Microplastics in agricultural soils: a new challenge not only for agro-environmental policy?

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Paper prepared for presentation at the 172nd EAAE Seminar '*Agricultural policy for the environment or environmental policy for agriculture?*'

May 28-29, 2019.

Brussels.

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Abstract

Microplastic pollution has recently gained the attention of the public media, politics and research. Microplastics (i.e., plastic particles less than 5mm in size) have been identified as a global environmental threat for terrestrial and aquatic ecosystems and human health. Agriculture is assumed to be both victim and polluter of microplastic pollution. Agricultural soils receive microplastic immissions from tire wear and fragmented macroplastic that enters the environment through littering. Furthermore, farmers who fertilize their arable land with sewage sludge and compost unintentionally apply the microplastic particles contained in these biosolids. On the other hand, agricultural soils may emit microplastics into aquatic environment. Because of this ambivalent position as both victim and polluter, the information on microplastic pollution is of current interest for agricultural production and might become a relevant topic for agro-environmental policies in the future. Our research aims to quantify the microplastic immissions into agricultural soils and emissions from agricultural soils into aquatic systems. We use different analysis approaches and interdisciplinary modelling to address these aims for two case studies in Germany. Because research in microplastics is a relatively new concern, we combine different methodological approaches in a complementary way.

1. Introduction

Microplastic pollution has recently gained the attention of the public media, politics and research. Microplastic is publicly perceived as a serious threat for terrestrial and aquatic ecosystems and human health (Van Sebille et al. 2015, Koelmans et al. 2017, Geyer et al. 2017, Rochman 2018, SAPEA 2019). However, the current knowledge on microplastic pollution of agricultural soils is not sufficient to draw conclusions on environmental impacts and mitigation requirements (Brodhagen 2017, da Costa 2018). High public interest in microplastic pollution motivated substantial spending of research funds (e.g., BMBF 2017). Agro-environmental policies, as well as the agricultural sector itself, might be required to react rapidly once defensible and validated results justify an adaptation of agricultural practice to mitigate microplastic immissions into agricultural soils. Thus, research is challenged to provide more information on a pollutant which is often invisible to the bare eye, ubiquitous and attributed to unknown risks.

1.1 Literature and state of the art

Research on microplastic started recently within the context of the global problem of plastic pollution. The number of studies on microplastic has increased significantly since 2010 (Geyer et al. 2017, SAPEA 2019). Methods and standards for detecting and quantifying microplastic in environmental samples and organisms are at an early stage of development (e.g., Hidalgo-Ruz et al. 2012, Rocha-Santos and Duarte 2015, Qiu et al. 2016, Dehaut et al. 2016, Phuong et al. 2016, Hanvey et al. 2017, Renner et al. 2018). However, microplastics have been found in nearly all environmental systems and in various species (e.g., Cole et al. 2013, Wright et al. 2013, Desforges et al. 2015, Gutow et al. 2016, Peters and Bratton 2016, Ziccardi et al. 2016, Horton et al. 2018).

While pollution by micro- and macro-plastics in aquatic ecosystems has been studied and discussed since the 1970s (Bertling et al. 2018, SAPEA 2019), microplastic pollution in terrestrial systems has only recently gained attention and is now being discussed as a potential environmental threat (e.g., Wright et al. 2017, Gasperi et al. 2018, Revel et al. 2018, Ogonowski et al. 2018, Hurley and Nizzetto 2018). Knowledge on microplastics in soils is based on empirical analysis and experiments from only a few studies.

1.2 Polluter and victims

Microplastic pollution concerns many different economic sectors as either polluters and/or victims of environmental pollution. Some economic sectors, such as producers of personal care products, have already reduced their microplastic use as a consequence of policy instruments or consumer pressure. Other economic sectors, such as the fishing industry, may risk economic losses due to the microplastic pollution if it negatively impacts production.

Agricultural soils receive immissions of microplastics from tire wear and fragmented macroplastics that enter the environment through littering. Furthermore, farmers who fertilize their arable land with sewage sludge and compost unintentionally apply the microplastic particles contained in these biosolids. The accumulated microplastic in soils from these different sources might affect the soil ecology and thus soil productivity (e.g., Duis and Coors 2016, Rillig et al. 2017, Huerta Lwanga et al. 2017, Brodhagen et al. 2017, Horton et al. 2017, Stöven et al. 2015, Nizzetto et al 2016, Steinmetz et al. 2016). Agricultural producers who use plastic mulch films might risk microplastic contamination by fragmentation larger foil pieces unintentionally left in the field. Thus, agriculture can be seen as victim of microplastic pollution on the one hand, but, may also play a role as polluter on the other hand. Agricultural production is suspected to emit microplastics from soils into aquatic systems. Thus, negative effects might be transferred through agricultural soils to other ecosystems and economic sectors (e.g., fishery).

