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Mapping of agriculture plastic waste

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Abstract

The current intensification of the use of plastic materials in agriculture, although has increased significantly the productivity, is also generating growing adverse effects on the environment of the agro-ecosystem. The agriculture is responsible for a massive use of plastic materials, in addition to energy and water inputs, chemical fertilizer and pesticides. Besides the pollution generated during the manufacture, at the end of their lifetime plastic materials used for crop covering, soil mulching, packaging, containers, pots, irrigation and drainage pipes, may became a pollution source when improperly disposed, leaved on the ground or burned. Instead the agricultural plastic waste (APW), if correctly collected, can be used as a new secondary raw material or as an energy source. An adequate APW management can prevent economical losses and environmental damages.

The territory of the Barletta, Andria, Trani Province (BAT), in the Apulia Region, South Italy, is an agricultural area characterized by vineyards, olive groves, orchards and vegetables; it represents an area of intense production of plastic wastes and with a widespread problem linked to the application of unacceptable disposal practices.

The goal of this study is to define and quantify the different types of plastic waste produced by the agricultural practice in a restricted area of the municipal area of Trani and Barletta, to localize the points where the most remarkable quantities of them are generated, and to provide the local Authorities and the decision makers of a useful tool for implementing an efficient and effective waste management. A dedicated geo-referenced database was designed using land use maps in a GIS environment and applying a methodology that can be functional for any kind of agricultural plastic waste. The resulting database gives updated and complete information on the plastic waste generation, over the land, related to the cultivation kind.

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Keywords: waste disposal; G.I.S.; land management; suistanaibility

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1. **Introduction**

Currently the intensive and semi-intensive agricultural practices involve ever more a great use of plastic materials such as greenhouse and tunnel covering films, direct coverings, shading and protective nets, soil mulching and solarization films, irrigation and drainage pipes, silage films, nets for harvesting and post-harvesting operations, packaging containers and sacks, pots, strings and ropes (Picuno, 2014; Vox et al., 2010). In 2010 over 265 million tons of plastic were produced worldwide, 2% of this volume was the used in agriculture (Briassoulis et al., 2013; Picuno, 2014), replacing progressively over the years the usage of greenhouse glass coverings and straw or paper for mulching (Scarascia et al., 2011). In Italy the average annual consumption of agricultural plastic materials accounts to more than 350,000 tons (Picuno et al., 2012a).

The extensive and expanding use of plastic materials is due to some their essential properties such as light weight, simplicity of use, low purchase cost, cheap installation and management, and good mechanical resistance. Some of the advantages provided by plastics use in agriculture result from protection from adverse weather conditions, more efficient use of water and farm land, increase in the quality and quantity of the production, reduction of use of weed killers, advanced or delayed harvests (Briassoulis and Schettini, 2003; Briassoulis et al., 2013; Picuno et al., 2012a). The greenhouses exploit solar energy obtaining a suitable internal microclimate for the optimization of the growth and development conditions of the plants. The alteration of the spectral wavelength distribution and quantity of the solar radiation, passing through the nets and film influence plant growth and productivity involving the photosynthetic, photomorphogenetic, phototropic and photoperiodic plant response (Schettini et al., 2011; Castellano et al., 2008; Mistriotis and Castellano, 2012). The constant research of new blends, polymers, and of innovative plastic films and nets has enabled a significant increase of the productivity, quality and homogeneity in protected cultivation and where the agriculture is most intensive with high value added (Schettini and Vox, 2012; Sica et al., 2015; Santagata et al., 2014; Picuno, 2014).

