Contribution to early policy recommendation

Use and Management of Agricultural Plastics

Chemical and plastic pollution is outside the safe operating space of the planetary boundary for novel entities and there is a severe global threat from plastic pollution. The urgent need to address and reduce plastic pollution in the terrestrial agro-ecosystem requires adequate risk assessment before agro-plastics enter the market and monitoring their fate after application. There is a consensus that agricultural plastic cause plastic pollution to soil. Policy, regulatory and management actions deemed to prevent such a pollution are expected.

MINAGRIS and PAPILLONS: Two multi-actor projects are in place to combat soil pollution associated with agricultural plastics.

BACKGROUND: The H2020 work programme supports two projects with 20 partners each across the European countries. Both PAPILLONS and MINAGRIS started in 2021, with the aim to unfold the ecological and socioeconomic effects of soil pollution associated with the use of agricultural plastics (AP). *In particular*, the two projects will establish an inventory of the uses of AP in Europe, explore the effects of AP on soil quality (soil biota, soil structure), and study fate, fragmentation, microbial colonisation and decay of AP in soil. Overall sustainability performance assessment of AP use in comparison to alternative techniques, large scale dissemination of results and involvement of end-users, the youth, students and the various societal groups will be addressed to raise awareness and develop ways out of a world of plastic pollution and into a world of sustainable use of plastics in agricultural applications.

Notes on endorsements: The present document was prepared and approved by PAPILLONS and MINAGRIS partners. The following research groups belonging to PAPILLONS: Agricultural University of Athens, University of Bari and Institute of Polymers, Composites and Biomaterials-CNR, have abstained from approving the document as they are not endorsing it.

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I. Major knowledge gaps

We have identified the following knowledge gaps in relation to AP pollution of agricultural soils:

1. Insufficient systematic knowledge on the amounts of (micro and nano) plastics that are unintentionally introduced into agricultural soils through agricultural practices (such as irrigation from plastic contaminated surface waters, and application of compost/sewage sludge/manure contaminated with plastics) or from other polluting sources (littering, tyre wear, etc.). Several reports have been published recently addressing the use of AP (e.g. Eunomia, FAO, UNEP)[1,2], but quantification of the resulting soil pollution linked to the various AP sources is still lacking. A concerted effort to consolidate confidence in the inventories is necessary. These data should be available for all stakeholders, including the independent science sector, AP users and producers, NGO's, regulatory bodies and policy makers. The Circular Plastic Alliancex is a EU initiative aimed at taking actions in optimizing the recovery and recycling as well as the overall value chain of plastic materials, including those used in agriculture (https://ec.europa.eu/growth/industry/strategy/industrial-alliances/circular-plastics-alliance_it)

2. No study has empirically analysed the long term effects of the accumulation of debris from the fragmentation of conventional polymer-based AP on soil health, soil biodiversity and related soil ecosystem services under different soil conditions (e.g. temperature, moisture)[3]. Scientific works have emerged during the last 3 years documenting interactions between soil microbiome and soil fauna, and micro- and nanoplastic pollution[3–13]. Some studies have highlighted adverse effects on the viability of organisms and important ecological functions, already at environmentally relevant micro- and nanoplastic concentrations[5,10]. Toxicological data from a longer-term temporal exposure framework are essential for assessing the sustainability of several practices based on AP. The actual risk assessment does not take chronic risks into consideration nor risks for soil health, biodiversity and ecosystem services.

3. Lack of knowledge on long-term effects resulting from the use of biodegradable polymer alternatives in AP applications (e.g. biodegradable mulching films).[14–34] The EN 17033: 2018 standard sets criteria for degradability and adverse ecological effects associated with these materials. However, these tests are generally conducted under standard laboratory conditions (20-25°C, constant soil humidity), and it is unclear whether they sufficiently represent the range of conditions (pH, texture, temperature and moisture) that reflect all European agricultural environments in which these products are used. Also, the transport of macro-, micro- or nanoplastics by wind may bring biodegradable plastics to the surrounding environments, in which degradation rate might differ from the soils used for testing[35–43]. No data on plastics degradability in water (e.g. ground and surface waters) are required for certification. This assessment would be important as the degrading plastic particles could be transferred to different environmental compartments than those they are certified for.

4. Lack of available data on the composition and long-term effects of chemical plastic additives used in AP products. Safety requirements for the chemical additives present in AP used in contact with both soil and crops in protected cultivation systems are set as part of the authorization of chemical use within the REACH registration. We argue that the current fragmentary knowledge on the use and degradation/ageing of AP can result in a misestimation of the risks.

