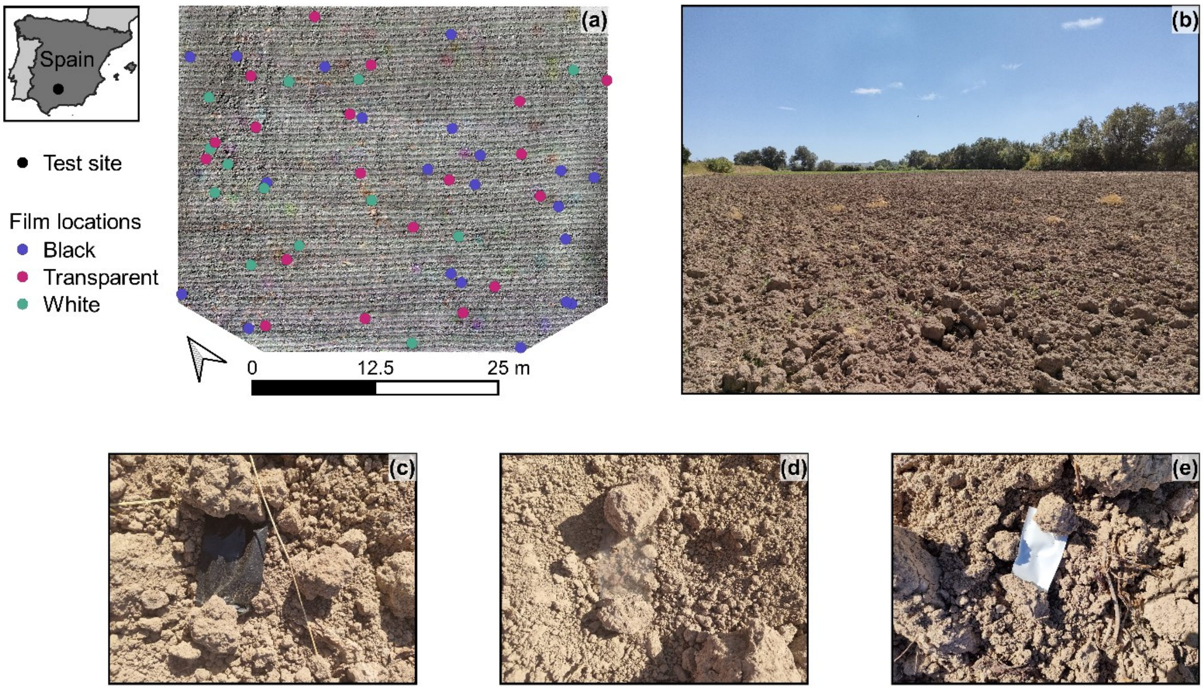



*Figure 2 - Location of the study area, distribution of plastic films in the study area (a), field picture (b), and examples of black (c), transparent (d), and white (e) films placed on the field. The geometry of the study area was chosen to maximise the number of plastic films, that are represented by coloured dots (a). On the upper-left corner, the orthomosaic was obtained from the UAV images.*

39. Line 210-312 random points does it mean training data was balanced for each class in like 211?how many pixels were plastics exactly?

*With a 5-fold cross validation, 80 % of the data is used for training and 20 % for validation, at each fold. As the distribution of the observations in the fold is random, it tends to represent the real distribution of samples on the field, which is not balanced for each class. We add the following text to specify the distribution of the observations (lines 250-251):*
*"At each fold, 80 % of the observations is used for training and 20 % of the observations is used for validation."*
*The number of pixels used for plastic films corresponds to the number of films placed on the field (i.e., 53 (line 234)). In the case of training data however, a buffer of 1 cm was applied (line 252), and the number of pixels increases to around 20 for each observation, in the case of images with 0.5 cm/pixel of spatial resolution. However, the number of pixels included depends on the image resolution, and we would keep the spatial reference instead of specifying the number of pixels.*

40. Line 229 what are the numbers in the brackets (3.1….), why the specific index values as features can the results be shown of the products?

*We apologise for the confusion. The numbers in brackets indicate the equation numbers, not specific values of the indices. We separated the band ratios and corresponding equation numbers in the revised manuscript (line 268-269):*

$$\frac{Red}{Green + Blue} \quad (3.1)$$

$$\frac{Green}{Red + Blue} \quad (3.2)$$

$$\frac{Blue}{Red + Green} \quad (3.3)$$

41. Line 231-233-is this part of step 4 or summary of the 4 steps?

*This is part of step 4. We used the same indentation to highlight it. However, we modified the text to avoid confusion (line 270-271):*
*"The addition of the band ratios in dataset 4 was done to ensure that at least one RGB dataset had the same number of bands as the multispectral datasets […]"*

42. Line 244-245 about Figure 3 can be confirmed by a simplified spectral unmixing test of the soil and plastic at simulated pixel amounts say 0.1, 10, 50, 100%. The spectra of the background material is needed also to check for a baseline correction if needed.

*We believe that the comment requires clarification regarding the experimental setup, rather than spectral unmixing. The spectra of pristine films were acquired on the plastic film surface* *only, and not on a mixture of films and soils. The statement in lines 244-245 refers to the possibility that the background soil may influence the film spectra, implying a film transmissivity greater than 0 %. This is very evident for transparent films, where spectral signatures follow the soil spectra (Fig. 3). For black and white films, Fig. 3 does not exhibit the same pattern, and our experimental setup does not enable us to obtain the radiative properties of plastic films, but only a measure of reflectance.*

*We add a discussion on the limitation of our experimental setup, related to transparent film spectra, in the manuscript at lines 385-389:*

*"Transparent film spectra are highly influenced by soil spectra (Fig. 3), and our experimental setup allowed to acquire the resulting reflectance of soil and plastic films. An experimental setup such as the one used by Jones et al. (2021) would allow a complete characterization of spectral radiative properties — reflectivity, transmissivity, and absorptivity — and provide insights into spectral changes of transparent films with different backgrounds."*

43. Line 261-based on the analyses and Figure 4 plot is the ND_1715 really useful? Or what is the benefit of using it in monitoring plastics?

*We agree that the other indexes have better performance in plastic detection. However, HI_1732 and HI_1215 are narrow band indexes that are not suitable for broad band sensors. ND_1715 instead, shows how plastic absorption features can be detectable from a broad band sensor. We specified the applicability of the index in the discussion (line 487-491):*

*"Within currently available indexes, even the broadband index ND_1715 resulted very effective in identifying plastic films from other elements that could possibly be found on cropland […] demonstrating the effectiveness of broad bands located at plastic absorption features and encouraging the development of multispectral cameras tailored to plastic detection."*

44. Figure 4 can be supported by a separability metric value. Figure can be made bigger to allow visual check to see if there are overlaps such as in the (c)

*We agree that separability metric values could add value when the separability between the classes is not clear. However, we believe that the separation between the classes can be already appreciated in the figures and separability metric would not add value to our discussion.*

*We included an axis break in Fig. 4c to make the separation between classes clearer.*

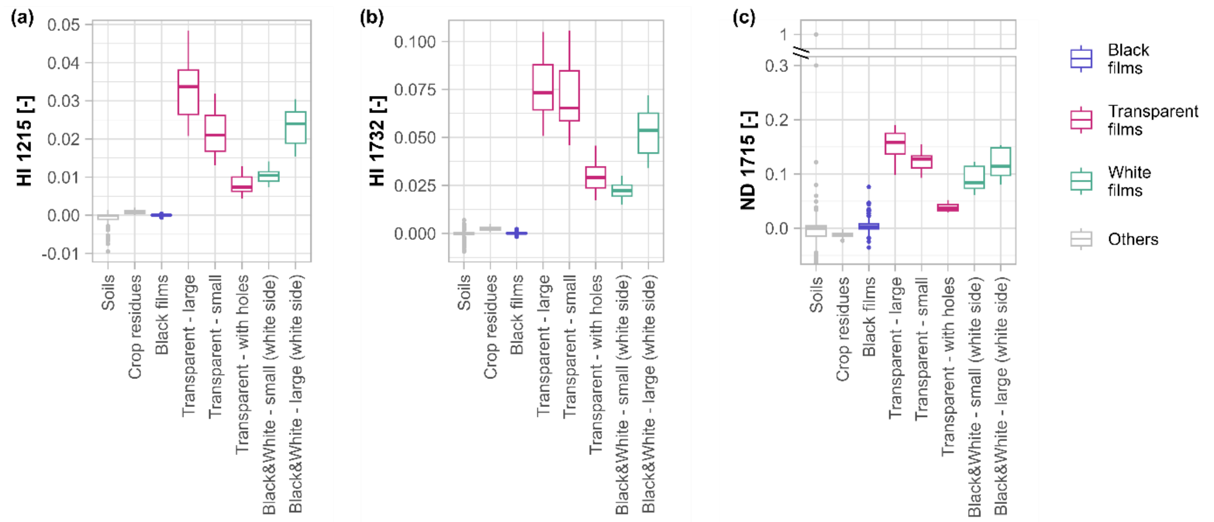



*Figure 4 - Boxplots of plastic index values for plastic films, soils, and crop residues. Index values include pristine, crumpled, dirty, and crumpled and dirty films. Values for all black films (i.e., Black - type 1, Black - type 2, Black&White - small (black side), Black&White - large (black side), Black - biodegradable) were aggregated, as they did not represent any relevant value. An axis break was used in (c) to enhance the visualization of the plot.*