Because of this ambivalent position as victim and polluter, the information on microplastic pollution is of current interest for agricultural production and might become a relevant topic for agro-environmental policies in the future.

As victim, the agricultural producers need information about the ecological and economic risk to their farms resulting from MP contamination. They require information on main contamination pathways and mitigation measures. Agricultural and environmental politics require clarity to design measures to protect agricultural soils. **As polluter** the agricultural sector requires clarity to be informed about negative environmental impacts resulting from microplastic emissions from agriculture. As agriculture is associated with several other negative environmental impacts (e.g., reduction of water quality, greenhouse gas emissions, biodiversity reduction, GMO, glyphosate), knowledge about further pollutant potential is important. Furthermore, agricultural and environmental politics require information to design measures to reduce microplastic pollution resulting from agricultural production.

1.3 Aims of the paper

The paper at hand presents a research project in progress. The project quantifies both the microplastic immissions into agricultural soils and emissions from agricultural soils into aquatic systems. The paper (i) describes the combination of complementary research approaches to present an approximation of the whole problem of microplastic immission in agricultural soils and to fill different knowledge gaps, and (ii) complements the body of literature on analysis and review articles with an article on integrated research, which considers soil analysis, bottom-up top down analysis and interdisciplinary modelling. Furthermore, (iii) the presentation of research methods and objectives in this paper could be of interest for stakeholders and politicians.

2. Background: Microplastic pollution

Microplastic particles have heterogenous in size, shape, density and chemical additives. Therefore, they can have different impacts on different environmental systems and organisms (Huerta Lwanga et al. 2017, Horton et al. 2017, Hurley and Nizzetto 2018). Microplastics are emitted by different polluters from different materials. Thus, the particles vary in their physico-chemical characteristics and thus in their life cycle and impacts on environmental systems and organisms. As simplified categorization microplastics can be differentiated according to their general origin and according to the economic sector from which they originate (i.e. the polluters) or to which they emit (i.e., the victims of microplastic pollution). Table 1 presents different economic sectors as polluter and victims.

According to Bertling et al. (2018) the origin of microplastic can be differentiated into three types: as "primary microplastics" of types A and B and as "secondary microplastics." Primary microplastics of Type A, are plastic particles originally produced to be used as microplastics (e.g., micro-beads in care products, or pellets). Primary microplastics of Type B, are plastic particles emitted from plastic material during usage (e.g., tire wear). Secondary microplastics are fragments of plastic particles emitted as macroplastic into the environment (e.g., plastic bags littered in the environment).

2.1 Microplastic pollution and agriculture

Most of the economic sectors can be seen as (mainly) polluter or (mainly) victim of microplastic pollution. As an example, the personal care and cosmetic industry add micro breads as primary microplastic of type A to increase the effectivity of cleaning products. The plastic industry emits primary microplastic of type A by unintentional release of plastic pellets. The textile and tire industries are responsible, together with the users of textiles and cars, for the emission of primary microplastics type B. Households litter macro plastic into the environment or plastic mulch film fragments unintentionally remain in the soil after removing the mulch film.

The tourism sector is mainly impacted as victim by reduced tourist demand caused by polluted (mainly aquatic) ecosystems. The tourism sector contributes also the littering by tourists, but the main dominating impact results from microplastic pollution from other sectors (the society and households). Also, fishery is mainly a victim because microplastics are a risk to the aquatic ecology and thus a risk to reduce fish stock and productivity. However, fishery also acts partially as polluter though the fishery equipment and marine vehicles emitting primary microplastic Type B. Waste water treatment plants and compost plants are victim and polluter. They are forced to use raw materials (waste water and organic waste), which are contaminated by microplastic, but they also supply products which contain microplastics to agricultural producers (e.g., sewage sludge and compost).

Agricultural production also holds an ambivalent position in the microplastic pollution problem. Microplastic is emitted onto agricultural soils from tire wear and littering via runoff and airborne distribution. Sewage sludge and compost contaminated with microplastics are used as fertilizer in agriculture. Thus, agricultural soils are sinks for microplastic particles that might have negative impacts on soil structure and organisms. Furthermore, soils contaminated with microplastic are exposed to the unknown risk of additives in the plastic particles. Impacting the bio-physico-chemical soil characteristics might impact soil ecology and productivity. When applying plastic film (e.g. as mulch film) secondary microplastic is unintentionally emitted into the environment through the process of fragmentation.

