

Archives of Environmental Science and Technology

Review Article

remote sensing monitoring in the Management of microplastic pollution among agricultural soils

Berg S^{1*}, Johansson L² and Pedersen E³

¹Department of Clinical Environmental Science, Tajo Institute for Advanced Environmental Technology, Denmark

²Division of Environmental Science, Po Institute for Advanced Environmental Science, Finland

³Department of Environmental Science, Parana Institute for Advanced Environmental Technology, Sweden

*Address for Correspondence: Solveig Berg, Department of Clinical Environmental Science, Tajo Institute for Advanced Environmental Technology, Denmark; E-mail: solveig.berg@tajo.edu

Received: 24 July 2025; Accepted: 30 October 2025; Published: 21 January 2026.

Citation of this article: Berg S, Johansson L, Pedersen E (2026) remote sensing monitoring in the Management of microplastic pollution among agricultural soils. Arch Environ Sci Technol, 1(1): 01-06. DOI: [10.5281/zenodo.22812727](https://doi.org/10.5281/zenodo.22812727)

Copyright: © 2026 Solveig Berg, et al. This is an open access article distributed under the [Creative Commons Attribution License](#), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Abstract

Plastic mulch films, sewage sludge amendment, and irrigation-borne debris have made agricultural soil a major, still poorly quantified microplastic reservoir. This review synthesizes remote sensing studies mapping plastic-mulched farmland by satellite, radar, and unmanned aerial platforms alongside ground-truthed soil microplastic surveys, asking how well mapped mulch extent serves as a proxy for actual soil contamination.

Multispectral and radar classification of plastic-mulched cropland now routinely reaches 85-93% accuracy, but no reviewed study paired that mapping directly with co-located, depth-resolved soil microplastic sampling. Ground surveys show sludge amendment and irrigation contribute substantially alongside mulch degradation. Adapting the tighter spectral validation methods already used for floating marine litter could close this gap and convert mulch-extent mapping into an actionable soil microplastic management tool.

Keywords: microplastics; agricultural soil; remote sensing; plastic mulch; soil pollution monitoring

1. Introduction

Plastic mulch films, greenhouse sheeting, and plastic-laced compost and sewage sludge have made cultivated land one of the largest reservoirs of microplastic contamination on the planet, with modelled inputs to agricultural soils now estimated to exceed those reaching the open ocean surface each year [1]. Rillig first framed the soil compartment as an overlooked microplastic sink, noting that particles shed from mulch, irrigation infrastructure, and atmospheric deposition accumulate in a matrix with far slower turnover than surface water [2], and subsequent reviews have confirmed that terrestrial systems, and agricultural soils specifically, receive a disproportionate and still poorly quantified share of global plastic loading [3,4,5]. Repeated tillage, plastic mulch degradation, and sludge or compost amendment layer these inputs into distinct depth and particle-size distributions that differ systematically from aquatic microplastic pollution [6,7].

Ground-based surveys, relying on sieving, density separation, and spectroscopic identification of extracted particles, remain the analytical gold standard for confirming microplastic identity and polymer type [8,5]. They are, however, destructive, labor-intensive, and spatially sparse: a single farm-scale survey typically samples a few dozen to a few hundred points, which is adequate for characterizing contamination at one location but cannot support the regional and multi-year surveillance that policy on plastic mulch use, sludge application, or soil remediation now requires [9,10]. Remote sensing offers a complementary route to that surveillance gap. Because intact plastic mulch and macro-scale plastic residue produce a distinctive spectral, textural, and dielectric signature relative to bare soil and vegetation, multispectral, radar, and unmanned aerial platforms have been used with increasing success to map plastic-covered cropland at scales from individual fields to entire provinces [11,12,13].

This review synthesizes the remote sensing literature on monitoring plastic contamination in agricultural land use, considers how well mapped plastic-mulch extent serves as a proxy for the microplastic pollution that mulch degradation generates, and evaluates where the method has, and has not, been validated against ground-truthed soil microplastic measurements. We further draw on the marine and coastal remote sensing literature, where optical and hyperspectral detection of floating plastic debris is more mature, to identify transferable methods and sensor requirements for the agricultural soil problem [14,15,16].

