Mapping and Disposal of Irrigation Pipes for a Sustainable Management of Agricultural Plastic Waste

Ileana Blanco, Giuliano Vox, Fabiana Convertino, and Evelia Schettini

Abstract Plastic materials are largely used in agricultural activities. Plastic products are commonly employed as covering in greenhouses and tunnels, for soil mulching, silage, pots, and containers and for irrigation and drainage pipes. The use of plastic products provides several benefits for agricultural production. However, the downside is represented by the large amount of generated agricultural plastic waste (APW). There is a need of a conscious and sustainable management of APW from an environmental and economic point of view. APW should be considered as a resource, in the optic of a circular economy. To this end, the definition of a rigorous approach for agricultural plastic detection, mapping, collection, and disposal is required. In this study, the attention was focused on the irrigation pipes. An agricultural area, characterized by a variety of crops, in Apulia region (Southern Italy) was considered as case study. The paper proposes a territorial analysis, performed using a Geographical Information System (G.I.S), for mapping areas of use of irrigation pipes and of waste production from these. As a result, a georeferenced database and the quantification of the potential waste were obtained. This allows identifying critical areas for plastic waste production due to irrigation pipes and can be used as tool for planning a proper collection and disposal strategy.

Keywords Sustainability · G.I.S. · Land Use · Plastic Detection · Agricultural Plastic Waste · Waste Valorization

I. Blanco
Department of Biological and Environmental Sciences and Technologies (DiSTeBA), University of Salento, S.P. 6 Lecce - Monteroni, 73100 Lecce, Italy

G. Vox · F. Convertino (✉) · E. Schettini
Department of Agricultural and Environmental Science (DISAAT), University of Bari "Aldo Moro", Via Amendola 165/A, 70126 Bari, Italy
e-mail: fabiana.convertino@uniba.it

V. Ferro et al. (eds.), *AIIA 2022: Biosystems Engineering Towards the Green Deal*, Lecture Notes in Civil Engineering 337,
https://doi.org/10.1007/978-3-031-30329-6_110

1 Introduction

In 2020, the 3.2% of the total European demand for plastic products, equal to 49.1 million tons, came from the agriculture sector. In the same year, more than 29 million tons of plastic post-consumer waste was collected in Europe, 23% of which still sent to landfill [1]. The large use of plastic in agriculture is mainly due to the spread of intensive and semi-intensive agricultural practices [2, 3]. Plastic products are used due to their peculiar characteristics, such as: lightness and good mechanical properties, versatility of applications, ease of installation, use and management, and low cost. Plastics can be processed in many ways to obtain different shapes and due to their characteristics, they have significantly replaced other traditional materials. In agriculture, plastics are used both in open field and in protected cultivation. Agricultural plastics can be classified based on their application into covering and shading, mulching, solarization and direct covering, irrigation pipes (IPs), pots, bags and various containers, packaging, sacks and strings and materials for transport, storage, and sale agricultural products.

The use of plastic products in agriculture has simplified many activities and brought a positive contribution to the production. Most of the plastic materials used in agriculture are made of synthetic petrochemical polymers. Base polymer, additives, physical characteristics, and thickness differ in the various products [4].

As the plastic products are so largely used in agriculture, these are also one of the main sources of waste. Much of the agricultural plastic waste (APW) in Mediterranean area is made of after-use covering and mulching films, IPs, and nets [5–7]. Given their chemical composition, plastic products at the end of their useful life need to be properly collected, disposed of, and possibly recycled. Moreover, these products are often dirty of soil or organic matter and contaminated by chemicals. This represents a serious environmental issue, requiring proper efficient disposing solutions, often expensive. However, APW is very often managed in improper ways. Abandonment in field, open field burning, burying in soil, and dis-posing in landfills are very widespread practices. Serious environmental and eco-nomic consequences, as ecosystems degradation, soil, water and food contamination, release of dangerous pollutants, arise from such wrong practices [3, 4].