5. Insufficient understanding of the lifecycle of AP products with regard to fragmentation into micro- and nanoplastics. This includes a lack of models to assess the lifetime of each AP product and identify when plastics should be removed from the field to avoid fragmentation. Such a model should depend on the physical and chemical properties of the AP, their thickness as well as the climate zone, environmental conditions, agricultural plastics use, and so on.

6. Uptake of micro and nanoplastics by crops and their accumulation in the terrestrial food chain has been proven in recent studies. [44–48] Still, the risk for human health by such uptake processes has not been studied and remains unknown. The associated risk for consumers should be quantified and considered in a future risk assessment approach.

7. Limited knowledge about the interaction of APs with other organic pollutants intentionally (pesticides) or unintentionally (veterinary drugs) released in agricultural soils. [49–57] Pesticides and veterinary drugs are regularly present in agricultural soils and are expected to interact with (conventional and biodegradable) plastics. Studies on the transport of plastic residues with adsorbed pesticides and the related risks for environmental and human health are limited. Furthermore, little is known about the interactive effects of plastics and pesticides or veterinary drugs on soil ecosystem functioning. The effects of AP on the soil biota and agricultural production could be magnified in the presence of other organic pollutants and this is something that should be looked at under realistic agricultural scenarios.

8. No comprehensive understanding of the role of the plastisphere as a carrier for the dispersal of plant and human pathogens, and antibiotic resistance genes (ARGs).[58–63] Plastisphere, the interface of plastics with soil, offers a hotspot for microbial colonization. Thus microplastics transport in the soil profile could facilitate, short or long-distance dispersal of plant and human microbial pathogens. The latter could confer ARGs that might be further dispersed as a cargo of microplastics. The potential of plastics to act as carriers of hazardous microorganisms in agricultural soils, threatening agricultural production and human health, remains unknown. We suggest the development and implementation of tools to better understand and quantify the contribution of MPs in the dispersal of pathogenic organisms and ARGs from agricultural soils to the human population.

Our early policy recommendations

PAPILLON and MINAGRIS started recently; however, with the expertise available in both project consortia and based on a first screening of knowledge gaps (above), we are already able to outline preliminary policy recommendations – both knowledge gaps and policy recommendations will be refined and backed up based on a concerted and aligned scientific effort in both projects – will yield a concrete set of actionable policy recommendations by 2025 in support of the EU zero pollution strategy and new EFSA regulations for pre market procedures and the use of agroplastics.

In the following, whenever not specified otherwise recommendations are given for both conventional and biodegradable platic-based materials.

PR1: Long-term environmental and agricultural sustainability should be the primary goal of new policies addressing AP use and management in Europe.

- PR1a: Pollution of soils by non-degradable plastics is poorly reversible and the related ecosystem and human health risk should be addressed by adequate means. Soil is a non-renewable resource. Conventional plastics can persist for decades or even centuries in the environment, so practices that result in continuous releases of plastic debris, however small, should be critically evaluated with regard to their sustainability. Policy should acknowledge this by taking into consideration the ecological and agricultural risks posed by an underlying increase in soil pollution over the medium and long-term. Unknown risk for human health through the accumulation of micro and nanoplastics in the food chain should be taken into consideration as well as the off-site effect by transport of plastic debris to the surrounding environmental compartments. Hence, we recommend that **policy development should incorporate the definition of sustainability criteria** that consider long term environmental and agricultural pressures and impacts. Plasticulture should be endorsed by the policy when the **social and environmental benefits (and not only economic benefits) exceed the social and environmental costs**, and this should be assessed based on a medium and long-term holistic perspective.

- PR1b: The use of biodegradable polymers as alternative materials for AP products should follow strict criteria related to safe and sustainable -by-design. Evaluation of current standards for certifying biodegradability is needed with regard to their suitability to represent the range of environmental conditions in which biodegradable AP are (and will be) used in Europe. Consideration should also be given to the potential for residues of biodegradable AP products to enter water systems, in which they may represent persistent pollution. Transport by wind and the resulting pollution of the surrounding environment should as well be taking into consideration. The sustainability of long-term biodegradable AP use should be considered, particularly with regard to the potential risks of particles undergoing degradation, **the accumulation of degradation products or other alterations to soil systems (e.g. changes to soil structure or nutrient balance) resulting from repeated applications** of biodegradable polymers to soils over the medium and long term should be taken into consideration in risk assessment.

- PR1c: The fate of additives from all AP and the related risk should be taken into consideration as well as the synergistic effect of plastic debris and pesticide residues. **The additives (all REACH approved) should be disclosed (as for other type of products) to the retailers, users and the public.** Bioaccumulation in the food chain and the synergetic risk for human health should be studied and included into the approval procedure.