2. Methods

We synthesized peer-reviewed studies published between 2010 and 2022 that either (i) used satellite, radar, or unmanned aerial system (UAS) imagery to map plastic-mulched or plastic-contaminated agricultural land, or (ii) reported ground-truthed measurements of microplastic abundance in agricultural soils that could plausibly serve as validation targets for such mapping. Search terms combined "plastic mulch," "agricultural soil," "microplastic," and platform-specific terms ("Landsat," "Sentinel," "Radarsat," "UAV," "hyperspectral") across the environmental science and remote sensing literature. We extracted, where reported, the sensor and platform used, the spatial and temporal resolution of the imagery, the classification method (spectral index thresholding, decision-tree, object-based image analysis, random forest, or deep learning), and the reported overall classification accuracy or kappa coefficient [17,18,19].

For studies reporting ground microplastic concentrations, we recorded the sampling depth, extraction method, particle size range considered, and reported abundance, expressed per kilogram of dry soil or per square meter of surface area where convertible, to assess how directly reported concentrations could be reconciled with mapped plastic-cover extent [20,21,22]. We also reviewed the

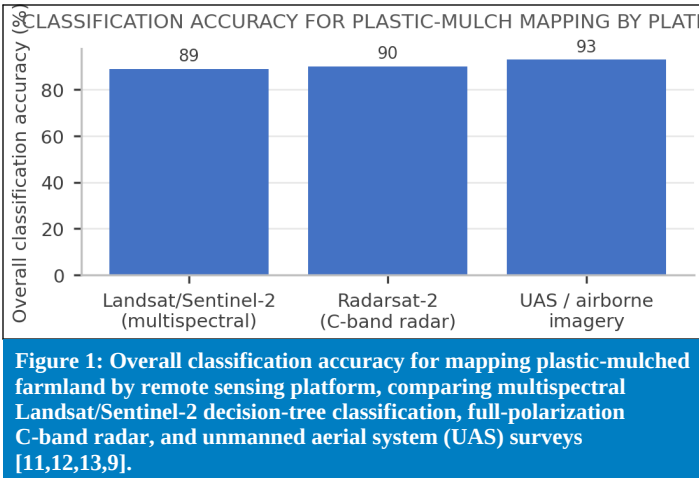
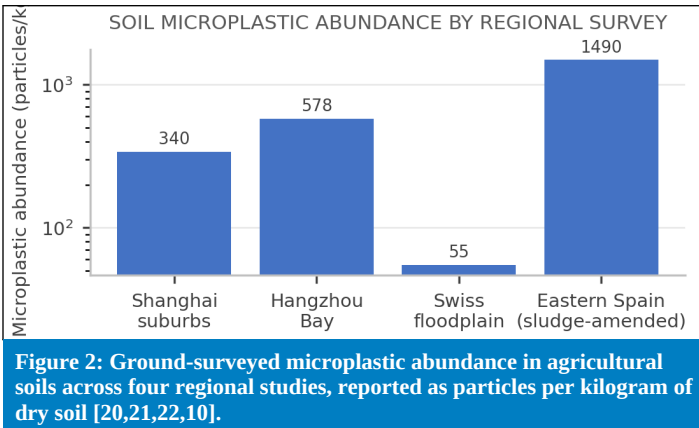
marine floating-litter detection literature for spectral and platform lessons applicable to soil-surface plastic, since optical separability of polyethylene and polypropylene from background substrate has been characterized in more controlled detail in that setting than for soil [16,23,24]. Because plastic mulch residue and airborne or waterborne microplastic transport are mechanistically linked but not identical measurement targets, we treat mulch-extent mapping accuracy and soil microplastic abundance as two related but distinct outcome measures throughout the synthesis, rather than assuming one is a direct surrogate for the other [7,25].

Table 1: Remote sensing platforms used to map plastic-mulched or plastic-contaminated agricultural land, with typical spatial resolution and reported classification performance [11,12,13,19,9].			
Platform / sensor	Typical resolution	Classification method	Reported accuracy
Landsat 5/8 (TM/OLI)	30 m	Decision-tree, spectral index	85-90%
Sentinel-2 (MSI)	10-20 m	Random forest, time-series	88-92%
Radarsat-2 (C-band, full pol.)	8-10 m	Polarimetric classification	~90%, cloud-independent
UAS / airborne imagery	<0.1 m	Object-based image analysis	>90%, farm-scale extent