On the other hand, microplastic is emitted from agricultural soils into other environmental systems (e.g., water bodies). Thus, the agricultural sector is also a polluter. Leaching through soil pores and tiles potentially transports microplastic particles to drainage and into the surface and ground water bodies. Soil erosion by wind or water transports microplastics into surface water and other environmental systems.

Table 1: Overview of selected economic sectors and economic agents characterized as polluter and victim of microplastic pollution

Sector	Polluter	Victim
Industries producing cosmetics, personal care, or washing powder	Adding micro beads to cosmetics and care products	
Textile industry/households	microplastic fibers from microfiber fleece during domestic washing	
Tire industry and transport sector/car drivers	Tire abrasion	
Plastic industry	Pellet losses	
Society/households	Littering in environment and compost	
Tourism		Reduction in tourist demand because of damaged marine ecosystems
Fishery		Reduced productivity of fish stocks because of impacted aquatic ecosystems
Water treatment plant and compost plants	Insufficient filtering, supplying microplastic contaminated sewage sludge and compost	Filtering microplastic-contaminated waste water and recycling microplastic-contaminated organic waste
Agriculture (landuse)	Emissions into aquatic and terrestrial systems	Immissions of microplastic from tire abrasion, littering
Agriculture (fertilization)	Emissions into aquatic and terrestrial systems	Immissions of microplastic from compost and sewage sludge
Agriculture (plastic mulch film application)	Immissions from abrasion and fragments, littering, emissions into aquatic and terrestrial systems	

2.2 Characteristics of microplastic as pollutant from agriculture

Agricultural production implies using natural resources and is associated with positive and negative environmental impacts. On the one hand, society identifies agricultural production with environmental services (e.g., retaining the cultural landscape). On the other hand, the society holds the agricultural sector responsible for negative environmental impacts (e.g., nutrient surplus, reducing water quality, soil erosion).

In Germany, the intensive agricultural production faces several pollutant and negative environmental impacts of different characteristics. Microplastic as pollutant is not the only complex problem because the manifold polluters and victims. The partially known characteristics and the characteristic assumed (not yet proven with evidence) are similar to the characteristics of better known pollutants.

The multiple characteristics of microplastics make it difficult to understand the fate and impact of this pollutant. For example, nitrate as a water-soluble substance, enters ground and surface water bodies through leaching and runoff. Phosphate is bound to soil particles and therefore transported by soil erosion into surface waters. Leaching to the ground water body is comparably minor. For microplastic the transport into groundwater has not yet been proven.

Table 2: Overview of characteristics of agricultural pollutant, which are comparable to the expected characteristics of microplastics. Source: own presentation

	Emission to agricultural soils/systems	**Transport to groundwater**	**Transport into surface water**	**Transport into other environmental systems**	**Environmental impacts**	**Risk for human health**	**Discussion in society**
Nitrogen	Fertilizer application (b)	Nitrate leaching (a)	Nitrate leaching and runoff (a)		Impairment of drinking water quality (a)	Risk for human health (a)	Agriculture as polluter of drinking water (a)
Phosphate	Fertilizer application (b)		Transport via soil erosion (wind and water) (a)		impacts on aquatic ecosystems (a)		Agriculture as polluter of aquatic ecosystems (a)
Greenhouse gas emissions (CO2, CH4, N2O) and emissions of particulates	Fertilizer application and resulting from production process (b,c)			Global, diffuse emissions (a)	Global and long term impacts (climate change) (a)		Climate change as global threat (a)
Glyphosate (Pesticides)	Application as production factor, difficult to substitute (c)			Point emissions (b,c)	Impact on ecosystems, complexity of impacts, accumulation in food chains (a)	Risk for human health (a)	Political discussions with different actors and interest (a)
GMO	Application as production factor (b,c)			Point emissions (b,c)	Impact on ecosystems, complexity of impacts (a)	Risk for human health (a)	Political discussions with different actors and interest (a)
Antibiotics	Application as production factor, difficult to substitute (b,c)		Leaching via natural drainage (a)	Point emissions (b,c)	Impact on ecosystems, complexity of impacts (a)	Risk for human health (a)	
a similar to all micro plastics in agriculture, b similar to micro plastics from fertilization with compost or sewage sludge, c similar to micro plastic resulting from plastic mulch film							

Table 2 presents well-known agricultural pollutants and their characteristics which we also expect to find for microplastic. The expected impacts on environmental systems and on human health drive the public discussion. For microplastic the discussion in public media (indicated by the number of publications) has reached a comparable level to other important environmental topics like for example “climate change” and “glyphosate” (Bertling et al. 2018, SAPEA 2019). This comparison of different threats and behaviors illustrates that microplastic potentially combines many different characteristics and expected risks of well-known pollutants. Transport mechanisms and environmental impacts are roughly comparable with well-known pollutants. However, because of the heterogenous characteristics of microplastic particles, the behaviour of microplastic may be in detail very different from the known pollutant. This complexity challenges the analysis methods to identify microplastic and it challenges the society and politics to assess the impacts and to design policies.

