Investigating the Use of Plastic and Its Disposal in Agriculture in Malta

Rainer Borg and Margaret Camilleri Fenech *

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Article

Investigating the Use of Plastic and Its Disposal in Agriculture in Malta

Rainer Borg [1] and Margaret Camilleri Fenech [2,*]

[1] Environment and Resource Authority, Malta, rainer.borg@era.gov.mt
[2] Institute for Climate Change and Sustainable Development, University of Malta
* Correspondence: margaret.camilleri-fenech@um.edu.mt

Abstract: The use of plastic in agriculture has become so omnipresent within the industry that it has acquired it own lexicon to become known as 'plasticulture'. However, since, compared to other industries the quantities consumed are low, little attention is granted to this waste stream. This is the case both with local and international policies even though it bears a close connection to soil health and therefore is a prerequisite to improve the sustainability of food production processes including food security. Using Malta as a case study, the research utilises quantitative and qualitative tools to identify and quantify the most common types of agricultural plastic waste generated and determines the attitudes of farmers towards a collection and recycling scheme. While it identifies that incineration and ploughing of plastic waste as regular practices, it also ascertains the willingness of farmers to acquire more knowledge about more appropriate methods to dispose of this waste stream thus guiding policy makers towards the need to initiate educational measures for farmers to prevent these harmful practices. Through stakeholder interviews the research highlights that the present lack of data is a major hindrance for policy to take account of this waste stream.

Keywords: agricultural plastic waste; disposal practices; extended producer responsibility; collection schemes; sustainable food production

1. Introduction

Plastic use is widespread. Some of the most prominent characteristics of plastic that contributed to its spiralling success include durability, lightness, strength, workability and low costs. These factors have facilitated its infiltration into various industries making its use ubiquitous across continents. In fact, the quantities of plastic produced have increased dramatically - while in 1976, worldwide plastic production amounted to 50 million metric tons, in 2021 the figure reached 390.7 million metric tonnes [1]. The latter figure includes fossil-based plastics (90.2 per cent), post-consumer recycled plastic (8.3per cent) and bio-based plastics (1.5 per cent) [2].

Agriculture is one of the industries where plastic use has increased drastically. During 2021, agriculture, farming and gardening consumed 4 per cent of the 390.7 million tonnes of plastic produced. While, in comparison to other industries the figure might not be impressive, the wide availability of plastic products, together with their low cost, have transformed agricultural production from one that is traditionally low in waste to an industry with significant waste related issues [3]. The usage of plastic within this industry has become so extensive that the term 'plasticulture', that is, the use of plastic materials for agricultural practices became customary [4].

The benefits of plastic posed to agricultural productivity are extensive. The material is utilised at various stages of the production process for example, to cover soil and reduce weeds, to protect and boost plant growth, extend the cropping seasons and increase yields, and to make tree guards which protect seedlings and saplings from animals and help provide a growth-enhancing microclimate. However, the appropriate collection and disposal of these plastics remains a question mark. In fact, the Food and Agricultural Organisation (FAO), in the report "Assessment of

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agricultural plastics and their sustainability" points out that the amount of plastics that are dispersed in the environment out of the 12.5 million tonnes of waste generated annually is unknown [5]. Informal disposal leads to the build-up which in turn results in micro-plastics, that are dispersed into various parts of the environment, through for example, surface run-off and its eventual migration into deeper layers affecting soil health and in turn food security [3].