3. Results

Across the reviewed mapping studies, classification accuracy for plastic-mulched farmland varied substantially by platform and method. Studies using multispectral Landsat or Sentinel-2 imagery with decision-tree or spectral-index approaches typically reported overall accuracies in the 85-92% range for distinguishing plastic-mulched fields from bare soil and vegetation at 10-30 m resolution [11,12,19]. Radar-based classification using full-polarization C-band data achieved comparable or slightly higher accuracy, and critically remained usable under the cloud cover that frequently obscures optical acquisitions during the planting season when mulch film is freshly laid and most spectrally distinct [13]. Time-series approaches that combine

multiple Sentinel-2 acquisitions across the growing season with random-forest classifiers further improved discrimination of plastic-mulched parcels from bare soil and from crops re-emerging through degraded film, reducing the seasonal misclassification that single-date imagery is prone to [26]. Unmanned aerial and very-high-resolution airborne platforms, when deployed for farm-scale surveys, achieved the highest reported accuracies (generally above 90%) but at the cost of spatial coverage practical only for individual farms or research plots rather than regional monitoring [9,24].



Ground-truthed soil microplastic surveys, by contrast, report highly variable abundances that only loosely track mapped plastic-mulch extent. Farmland surveys in the Shanghai suburbs found microplastic abundances ranging from roughly 78 to 1,075 particles per kilogram of

dry soil, with fragments and fibers dominating and abundance correlating with years of mulch use and with distance from plastic-processing facilities rather than with instantaneous field-level mulch cover [20]. Surveys on the Hangzhou Bay coastal plain similarly found that sewage irrigation and organic fertilizer application, not solely plastic mulching, contributed substantially to soil microplastic loading, indicating that mulch-extent maps alone underestimate total contamination in intensively managed regions [21]. European floodplain and sludge-amended soils showed comparable orders of magnitude, with Swiss floodplain sediments carrying microplastic concentrations linked to upstream urban and agricultural runoff rather than to local plastic mulch use at all [22,10,27].

The marine and coastal literature offers a more tightly validated spectral picture. Airborne shortwave-infrared hyperspectral imaging has demonstrated clear separability of polyethylene, polypropylene, and other common polymers from water, sand, and vegetation backgrounds, with distinctive absorption features near 1215 nm and 1732 nm enabling polymer-resolved classification rather than simple presence-absence detection [16]. Sentinel-2-based floating litter detection using partial spectral unmixing has achieved target identification against a fully quantified radiometric background in coastal test sites, a level of quantitative validation not yet matched in soil-surface plastic mapping [15,23].

4. Discussion

The evidence supports remote sensing as a genuinely useful tool for tracking the extent of plastic mulch application at field to regional scale, with multiple independent studies converging on 85% or higher classification accuracy using multispectral and radar platforms already in routine operational use [11,12,13,19]. This capability matters directly for microplastic pollution management, because mulch-film degradation is one of

the dominant and most policy-tractable sources of soil microplastic input, and regional mulch-extent time series can flag where degradation-driven loading is likely accumulating fastest, informing where soil sampling and remediation resources should be prioritized [28,7,29].

Table 2: Reported sources contributing to soil microplastic loading beyond plastic mulch film, drawn from regional ground surveys [21,10,27,25].		
Contributing pathway	Region studied	Reported relative contribution
Plastic mulch film degradation	Shanghai suburbs, China	Dominant; scales with years of mulch use
Sewage sludge / wastewater irrigation	Eastern Spain	Substantial vehicle for microplastic input
Organic fertilizer / sludge amendment	Hangzhou Bay, China	Comparable to mulch-derived input
Wind erosion transport	Semi-arid cropland	Redistributes low-density particles off-site

The gap the synthesis exposes is validation, not sensor capability. No study we identified paired systematic, multi-date remote sensing classification of mulch extent or condition directly against co-located, depth-resolved soil microplastic sampling at a comparable spatial scale; the mapping and ground-truth literatures have developed largely in parallel [5,30]. This matters because soil microplastic abundance depends on cumulative mulch history, tillage-driven vertical redistribution, wind and water erosion transport, and non-mulch inputs such as sludge and irrigation water, none of which a single-date or even multi-year mulch-extent classification captures on its own [25,31,32]. The marine floating-litter literature demonstrates what a tighter validation loop looks like: spectral libraries built from known polymer targets, radiometric calibration against a quantified background, and field campaigns timed to satellite overpass, all of which remain rare in the agricultural soil setting [16,14,15]. Closing that gap would let mulch-extent products function as a genuine leading indicator of soil microplastic risk rather than a loosely related land-cover statistic, and would let managers target the sludge-amendment and long-tenure mulch-use areas that ground surveys repeatedly flag as disproportionate

contributors, but that remote sensing alone cannot yet distinguish from well-managed, lower-risk plastic-mulched land [10,21,33].