3. Methods

The complexity of microplastic pollution requires the application of different research methods and modelling research. Knowledge derived from existing studies and results from empirical analysis are fed into disciplinary and interdisciplinary models.

3.1 Conceptual model to identify pathways to agriculture

In the first step, we built a conceptual model representing the different sources and pathways that are potentially relevant for microplastic emissions into agricultural soils and water oriented to existing conceptual models (e.g., Ng et al. 2018, Horton et al. 2017, Humer 2017, BKV GmbH 2018). Our model focusses on the soil and water nexus and describes the the different microplastic sources and pathways. Figure 1 presents the pathways of microplastic to agricultural soil and landscape and from there to the water bodies.

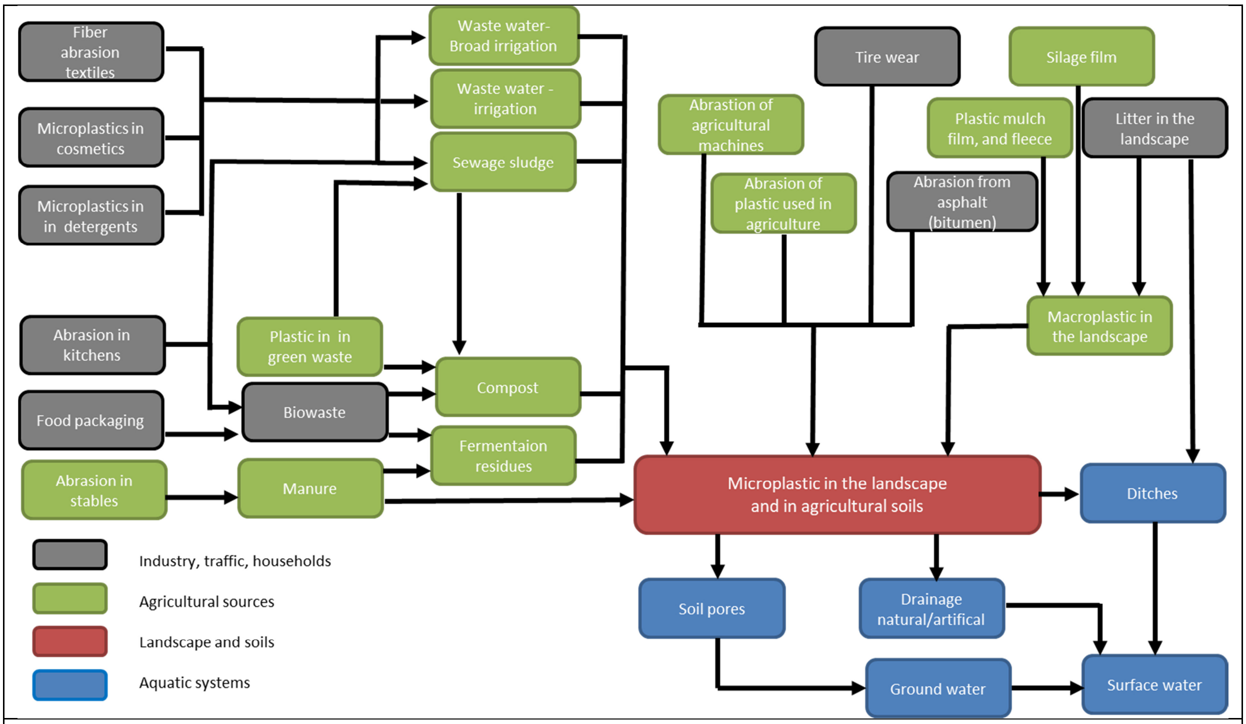
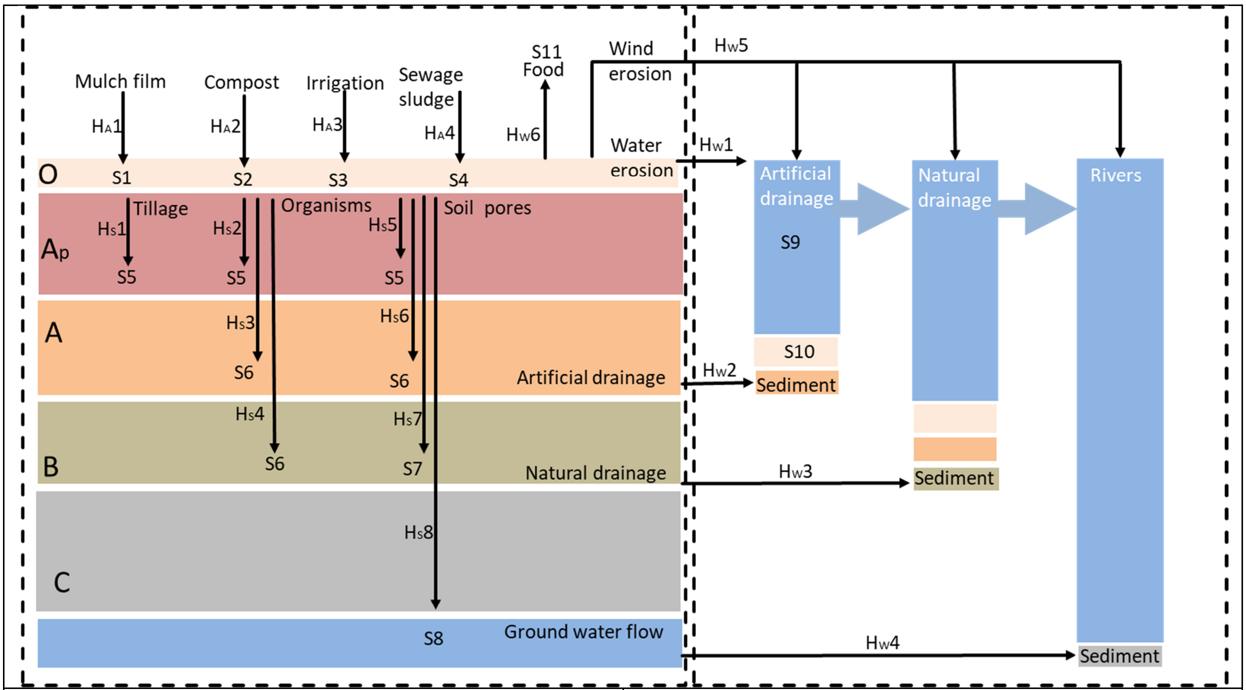