45. Line 273-what treatments?

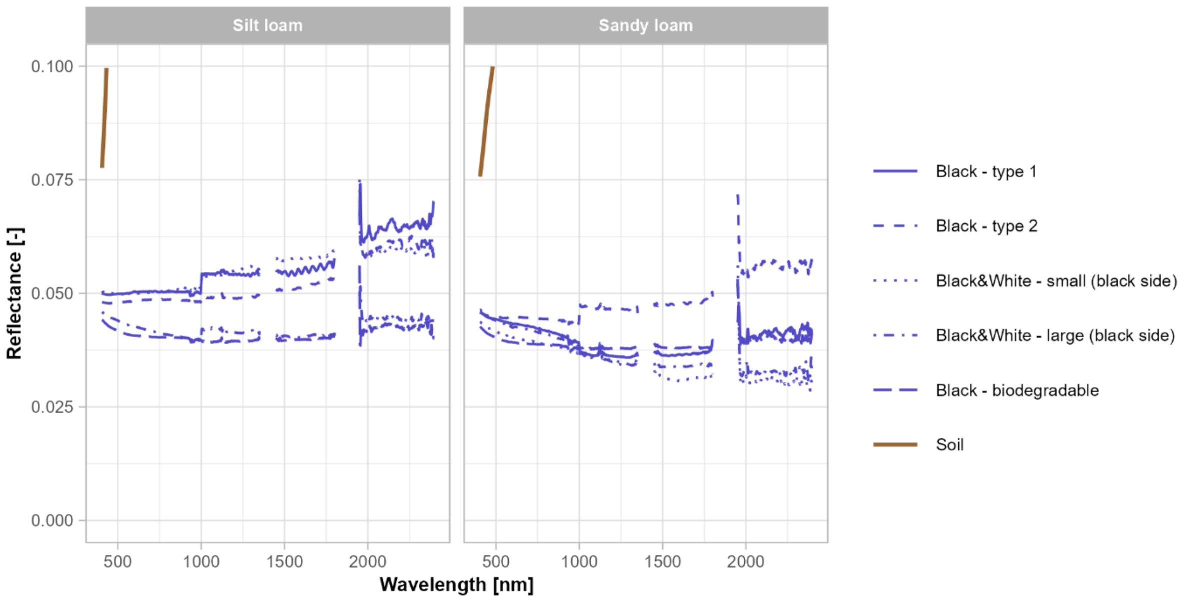
*We refer to all the treatments. We made this explicit by naming them at line 327-328: "Compared to pristine films, crumpled and dirty films decreased the reflectance variability between replicate of hyperspectral measurements."*

46. Line 323-polymer type details are missing see the experiment from Jones et al 2021 point 12

*We add the polymer type (LDPE) in the discussion and in the methodology.*

47. Line 326-the differences is shape can be better visible if all spectra are scaled or normalized

*We agree that scaling or normalisation would allow for a better visualisation of the differences. However, we included these plots in the supplementary material only (Supplement 5), as understanding these differences is beyond the scope of the study, which focuses on finding solutions for a better detection of the plastic residue on agricultural fields from a UAV. We believe that this is exemplified by the coefficient of variation reaching up to 135 % for black films (line 299), which implies that differences in spectra within the same black film can be higher than the differences in spectra between different black films. As these results were obtained from a spectroradiometer in proximal sensing, differences between black films will hardly be detectable from a sensor mounted on a UAV.*
*We referenced to the Supplementary material at the suggested lines.*




*Supplement 5 - Spectra of pristine black plastic films. On the left side, spectra acquired on silt loam; on the right side, spectra acquired on sandy loam.*

48. Line 329-336 where is this shown in the manuscript considering the assumption referencing to the white target was done every four minutes so the lighting is relative or as stated Lambertian and the plastics are also unique. The available data should be used to provide supporting proof to the statements here, was this the same situation in the crumbled data hints are in Figure 5 also?

*We are not sure to which part of the cited lines the reviewer is referring. We assume the reviewer is referring to the plastic films being a non-Lambertian reflector. This is supported both by literature (Goddijn-Murphy and Dufaur, 2018; Goddijn-Murphy et al., 2017), and by our data, i.e., the coefficient of variation presented in section 3.2. As stated in the discussion “The mean reflectance of white and transparent films showed much higher variability across replicate measurements compared to soils, resulting in higher coefficients of variation” (lines 392-393). At the same time, “[…] the presence of soil on the film surface increases the roughness of the films, favouring diffuse reflection and decreasing the variability of the reflectance between replicates.” (lines 400-401).*

49. Line 344 to 351-one suggestion to confirm the statements would be spectral unmixing and should be explored here even with  a simplified assumptions of the mixtures or the ones from the experiments.

*We believe that spectral unmixing could provide an estimate of the detectability of plastic films depending on the fraction of the pixel that is fully occupied by soil. For example, it would be useful to discuss whether a pixel composed of 50 % soil and 50 % plastic could still be detected as plastic. However, our statement referred to a homogeneous soil cover on the plastic film,* *with reference to our experimental setup. We believe that the results of spectral unmixing will hardly be relatable to a physical measure in the field without a proper experimental setup.*

50. Line 353-a plot can be used to confirm or demonstrate the sentence as difference are only presented in Figure 5

*Fig. 5 presents results for treated films only, and spectra are not comparable with the ones placed on the field. Our statement refers to UAV spectral shapes following similar patterns to the ones shown in Fig. 3 for pristine films. We clarified the statement as follows (lines 420-421):*
*"Film spectra acquired from UAV presented similar spectral shapes to the proximal sensing acquisitions (Fig. 3, Fig. 6)."*

51. Line 355- sentence unclear 'It must be accounted for, though,…..'

*We rephrased as follows (lines 423-425):*
*"However, it must be considered that the reflectance of white films in the UAV acquisitions was highly influenced by assigning the maximum reflectance of 1 to no data values, corresponding to saturated pixels."*

52. Line 367-explain how this was feasible and the link to glint issue

*The glint issue can cause very high reflectance and can saturate pixel values. White films are also characterized by high reflectance, and they also occasionally saturated pixel values. Thus, in correspondence of soil regions with glint issue, the two classes can be confused. We further specified this in the discussion (lines 441-443):*
*"[…] the topography of our study area might have emphasized the issue, creating soil surface angles that result in specular reflection and produce high reflectance values, comparable the ones of white films."*

53. Line 369-the data is available why not evaluate the brightness thresholding approaches or at least provide the raw data for potential use in future studies?

*We provided the reference at line 440 to demonstrate that these approaches can be effective and are a viable alternative. However, their implementation and their results may be site-specific (line 440), and one of the core messages of the paper is promoting technological development to overcome the limitations of site-specific methodologies, as outlined in the conclusion.*

54. Line 380-it is possible to explore the statements or claims here for the very fine pixel satellites for example 30cm/pixel from Pelican or WorldView?

*We are unsure whether the reviewer is referring to testing the proposed satellites for detecting plastic residue. In this case, satellites can help detect plastic residues in landfills or polluted urban areas, where the size of the plastic residues can be comparable to the spatial resolution of the satellites. In agricultural fields, plastic residues of this size are rarely found, and satellite data are ineffective.*

55. Line 383-is relevant for machine learning classification but also depends on the size of the objects of interest?

*We agree that the relationship with size of the object should be specified and we add this detail to the manuscript (lines 457-459):*
*"Overall, the results of our study suggest that the increased spatial resolution of an RGB camera should be favoured over the higher spectral resolution of multispectral cameras, when aiming at the detection of macroplastic residues of around 5 cm."*

56. Line 386-391-the discussion should also account for the labelling dataset size, supervised or unsupervised approaches

*We agree that the limitations introduced by the limited size of the ground observations should be accounted for. We add the following text to the manuscript (lines 466-468):*
*"Lastly, a high surface occupation of plastic film residues in agricultural fields is rarely documented, and our experiment was designed to replicate a realistic scenario. Future studies could consider increasing the size of the observations related to plastic films to have more robust results."*
*Regarding unsupervised approaches, we believe that are hardly applicable for plastic residue detection, and evidence from the literature would not support considering them.*

57. Line 394-contradicts a bit with the figure 3 as the spectra from Silt loam had higher values and yet in Figure 5 differences are high for sandy soils. In any case silt loam seems a better background—a figure is missing here to also support this sentence as well as paragraph to make a clear distinction between the films bright or dark ones.

*We believe that this comment arises from the confusion caused by using similar soil textures to those used in the proximal sensing setup. The soils shown in Fig. 3 could be referred to as 'clear silt loam' and a 'dark sandy loam', in contrast to the soils used for the example in line 394, a 'clear sandy soil' and a 'dark clay soil'.*
*The qualitative description of soil colour, clear or dark, is used to provide an example of spectral separation between soils and films. White films will be harder to distinguish on a more reflective soil, while black films will be harder to distinguish on a less reflective soil, and vice versa. This is also shown by the spectral distance between soils and films in Fig. 3. The soil texture, instead, is used as a proxy for the complexity of the topography, hence the presence*

*of shadows on the field. A clay soil will more likely have soil clods and a more complex topography compared to a sandy soil.*

*We apologise for the confusion, and we avoided using the same soil textures of the experimental soils. Instead, we used coarse-textured and fine-textured in the example of lines 471-477):*

*"A coarse-textured clear soil may represent the optimal site for detecting black films, providing a good contrast between the film and the background, and reducing the complexity of the topography by limiting the formation of soil clods. At the same time, such soils are more likely to induce sensor saturation and a lower contrast with clear films, making the detection of white films harder. On the contrary, a fine-textured dark soil may provide a good environment for white film detection, while black film detection would be limited by a decreased contrast and eventually hindered by the presence of soil clods and direct sunlight."*

58. Line 400-define the spectrum ranges referred to as visible, near infrared and be clear what exactly it means no any 'unique features'? there is a peak in the green for the WB_S and WB_L also there is an absorption feature in the near infrared of T_L

*We used the term 'unique feature' to describe features that are common to plastic as a material, and that could be found for every plastic, excluding black films that have absorbance close to 100 %. We rephrased as follows (lines 479-482):*

*"However, plastics films do not share any absorption feature in the visible and near infrared (Fig. 3), and their identification with currently available multispectral broadband sensors is mostly colour-driven and influenced by spectral shape ambiguities (Garaba, 2025)."*

59. Proposed algorithms can be tested see the suggested experiments in point 12-a spectral matching can be applied using the created libraries.

*We apologise but we could not find the reference to the part of the text, neither to point 12-a. We assume that the 'proposed algorithms' refer to the ones already discussed during other points of this review.*

60. A clear message about the use of UAVs should also combine the limitations that can be complemented by satellites.

*Similarly to point 54, we do not believe that satellites could contribute to the detection of plastic film residues on agricultural soils because of their limited spatial resolution. Thus, we would not consider them as complementary to UAVs.*

61. Line 436-should be revised as there are sensors offering open-access to hyperspectral remote sensing information of the environment see the suggested citations using drone, aircraft and satellite tools.