This in turn results in microplastic contamination. The latter has become one of the most widespread and long-lasting anthropogenic changes to the surface of our planet [6]. Furthermore, it has been identified as one of the most pertinent topics for biodiversity conservation on a global scale [7]. Yet the effects of plastic fragments on dry land are not popularized [8]. It should be further noted that plastics, including those reported as biodegradable, are more prone to disintegration than degradation [9]. Disintegration results in macroscopic plastic pollution which ultimately generates particles smaller than 5 mm, that is, microscopic. These particles, while being omnipresent, are also likely to gain new chemical compositions that impact soil fauna and hindering soil fertility and functions [8]. Additionally, chlorinated plastics can release harmful chemicals in the soil which leaches into groundwater or the surrounding water sources and ecosystems imparting a range of potentially harmful impacts on species that consume from the said water bodies [8]. The intake and uptake of microplastic can cause a new long-term stress factor for the environment. Presently, however there is a lack of standardised methods for determining microplastics in terrestrial ecosystems to produce an accurate assessment of the situation [8].

Despite its adverse impacts, research and quantification of plastic waste generated by the agricultural industry is limited. The lack of data and research on this topic, results from the false perception that the quantities generated by the agricultural industry are minimal or rather, not substantial enough to justify additional investigation or tackle through policies. This situation has prevailed for some time throughout Europe. In fact, the project LabelAgriWaste in 2006 sought to address this waste material and, in view that officially reported information on agricultural plastic was sporadic or even unreliable and unavailable, it was necessary to combine data from Ministries of Agriculture, statistical organisations, regional services, local agronomists, retailers and farmers, site visits and interviews with the sales departments of major producers, importers and converters if agricultural plastics. When no data was available, estimates based on the recorded cultivated areas were carried out [4]. More recently, 'Agriculture Plastics Europe', an association of companies and organisations involved in agri-plastics published figures about film sales in Europe based on 2018 [10]. The Food and Agricultural Organisation (FAO) based its collection rates figures on the presence of Extended Producer Responsibility (EPR) schemes in specific countries which are still very limited within the EU. In fact, no harmonised EPR scheme for plastic agricultural waste is presently in place.

This paper seeks to examine the current use of plastics in the agricultural industry and the disposal practices within the Maltese Islands. The use of a case study assists in the identification of trends including in neighbouring countries particularly when they are cultivating similar crops during a variety of seasons. The study aims to generate data sets from the target community to compensate for the present lack of data. Plastic waste audits also aided in producing detailed data which directly contributed to the closing of the data gap related to the quantities, type of plastic waste generated, and disposal methods used. The study also included a survey with local farmers and other stakeholders to discuss the present disposal practices and the existing waste policies together with any strategies to help tackle this problem.

2. Case Studies

The two case studies described below serve as a basis for the methodological approach adopted in this research. In the LabelAgri Waste Scheme, an overview of the agricultural plastic waste (APW) collection scheme is provided. The Nova Scotia case study, on the other hand, is utilised to guide the development of the questionnaire which was then used in the research presented here.

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2.1. The LabelAgriWaste Scheme

An initial step in this research was the review of projects and schemes focused on APW. A prominent project was the LabelAgriWaste Scheme[1]. The project came to life in view of the highly erratic disposal methods of APW within Europe mainly because only small quantities get recycled while the rest are either abandoned on-site or incinerated leading to the release of harmful substances. The project sought to develop the collection, sampling, labelling procedures and methods to valorise agricultural plastic waste streams by facilitating their routing to the most environmentally and economically viable disposal alternatives [11]. The reasons behind this mismanagement are often due to unawareness of the impacts that they impart both on the environment and the farmers' health. These practices are also illegal since European legislation forbids uncontrolled burning through incineration (Directive 2000/76/EC), uncontrolled burying of waste (Directive 99/31/EC and the uncontrolled discarding of waste (revised framework directive 2008/98/EC and Directive 91/689/EEC). However, the lack of technically efficient and cost-effective APW collection schemes push farmers to engage in these actions with little or no control from the relevant authorities. The tools involved revolve around standardised procedures and integrated methodologies which label the APW streams through optimum processing to facilitate their routing to the best final disposal alternative.

One of the results of the project was the depiction of the processes involved in the LabelAgriwaste scheme. This is noted in Figure 1 below.