APW can be managed in an economical and environmentally friendly way, in an optic of circular economy [8]. APWs, if appropriately collected, can be recycled, and used to produce other plastic materials. Thus, valorizing APW can lead to a double benefit: the reduction of waste generated, and the limitation of plastics produced with non-renewable materials [2, 9]. For any non-recyclable fractions, the energy recovery could be considered [4].

APW are generated all year round, but the accumulation of specific plastic waste products is linked to the season and the geographic area [3]. The issue related to APW location is well known [10]. A correct management of APW implies minimization, collection, sorting, treatment, and disposal [11].

The lack or the inefficiency of the existing management systems for APW is of-ten the main reason of the dangerous and illegal practices carried out by many farmers in European countries. Related issues are the lack of standard methods for APW types classification and quantification and for sites and flows identification within an agricultural area. Such tools could be useful to create a georeferenced database to be used for APW management. An efficient and sustainable APW management plan could be developed knowing the amount of APW generated in an area and where there is the highest APW concentration.

A georeferenced database for mapping and continuously updating information on APW can be realized by using geographical information systems (GISs) [7, 12–14]. GISs allow storing, georeferencing, analyzing and displaying large amount of data. Using a GIS can be precious to make territorial analyses, to identify APW generation sites and relative quantities, to select disposal sites by considering infrastructure, landscape constraints, social and economic factors.

The aim of this paper is to apply the approach based on GIS to quantify the APW due to IPs, with reference to the different crop types (CTs), in a South Italy rural area. This was made by applying specific plastic waste indices (PWIs). In this way, a georeferenced database of APW generated by IPs use was created. Such database can be easily managed and used as a tool by Authorities and Stakeholders for APW production monitoring and APW flows managing. This tool, continuously upgradeable, can support the sustainable development and planning of the rural territory and landscape.

2 Materials and Methods

The municipality of Noicattaro (Bari, Apulia Region, Southern Italy) was chosen as case study. The territory of Noicattaro has an extension of about 4080 ha and about 25,000 inhabitants. The area is particularly devoted to vineyards cultivation and partially to olive groves. Thus, the agricultural area is responsible for an intense production of APW due to the local crops production.

In this study, the attention was focused on APW generated by IPs use. A GIS database was created, APW generated by IPs was georeferenced on the land.

The free software QGIS [15] was used. This allowed the elaboration of land use map starting from data provided by the territorial information system of the Apulia Region [16]. Land use map was used for selecting and highlighting the different crop production that imply IPs use and in turn APW generation. Before quantifying the APW due to IPs, crop classification was verified by photointerpretation using Google satellite images. The different crop areas were manually adjusted in QGIS and checked for correspondence with the CT. To quantify the APW from IPs, PWIs, as defined by Blanco et al. [7], were adopted. PWIs are available for the different plastic applications and for the CTs. The ones concerning IPs are shown in Table 1.

The PWIs, each to the relative CT, were attributed to the land use map features. The APW was quantified and georeferenced and the APW map of Noicattaro was produced. Then, the suitable location for the collection centre was identified. The position of the collection centre was defined by considering the centroids for the

Table 1 Plastic Waste Index (PWI) for irrigation pipes and different crop types

Crop type	Pipe length [m ha^{-1}] PL$_{25}$[a]	PL$_{100}$[b]	Life [month]	PWI [kg ha^{-1} yr^{-1}]
Vineyards	4001.33	200.13	215.36	83.33
Olive groves	1600.00	200.00	216.80	50.00
Orchards	2500.00	200.13	217.28	62.50
Vegetables	3000.00	200.40	216.16	69.44
Greenhouses	4500.00	300.00	216.00	104.17

[a]: length of pipes with diameter of 25 mm, [b]: length of pipes with diameter of 100 mm

different CTs areas, appropriately weighted. The presence of territorial constraints, as defined by the Regional Territorial Landscape Plan of the Apulia Region (PPTR), was considered too.