Agricultural practices produce many and different wastes mainly related to the use of plastic materials, energy, water, pesticides and fertilizers, and to the generation of biomass and livestock slurry. Plastic materials are characterized by a short duration; the plastic films in particular are affected by a progressive deterioration of their mechanical and spectro-radiometric properties mainly due to their thickness, their exposition to the solar radiation and to pesticides, the variations in temperatures and relative humidity, the wind and rainfall actions, and the installation mode (Picuno, 2014). As a consequence the frequent replacement of films and the use of other plastics generate large amounts of post-consumer material that need to be properly managed (Al-Maaded et al., 2012; Briassoulis et al., 2012, 2013, 2014; Delbert and Hemphill, 1993). In Italy the estimated quantity of agricultural plastic wastes (APW) amounts to about 200,000 t/year, 55% of which comes from protected cultivation that is from greenhouse coverings, low tunnels, soil mulches, vineyards films and nets (Picuno et al., 2012a). At the end of their useful life plastic wastes are often burned in the open field, abandoned in the fields or along watercourses, buried in the soil, disposed in the landfills; inappropriate disposal of APW causes soil and water contamination, releasing of harmful substances and air pollutants, food contamination, soil quality degradation, as well as also aesthetic pollution and landscape and the agro-ecosystem degradation (Briassoulis et al., 2013). The APW represent an environmental and economic problem and at the same time an opportunity to be exploited to recover energy and reduce the amount of agricultural plastics produced with fossil raw resources. They are composed by a limited range of plastics such as polyethylene (PE), ethylenvinylacetate (EVA), polypropylene (PP), polyvinylacetate (PVC) (Scarascia et al., 2011), being therefore suitable for a technically and economically feasible mechanical recycling; the APW could be used to produce new secondary raw material (Picuno et al., 2011; Picuno, 2014). The energy recovery is a possible option to be taken into account for non-recyclable waste, as alternative to the disposal in the landfills, the plastic being characterized by an high heating value (Delbert and Hemphill, 1993; Scarascia Mugnozza et al., 2011).

The lack or the inefficiency of agricultural plastic waste management schemes in most of the European countries (Briassoulis et al., 2013), the complexity and continuous evolution of the Italian legislation, and especially the lack of input and output data on the use of plastics in agriculture, make the APW management very expensive and complicated.

The territory of the Barletta, Andria, Trani Province (BAT), in Apulia Region, South Italy, is an agricultural area characterized by vineyards, olive groves, orchards and vegetables; it represents an area of intense production of

plastic wastes and with a widespread problem linked to the application of unacceptable disposal practices. The local Authority of the BAT Province is interested in resolving the management problem of the plastic waste flux by introducing modernization actions for the farms in the area as studied in the project "Agricultural Waste valorisation for a competitive and sustainable Regional Development - AWARD" (AWARD, 2015).

The environmental and landscape aspects connected to the agricultural activities must be taken into account and analyzed when planning the extra-urban land at macro-scale (Picuno et al., 2011); the waste generated by the agricultural sector must be considered in choosing the layout and in designing the territory for the location of suitable structures for waste management.

The goal of this study is to define and quantify the different types of plastic waste produced by the agricultural practice in a restricted area of the municipal area of Trani and Barletta, to localize the points where the most remarkable quantities of them are generated, and to provide the local Authorities and the decision makers of a useful tool for implementing an efficient and effective waste management.

A Geographical Information Systems (G.I.S.) is an excellent computer tool for landscape modeling and analysis, able to capture, store, retrieve, manage and display huge amounts of spatial data (Rogge et al., 2008; Lee et al., 1999; Tortora et al., 2015). Data can be organized in layers, combined and integrated in order to produce comprehensive information about a region or a phenomena (Lee et al., 1999). A G.I.S.-based model for the management of solid wastes can improve the efficiency of waste management procedures by reducing the overall costs of collection and transfer to disposal sites (Khan and Samadder, 2014). The pertinence of G.I.S. in the agricultural sector has been demonstrated by many studies, in particular for the management of the agricultural plastic waste flux (Picuno et al., 2012b, Scarascia Mugnozza et al., 2008), thanks to its attitude in synthesizing complex land relations (Toccolini, 1998). A GIS model if used as a decision support tool can provide great assistance for landscape planners and policy makers (Ghose et al., 2006; Rogge et al., 2008)

The main focus of this paper was to create a dedicated geo-referenced database in a GIS that summarizes the complete information on the agricultural plastic waste flows, always updatable, useful to their monitoring and management.

2. Materials and methods

The research was focused on a restricted area of the municipality of Trani and Barletta, included into the Province of Barletta-Andria-Trani (BAT), an Italian province in the Apulia Region. The area of study, having an extension of about 1,500 hectares, is located between the towns of Trani and Barletta in Apulia (Fig. 1).

The area is characterized by a wide diffusion of vineyards which are grown using the "tendone" technique, a traditional grape cultivation system with a supporting structure that may be covered with a plastic films or nets (Picuno et al., 2011; Vox et al., 2012); vineyards are identified as one of the major contributors to the generation of plastic waste in the selected area (Sica et al., 2015).