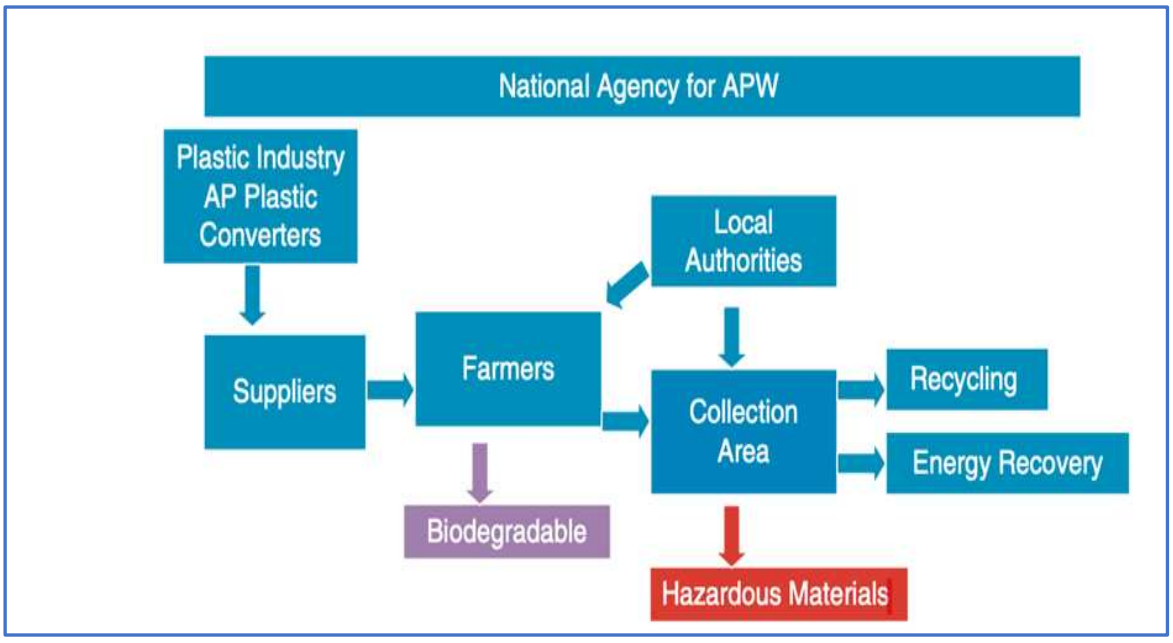

Figure 1. The agricultural plastic waste chain according to the LabelAgriWaste labelling scheme. Source: Briassoulis, et al., 2010.

As can be noted in Figure 1, APW is traced throughout the cycle, starting from the suppliers of the plastic converter until it reaches the farmers to its eventual final disposal. Throughout the depicted cycle, the labelling of waste is a preliminary factor. This allows for the preferred plastics to be disposed of in the most efficient manner both economically and ecologically. Specific guidelines are placed for the use, collection, transportation and treatment of APW. The starting point is assigning the responsibility of the management of APW to a national agency which would serve to control the

[1] The project, 'Labelling agricultural plastic waste for reuse or disposal (LabelAgriWaste)' was coordinated by the Agricutural University of Athens and funded through the Cordis EU. It was implemented between Janaury 2006 and July 2009.

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financial schemes that include payments and refunds, together with the farmer's association. The agency would also be responsible for the running of the physical aspect of the scheme which includes collection centres and data gathering and analysis. However, the agency should also be responsible for the financial and marketing front together with the handling of the disposal of APW including the scheme permits. The plastic industry and converters must ensure the traceability of AP in all forms to avoid issues with free riders. Their involvement is vital since they are the ones ensuring that the materials are appropriately labelled with specific details about disposal requirements. The farmers' lobby, on the other hand, must follow simple and practical guidelines about the use and installation of plastic materials, its removal including the sorting and storing of the material. These guidelines serve to assist farmers in the recording and reporting of the use of plastics. The collection should be run by SMEs and managers, who are responsible to organise and equip the collection stations and ensure that the best disposal method is utilised. Recycling facilities and energy recovery are considered as the bidders for APW also in view that they can provide certification for disposal.