Land-use change monitoring more broadly has long relied on exactly this kind of layered remote sensing and ground-validation approach to convert land-cover classification into an actionable management signal, and the plastic-mulch problem is well positioned to follow that same trajectory as UAS-based calibration campaigns and hyperspectral soil-surface libraries mature [34,17].

5. Conclusion

Remote sensing already provides operationally accurate maps of plastic-mulched agricultural land at scales that ground survey alone cannot reach, and that capability is directly relevant to managing the microplastic pollution mulch degradation generates. What is still missing is a validated, quantitative link between mapped mulch extent or condition and the depth-resolved soil microplastic concentrations that ultimately determine ecological and agronomic risk. Building that link, by pairing multi-platform mulch-extent time series with systematic, co-located soil sampling and by adapting the spectral and radiometric calibration methods already demonstrated for floating marine litter, is the most direct route to turning remote sensing from a land-cover mapping tool into a genuine microplastic pollution management instrument for agricultural soils.

6. References

1. Nizzetto, L., Futter, M., Langaas, S. (2016) Are agricultural soils dumps for microplastics of urban origin? Environmental Science & Technology, 50(20): 10777-10779. DOI: [10.1021/acs.est.6b04140](https://doi.org/10.1021/acs.est.6b04140)
2. Rillig, M.C. (2012) Microplastic in terrestrial ecosystems and the soil? Environmental Science & Technology, 46(12): 6453-6454. DOI: [10.1021/es302011r](https://doi.org/10.1021/es302011r)
3. Horton, A.A., Walton, A., Spurgeon, D.J., Lahive, E., Svendsen, C. (2017) Microplastics in freshwater and terrestrial environments: evaluating the current understanding to identify the knowledge gaps and future research priorities. Science of the Total Environment, 586: 127-141. DOI: [10.1016/j.scitotenv.2017.01.190](https://doi.org/10.1016/j.scitotenv.2017.01.190)
4. Hurley, R.R., Nizzetto, L. (2018) Fate and occurrence of micro(nano)plastics in soils: knowledge gaps and possible risks. Current Opinion in Environmental Science & Health, 1: 6-11. DOI: [10.1016/j.coesh.2017.10.006](https://doi.org/10.1016/j.coesh.2017.10.006)
5. He, D., Luo, Y., Lu, S., Liu, M., Song, Y., Lei, L. (2018) Microplastics in soils: analytical methods, pollution characteristics and ecological risks. TrAC Trends in Analytical Chemistry, 109: 163-172. DOI: [10.1016/j.trac.2018.10.006](https://doi.org/10.1016/j.trac.2018.10.006)
6. Zhang, G.S., Liu, Y.F. (2018) The distribution of microplastics in soil aggregate fractions in southwestern China. Science of the Total Environment, 642: 12-20. DOI: [10.1016/j.scitotenv.2018.06.004](https://doi.org/10.1016/j.scitotenv.2018.06.004)
7. Huang, Y., Liu, Q., Jia, W., Yan, C., Wang, J. (2020) Agricultural plastic mulching as a source of microplastics in the terrestrial environment. Environmental Pollution, 260: 114096. DOI: [10.1016/j.envpol.2020.114096](https://doi.org/10.1016/j.envpol.2020.114096)
8. Zhang, S., Yang, X., Gertsen, H., Peters, P., Salanki, T., Geissen, V. (2018) A simple method for the extraction and identification of light density microplastics from soil. Science of the Total Environment, 616-617: 1056-1065. DOI: [10.1016/j.scitotenv.2017.10.213](https://doi.org/10.1016/j.scitotenv.2017.10.213)
9. Piehl, S., Leibner, A., Loder, M.G.J., Dris, R., Bogner, C., Laforsch, C. (2018) Identification and quantification of macro- and microplastics on an agricultural farmland. Scientific Reports, 8: 17950. DOI: [10.1038/s41598-018-36172-y](https://doi.org/10.1038/s41598-018-36172-y)
10. Corradini, F., Meza, P., Eguiluz, R., Casado, F., Huerta-Lwanga, E., Geissen, V. (2019) Evidence of microplastic accumulation in agricultural soils from sewage sludge disposal. Science of the Total Environment, 671: 411-420. DOI: [10.1016/j.scitotenv.2019.03.368](https://doi.org/10.1016/j.scitotenv.2019.03.368)