The base map material used was:

- Regional technical map (CTR) at a scale of 1:5,000: it is obtained from an aerial flight performed in 2006; it is placed in the WGS 84 / UTM zone 33N reference system;
- Digital color orthophoto at a scale of 1:5.000: it is obtained from an aerial flight performed in 2011; it is placed in the WGS 84 / UTM zone 33N reference system and has a pixel ground resolution of 50 cm;
- Land use map of the Region of Apulia at a scale of 1:5,000: it derives from an orthophoto having 50 cm pixel; the land use polygons are based on the same geometric elements of the Regional technical map with legend complying with the European CORINE Land Cover Changes Database and an extension to the fourth level.

The base maps and the main agro-environmental components, the infrastructural components and the municipality boundaries characterizing the territory were managed in ESRI ArcMap10, a GIS software, for constituting an adequate base map system.

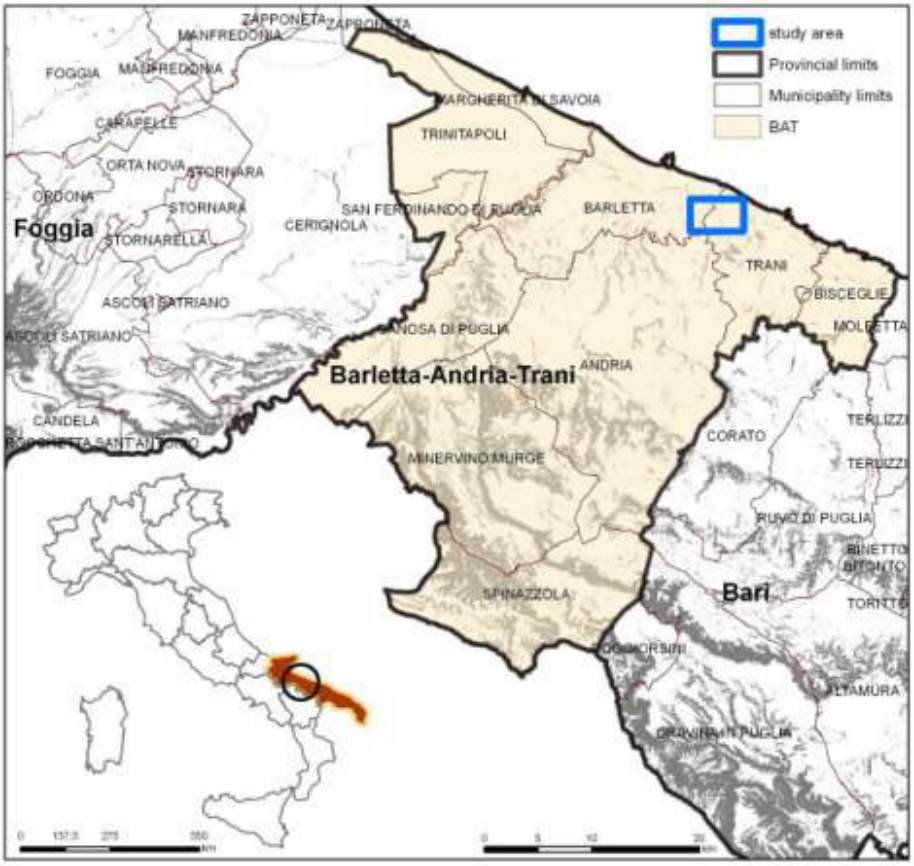

Figure 1 - The study area with the indication of the restricted area where the GIS modeling was applied.

The applied methodology is summarized in the following steps:

- Preparation of the base map suitable to be managed in ArcMap according to the specific research purpose;
- Selection and highlighting on the land use map of the crops generating plastic wastes;
- Detection of the land use with respect to the different typologies of plastics used in the area;
- Creation of a geo-database summarizing the complete information on the agricultural plastic waste;
- Database validation;
- Attribution of indicators of plastic production for each crop in the land;
- Quantitative evaluation of agricultural plastic waste;
- Realization of the APW maps.