Concerning IPs, these are made of header tubes of HDPE, having a diameter of 100 mm, and secondary tubes of HDPE, with a diameter of 25 mm [7]. Thus, the PWI [kg ha^{-1} yr^{-1}] of IPs for all the crops was obtained as [7]:

$$PWI = (PL_{25} \cdot PW_{25} + PL_{100} \cdot PW_{100}) \cdot life^{-1} \cdot U_{cvp} \tag{1}$$

where: PL_{25} and PL_{100} [m ha^{-1}] are the lengths of pipes with diameter of 25 mm and 100 mm, respectively; PW_{25} and PW_{100} [kg m^{-1}] are the weights of pipes with diameter of 25 mm (0.25 kg m^{-1}) and 100 mm (2.5 kg m^{-1}), respectively; *life* [months] is the plastic useful lifetime; U_{cvp} (12 months yr^{-1}) is the pipes unit factor for converting the results in kg ha^{-1} yr^{-1} unit.

The base map materials used consisted of the Google satellite images, the municipality boundaries and the Land Use (LUS) Map of the Apulia Region. These were freely provided and derived from the 2006 orthophotos, with 50 cm pixel resolution, updated in 2011. The map legend complies with the European CORINE Land Cover Changes Database with an extension to the fourth level. The maps elaborated with QGIS were placed in the WGS 84 / UTM zone 33N reference system. The Apulia LUS map containing the data on the CTs distribution consists of several shapefiles related to the analysed area. These shapefiles were merged in QGIS to create one, that was clipped according to the municipality boundaries, to limit the information to the study area.

Only crops associated with APW due to IPs were selected on the LUS map. After checking the CT features by photointerpretation, the database of the LUS map was extended by adding in the attribute table new fields about the area of each feature (S_i, m^2) and the PWI for IPs for each CT (PWI_{CT}). Finally, the amount of APW for CT (APW_{CT}, kg yr^{-1}) was obtained by:

$$APW_{CT} = S_i \cdot PWI_{CT} \tag{2}$$

The sum of the amount of APW of the different CTs provided the total quantity of APW due to IPs in the territory of Noicattaro.

The GIS information was used to identify a suitable location for the first collection centre. The QGIS centroid tool for localizing the geometric centre of the features allowed to locate the collection centre.

3 Results and Discussion

The crop distribution in the study area obtained by the selection on the LUS map was showed in Fig. 1 together with the map modified after the photointerpretation. The corrected map suggested that vegetables and vineyards were overestimated in the unmodified map, while orchards and olive groves underestimated.

The predominant CT are the vineyards (80.37%), followed by olive groves and negligible percentage of orchards and vegetable/greenhouses (Fig. 2).

The application of the PWIs on the LUS map allowed to identify the spatial distribution of APW due to IPs in Noicattaro. The density of waste due to pipes was shown in Fig. 3. The most diffuse areas (vineyards) are characterized by a high PWI. As highlighted in Fig. 3, the APW due to IPs in Noicattaro is mainly generated in vineyards cultivation (166.42 t yr^{-1}). This accounts for about the 87% of all the APW from IPs in the study area.