Figure 1: The conceptual model of microplastic pathways to agriculture and water. Source: own presentation

3.2 Hypothesis on transport and accumulation processes

One important partial research focus is the identification of microplastic emissions from agricultural soils, the transport and accumulation within the soils and the transport into the water bodies. To highlight all possible transport and accumulation processes of microplastics in soils, we formulated a set of hypotheses to guide decisions for sampling strategies. Since microplastic analytics in solid samples are time-consuming, it was proven necessary to develop an accurate workflow of analysis that allows maximum knowledge gain with a minimum number of sample results.



Hypothesis (H):

HA1: Mulch film application results in measurable accumulation of MP in agricultural soils
HA2: Compost application results into significant accumulation of MP in agricultural soils
HA3: Waste water irrigation results into significant accumulation of MP in agricultural soils
HA4: Sewage sludge application results in significant accumulation of MP in agricultural soils
HS1: Tillage transports MP into Ap layer
HS2: Organisms transport MP into Ap layer
HS3: Organisms transport MP into deeper A layer
HS4: Organisms transport MP into B layer
HS5: Soil pores transport MP into Ap layer
HS6: Soil pores transport MP into deeper A layer
HS7: Soil pores transport MP into B layer
HS8: Soil pores transport MP into C layer and groundwater
HW1: Water erosion transports MP into drainage ditch
HW2: tiles transport MP into receiving (surface?) waters
HW3: natural drainage transports MP into drainage ditch
HW4: ground water flow transports MP into rivers
HW5: Wind erosion, transporting MP into surface water
HW6: nano particles or toxic substances released from MP enter the human food chain via crops

Samples (S) and anysis:

S1: Soil sample on sites with mulch film application
S2: Soil sample on sites with compost application
S3: Soil sample on sites with waste water irrigation
S4: Soil sample on sites with sewage sludge
S5: Soil sample in corresponding sites in Ap layer
S6: Soil sample in corresponding sites in deeper A layer
S7: Soil sample in corresponding sites in B layer
S8: Soil sample in corresponding sites in ground water layer
S9: water sample in corresponding drainage after erosion event
S10: sediment sample in corresponding drainage
S11: crop and food analysis