The project made use of various pilot stations that were set up in Greece, Spain, France and Italy mainly to identify issues, collect real data and test alternative procedures. One of the prevailing issues is that of free riders due to lack of traceability. In relation to the polluter pays principal issues arise from the farmers' standpoint. This is in view of illegal practices in the handling of APW.

The framework presented in the LabelAgriWaste scheme was examined and disseminated in the context of its subject and place of study. The several issues that were highlighted outline ongoing illegalities within the sector. Further to this, the countries where pilot stations were set up all had issues with the lack of infrastructure for APW. This, together with the similarity in climatic conditions, provides a valuable connection between the locations involved in this scheme and that of the Maltese Islands which will be tested in this research.

2.2. Nova Scotia, Canada

In this section the study of Muise et al., 2016 [11] is introduced. This study focused on the attitudes for the recovery and recycling of agricultural plastic waste in Nova Scotia, Canada. While the location of the study is very distant from the Maltese Islands, it provided insight into the way in which farmers and stakeholders might react when APW disposal is regularised.

Using a mixed-method approach, Muise et al., 2016, targeted APW generators including waste management groups and delved into the generation and disposal attitudes towards APW. Through a questionnaire, it classified farmers according to demographics (gender & age) together with the period in which the farm was in operation and the percentage revenue. These two aspects provided the research with basic knowledge about the target population and the trends associated with the workforce in question together with a timeline trend associated with the farm work and its general profitability. Following this, farmers were asked to outline the five most important commodities produced on their farm in relation to their financial value to outline the most popular trend in production in relation to the region and target population in question. The next question allowed the farmers to list which commodities contribute most to the generation of APW to outline the correlation between a commodity and plastic dependability, thus delineating aspects of plastic dependability for particular crops.

The questionnaire then shifted to disposal practices of APW. To obtain a behavioural snapshot related to sustainable disposal methods, farmers were asked whether the recycling or safe disposal of APW was important for them. This question was then followed by a series of questions with predetermined responses which reflect behaviours highlighted through previous literature. These questions included the practices which farmers engaged in to dispose of APW and the quantities produced with an estimate in kilograms. Finally, farmers were asked as to whether additional information was required as to how the particular APW must be recycled or reused. These questions set a predicative scenario for potential sustainable disposal projects in the industry.

Respondents were then questioned as to whether they experienced any hindrances to collect waste in one location on their farm for it to be collected by recyclers. The barriers outlined here provided an overview of the difficulties which limit the appropriate management of APW.

 doi:10.20944/preprints202310.1732.v1

The willingness to pay (WTP) for an APW collection scheme was also queried. In the final stage of the questionnaire, farmers were asked which entity should be assigned the organisational and financial responsibility to manage the collection scheme. Respondents were instructed to determine this by ranking, from most responsible to least responsible, the pre-determined stakeholders. These included plastic producers/ importers, farmers, municipal and federal governments.

The research concluded that while the farmers were not dissatisfied with landfilling and incineration of APW, they did emphasize the need for a recycling programme that was easy to engage with and does not impose a heavy financial burden. Similar results were obtained by Levitan & Barros, 2003 [12].

Furthermore, farmers pointed out that were *not* willing to transport APW to the disposal points themselves therefore making curb side or on-site collection as the most viable options. However, most respondents noted that there were no barriers to participate in recycling programmes even though storage might be an issue.

It can therefore be concluded that the farming community in Nova Scotia was prepared to contribute to a recycling programme. However, strong institutional and peer support are necessary to transition from intentions to actions. On the other hand, when farmers are met with limited options for APW management they are more likely to burn, bury or landfill the material. This notion is supported by the LabelAgriWaste programme examined in the previous section.