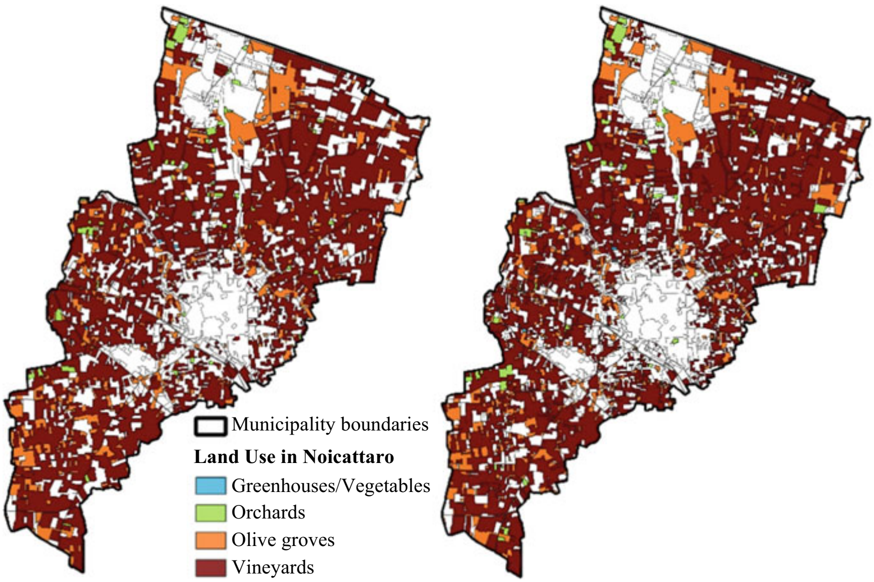

Fig. 1 Land use in Noicattaro: map as taken from database (on the left) and corrected through photointerpretation (on the right)

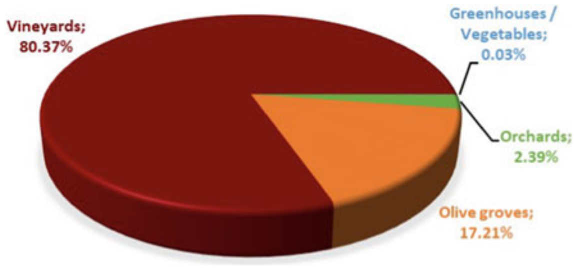

Fig. 2 Percentage distribution of land uses in Noicattaro

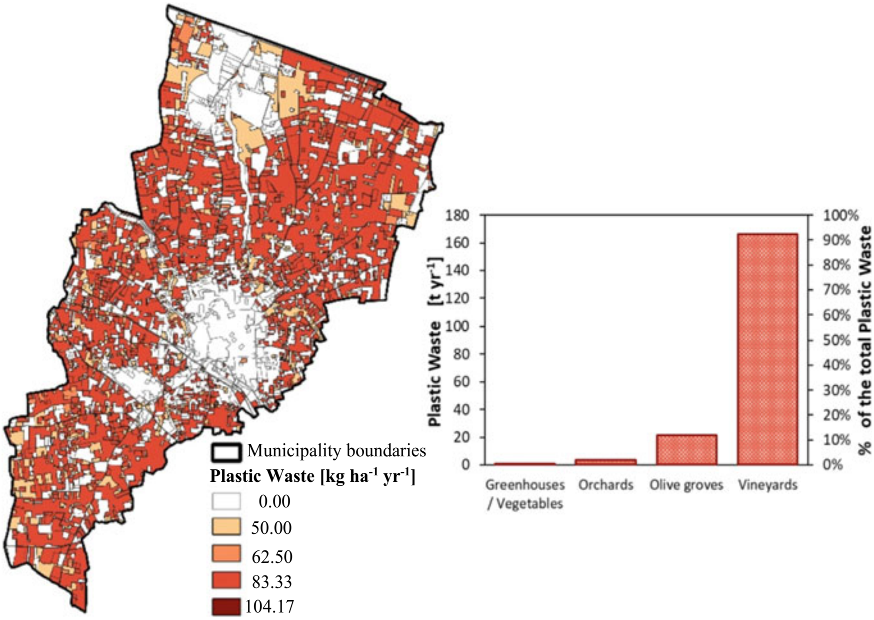

Fig. 3 APW in Noicattaro: distribution of APW density (on the left) and total amount of APW per year and crop type (on the right)

Finally, the most suitable location for the collection centre for APW made of IPs was defined considering the quantities and the distribution on the land (Fig. 4). The collection centre position was defined with a buffer zone of radius equal to 500 m.