Soil Layer:
O: surface 0-10cm
Ap: tillage layer (0-30cm)
A: 30-60cm
B > 60cm

Figure 2: Hypothesis on transport an accumulation processes of microplastic in soils. Source: own presentation

3.3 The analysis of soil samples

To sample agricultural soils we identify suitable sites on which we expect microplastic contamination (e.g. from long time application of microplastic containing fertilizer). We target two types of sites: i) Sites for which the history of application, usage and treatment are documented over a long time scale (e.g., experimental sites). We identify the suitable experimental sites by literature research and analysis and expert interviews. ii) Sites from which we expect microplastic emissions from agricultural soils into the water bodies (e.g., via soil erosion). To identify these sites we run a spatial analysis using geographic data of modeled erosion risk and sewage sludge application to identify relevant fields that are located close to surface waters. Different research institutions specialized in microplastic analysis quantify the microplastic content of the soils samples under using different methods for extraction and analysis.

3.4 Bottom-up modelling

We upscale the results of the soil samples analysis at regional level by using the data base of the Regional Agriculture and Environment Information System "RAUMIS" (Thünen Institute 2018a). The extended RAUMIS data base allows to extrapolate the site-based microplastic contamination rates to the regional level by the regionally applied amounts of sewage sludge and compost. The extension of the RAUMIS data base is derived from literature research and experts interviews and based on statistical data.

The results of the bottom-up model provides modelled results measured on **measured immission factors** to quantify the microplastic contamination. The measured immission factors consider processes, which cannot be modelled based on the data base used, i.e., the losses via erosion, leaching and decomposition, the immissions based on historical application. Of course the measured immission factors still contain the errors, deviation and losses resulting from the extraction and analytic processes.

3.5 Top-Down modelling

In parallel to the bottom-up model, we apply a top-down approach in which we use national data to represent the sector-based microplastic emission from different sources of microplastic, which could be relevant for agricultural soils. We downscale the sector level information at regional level by using the RAUMIS database. The results of the top-down model are based on global (or sectoral) emission factors, and provide microplastic contamination, we would expect without considering losses from transportation or decomposition processes. Furthermore, in the first step we consider only microplastic immissions from sewage sludge and compost and not from tire wear and the littering of (macro) plastic, which could emit large quantities of microplastic into soils. The comparison between the **measured results** and the **normative results** indicates the quantity of microplastic hidden in the black box of non-modelled processes (i.e., the losses or unknown sources). This information will support the defining further research questions.

The results of the top-down model are the input data for the hydrological model mGROWA and MEPhos (Herrmann et al. 2015, Tetzlaff, B. and Wendland, 2012), which simulates the microplastic immissions into the water bodies. The integrated model approach using RAUMIS the hydrological models mGROWA and MEPhos allows the identification of hotspots of microplastic contamination. The integrated model RAUMIS-mGROWA is applied to the focus study regions Weser and Warnow river basin. The top-down approach and the integrated model RAUMIS-mGROWA- MEPhos have been successfully applied in different projects (i.e., the AGRUM projects) to quantify nitrogen and phosphate pollution in Germany. The results support the German federal government in the evaluation of policy measures to monitor the implementation of the EU Water Framework Directive (Thünen Institute 2018b).

4. Results

The research in progress focuses on Germany, as a European country characterized by intensive agricultural production. Germany borders on two European marine ecosystems (i.e., the North Sea and the Baltic Sea) into which microplastics can be emitted from agriculture. Within Germany, we focus on the Weser and the Warnow river basin for which we model microplastic concentrations in a regional scale. The investigation of both study regions are parts of two interdisciplinary BMBF projects funded in the FONA research framework program “Plastic in the Environment – Sources, sinks, solutions” (https://bmbf-plastik.de/en): PLAWES and MicroCatch_Balt.

4.1 Identification of samples sites, soil sampling and soil analysis

Using literature research and expert interviews, we identified the experimental sites of the Agricultural Investigation and Research Institute in Speyer, in Rhineland Palatinate as very suitable sites for soils samples to quantify microplastics in agricultural soils. The fields have been treated with compost and sewage sludge of different intensities for more than 30 years to study impact of fertilization with biosolids on soil productivity. The first sampling considers the soils with the highest intensities of sewage sludge application in three different soil horizons (see Section 3.2). The first sampling provides information on the microplastic content, in agricultural soils with known application rate.

The sites for sampling soil with particular characteristics for microplastic transport into aquatic systems are identified by using the extended RAUMIS database at field scale level, by geographic data analysis and focus on the study regions of the Weser and the Warnow river basin. The results of these soil samples provide the information on the emission of microplastic from soils to water systems. The identification of the emission sites is current work in progress.