*To the best of our knowledge, open-access hyperspectral remote sensing data are available for satellites only. As discussed in comment 54 and 60, we would not consider the use of satellites for plastic film residues detection on agricultural soils.*

62. Figure 1 should be made bigger to fit margins of the text, labelling for the setup should be improved larger text, where is the white reference, distances can be added

*The figure was made bigger. We gave more informative names to the samples, added the size of the O-ring to give a reference for the distances, and added a label for the white reference*

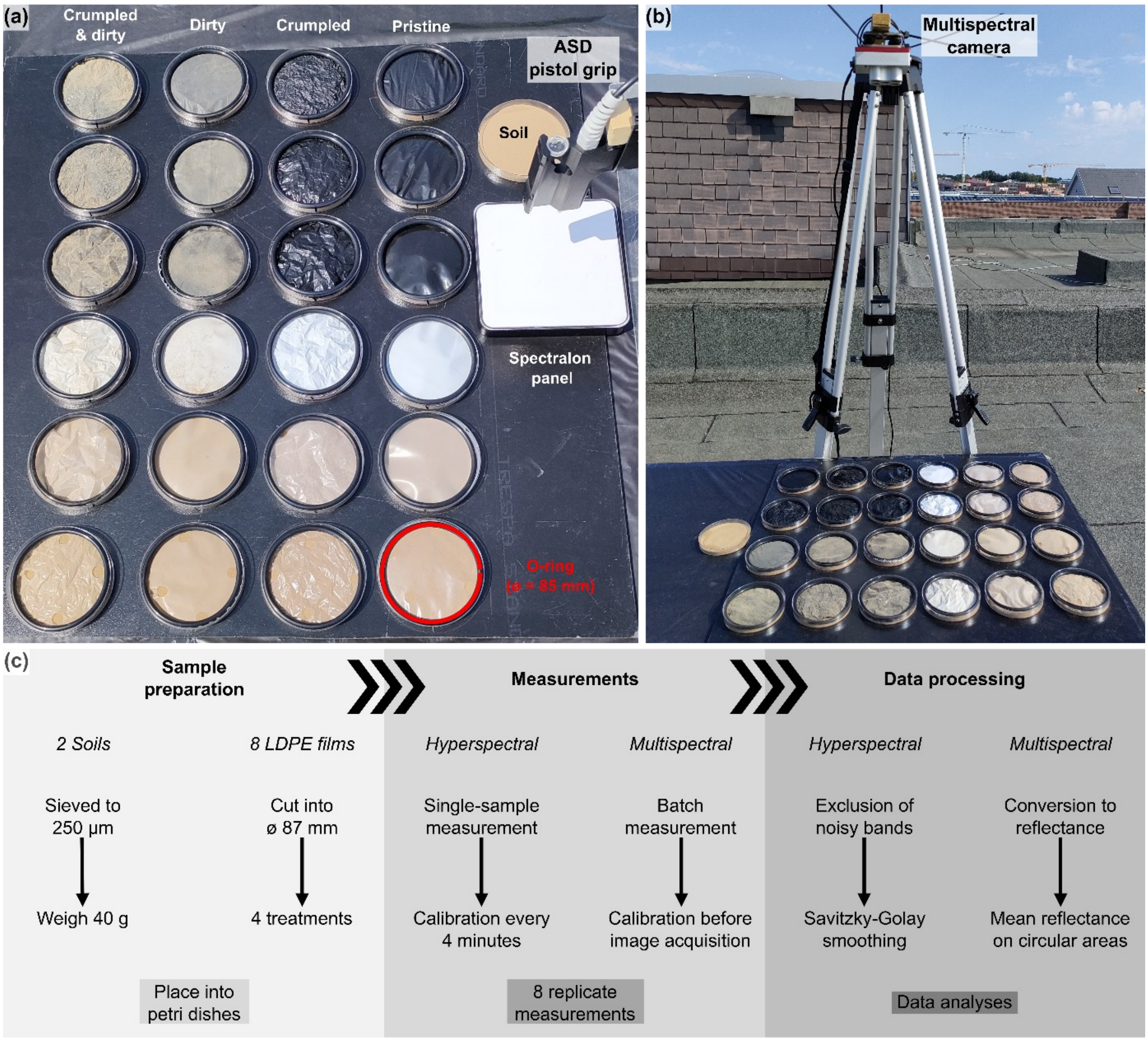



*Figure 1 - Experimental setup used for acquiring reflectance measurements of plastic films from a spectroradiometer (i.e., ASD) (a) and a multispectral camera (b), and workflow used (c). The same batch of samples is represented on the left (a) and on the right part of the image (b). On the left side (a), columns were labelled according to the treatment; different rows show different film types, from top to bottom: Black - biodegradable, Black - type 1, Black&White - small (black side), Black&White - small (white side), Transparent - large, Transparent - with holes. Film names refer to Table 1.*

63. Line 112-a figure should be included to show the ‘different conditions’ and the soil sample can be included as a foto

*Fig. 1 already shows the different conditions and the soil sample. We assume that the improvements of the figure based on comment 62 allow for a better visualisation.*

64. Line 121- the sentence must be highlighted in the figure 1 or a figure be provided

*Thank you for the input. We add a label to provide an example of the O-rings.*

65. Table 1-polymer type is missing, is the header use specific or it is better 'Common Use'other give reference for the use defined. How was the thickness obtained or was provided by manufacturer explain.

*We add the polymer type in the caption, as it is the same for all the films (LDPE).*
*We agree that 'Common use' better suits the meaning of the header and we changed it accordingly.*
*The thickness was obtained by 10 different measurements with a micrometer. We specified this in the caption of Table 1:*
*"Thickness was obtained from the average of 10 measurements performed with a micrometer."*

66. Figure 2 can have the coordinates northing and easting added, figure made bigger, RGB image of the drone survey is missing only a side view is given in (b).

*We believe the figure has already many details, including locations of the study site, and we would avoid overloading the image with the coordinates. Moreover, the exact location of the field is already provided at line 201.*
*We add the RGB image of the drone survey and modified other details of the figure based on comment 38 and 66 of reviewer 1, and on comment 6 of reviewer 2.*

67. Figure 3 should be made bigger and improved better with subplots of each material or groups as in the legend black films, transparent, white films.
    a. The scales must be specific to the material to allow shapes to be visualized

*Similarly to comment 47, we agree that scaling the spectra and building subplots allow for a better visualisation of the results and we included them in the supplementary material. However, we believe that these differences are outside of the scope of the study and could hardly be discussed in the manuscript. We believe that the main results regarding the UAV detection of plastic films on agricultural land can be effectively visualised at the current scale, as shown in Fig. 3.*
*Specifically, differences within the same group of films (black, transparent, and white) cannot be discussed at this early stage of the research field, as the spectral properties of plastic films can vary based on plastic type, thickness, or additives, which can be quite broad and are often unknown. At the same time, differences between films of different groups can be appreciated*

*at this scale. Moreover, the presence of unique plastic absorption features documented in previous literature and used for the indices in Fig. 4 can be appreciated at this scale.*

b. What are the locations of the absorption features this should be highlighted

*We highlighted the location of absorption features in Fig. 3.*

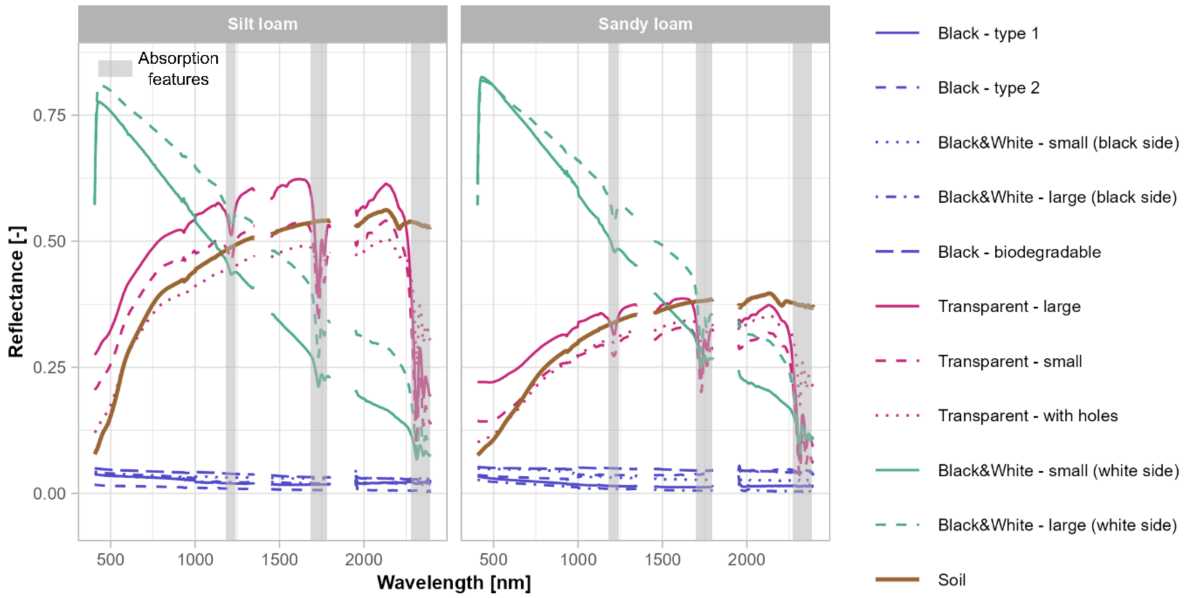



*Figure 3 - Spectra of pristine plastic films and of soils used as background. On the left side, spectra acquired on silt loam; on the right side, spectra acquired on sandy loam. Film colours are represented by different colours, and variation within film colours are represented by line shapes. Region of absorption features are highlighted in light grey. Film names refer to Table 1.*

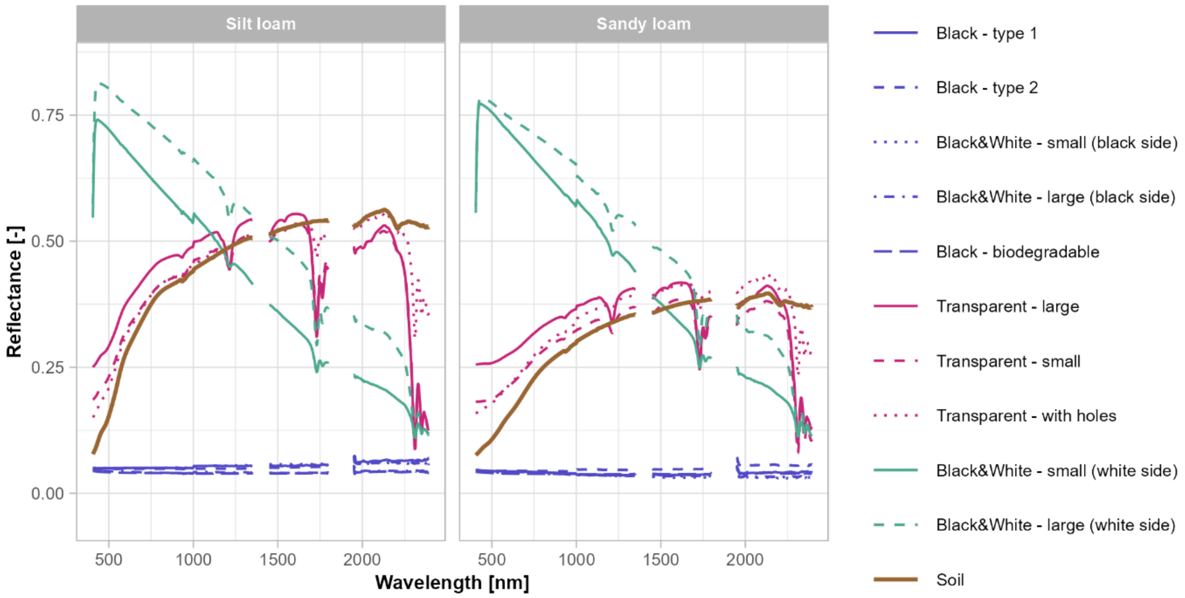
c. Why is the sandy plastics less reflective? Discuss this more