The suitable position was defined considering the sensitive areas indicated in the Apulia PPTR (Fig. 4). It was taken care that the collection centre was not in the areas with landscape restrictions. Because the centroid of the features fell in the landscape constraint area around “Lama San Giorgio” and “Torrente Chiancarello”, it was moved just outside this area to avoid conflict with this sensitive area. This map can be a useful tool for making a first selection of suitable area for a collection centre.

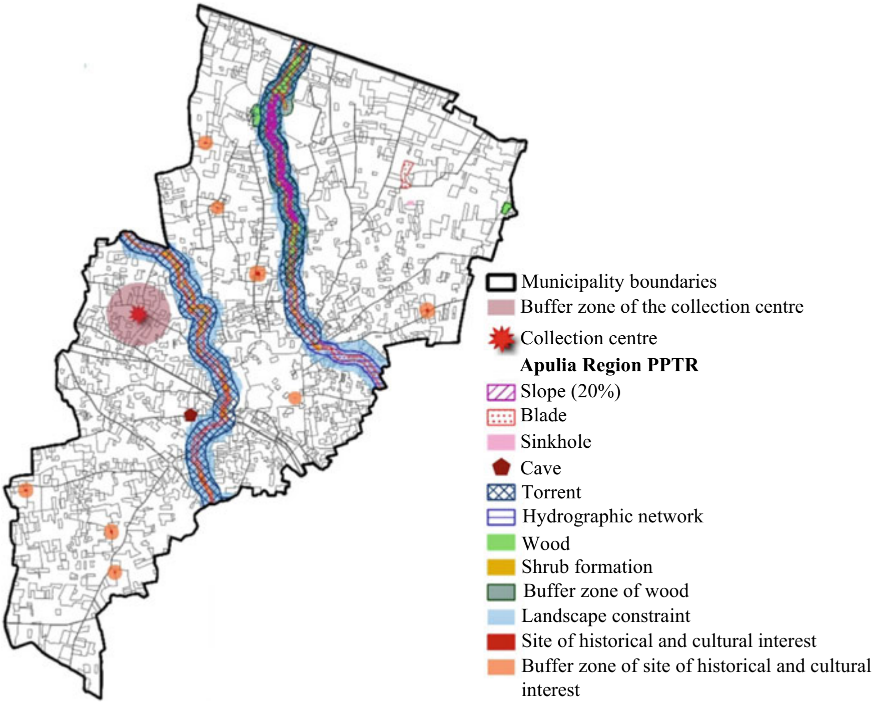

Fig. 4 Suitable location of the collection centre

The collection centre location was defined within the municipality boundaries of Noicattaro. The proposed methodology can be extended to include some surrounding municipalities for defining a common collection centre. This would be useful considering that the APW management could be implemented more efficiently on an intermunicipal scale.

4 Conclusions

The spread of intensive and semi-intensive agricultural practices implies the use of huge quantities of plastic products. This means also that large amounts of plastic waste are generated and that these need to be disposed of in the most proper way to limit the negative impact on the ecosystem. An efficient management system is necessary. The Apulia Region, in Italy, is characterized by a relevant consumption of plastic products for agricultural activities. One of the most produced agricultural plastic wastes is due to irrigation pipes used for several crop productions.

In the municipality of Noicattaro, the highest production of plastic waste made of pipes is generated in vineyards cultivation. A territorial analysis based on the use of a GIS was proposed. It allowed to update the available land use map, adding information related to the plastic products use and waste generation. The result is a georeferenced database, continuously upgradeable through land use and plastic waste changes monitoring.

This can be a precious tool for decision makers and planners to quantify and localize agricultural plastic waste generation, to identify the most suitable areas for collection centres and to analyze possible development scenarios for rural areas.

Acknowledgements The contribution to programming and conducting this research was equally shared between the Authors.

This research was carried out as a part of the Project "Plastic in Agricultural Production: Impacts, Lifecycles and Long-term sustainability—PAPILLONS", financed by the European Union—Topic: SFS-21-2020 Emerging challenges for soil management—Sub-Topic B [2020]: Emerging challenges for soil management: use of plastic in agriculture (RIA)—Grant agreement ID: 101000210.