4.2 Microplastic concentrations and emission factors

The comparison of the literature for microplastic concentration found by different authors in the sources compost a sewage sludge illustrate significant variation (Table 3). The differences may result from differences of the samples but for a large part for differences in the methods for sample preparation (e.g., extraction of the microplastics from the soils) and analysis. Thus, the comparison illustrates the high demand for further research and the required cautions for interpreting the results derived from own sample analyses. The literature values represent the first starting point for our research. However, because of the big differences, we need to consider the published values cautiously, critically and consider them as subject to revisions.

Table 3: Selected literature values, sorted according to the mean. Source: Own compilation

Source	Mean (d)	Minimum	Maximum	Unit	Original Publication
Compost	601	2.4	1200	mg kg-1	Bläsing and Amelung (2018)
	900	n.a.	n.a.	mg kg-1	BKV GmbH (2018)
	50000	n.a.	n.a.	mg kg-1	Brinton (2005), Humer (2017) ©
Sewage sludge	2500	1000	4000	items kg-1	Barnes et al. 2009 (b)
	2750	1500	4000	items kg-1	Zubris and Richards (2005) (a)
	10000	4200	15800	items kg-1	Mahon et al. (2017) (a)
	12500	1000	24000	items kg-1	Mintenig et al. (2017) (a)

Study in which the original publications are quoted (a) Bläsing and Amelung (2018), (b) Huerta Lwanga 2016, (c) Ng et al. (2018). (d) Note: The average is computed based on maximum and minimum only to the data. Statistical information are provided by the median. This selection serves only demonstrative purposes and is by far not complete.

4.3 The top down analysis

Since the analysis of the soil samples is still under progress the results from the bottom-up model have not been simulated yet. We reduce the described analysis in this paper to sewage sludge and compost and exclude the sources of plastic mulch film, tire wear and littering from our analysis, knowing that these emission sources will need to be subject to further research.

For the top-down analysis we use the extended RAUMIS-Database for a regional analysis of the quantities of sewage sludge and compost used as agricultural fertilizer. We derive the data presented in Figure 3, from the official statistics for sewage sludge, biowaste and compost.

The regional sewage sludge quantities are the quantities the regional waste water treatment plants supply to agricultural producers. However, the data do not inform about the sites of application. Thus, we consider the regional data of supply as proxy to indicate the region of application. The regional quantities of compost applied to agricultural area we derive as a proxy from statistical data on compost at national and at federal state level. and level

The regional analysis identifies four hot-spots regions, in which the fertilization with both sewage sludge and compost allow a higher microplastic contamination of agricultural soils to be expected. One bigger region is of particular interest with NUTS3 regions in northeastern North Rhine-Westfalia, and in southwestern and western Lower Saxony (Figure 3 the biggest red circle). These regions are partially located in the Weser river basin and could be of particular interest for the project PLAWES to identify sites with the required attributes for soil sampling.

The more detailed regional analysis requires the extending the RAUMIS data base by sewage sludge and compost data at municipality or even field scaled level, which indicate the geographic position of application. The higher resolution of the microplastic immissions and the linkage to the hydrological model GROWA are the subject of the next research steps.

The top-down analysis considers only the sewage sludge and compost as the expected agricultural inputs with the highest contamination of microplastics. It does not consider the microplastic immissions from plastic mulch film and other non-agricultural originating sources (tire wear and littering). Furthermore, the top-down analysis describes only the representative year 2016. We assume that in past years the regional distribution is similar because the application of sewage sludge and compost is a principle decision to consider fertilizing their soils with urban waste products, which have been already under criticism because of other pollutant (e.g., heavy metals). Fertilizing with compost or sewage sludge is particularly attractive for the farm types “crop farms without own manure production” to increase or retain the humus content of soils (Brandes and Kreins 2019). Such farms may then follow the practice of sludge and compost fertilization practice over the long term.