PR2: Policies should promote a better and more traceable end-of-life management for APs, harmonized across Europe.

- PR2a: For conventional polymers used in plasticulture, materials, practices and waste management approaches that sustainably minimize the environmental footprint should be privileged above the status quo. Our group understanding is that current materials and practices do result in pollution – at least in some parts of Europe – with AP mismanagement in post-use being a major source of this pollution. Policies that encourage effective application, maintenance, removal and waste handling of AP will result in lower micro- and nanoplastic inputs to soils. Key instruments include, for example, extender producer responsibility schemes and technology and systems that enable a full traceability of materials in pre and post use. The CPA initiative is taking care of these end of life aspects. **Any use of AP should be tightly linked (by law) to an approved and traceable material and waste management protocol.**

- PR2b: Policy should cautiously consider the implications of setting European average flat thresholds when converting policies into regulation. In Europe, the use and management of AP can vary significantly from region to region. Different environmental, economic and agricultural drivers will determine different outcomes for policy implementation and impacts in different parts of Europe. If flat average thresholds are to be adopted for the whole of Europe (e.g. an undesirable acceptable pollution release), these should be designed taking into consideration sensitive regions and different scenarios related to the use and (mis-) management of AP. The processes that facilitate or accelerate soil pollution from different AP products are diverse and take place at different scales in different regions. Such legislation should incorporate a common and rational management of plastics at the European level; the EC should promote sustainable management by means of increasing the traceability of plastics used in agriculture and the generated plastic waste.

- PR2c: Policy should focus on strongly disincentivising international trade of plastic waste unless there is a verified guarantee that the recipient countries are capable of effectively processing these materials through the formal economy sector with due safeguarding of labour and environmental standards. Mismanagement of waste causes severe environmental and social issues. **Closing the loop of the agricultural plastic life cycle within national or EU borders should be a main focus of the policy.**

- PR2d: A system with zero plastic wastes and pollution must be enhanced through closing the loop between producers and users. The producers also should be responsible of the collection or re-use of the plastic agricultural materials after being used or efficient systems should be stablished on national base, e.g. an EPR system as proposed in the FAO report.

PR3: Policy on AP use should be harmonised with other existing policies or regulatory frameworks.

- PR3a: The EC should align AP policies and regulation with the management strategies adopted in existing chemical and pesticide regulatory frameworks, which are based on the concept of risk assessment and risk management. Littering and micro-/nanoplastic that is unintentionally released from AP during use and end of life could be handled via chemical regulation infrastructure, for example as part of REACH. AP use should also acknowledge the new elements emerging from the Soil Health Strategy, whereby new Environmental Quality Standards for agricultural soils may be set (e.g. **the maximum amounts of plastic a soil can contain to be legally used in agricultural production**). Risk management-based approaches acknowledge both controlled and small risks for environmental and/or human health, and at the same time prevent exposure levels from increasing over time (to the best knowledge). Policy on AP use should also be harmonized with the emerging policy and future regulation linked to EU Soil Health Strategy. Threshold values for plastic debris and the related additives in soils should be introduced into EU soil legislation and Water framework directive as well into the Legislation on Air Pollution.

- PR3b: The EC should build on PAPILLON and MINAGRIS recommendation and define a risk assessment for plastic fragments and associated chemical additives originated from both conventional and biodegradable plastics used on field. Regulation can be based on assessment of risk under field conditions. This could be based on the well-validated and tested EU regulatory frameworks based on risk management. and make necessary adjustments and modifications tailored to the particular needs of plastic products sourcing these fragments. The EU REACH and the pesticide regulation represent examples of risk management-based regulations which could inspire a regulation for AP used on field. When in place, this framework will guarantee the introduction in the market of APs which do not entail risks for the environment, agricultural production and human health. Such a framework should be based on data generated from toxicity and ecotoxicity tests which when coupled with exposure estimations will provide a robust risk assessment. First literature evidence suggests undesirable effects of APs on the soil biota with unknown reciprocal effects on ecosystem functioning and agricultural production. The development and implementation of such a risk assessment framework is hence considered a priority for minimizing unacceptable effects on environmental integrity and human health.

- PR3c: Policy on AP management should be drawn taking into consideration the provisions and goals of the Water Framework Directive as well as the Marine Framework Directive and should be included into the assessment of atmospheric pollution. Environmental cost analysis of AP should include an assessment of the impacts deriving from the transfer of plastic debris pollution from agricultural soils to other parts of the ecosystem, including the trophic web. Plastic pollution in soil can be transferred to water ecosystems and be spread by wind into the surrounding environment. Agricultural soils are believed to be important reservoirs of plastic pollution and potential significant sources of water and ecosystem pollution. Synergistic effects of plastic debris and pesticide residues and their transport to the surrounding environment may affect the ecosystem.