*Plastic on sandy soil is less reflective, but only for transparent films. This is due to the sandy loam being less reflective compared to the silt loam, in our soil samples used. As "transparent film reflectance changes according to the soil" (line 287-288), the transparent plastic on sandy soil result less reflective. We specified this at line 303-304:*
*"The transparent films generally follow the spectrum of the soil background, and transparent films on a less reflective soil result in lower reflectance of plastic films, and vice versa."*

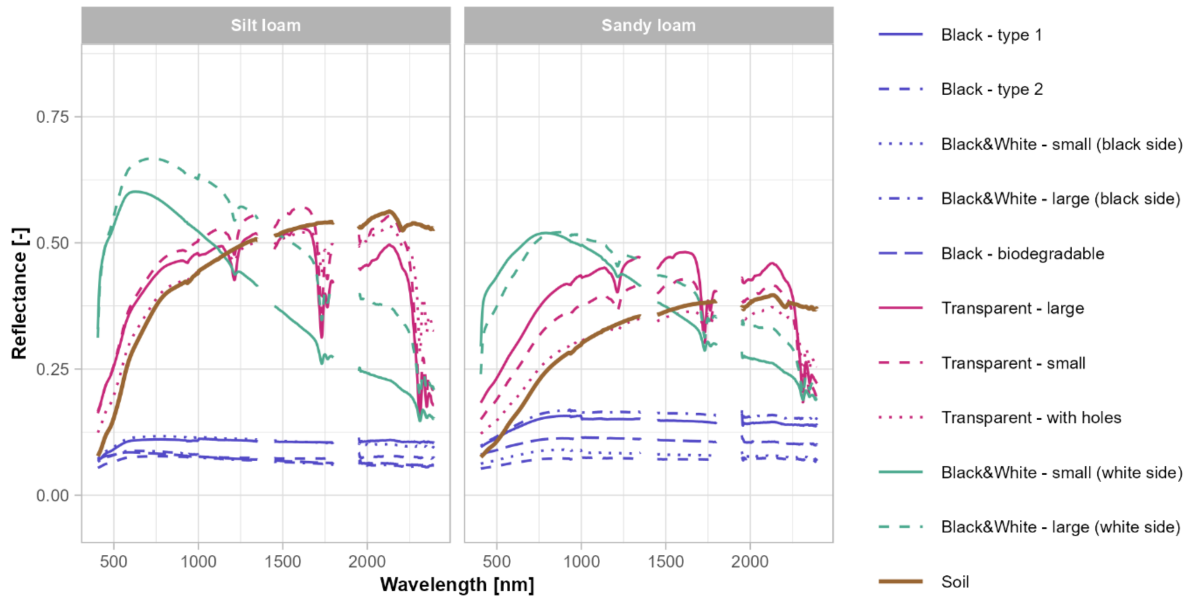
68. Figure 5,the plots of the actual reflectance are required here as the difference does provide minimal details although the format of the figure is good. Either have the actuall measured values presented or in the supplementary material because what is the meaning of the difference? Was this maybe due to background or rather experimental setup? This is not evident in the column 1 with clean samples and the lower values also what does it mean negative difference?

*We add the plots of the actual reflectance of the treatments to the supplements (Supplement 2–4). The plots in Fig. 5 represent the difference in reflectance between pristine films and* *treatments. Hence, a difference close to 0, like in the case of crumpling, mean that no differences were found. A negative difference means that the treatment increased the reflectance, like in the case of dirty black and transparent films. We add the following text to specify this relationship (lines 334-336):*

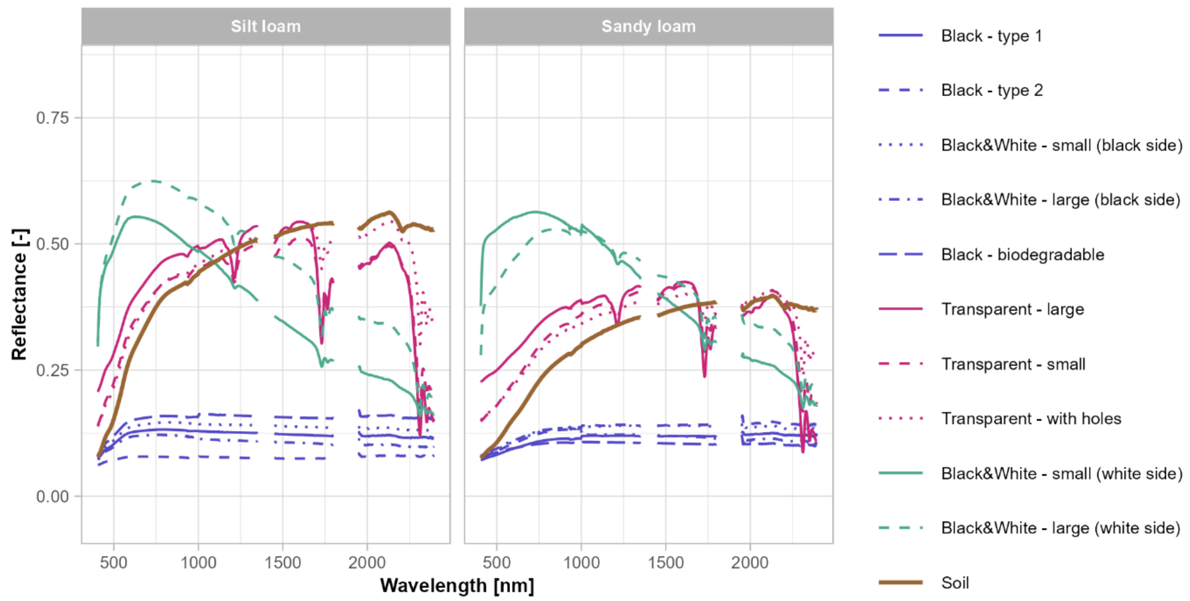
*"Black film reflectance also changes when covered by soil, but the negative values of reflectance difference in Fig. 5 indicate that the presence of soil increased the reflectance of the plastic films."*




*Supplement 2 - Spectra of crumpled plastic films and of soils used as background. On the left side, spectra acquired on silt loam; on the right side, spectra acquired on sandy loam. Film colours are represented by different colours, and variation within film colours are represented by line shapes.*




*Supplement 3 - Spectra of dirty plastic films and of soils used as background. On the left side, spectra acquired on silt loam; on the right side, spectra acquired on sandy loam. Film colours are represented by different colours, and variation within film colours are represented by line shapes.*




*Supplement 4 - Spectra of crumpled and dirty plastic films and of soils used as background. On the left side, spectra acquired on silt loam; on the right side, spectra acquired on sandy loam. Film colours are represented by different colours, and variation within film colours are represented by line shapes.*

69. Figure 6-add joining line for visualizing the multispectral data and subplots could improve the figure

*We add joining lines to the figure but we would avoid having subplots, as they would reduce comparability between spectra.*

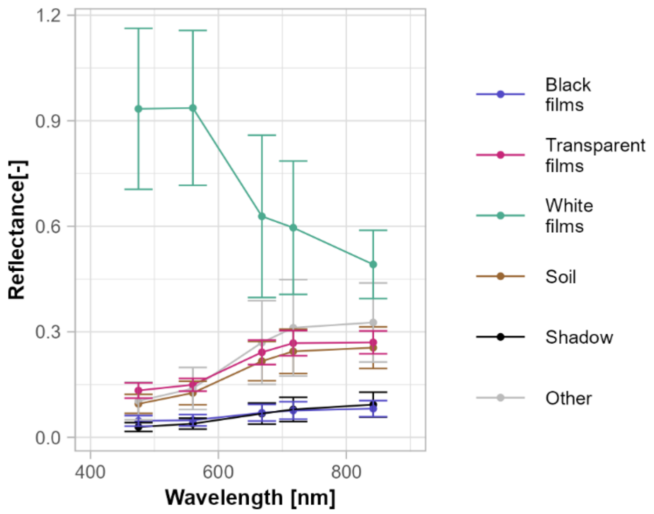



*Figure 6 - Reflectance of plastic films divided by colour (i.e., black, transparent, white), compared to soil reflectance, shadow, and other non-plastic objects found on the experimental site.*

70. Figure 8 too small

*The figure was made bigger and a classified map was added to the figure, based on comment number 29 of reviewer number 1.*

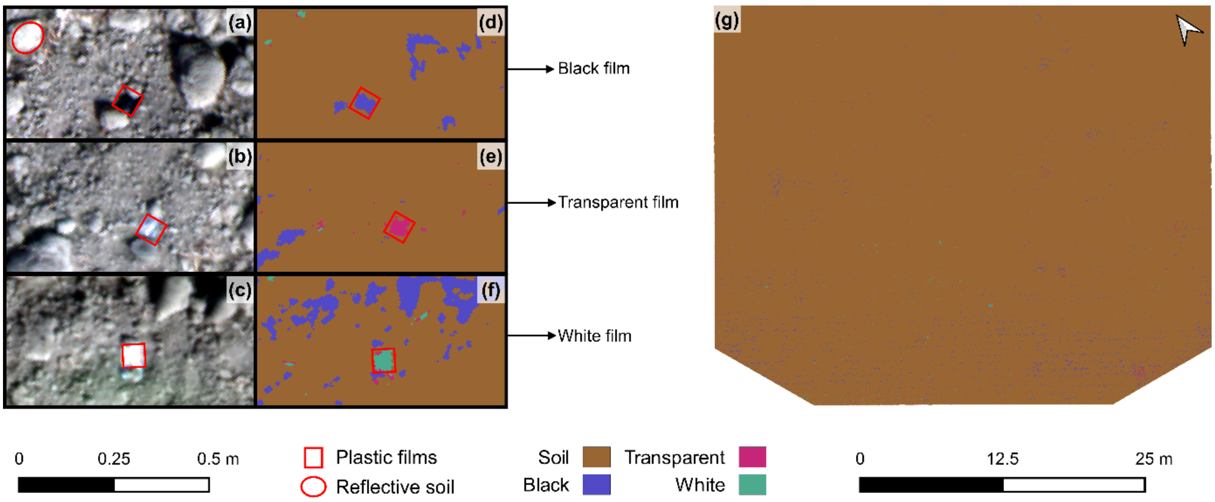



*Figure 8 - Detail of the true colour images (a–c) and associated classification results (d–f) obtained with the multispectral 0.5 cm dataset. The classified map is shown in panel (g). On images (a–f), the exact location of the plastic films is highlighted. On image (a), the example of a highly reflective soil region is highlighted.*

71. Confusion matrix and important feature summary for the Random Forest classifier are missing.

*We agree that the confusion matrix and the feature importance summary are usually provided in remote sensing classification. However, we believe that the metrics provided in our study are more solid indicators of the performances of the algorithm. Specifically:*

- *The scarce number of plastic films compared to the other classes, result in overall accuracies close to 100 %, and driven by the non-plastic classes. Instead, the metrics provided in Fig. 7 are more comprehensive and account for false detection of plastic.*
- *We used different datasets to compare the accuracy of detection with different features, allowing to reflect the use of different features against a concrete measure of detection accuracy. We believe a feature importance rank can be more useful when many features are considered, hampering the comparation of classification results with different datasets.*

# Point by point response - Referee #2

# Plastic film residues on cropland: monitoring soil contamination through optical remote sensing

Alessandro Fabrizi, Peter Fiener, Kristof Van Oost, Florian Wilken

We thank the reviewer for acknowledging the study and for providing constructive feedback. We are glad that the reviewer shared their expertise to identify critical points and improve the quality and reproducibility of the study.