The land use map of the Region of Apulia needed to be “geo-processed” in order to have a base map suitable to be managed in ArcMap according to the specific research purpose. Actually the land use map, downloadable from the website of Apulia Region, is updated to 2011 and available in different shape files, depending on the detected area, that need to be merged; after that, the resulting shape file was clipped on the study area, in order to limit the amount of data to handle.

The land use map was subjected to subsequent further processing for highlighting on the map only the crops generating plastic wastes. The thematic land use map provides the data on the spatial distribution of the different crops; however it was necessary to detect some additional information about the typology and characteristics of covering structures for the specific cultivation. The implemented methodology of territorial analysis, realized by

means of a GIS, permits to enrich the land use map adding a further classification according to the presence or not of a covering system, and on the kind of cladding material employed whether film or net.

The database was updated to 2014 and enriched with detailed data on spatial distribution and typology of the selected crops, and on the plastic materials employed for their cultivation. The additional data were obtained by the overlay mapping of the base map material and by the parallel operation of photo-interpretation of the web-mapping tools Google Maps 2014 and Google Earth 2014. The results obtained were validated through a series of sample field inspections.

The average plastic consumption values per hectare (kg $ha^{-1}yr^{-1}$) for every application were derived from the results of the research activities carried out under the project "AWARD"; the amount of the waste generated was assessed taking into account the crop typology (e.g. vineyard, olive groves, orchards, arable land and vegetable crops), the different type of plastic material used (films, nets, irrigation pipes, tanks of pesticides and herbicides, sacks of fertilizers), the periodicity of the waste generation mechanism (AWARD, 2015).

Finally the GIS database was used to quantify the total production of the APW in the study area and to generate thematic maps for having a spatial distribution of the plastic waste densities.

3. Results and discussion

A dedicated geo-referenced database was created by using the base map material in a GIS. The area of study incorporates the land of Trani for an area of 987 ha, the land of Barletta for an area of 503 ha and the land of Andria for an area of 10 ha. The figure 2 highlights the crop distribution in the study area: the 47% of the territorial surface is cultivated with vineyards, the 30% with olive trees and 11% is arable land (cereals and vegetables).

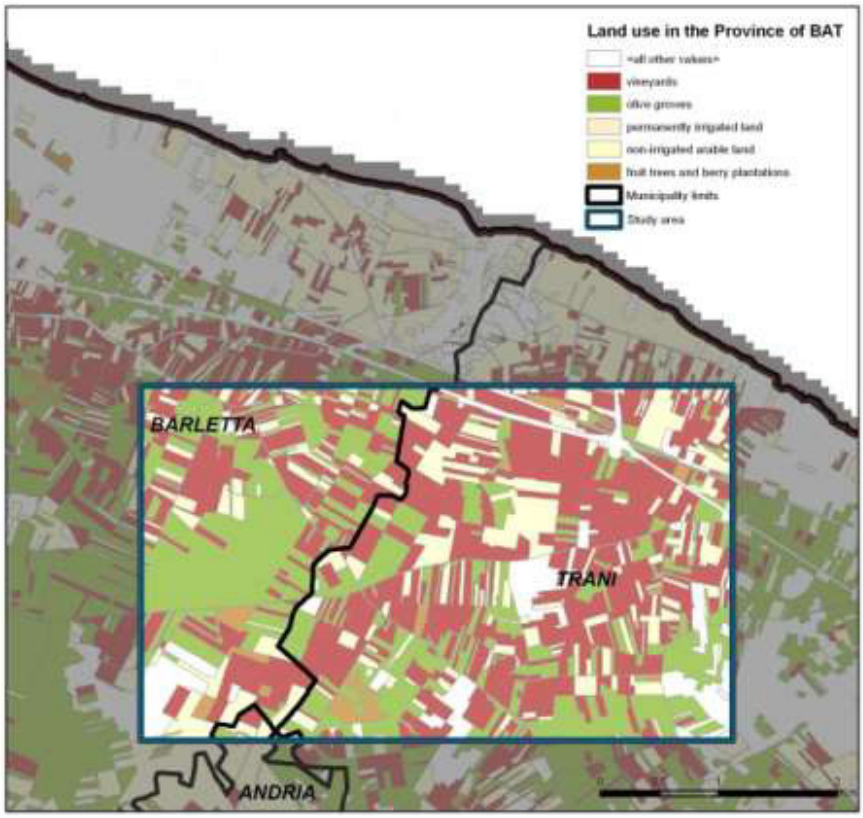

Figure 2 – The Land Use map on the study area.