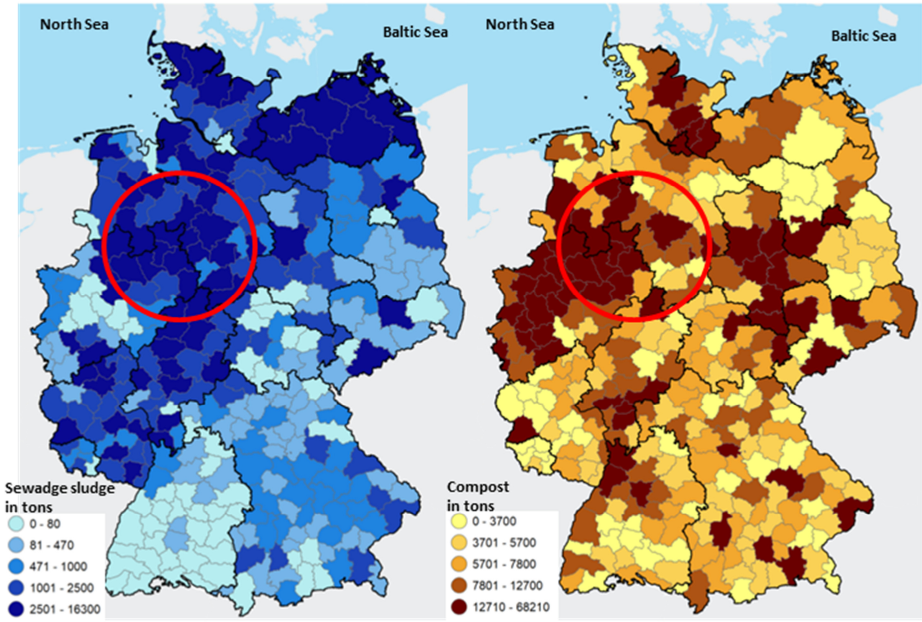


Figure 3: Regional quantities of sewage sludge (left) and compost (right) produced for agricultural use in Germany in 2016.

5. Conclusions and outlook

High public, political and scientific interest in microplastic pollution recently motivated increased efforts to close knowledge gaps of the microplastic puzzle (e.g., BMBF 2017). Thus, it could be possible that research soon will provide information for better understanding of the immissions, impact and fate of microplastics in agricultural soils. Microplastic is publically perceived as a serious threat for ecosystems and human health. Agro-environmental policies, as well as the agricultural sector itself, might be required to react rapidly once defensible and validated results justify an adaptation of agricultural practice to mitigate microplastic immissions into agricultural soils. Microplastic pollution in terrestrial and aquatic ecosystems results from many different sources and presents a complex problem involving a wide range of actors. Thus, evaluation of the situation of microplastics and the design of mitigation policies (if needed) require interdisciplinary research, which links information from different methods and approaches. Among these are: biochemical analysis of soil and water; analysis of impacts in ecosystems; interdisciplinary and economic modelling, and economic assessment. Furthermore, the design of effective and efficient mitigation policies requires the consideration of many different sectors including polluters and victims, e.g., the personal care product industry, transportation, wastewater management, compost production, agriculture, water supply, and fishery.

Our paper presents a research project which aims at providing information on microplastic in agricultural soils for a German study region. The presented regional analysis identifies hot spots where relatively high microplastic immissions can be expected. However, the top down-model analysis does not consider transportation or decomposition processes of microplastic. Furthermore, it considers preliminarily only microplastic immissions from sewage sludge and compost, but the microplastic immissions from sectors other than agriculture could be much higher than the immission factors from the agricultural production factors. Tire wear and the littering of (macro) plastic could emit large microplastic quantities into agricultural soils and surface waters. Thus, the microplastic immissions from agricultural production factors (sludge, compost, plastic mulch film) could be relatively low compared to immissions resulting from the transportation sector and littering. Thus, agriculture could be rather a victim of pollution than a polluter, which then would require corresponding policies targeting the polluting sectors.

This paper presents only the starting point of our research and most of the works described still need to be executed. However, the description of the microplastics characteristics and the research methods illustrate the complexity of the research question and the need for a holistic interdisciplinary approach. The further research steps in the framework of the projects will bring new knowledge, which will still be considered as pioneers work, subject to huge efforts for validation and revision.

One important aspect in this context is to allow a participation in the research for the stakeholders from the concerned industries (e.g., agricultural producers, waste-water treatment plants, compost producers, plastic mulch film industry, authorities (e.g., agricultural and environmental ministries) and policy-makers. With microplastic as relevant topic with high public interest, sharing the information and keeping stakeholders updated could be of essential importance to allow a realistic estimation of the situation (as early as possible) and the earliest possible initiation of measures to avoid microplastic pollution in agricultural soils (if required). Thus, the research on microplastic is not only challenging due to its complexity but also due to its importance for many different stakeholders and the public interest. Therefore, microplastics in agricultural soils may not only be a new challenge for agro-environmental policy, they may present a new challenge for polluters and victims and for all those interested in tackling microplastic pollution as part of the global problem of plastic pollution: the “21st Century Challenge”.

6. Literature

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