Please find below our detailed answers (in italics). Line numbers refer to the marked-up manuscript version.

**General comments:**

1. More specifically, the study uses a small number of plastic film samples in the field study, especially considering that they were used to train random forest models. Twenty-one black films, 19 transparent films, and 13 white films were placed on the field, and for validation purposes, only 4.2, 3.8 and 2.6 number of points were used for validation for the black, transparent and white plastic films (according to Figure 7), respectively. The concern is that the training and validation of the classification models are not reliable enough.

*We agree that a higher number of plastic film samples would have been beneficial for interpreting the results. However, the field experiment aimed to simulate a UAV survey on an agricultural field using plastic films, and the surface occupation of plastic films relative to the overall area of the field was designed to replicate a realistic scenario. We believe that this issue will recur with plastic film residue mapping on agricultural land. Heavily polluted agricultural fields are rarely documented, especially in Europe, and finding a high number of plastic film samples bigger than 5 cm for training and validation will be the exception. We included the following text in the revised manuscript (line 466-468):*

*"Lastly, a high surface occupation of plastic film residues in agricultural fields is rarely documented, and our experiment was designed to replicate a realistic scenario. Future studies*

*could consider increasing the size of the observations related to plastic films to have more robust results."*

2. Additionally, valuable information is lacking in the study. Specific examples follow below, but for example, in the methods section, information is lacking on the soil used in this study, as little or no chemical or physical data is provided (e.g. organic matter, pH, etc.). Soil properties can greatly affect spectral results as thus are important in this study.

*We addressed the issue at the relative comments 8 and 15, following in this document.*

3. The description of the plastics used in this study it is not detailed enough. Which type of plastics was used, beyond the plastic color? This information is vital, especially as one of the aims of the study was to 'build spectral libraries for the most common plastic films used in agriculture' (line 180).

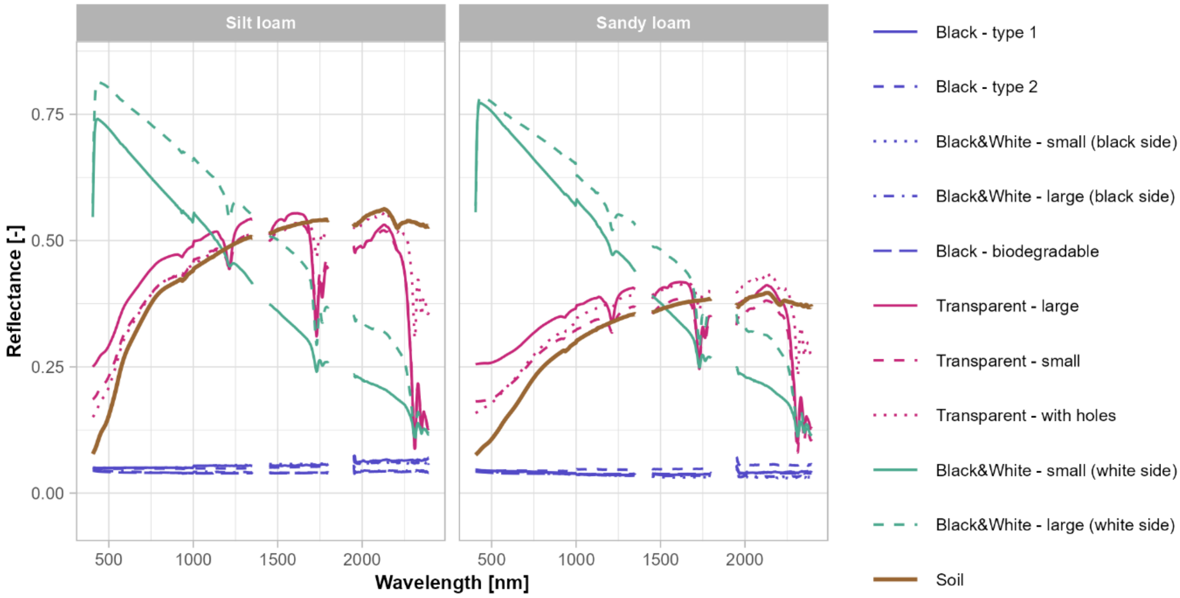
*We agree that the information is vital and is missing. The plastic used was LDPE, obtained from plastic film manufacturing companies. We included the information in the methodology, in the discussion, and in Table 1.*

4. Additionally, some of the methods are not described sufficiently- for example the process of calculating the producers' accuracy in the field study. How many points were used for validation? How were validation points created? This is especially important with the small dataset that was used in this study.

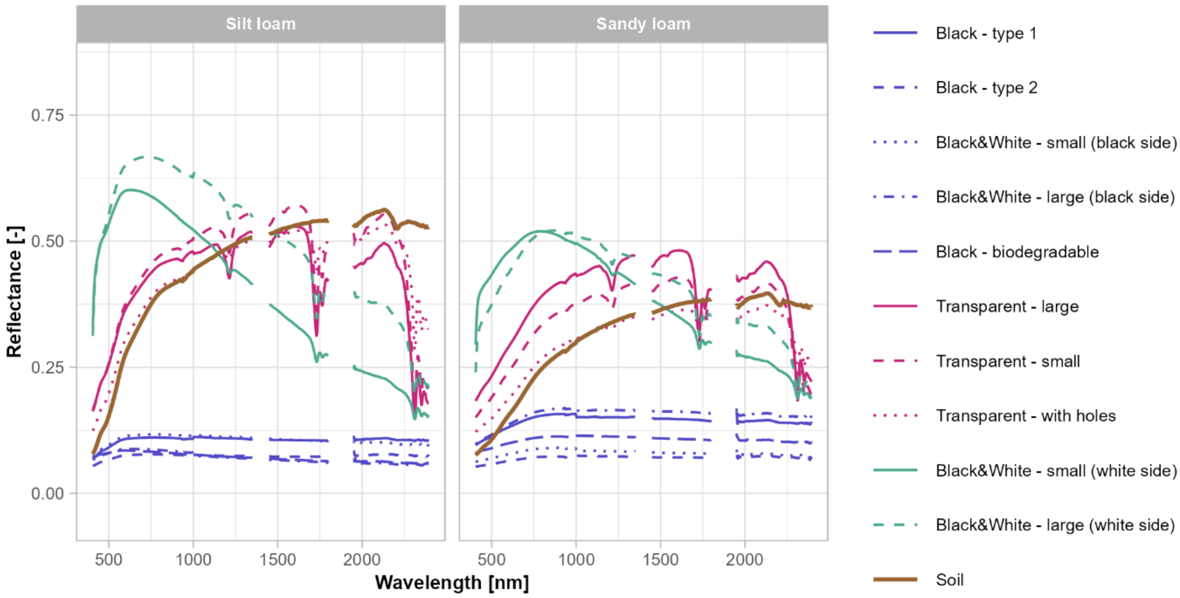
*The producer accuracy was calculated as the ratio between the number of plastic films correctly detected and the number of plastic films placed in the field. We add the following text at lines 273-275:*
*"The detection of the plastic films placed on the field was evaluated against the ground observations by calculating the producer accuracy as the ratio between the number of plastic films correctly detected and the number of plastic films placed on the field."*
*The producer accuracies provided in Fig. 7 represent the mean and standard deviation of the producer accuracy calculated across the 5-folds used in the study. In each fold, 80 % of the ground observations were used for training, and 20 % were used for validation, ensuring that the observations used for validation were different at each fold. We add the following text at lines 250-251:*
*"At each fold, 80 % of the observations is used for training and 20 % of the observations is used for validation."*

5. In the results section, important results are not displayed, such as the spectra of the crumpled, dirty, and crumpled + dirty plastics films.