The analysis of the obtained results (tab.1) shows that the total amount of produced agricultural plastic waste per cultivated area and per year is about 250 tonnes, of which the largest contribution, accounting for 63%, is obtained from the plastic covers of the vineyards and 35% is due to irrigation pipes of all the irrigated crops (vineyards, olive trees, vegetables, orchards).

Table 1 – Total Agricultural Plastic Waste in the study area per waste typology

Agricultural Plastic Waste typology					
Covering films and nets (kg per year)	Irrigation pipes (kg per year)	Containers (kg per year)	Bags (kg per year)	Olive nets (kg per year)	Total (kg per year)
155,000	85,000	3,400	1,900	200	245,500

The Figure 3 presents the territorial distribution of the estimated agricultural plastic waste generated annually per hectare of cultivated area from irrigation pipes. The higher density of plastic waste is recorded in the area with vineyard due to the higher amount of irrigation pipes used; lower values are related to the areas cultivated with olive trees (Fig. 3).

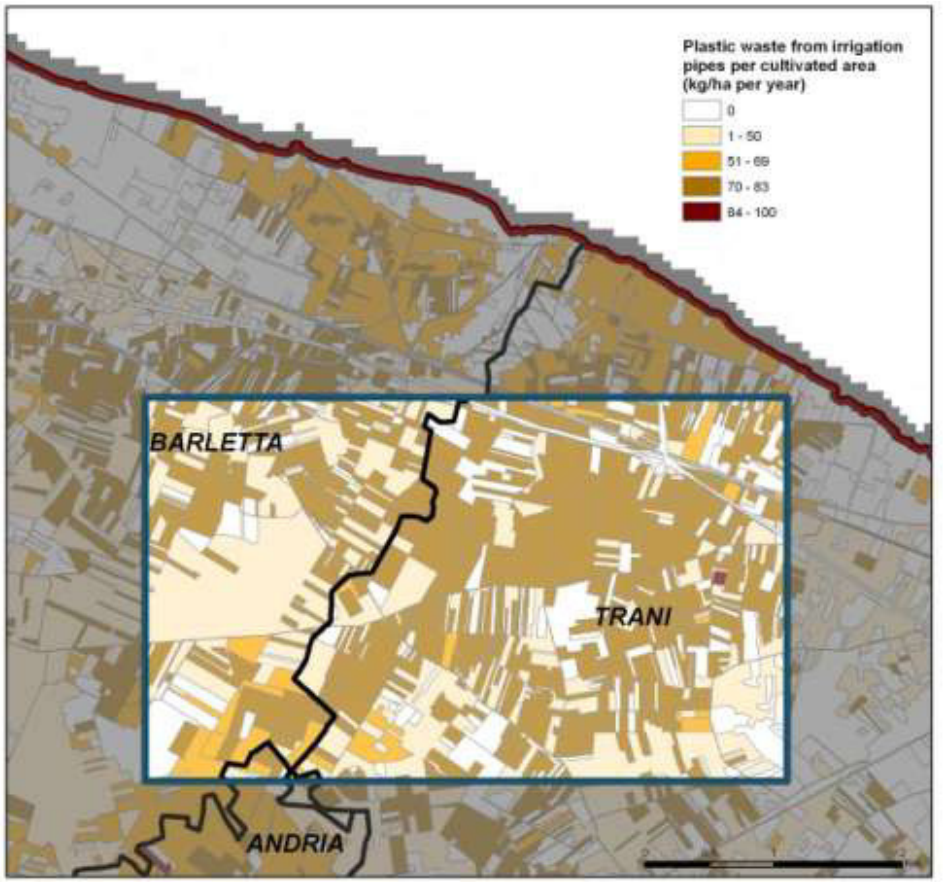

Figure 3 - The distribution of the amount of plastic waste deriving from irrigation pipes (kg $ha^{-1}yr^{-1}$)

The Figure 4 shows the distribution of the amount of plastic waste deriving from covering films and nets, that mostly contribute to the waste production. A high difference in waste production was pointed out between the areas cultivated with vineyards and the other cultivated areas because films and nets are mostly applied for vineyard

protection (Fig. 4); the waste density ranged from 159 kg $ha^{-1}yr^{-1}$ for a vineyard covered with net to 773 kg $ha^{-1}yr^{-1}$ for a vineyard protected with film and net.