11. Lu, L., Di, L., Ye, Y. (2014) A decision-tree classifier for extracting transparent plastic-mulched landcover from Landsat-5 TM images. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 7(11): 4548-4558. DOI: [10.1109/JSTARS.2014.2327226](https://doi.org/10.1109/JSTARS.2014.2327226)
12. Hasituya, Chen, Z., Wang, L., Wu, W., Jiang, Z., Li, H. (2016) Monitoring plastic-mulched farmland by Landsat-8 OLI imagery using spectral and textural features. Remote Sensing, 8(11): 353. DOI: [10.3390/rs8110353](https://doi.org/10.3390/rs8110353)
13. Hasituya, Chen, Z. (2017) Mapping plastic-mulched farmland with C-band full polarization Radarsat-2 data. Remote Sensing, 9(3): 216. DOI: [10.3390/rs9030216](https://doi.org/10.3390/rs9030216)
14. Topouzelis, K., Papageorgiou, D., Suaria, G., Aliani, S. (2019) Floating marine litter detection algorithms and techniques using optical remote sensing data: a review. Marine Pollution Bulletin, 149: 110624. DOI: [10.1016/j.marpolbul.2019.110624](https://doi.org/10.1016/j.marpolbul.2019.110624)
15. Biermann, L., Clewley, D., Martinez-Vicente, V., Topouzelis, K. (2020) Finding plastic patches in coastal waters using optical satellite data. Scientific Reports, 10: 5364. DOI: [10.1038/s41598-020-62298-z](https://doi.org/10.1038/s41598-020-62298-z)
16. Garaba, S.P., Aitken, J., Slat, B., Dierssen, H.M., Zielinski, O. (2018) Sensing ocean plastics with an airborne hyperspectral shortwave infrared imager. Environmental Science & Technology, 52(20): 11699-11707. DOI: [10.1021/acs.est.8b02855](https://doi.org/10.1021/acs.est.8b02855)
17. Blaschke, T. (2010) Object based image analysis for remote sensing. ISPRS Journal of Photogrammetry and Remote Sensing, 65(1): 2-16. DOI: [10.1016/j.isprsjprs.2009.06.004](https://doi.org/10.1016/j.isprsjprs.2009.06.004)
18. Lu, L., Di, L., Ye, Y., Zhang, C., Rahman, M.S. (2015) A phenology-based method for identifying plastic-mulched agricultural land from moderate resolution imagery. Photogrammetric Engineering & Remote Sensing, 81(11): 855-864. DOI: [10.14358/PERS.81.11.855](https://doi.org/10.14358/PERS.81.11.855)
19. Wang, Z., Wu, P., Zhang, Y., Chen, Z. (2021) Mapping plastic-mulched farmland with multi-temporal Sentinel-2 imagery using Google Earth Engine. Remote Sensing, 13(11): 2137. DOI: [10.3390/rs13112137](https://doi.org/10.3390/rs13112137)
20. Liu, M., Lu, S., Song, Y., Lei, L., Hu, J., Lv, W., et al. (2018) Microplastic and mesoplastic pollution in farmland soils in suburbs of Shanghai, China. Environmental Pollution, 242: 855-862. DOI: [10.1016/j.envpol.2018.07.051](https://doi.org/10.1016/j.envpol.2018.07.051)
21. Zhou, B., Wang, J., Zhang, H., Shi, H., Fei, Y., Huang, S., et al. (2020) Microplastics in agricultural soils on the coastal plain of Hangzhou Bay, east China: multiple sources other than plastic mulching film. Journal of Hazardous Materials, 388: 121814. DOI: [10.1016/j.jhazmat.2019.121814](https://doi.org/10.1016/j.jhazmat.2019.121814)
22. Scheurer, M., Bigalke, M. (2018) Microplastics in Swiss floodplain soils. Environmental Science & Technology, 52(6): 3591-3598. DOI: [10.1021/acs.est.7b06003](https://doi.org/10.1021/acs.est.7b06003)
23. Papageorgiou, D., Topouzelis, K., Suaria, G., Aliani, S., Corradi, P. (2022) Sentinel-2 detection of floating marine litter targets with partial spectral unmixing and spectral comparison with Native floating macroalgae. Remote Sensing, 14(23): 5997. DOI: [10.3390/rs14235997](https://doi.org/10.3390/rs14235997)
24. Fallati, L., Polidori, A., Salvatore, C., Saponari, L., Savini, A., Galli, P. (2019) Anthropogenic marine debris assessment with unmanned aerial vehicle imagery and deep learning. Science of the Total Environment, 693: 133581. DOI: [10.1016/j.scitotenv.2019.133581](https://doi.org/10.1016/j.scitotenv.2019.133581)
25. Rezaei, M., Riksen, M.J.P.M., Sirjani, E., Sameni, A., Geissen, V. (2019) Wind erosion as a driver for transport of light density microplastics. Science of the Total Environment, 669: 273-281. DOI: [10.1016/j.scitotenv.2019.02.382](https://doi.org/10.1016/j.scitotenv.2019.02.382)
26. Yu, X., Yi, W., Liu, X., Ma, S. (2021) Extraction of plastic-mulched farmland based on time-series Sentinel-2 imagery and random forest. Journal of Remote Sensing, 25: 1035-1046.
27. van den Berg, P., Huerta-Lwanga, E., Corradini, F., Geissen, V. (2020) Sewage sludge application as a vehicle for