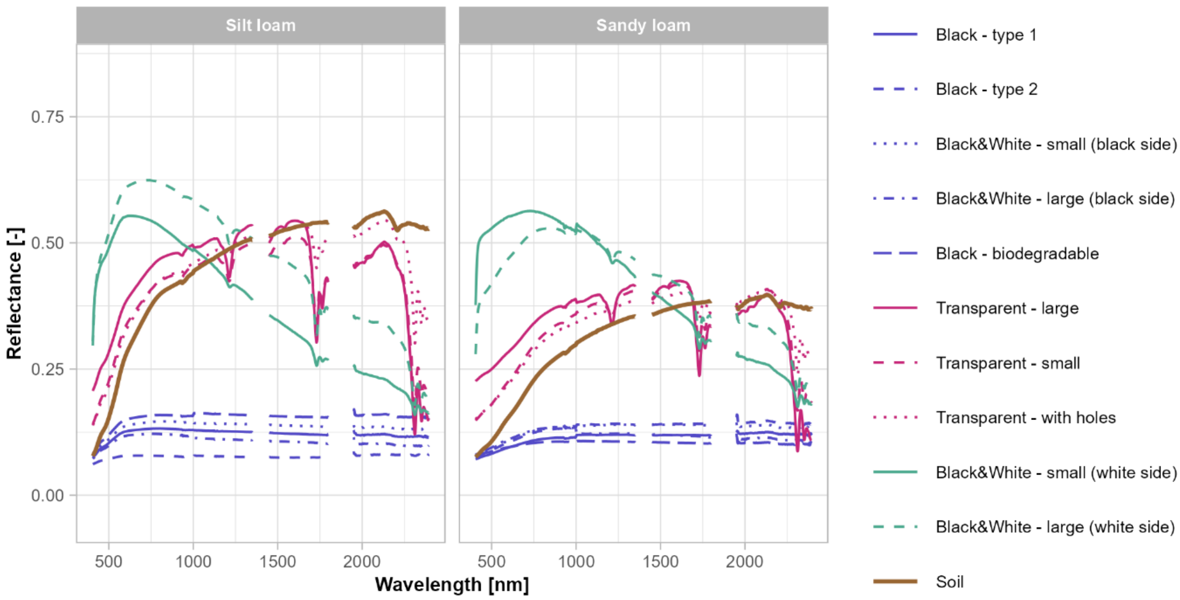
*We agree that the spectra of the treated films could add value to the scientific community, and we included them in the supplementary material of the revised manuscript (Supplement 2–4). However, we believe that Fig. 5 and the numbers provided on the coefficients of variation in section 3.2 already highlight the changes occurring from pristine films to crumpled, dirty, and crumpled + dirty films, which is one of the main objectives of the experiment.*




*Supplement 2 - Spectra of crumpled plastic films and of soils used as background. On the left side, spectra acquired on silt loam; on the right side, spectra acquired on sandy loam. Film colours are represented by different colours, and variation within film colours are represented by line shapes.*




*Supplement 3 - Spectra of dirty plastic films and of soils used as background. On the left side, spectra acquired on silt loam; on the right side, spectra acquired on sandy loam. Film colours are represented by different colours, and variation within film colours are represented by line shapes.*




*Supplement 4 - Spectra of crumpled and dirty plastic films and of soils used as background. On the left side, spectra acquired on silt loam; on the right side, spectra acquired on sandy loam. Film colours are represented by different colours, and variation within film colours are represented by line shapes.*

6. Images or results from the multispectral images acquired in the controlled outdoor experiment and of the field in the field scale study are not shown as would be expected.

*We included an RGB composite image of the field-scale study in the revised manuscript, in Fig. 2. We also add examples of plastic films placed on the films in Fig. 2.*
*However, we are not quite sure about how the reviewer would like to include images of the controlled outdoor experiment. We believe that Fig. 1 already shows the setup of the experiment and the differences between the plastic film samples. Moreover, several multispectral images were acquired, as we had 82 samples and 5 replicate measurements for each sample.*

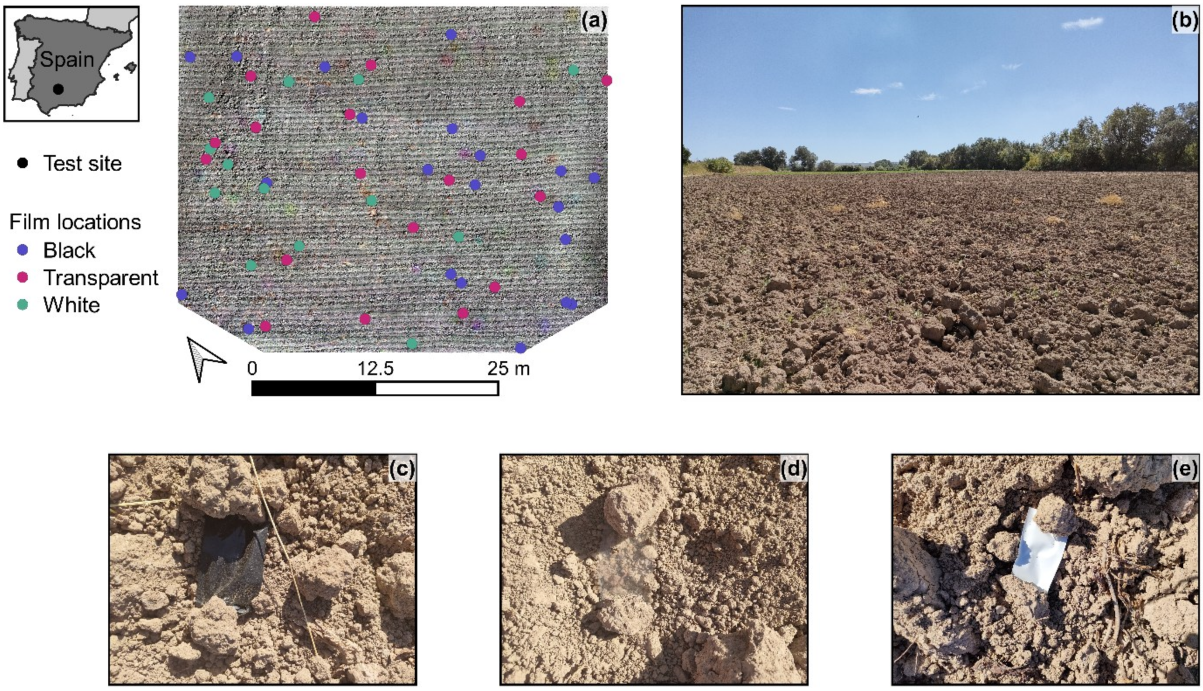



*Figure 2 - Location of the study area, distribution of plastic films in the study area (a), field picture (b), and examples of black (c), transparent (d), and white (e) films placed on the field. The geometry of the study area was chosen to maximise the number of plastic films, that are represented by coloured dots (a). On the upper-left corner, the orthomosaic was obtained from the UAV images.*

**Specific comments:**

*Methods:*

Section 2.1.2 (lines 109-132):

7. Line 113-114: how was it ensured that all the plastic films were equally 'dirty'? was the entire plastic film covered by soil? From Figure 1, it seems like there is a relatively thick layer of soil that mostly obscures some of the plastic films, but not others. It is hard to understand if that was actually so from the description. which soil was used to make the films dirty? the choice of soil could greatly affect the spectra (clayey vs sandy soils for example).

*The plastic films were not equally dirty. Instead, the methodology to make the films dirty was the same. As described at lines 133-134, 'dirtiness was obtained by rolling the films into a dry soil volume, thus creating a layer of soil particles attached to the film'. Both soils were used to* *make the films dirty, and the results are shown separately in Fig. 5. We add the details to the text as follows (lines 139-140):*

*"The two soils were used to make the films dirty and as backgrounds for the measurements on plastic films."*

*We agree that differences between films are visible in Fig. 1, and the amount of soil on the films was not equal. However, we believe that this represents field conditions. Different plastic films exhibit varying properties, such as surface roughness or surface resistivity, which influence soil particle retention on their surface. Moreover, plastic particles will be more or less visible depending on the contrast with the background. We add these considerations to the discussion section (lines 412-414):*

*"Our experimental setup did not allow for controlling the amount of soil placed on the films, but aimed at representing field conditions, where soil particle retention of the film surface varies based on film properties."*

8. Lines 115-118: the description of the soils used in this study should be more detailed with at least some chemical and physical data (organic matter etc.). This is important for spectral studies, as soil parameters strongly affect reflectance.

*One of the soils used in the proximal sensing experiment is a standard soil provided by a German company, and all relevant information come from laboratory analyses. The other soil used in proximal sensing could be provided with regional values, but no laboratory analyses were performed. We add the relevant information at lines 135-139:*

*"A field soil (i.e., directly collected from a site), coming from arable land in the Belgian loam belt, where soils are characterized by organic carbon content of 1.26 ± 0.37 % C and classified as silt loam according to USDA classification (Zhang et al., 2021), and a standard soil (LUFA 2.2), characterized by organic carbon content of 1.72 ± 0.54 % C and classified as sandy loam according to USDA classification, were used for the experiment. "*

9. Line 117: I'm curious to know why such a fine sieve was used in this study. Isn't a 2 mm sieve more common in similar soil studies?

*The sieve was chosen to have a stable soil spectrum and to ensure that plastic films were as flat as possible. This was especially important for pristine films, not crumpled, where soil roughness could have caused some crease patterns. We add the following text to justify the choice (lines 140-142):*

*"Both soils were sieved down to 250 μm, to remove coarser organic and inorganic matter, enabling the acquisition of stable soil spectra and ensuring that pristine films surface would not be influenced by soil roughness."*

10. Lines 110-111: Which plastics were used? What was their chemical composition (e.g., LDPE)? It is known that different plastics will have different reflectance, and therefore providing this basic information is critical.

*The plastic used was LDPE, obtained from plastic film manufacturing companies. We included the information in the methodology, in the discussion, and in Table 1.*

11. Additionally, what do all the treatment names symbolize- BIO, B_1, BW_2 etc.? I suggest giving the samples more informative names. it is unclear what it means that black and white films were double sided and used on both sides.

*We replaced all the acronyms with explicit names throughout the manuscript. Please refer to Table 1 for the new names.*

*Table 1 - Specifications of the LDPE plastic films used for the experiment. Thickness was obtained from the average of 10 measurements performed with a micrometer.*

<table>
<tr><th>Name</th><th>Thickness (μm)</th><th>Application mode</th><th>Common use</th><th>Duration use</th><th>Colour</th></tr>
<tr><td>Black - type 1</td><td>18 ± 2</td><td rowspan="6">On the soil surface</td><td rowspan="3">vegetables or fruits</td><td rowspan="3">one growing season</td><td rowspan="3">black</td></tr>
<tr><td>Black - type 2</td><td>18 ± 1</td></tr>
<tr><td>Black - biodegradable</td><td>15 ± 2</td></tr>
<tr><td>Black&White - small (black side)<br>Black&White - small (white side)</td><td>99 ± 3</td><td rowspan="2">asparagus</td><td rowspan="5">multiple growing seasons</td><td rowspan="2">black/white</td></tr>
<tr><td>Black&White - large (black side)<br>Black&White - large (white side)</td><td>143 ± 5</td></tr>
<tr><td>Transparent - with holes</td><td>44 ± 2</td><td rowspan="3">vegetables or fruits</td><td rowspan="3">transparent</td></tr>
<tr><td>Transparent - small</td><td>157 ± 1</td><td rowspan="2">large tunnel film for greenhouses</td></tr>
<tr><td>Transparent - large</td><td>185 ± 6</td></tr>
</table>

12. Table 1: this table is confusion- From ‘application mode’ column and onwards- is this information relevant to the plastics used in the experiment? For example, were B_1, B_2 and BIO used for one growing season in fruit or vegetable fields prior to the experiment, or is this their common use? Sample names are not consistent, with some ending with numbers (B_1 and B_2) and some ending with letters. What do the numbers and letters signify?