3. Materials and Methods

The use and eventual disposal of agricultural plastic is geographically concentrated. This facilitates the collection and eventual treatment. Furthermore, the material tends to be homogenous and therefore adds value for the recycler although issues of contamination with soil, pesticides, vegetation, organic waste and inert materials might be present [13].

This research study is focused on horticultural farms. The Farm Structure Survey published by the National Statistics Office (NSO) in 2016 [14], notes that there were 1,503 full-time farmers operating in Malta and Gozo, while the figure for part-time farmers stood at 17,934. In view of this, a sample size of 64 full-time and 66 part-time farmers was determined. The establishment of the sample size is based on stratified random sampling with the population divided into two strata - full-time and part-time farmers. The sample size was determined using a 95 per cent confidence level, that is, one can be 95 per cent certain that the respondent answered truthfully. In the case of the part-time farmers, the sample was obtained based on the confidence interval adopted in the hypothesis testing. In addition to this, a confidence interval of 12 was adopted. This figure refers to the margin of error, that is, there is a +/-12 per cent to be adopted to every response in reference to the response's certainty [15].

The research commenced with a number of audits. However, further stratification was required to produce a statistically representative sample particularly since the audits included a set of in-depth questions to quantify the plastic equipment utilised and disposed of during different time frames. This information was further supplemented with additional data in relation to disposal rates, seasons, and crop types. The in-depth information collected from the audits, together with the literature review, were then utilised as a basis for the questionnaires. Following this, interviews with stakeholders who acted as decision makers for the target market were carried out. This approach ensured that a holistic viewpoint of the theme was established. An overview of the methodology applied in the research is given in Figure 2.

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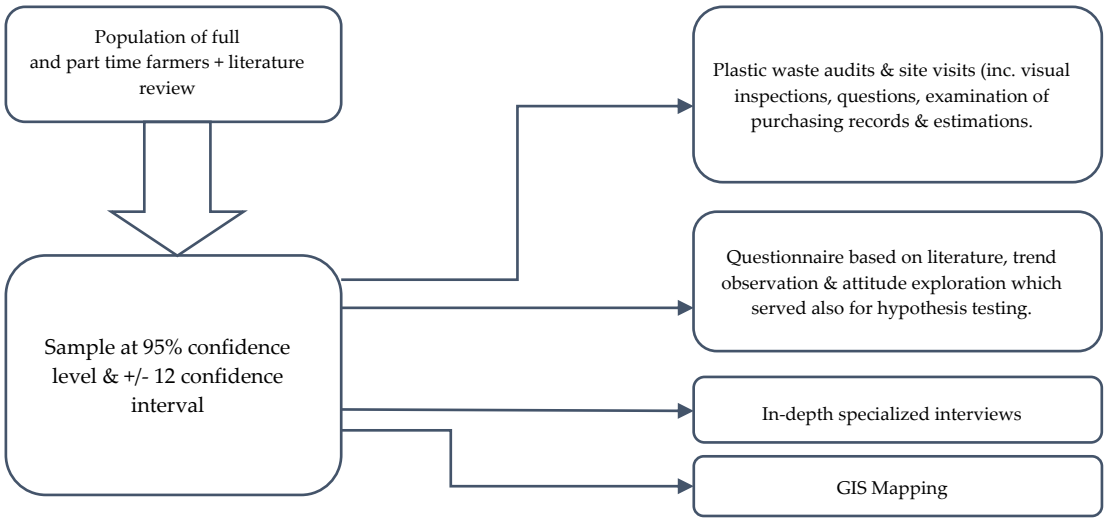

Figure 2. Methodological structure adopted during the research. Source: Authors.

The study, therefore, adopted a mixed-method approach. This is in view that the research questions could not be answered through a single approach. A mixed-method approach allowed the researchers to simultaneously answer confirmatory and investigative questions and therefore verify and generate theory within the same study. It has also been suggested that using a mixed method can offset the disadvantages that certain methodologies have when utilised by themselves [16].