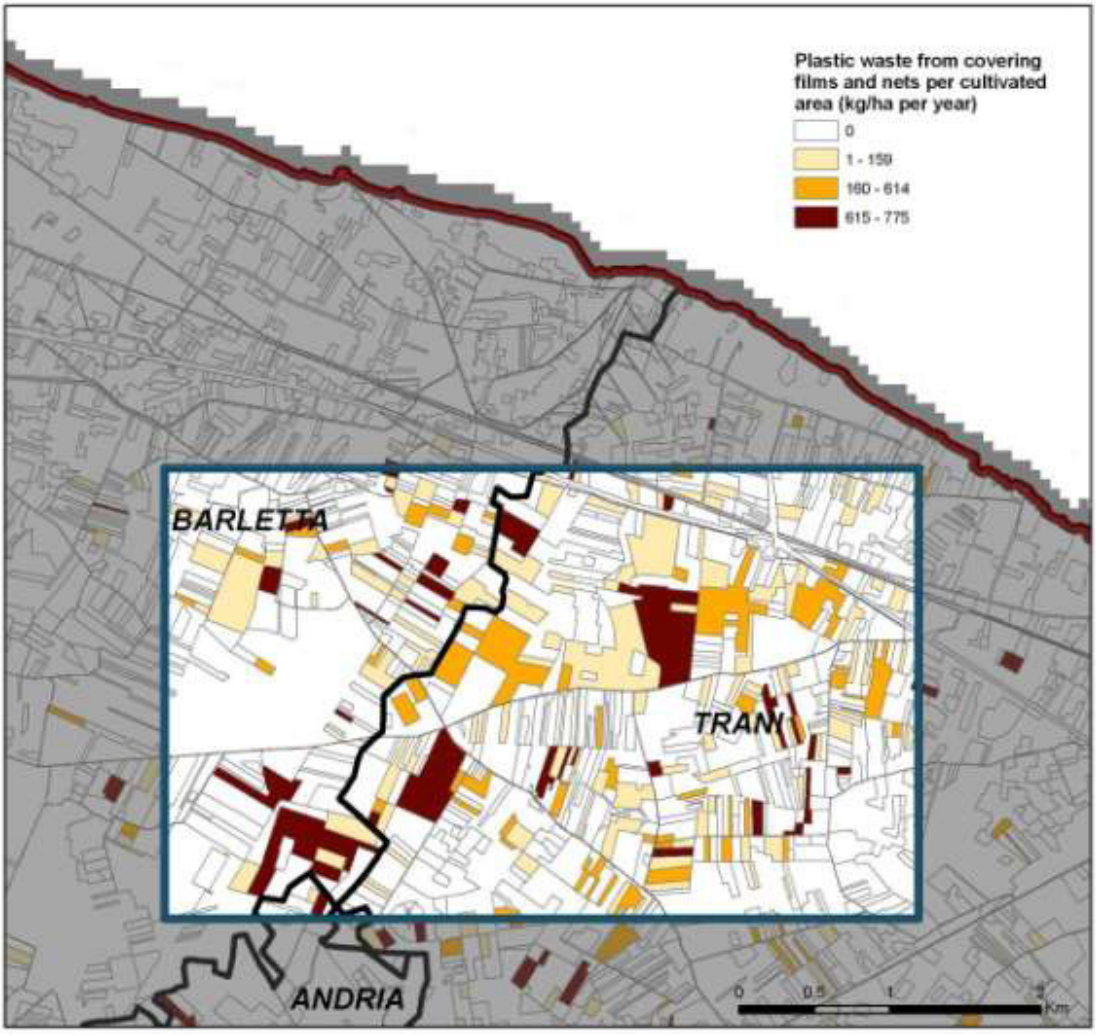

Figure 4 - The distribution of the amount of plastic waste deriving from covering films and nets (kg $ha^{-1}yr^{-1}$).

The Figure 5 shows the overall density of produced waste resulting from the sum of the obtained values per all the waste individual types. The presence of waste generated by films and nets strongly influenced the overall density of APW, the contribution from other plastic waste kinds being very low. The waste density ranged from 3.3 kg $ha^{-1}yr^{-1}$ for a non irrigated arable land to 861 kg $ha^{-1}yr^{-1}$ for a vineyard protected with both film and net.