*We believe that giving the common use and the application modes could be relevant for future studies, to understand which type of film uses were covered by this study. However, the films were pristine and not used before the experiment. We changed the name of the column 'Use' with 'Common use', to indicate that the films were not used before the experiment.*

More comments in the methods section:

13. Lines 138-140: What caused the 'rapidly changing light conditions' in samples BW_S and BW_L and not in other samples?

*The changing light conditions do not depend on the samples. As the experiment was carried out outdoor, the changing light conditions depend on the weather conditions only.*

14. Line 147: why was it decided to present the spectra of the pristine films only? In field conditions, it is expected to encounter crumpled or dirty plastic films, therefore, viewing their spectra is very interesting.

*As already outlined in comment number 5, we believe that Fig. 5 and the numbers provided on the coefficients of variation in section 3.2 already highlight the changes occurring from pristine films to crumpled, dirty, and crumpled + dirty films. However, we included the spectra of the treatments in the supplementary material.*

15. Lines 174-175: Soil in the field study is also not sufficiently described. Were chemical or physical analyses conducted? Once again, this can greatly affect reflectance results and the ability to identify the plastics.

*The soil used in the field experiment could be provided with regional values, but no laboratory analyses were performed. We add the following text to provide the details (line 203-204):*
*"The typical soil at this location is a calcaric Luvisol soil according to FAO classification (Junta De Andalucía, 2005), with soil organic carbon content of 0.77 ± 0.64 % C (Muñoz-Rojas et al., 2012)"*

16. Lines 185-190: How was elevation calculated? From the UAV images? If so, what was the flight overlap and what method was used to calculate elevation?

*The elevation was calculated from the digital surface model obtained from UAV image processing in Pix4D. The elevation was calculated relatively to the lowest point on the field. Flight overlap was set to 70 %. However, this may have decreased during the flight, as flight altitude was observed to be variable during image processing. We are not quite sure whether* *this was related to a real decrease in flight altitude or to an incorrect data acquisition from the UAV.*

*However, we substituted the image of Fig. 2a with the RGB composite. Both reviewers requested the inclusion of the RGB composite, and we would avoid increasing the number of figures.*

17. Line 196: which GIS software was used? How were the random points generated for spreading the plastic films?

*ArcGIS Pro was used for the classification, and the random points were generated with QGIS. We specified the information in the text.*

18. Lines 198-203: The number of samples in the field study are very few. Especially when training a model and then creating validation points, this number of samples seem highly insufficient.

*We addressed this point in one of the main comments (number 1).*

19. Lines: 204-209: were Ground Control Points (GCPs) placed in the field for generating the orthomosaics?

*One GCP was on the part of the field used as the study area in this work. The GCP was part of five GCPs placed on a larger portion of the field, initially designated as our study area. However, the GCP was not used for generating the orthomosaics. We are aware that this does not guarantee correct georeferencing of the images and may have caused some band misalignment, which is visible in band composites through halo artefacts. However, we believe that a correct georeferencing of the images may be more relevant in applications such as change detection. Moreover, our field study does not aim at providing a benchmark for plastic film detection. Our results are used to define the ideal sensor for plastic film detection by comparing visible spectra with non-visible spectra on a multispectral camera. The bands are compared as part of the same camera during the same survey. We add the following discussion to account for survey flaws (lines 430-435):*

*"The results of our study might have been influenced by structural flaws of the survey, such as the absence of ground control points or the low overlap of images during flight, which can fall below the recommended threshold of 70 % when flying at 7 m above ground with the camera used. This could have resulted, for example, in band misalignment and halo artifacts that are visible in the RGB composite (Fig. 2a). However, general considerations can be made on how detection accuracy changes depending on the film colour and on the region of the spectrum used."*

20. Lines 214-215: This seems problematic as adjacent pixels are spatially highly autocorrelated. Was this done for the plastic film training points as well?

*The buffer was applied to the plastic film training point as well. However, the validation points were always extracted on different films to avoid the influence of spatial autocorrelation on the evaluation of the classification results. We add more details to the methodology at lines 252-253:*

*"The buffer was applied after the division between training and validation data, to avoid the selection of validation data within the buffer."*

21. Lines 234-240: How many points were actually used in the validation process? How were they created? It is important to understand exactly what was done in this section because of the small amount of samples. this section should be as detailed as possible, perhaps creating a workflow chart to describe all the steps that were done in the field study, including the validation process.

*We addressed this point in one of the main comments (number 4).*

*Results:*

22. Lines 245-246: the closeness of the transparent films to the soil spectra seems to depend on the spectral region, and there are clear changes across the spectral region. For example, in the left panel of Figure 3, between 500 till around 750 nm, T_H is closest to the soil reflectance, but then at around 1450-1600 nm, T_S is closest, and also at around 2,000 nm. Also, in the right panel there are changes across the spectrum, with 'T_L', which is the thickest film, sometimes being 'closest' to the soil spectrum. The relationship between the spectral region and the reflectance is interesting and important, as spectral indices can be derived from them.

*We agree that the relationship between transparent films and soil spectra is interesting. However, this depends on the transmittance of the plastic films, which could not be measured in our experimental setup, that allowed to acquire measure of reflectance only. Moreover, these relationships could change substantially, based on the film considered, and on the additives used. We believe that the use of indices in these spectral regions would be less effective than the proposed indices, which exploits absorption features common to all plastic films.*

*We add the following text in the discussion to acknowledge the changing distance between soil spectra and plastic film spectra (lines 289-295):*

*"However, the distance between the plastic film and the soil spectra changes across the spectral region. For instance, Transparent - with holes is closer to the spectra of silt loam in the visible, while Transparent - small gets closer in the NIR and SWIR (Fig. 3). On sandy loam, Transparent - with holes and Transparent - small spectra are very close in the visible, while Transparent - large gets closer to the soil spectra in the NIR and SWIR (Fig. 3). These relationships could be due to different additives in the plastic films, targeting different uses and*

*influencing the transmittance of the films. Transmittance measurements could further elucidate how plastic film transmittance changes across the spectral region, and could be a relevant topic for crop production (Jones et al., 2021).”*

23. Lines 256-258: The claim is that HI_1215 and HI_1732 allow to distinguish between white and transparent plastic films. However, from Figure 4, this does no seem to be so clear-cut. In panel (a) transparent film T_S and white film WB_L have index values that are quite close, with large variation that assumingly does not lead to any significant differences. The same can probably be said for T_H and WB_S, and in panel (b), for T_H and WB_S. Please provide significant letters in the graph.

*We agree that is not possible to distinguish white and transparent films with these indexes. We meant that white and transparent films could be both distinguished from soils and crop residues, but a distinction between films is not possible. We apologise for the confusion and we rephrased as follows (lines 307-309):*
*“As a result, HI_1215 and HI_1732 allow distinguishing all non-black films, in both pristine and treated conditions, from soils and mixtures, and from crop residues (Fig. 4a,b).”*

24. Please also indicate if the graph is showing pristine or treated plastic films, as these is not clear, and the claim made in Lines 256-256 cannot therefore be checked. Results of all the treatments should be shown to be able to observe the treatment effect,

*The values of the indices include pristine films, as well as crumpled, dirty, and crumpled + dirty films. Despite showing the treatments in separate figures could increase the detail of the manuscript, we believe that the separability of plastic with the indices can already be appreciated in the figure. Hence, we would like to present the treatments in a single figure to limit the number of figures and streamline the reader's attention.*
*We add details to the caption of Fig. 4 in the revised manuscript (line 321-322):*
*“Index values include pristine, crumpled, dirty, and crumpled and dirty films.”*

25. Line 273-275: Figures showing the reflectance of all the treatments (pristine, crumpled, crumpled + dirty, dirty) film are missing. It would be easier to visually see such results, and also see how the treatments affected the reflectance. It would be expected that the dirty films would have a reflectance more similar to the soil reflectance if they were completely or mostly covered by soil.

*Thank you for the input. As already outlined in comments 5 and 14, we add the complete spectra of all treatments in the supplementary material only. We add a reference to the Supplements at the suggested lines for enabling the comparison of spectra.*

26. Lines 276-282: Showing the reflectance of all the treatments, as suggested above, would allow a better comparison of the differences between the treatments. It would be expected

for the black films to have a higher reflectance across the entire spectrum. It would be very important to see if the clear absorption peaks also exist in the dirty films. The peaks would indicate how spectrally visible the plastic is even when covered with soil.

*We add the figures of the dirty films in the supplementary material, showing that absorption features could be visible there as well. However, we want to highlight that the index values of figure 4 comprise dirty films as well. As already discussed in comment number 24, we changed the caption of Fig. 4 to make this clear.*

27. Figure 6: from the graph it seems that only white films can be detected with UAV multispectral sensors. Black films and shadow overlap, while transparent and soil overlap. The question is how 'white' does the white plastic have to be- if it got covered with soil particles, or mixed in the soil and torn, which is what will likely happen in field conditions, would it still have a distinguishable reflectance? Providing reflectance of the dirty, and crumpled + dirty treatments, as previously suggested, could provide an answer to this question.

*We agree that this is a very interesting question with practical implications. From our experimental setup, white films are still white enough to be detected (Supplement 3-4).*
*However, as already outlined in the discussion, "a progressive deterioration of plastic spectra is expected, until reaching a soil cover at which plastic films will not be detectable anymore. Identifying this threshold of soil cover will be helpful in delineating the boundaries of remote sensing use for detecting plastic film residues on cropland." (lines 409-412). Further studies should investigate what is the threshold for which films will still be detectable under a soil layer. Our experimental setup did not allow to control the amount of soil on the film surface. However, we provided additional details and possible directions for future studies (lines 412-417):*
*"Our experimental setup did not allow for controlling the amount of soil placed on the films, because the methodology used to make the films dirty aimed at representing field conditions, where soil particle retention of the film surface varies based on film properties. Moreover, indoor spectroscopy would allow exploiting a higher signal-to-noise ratio and better control on the amount of soil placed on the films compared to outdoor measurements, where wind can remove soil particles from the film surface."*

28. Figure 7: for the black, transparent and white plastic films, there were only 2.6-4.2 number of points used for validation. This is problematic, as previously discussed. Figure 7b- what does the factor in the Y-axis refer to?

*Thank you for the input. The reasons behind the scarce number of samples were already discussed in comment number 1.*

*Regarding Fig. 7b, the factor refers to how many times the pixels covered by plastic films were overestimated, compared to the expected number. The expected number is known because it was derived from the plastic films placed on the field, and it was calculated as described at the end of section 2.2.3. We add the following text to the figure caption, to make the meaning of the y-axis clear (lines 372-373):*

*"The factor of plastic overestimation was calculated as the ratio between the detected number and the expected number of plastic-covered pixels"*

29. Figure 8: Providing a classified map of the entire field would be beneficial and is expected in such a study that used a UAV to map plastic contamination in the field scale.