References

1. Plastics Europe: Plastics - the Facts 2021: An analysis of European plastics production, demand and waste data (2021)
2. Picuno, P.: Innovative material and improved technical design for a sustainable exploitation of agricultural plastic film. Polym-Plast Tech. Mat. **53**, 1000–1011 (2014). https://doi.org/10.1080/03602559.2014.886056
3. Briassoulis, D., Babou, E., Hiskakis, M., Scarascia, G., Picuno, P., Guarde, D., Dejean, C.: Review, mapping and analysis of the agricultural plastic waste generation and consolidation in Europe. Waste Manag. Res. **31**, 1262–1278 (2013). https://doi.org/10.1177/0734242X13507968
4. Scarascia Mugnozza, G., Sica, C., Russo, G.: Plastic materials in European agriculture: actual use and perspectives. J. Ag. Eng. **3**, 15–28 (2011). https://doi.org/10.4081/jae.2011.3.15
5. Briassoulis, D., Hiskakis, M., Babou, E., Antiohos, S.K., Papadi, C.: Experimental investigation of the quality characteristics of agricultural plastic wastes regarding their recycling and energy recovery potential. Waste Manag. **32**, 1075–1090 (2012). https://doi.org/10.1016/J.WASMAN.2012.01.018
6. Lanorte, A., De Santis, F., Nolè, G., Blanco, I., Loisi, R.V., Schettini, E., Vox, G.: Agricultural plastic waste spatial estimation by landsat 8 satellite images. Comput. Electron. Agric. **141**, 35–45 (2017). https://doi.org/10.1016/J.COMPAG.2017.07.003
7. Blanco, I., Loisi, R.V., Sica, C., Schettini, E., Vox, G.: Agricultural plastic waste mapping using GIS. A case study in Italy. Resour. Conserv. Recycl. **137**, 229–242 (2018). https://doi.org/10.1016/J.RESCONREC.2018.06.008
8. Plastics Europe: the circular economy for plastics: a European overview (2022)
9. González-Sánchez, C., Martínez-Aguirre, A., Pérez-García, B., Martínez-Urreaga, J., De La Orden, M.U., Fonseca-Valero, C.: Use of residual agricultural plastics and cellulose fibers for obtaining sustainable eco-composites prevents waste generation. J. Clean. Prod. **83**, 228–237 (2014). https://doi.org/10.1016/J.JCLEPRO.2014.07.061
10. De Lucia, C., Pazienza, P.: Market-based tools for a plastic waste reduction policy in agriculture: a case study in the south of Italy. J. Environ. Manag. **250** (2019). https://doi.org/10.1016/j.jenvman.2019.109468

11. Horodytska, O., Valdés, F.J., Fullana, A.: Plastic flexible films waste management – a state of art review. Waste Manag. **77**, 413–425 (2018). https://doi.org/10.1016/J.WASMAN.2018.04.023
12. Schettini, E., Scarascia Mugnozza, G., Blanco, I., Convertino, F., Vox, G.: Agricultural plastic waste. In: Colangelo, F., Cioffi, R., Farina, I. (eds.) Handbook of Sustainable Concrete and Industrial Waste Management, pp. 255–268 (2022)
13. Jiménez-Lao, R., Aguilar, F.J., Nemmaoui, A., Aguilar, M.A.: Remote sensing of agricultural greenhouses and plastic-mulched farmland: an analysis of worldwide research. Remote Sens. **12**, 2649 (2020). https://doi.org/10.3390/RS12162649
14. Vox, G., Loisi, R.V., Blanco, I., Scarascia Mugnozza, G., Schettini, E.: Mapping of agriculture plastic waste. Agric. Agric. Sci. Procedia. **8**, 583–591 (2016). https://doi.org/10.1016/j.aaspro.2016.02.080
15. QGIS https://www.qgis.org
16. SIT Puglia http://www.sit.puglia.it