- PR3d: The use of AP in a given region and the potential losses produced on landscape socio-ecological value should be considered by the policy. Plasticulture produces economic benefits primarily for farmers, but farmers are not the only users of the landscape. Incentives or deterrents for plasticulture should be evaluated case by case in different socio-geographical contexts. Such an evaluation should take into consideration the value attributed by multiple stakeholders (locally) and by the associated expert assessments and should consider both historical heritage, landscape value and social and indirect economic aspects along with ecological and direct economic aspects.

- PR3e: In line with other regulatory frameworks currently in place for chemicals, the EC could impose an early public release of product information for plastics coming into the market stimulating prompt risk assessment that might prevent unacceptable environmental risks for plastics carrying toxic additives. Currently, the chemical composition of additives used in the production of agricultural plastics remains undisclosed for researchers and the general public. We argue that such additives could be associated with adverse effects on the soil biota. The lack of information on additive chemistry prohibits adequate estimation of the risk associated with their environmental release along with plastics.

- PR3f: Data and operational tools should be developed and taken up by policy makers that enable to assess plastic-related soil pollution against local-to-global pollution boundaries in support of EU's zero-pollution ambitions for chemicals and plastics. Global chemical pollution (including plastic additives) and conventional plastic pollution of soil and other environments has been evaluated to currently exceeds a "safe operating space" for pollution by novel entities, which mainly consist of chemicals and plastics (http://doi.org/10.1021/acs.est.1c04158) To ensure that agricultural applications of plastic-based products is pushed back within a "safe operating space", data and novel tools are needed that allow for quantifying pollution pressure, relate it to environmental carrying capacities in soils, and assign it to the different plastic applications. Based on results from such data and tools, new plastic-based materials and products for agricultural (and other) applications should be designed and produced in alignment with forthcoming criteria set out in the safe and sustainable-by-design (SSbD) policy framework under the European Green Deal.

PR4: New policy should encourage the development and maintenance of databases that collect information about AP use and end-of-life handling and should utilise models for effective AP management practices.

- PR4a: The EC should aim to maintain accurate and updated inventories of AP use (of both conventional and biodegradable plastics) and management across the entire life cycle, to adequately track policy impacts and tune policy instruments. Industry and/or retailers should be actively involved in the maintenance of these records at the national or, preferably, regional level. This is instrumental to track the performance of policy instruments in terms of their circularity and the sustainability of the sector.

- PR4b: The EC should impose that conventional plastic products must be removed from fields and disposed of properly before any fragmentation occurs to avoid the spread of micro- and nanoplastics. It is possible to predict the useful lifetime of a given material based on factors such as the climate of the area or the cultivation techniques employed. Farmers must not use the plastic products beyond that time. One possibility could be the use of microchips or barcodes to monitor the presence of plastic in field and subsequent disposal.

- PR4c: Monitoring systems should be established EU wide to assess the distribution of plastic debris in the terrestrial, aquatic and atmospheric environment. Comparing monitoring data with threshold values for offsite transport and soils should form the base for policy measures with respect to AP use and management.

- PR4d: The EU should encourage the creation of a widespread system of collection, storage, management and recycling of AP waste in each country. Extended producer responsibility schemes could form part of this initiative. More centres for collection/storage/recycling should be established in regions with more intensive AP use.

PR5: Plastic pollution in agricultural soils should be looked under the lenses of a wider soil pollution context where all interacting agricultural pollutants should be considered

- PR5a: EC should bring together expertise from the different pollutant sectors encouraging interaction and setting up rules and basis for common actions towards averting the pollution of agricultural soils. Microplastics and nanoplastics accumulate in agricultural soils along with pesticides, veterinary drugs and metals. The interactive effects of these pollutants on soil ecosystem functioning is overlooked in the current chemical regulatory frameworks. Good knowledge of the interactions between microplastics and other agricultural soil contaminants would provide a holistic overview of risk associated with pollutants commonly encountered in agricultural soils.

- PR5b: Novel risk assessment approaches should quantify the contribution of plastics in antibiotic resistant gene (ARG) global dispersal. Recent research evidence by members of MINAGRIS and PAPILLON suggest that microplastics could facilitate environmental dispersal of ARGs. This raises serious concerns for humans and consumers health. EU should encourage joint research with environmental chemists, epidemiologists, clinical microbiologists, microbial ecologists and bioinformaticians that would determine the relevance of microplastics as facilitators of ARG dispersal, identify relevant environmental pathways and means to avert the associated risk.

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