*Thank you for the suggestion. We provided the classified map in Fig. 8.*

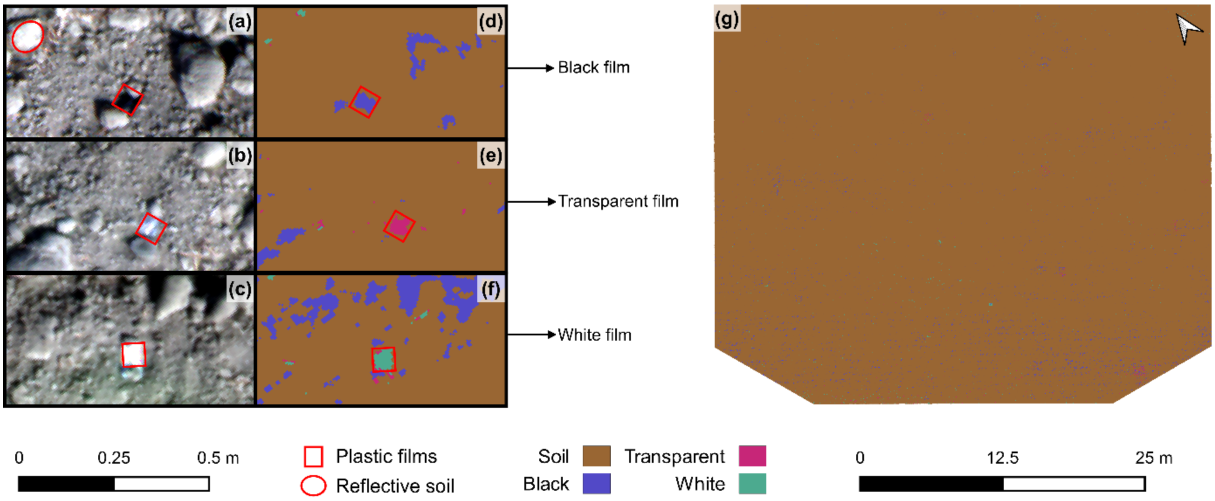



*Figure 8 - Detail of the true colour images (a–c) and associated classification results (d–f) obtained with the multispectral 0.5 cm dataset. The classified map is shown in panel (g). On images (a–f), the exact location of the plastic films is highlighted. On image (a), the example of a highly reflective soil region is highlighted.*

**Technical corrections:**

30. Figure 6: It is difficult to see the values of the different treatments on the graph, as some treatment values on top of the other. For example, the soil reflectance values cannot be seen at all in the figure. Please change the figure. A suggestion is to place the dots next to each other, instead of on top of each other.

*Based on the suggestion from reviewer number 1, we add joining lines to the plot. Moreover, we reduced the size of the points and increased the size of the plot. Altogether, we believe that the comparability between classes was improved. However, we would not move the dots, as their location correspond to the exact wavelengths of the multispectral camera.*

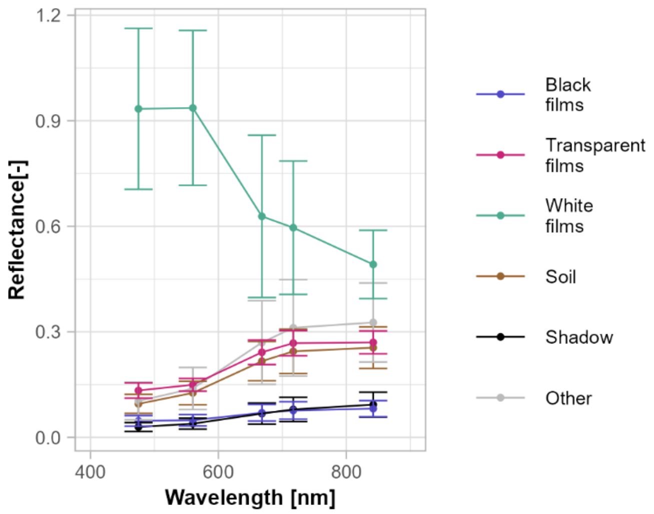



*Figure 6 - Reflectance of plastic films divided by colour (i.e., black, transparent, white), compared to soil reflectance, shadow, and other non-plastic objects found on the experimental site.*

31. Figure 8: please add the squares that indicate where the plastics are also on panels (d)-(f). Indicate which plastic is in which panel (white, transparent, black) so classification results can be compared.

*Thank you for the suggestion. We add the squares also on the classified maps, and indicated which plastic film is in which panel.*

## References


Colomina, I. and Molina, P.: Unmanned aerial systems for photogrammetry and remote sensing: a review, ISPRS J. Photogramm. Remote Sens., 92, 79-97, https://doi.org/10.1016/j.isprsjprs.2014.02.013, 2014.

Crucil, G. and Van Oost, K.: Towards mapping of soil crust using multispectral imaging, Sensors, 21, https://doi.org/10.3390/s21051850, 2021.

Crucil, G., Castaldi, F., Aldana-Jague, E., van Wesemael, B., Macdonald, A., and Van Oost, K.: Assessing the performance of UAS-compatible multispectral and hyperspectral sensors for soil organic carbon prediction, Sustainability, 11, https://doi.org/10.3390/su11071889, 2019.

Despini, F., Costanzini, S., Parmeggiani, D., and la Cecilia, D.: Analysis of hyperspectral data to define multispectral sensor specifications for enhancing plastic greenhouse detection, Remote Sens. Appl. Soc. Environ., 101802, https://doi.org/10.1016/j.rsase.2025.101802, 2025.

Frias, J. P. G. L. and Nash, R.: Microplastics: finding a consensus on the definition, Mar. Pollut. Bull., 138, 145-147, https://doi.org/10.1016/j.marpolbul.2018.11.022, 2019.

Garaba, S. P.: Towards advanced mapping of plastic greenhouses from EMIT, EnMAP and PRISMA hyperspectral missions, Environ. Chall., 22, 101398, https://doi.org/10.1016/j.envc.2025.101398, 2025.

Goddijn-Murphy, L. and Dufaur, J.: Proof of concept for a model of light reflectance of plastics floating on natural waters, Mar. Pollut. Bull., 135, 1145-1157, https://doi.org/10.1016/j.marpolbul.2018.08.044, 2018.

Goddijn-Murphy, L., Peters, S., van Sebille, E., James, N. A., and Gibb, S.: Concept for a hyperspectral remote sensing algorithm for floating marine macro plastics, Mar. Pollut. Bull., 126, 255-262, https://doi.org/10.1016/j.marpolbul.2017.11.011, 2017.

Jones, H., Black, T. A., Jassal, R. S., Nesic, Z., Johnson, M. S., and Smukler, S.: Characterization of shortwave and longwave properties of several plastic film mulches and their impact on the surface energy balance and soil temperature, Sol. Energy, 214, 457-470, https://doi.org/10.1016/j.solener.2020.11.058, 2021.
Junta de Andalucía. Mapa de Suelos de Andalucía: https://portalrediam.cica.es/VisorRediam/?lyr.add.wms=http%3A%2F%2Fwww.juntadeandalucia.es%2Fmedioambiente%2Fmapwms%2FREDIAM_Suelos_Andalucia%3F, last access: 9 April 2025.
Kawecki, D. and Nowack, B.: Polymer-specific modeling of the environmental emissions of seven commodity plastics as macro- and microplastics, Environ. Sci. Technol., 53, 9664-9676, https://doi.org/10.1021/acs.est.9b02900, 2019.
Landrigan, P. J., Raps, H., Cropper, M., Bald, C., Brunner, M., Canonizado, E. M., Charles, D., Chiles, T. C., Donohue, M. J., Enck, J., Fenichel, P., Fleming, L. E., Ferrier-Pages, C., Fordham, R., Gozt, A., Griffin, C., Hahn, M. E., Haryanto, B., Hixson, R., Ianelli, H., James, B. D., Kumar, P., Laborde, A., Law, K. L., Martin, K., Mu, J., Mulders, Y., Mustapha, A., Niu, J., Pahl, S., Park, Y., Pedrotti, M.-L., Pitt, J. A., Ruchirawat, M., Seewoo, B. J., Spring, M., Stegeman, J. J., Suk, W., Symeonides, C., Takada, H., Thompson, R. C., Vicini, A., Wang, Z., Whitman, E., Wirth, D., Wolff, M., Yousuf, A. K., and Dunlop, S.: The Minderoo-Monaco commission on plastics and human health, Annals of Global Health, 89, 23, https://doi.org/10.5334/aogh.4056, 2023.
Martin, C., Parkes, S., Zhang, Q., Zhang, X., McCabe, M. F., and Duarte, C. M.: Use of unmanned aerial vehicles for efficient beach litter monitoring, Mar. Pollut. Bull., 131, 662-673, https://doi.org/10.1016/j.marpolbul.2018.04.045, 2018.
Muñoz-Rojas, M., Jordán, A., Zavala, L., De la Rosa, D., Abd-Elmabod, S., and Anaya-Romero, M.: Organic carbon stocks in Mediterranean soil types under different land uses (southern Spain), Solid Earth, 3, 375-386, https://doi.org/10.5194/se-3-375-2012, 2012.
Scarascia-Mugnozza, G., Sica, C., and Russo, G.: Plastic materials in European agriculture: actual use and perspectives, J. Agric. Eng., 42, 15-28, https://doi.org/10.4081/jae.2011.3.15, 2011.
Steinmetz, Z., Löffler, P., Eichhöfer, S., David, J., Muñoz, K., and Schaumann, G. E.: Are agricultural plastic covers a source of plastic debris in soil? A first screening study, Soil, 8, 31-47, https://doi.org/10.5194/soil-8-31-2022, 2022.
Thompson, R. C., Olsen, Y., Mitchell, R. P., Davis, A., Rowland, S. J., John, A. W., McGonigle, D., and Russell, A. E.: Lost at sea: where is all the plastic?, Science, 304, 838, https://doi.org/10.1126/science.1094559, 2004.
Veenstra, T. S. and Churnside, J. H.: Airborne sensors for detecting large marine debris at sea, Mar. Pollut. Bull., 65, 63-68, https://doi.org/10.1016/j.marpolbul.2010.11.018, 2012.
Zhang, H., Shi, P., Crucil, G., Wesemael, B., Limbourg, Q., and Van Oost, K.: Evaluating the capability of a UAV-borne spectrometer for soil organic carbon mapping in bare croplands, Land Degrad. Dev., 32, 4375-4389, https://doi.org/10.1002/ldr.4043, 2021.