-
- microplastics in eastern Spanish agricultural soils. Environmental Pollution, 261: 114198. DOI: [10.1016/j.envpol.2020.114198](https://doi.org/10.1016/j.envpol.2020.114198) [10.1146/annurev.energy.28.050302.105459](https://doi.org/10.1146/annurev.energy.28.050302.105459)
28. Steinmetz, Z., Wollmann, C., Schaefer, M., Buchmann, C., David, J., Troger, J., et al. (2016) Plastic mulching in agriculture: trading short-term agronomic benefits for long-term soil degradation? Science of the Total Environment, 550: 690-705. DOI: [10.1016/j.scitotenv.2016.01.153](https://doi.org/10.1016/j.scitotenv.2016.01.153)
29. Qi, Y., Yang, X., Pelaez, A.M., Huerta Lwanga, E., Beriot, N., Gertsen, H., et al. (2018) Macro- and micro-plastics in soil-plant system: effects of plastic mulch film residues on soil and maize growth. Science of the Total Environment, 645: 1048-1056. DOI: [10.1016/j.scitotenv.2018.07.229](https://doi.org/10.1016/j.scitotenv.2018.07.229)
30. Ng, E.L., Huerta Lwanga, E., Eldridge, S.M., Johnston, P., Hu, H.W., Geissen, V., Chen, D. (2018) An overview of microplastic and nanoplastic pollution in agroecosystems. Science of the Total Environment, 627: 1377-1388. DOI: [10.1016/j.scitotenv.2018.01.341](https://doi.org/10.1016/j.scitotenv.2018.01.341)
31. Huerta Lwanga, E., Gertsen, H., Gooren, H., Peters, P., Salanki, T., van der Ploeg, M., et al. (2017) Incorporation of microplastics from litter into burrows of Lumbricus terrestris. Environmental Pollution, 220: 523-531. DOI: [10.1016/j.envpol.2016.09.096](https://doi.org/10.1016/j.envpol.2016.09.096)
32. de Souza Machado, A.A., Kloas, W., Zarfl, C., Hempel, S., Rillig, M.C. (2018) Microplastics as an emerging threat to terrestrial ecosystems. Global Change Biology, 24(4): 1405-1416. DOI: [10.1111/gcb.14020](https://doi.org/10.1111/gcb.14020)
33. de Souza Machado, A.A., Lau, C.W., Till, J., Kloas, W., Lehmann, A., Becker, R., et al. (2019) Impacts of microplastics on the soil biophysical environment. Environmental Science & Technology, 53(10): 6044-6052. DOI: [10.1021/acs.est.9b02212](https://doi.org/10.1021/acs.est.9b02212)
34. Lambin, E.F., Geist, H.J., Lepers, E. (2003) Dynamics of land-use and land-cover change in tropical regions. Annual Review of Environment and Resources, 28: 205-241. DOI: [10.1146/annurev.energy.28.050302.105459](https://doi.org/10.1146/annurev.energy.28.050302.105459)