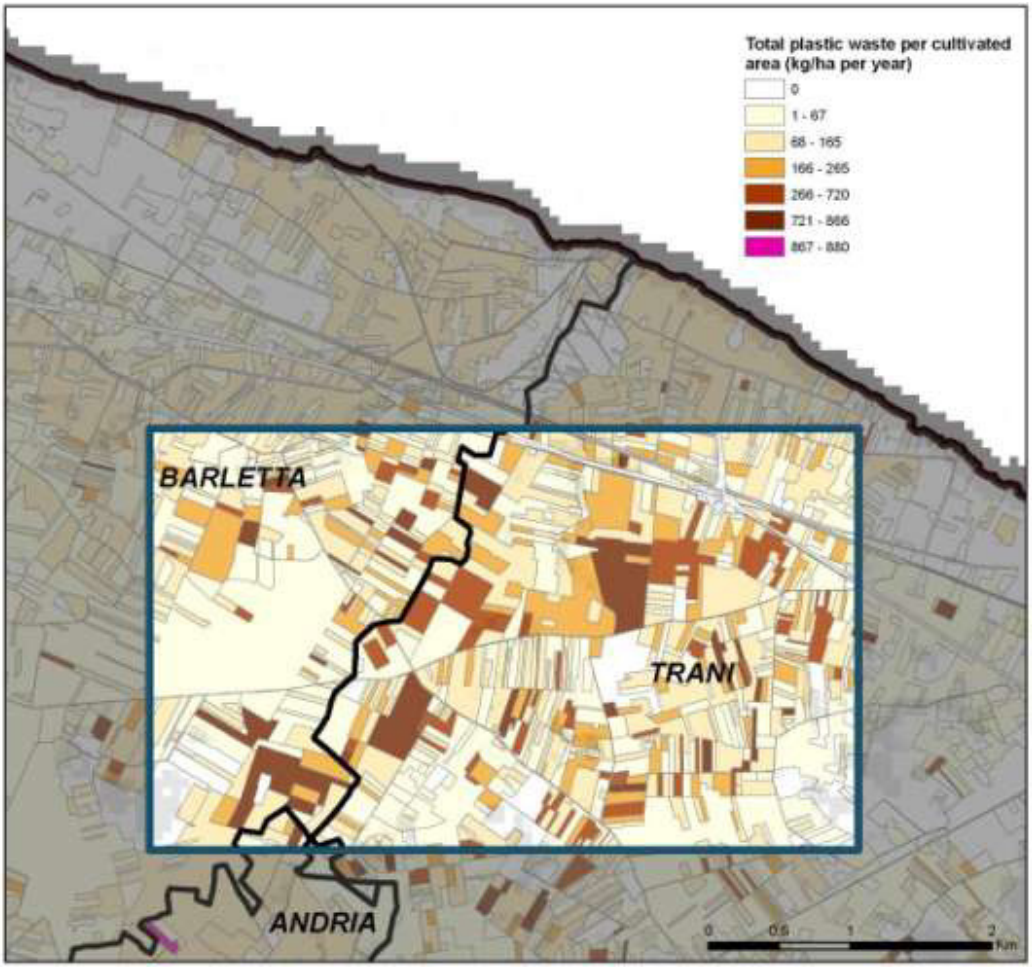

Figure 5 - The distribution of the overall density of APW (kg $ha^{-1}yr^{-1}$).

4. Conclusions

The agricultural practices generate huge quantities of after use plastic materials which constitute a waste that will need an appropriate collection and disposal. The largest amount of plastic waste produced in the Apulia Region derives mainly from the use of films and nets employed for crop covering and from the use of irrigation pipes. The proposed methodology, applicable to rural lands devoted to agriculture, has allowed the creation of a useful tool for the continuous monitoring of related APW flows and land use changes.

The dedicated geo-referenced database, created for the present study in a GIS, permits to define the generation areas of plastic waste all over the territory and to identify and localize the critical points of generation of APW. Furthermore this database increases the knowledge about the land, thus facilitating the implementation of action plans, helping decision makers and planners for selecting the best sites for disposal.

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