The initial phase consisted of an examination of literature focused on the topic. This contributed both to quantitative and qualitative information. Furthermore, the LabelAgriWaste Scheme described in Section 2.1 was reviewed. This scheme sought to tackle agricultural plastic waste by reviewing the product cycle and tracking disposal patterns by farmers. It collects, manages, and sells the waste, thus financing itself, while at the same time tackling issues related to waste disposal. Furthermore, the case study of Nova Scotia, described in detail in Section 2.2, was also examined. This was integrated into the survey questions to evaluate the attitudes towards the implementation of such schemes. These two cases served to provide an understanding of the ideal approaches of an APW collection scheme including the necessary methodologies to gauge the community's opinions.

In the following step the authors sought to acquire data sets from secondary sources. This included official agencies that oversee the industry in question and those which handle national statistical data. Typically, this data took a numerical form and represented various facets of the study, for example, population demographics, waste statistics and other data relevant to the study.

After the collection of secondary data was completed, the authors embarked on the collection of primary data. The waste audits which were carried out in the horticultural farms. Farmers were requested to provide purchasing information and trends related to the usage of plastic materials in their sites and fill in their own specific table. This data was compiled into tables, with each farmer filling their own table whereby the amounts stipulated, and the plastic material were depicted. The plastic waste was measured in kilogram and the consumption was computed on a yearly basis (see Appendix B.1). Following the compilation of data from the individual farms, a comprehensive table was compiled into one to provide the researchers with a total and average production of APW in kilograms per annum. A total of twenty-three farms participated in the audits. The sample was obtained through stratified sampling technique.

Surveys and questionnaires are typically adopted to collect data from a relatively large population, making it possible to count frequencies, attitudes experienced, processes, behaviours, and predictions within a large sample [17]. In this study, the first five questions of the survey were necessary to acquire the demographics of the respondents. The following ten questions (Questions 5 to 15) were utilised to obtain trends of local farmers and their approach to waste disposal. The final four questions

(Questions 16 to 20) aimed to explore attitudes towards a change in disposal methods including the farmers' willingness to pay a surcharge and comply with a new scheme.

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Question 11, which asks farmers if they "find any difficulties when disposing of plastic waste", question 15, which asks farmers "how they dispose of plastic waste produced of their farm" served as a basis for hypothesis testing and Question 14, which questions if farmers "would you be willing to change the way you dispose of waste?" were used as a basis for hypothesis testing. Hypothesis testing refers to a form of statistical inference that uses data from a sample to draw conclusions about a population probability distribution. It involves using the sample obtained from the target population to determine whether or not H^o can be rejected or not.

Initially, a tentative assumption is made about the parameter or distribution which is being requested. This assumption is termed as 'null hypothesis' and is denoted as H^o. On the other hand, an alternative hypothesis, which is denoted as H^a, which is the opposite of what is assumed in the null hypothesis.

Hypothesis 1:

i. The null hypothesis (H^0) stipulates that farmers *do* encounter difficulties to dispose of APW.
ii. The alternative hypothesis (H^a) stipulates that farmers *do not* encounter any difficulties to dispose of APW.

Hypothesis 2:

iii. The null hypothesis (H0) stipulates that farmers are not knowledgeable on the methods to dispose of APW.
iv. The alternative hypothesis (Ha) stipulates that farmers are knowledgeable of how to dispose of agricultural plastics.

Hypothesis 3:

v. The null hypothesis (H0) stipulates that farmers are willing to change their disposal patterns to safeguard the environment.
vi. The alternative hypothesis (Ha) stipulates that farmers are not willing to change their disposal patterns regardless of the environment.

While an online link was available to guide participants, the questionnaires were mainly disseminated physically. In this case the snowball and chain referral method were used to raise the necessary sample size. This method yields a sample through referrals made among people who share or know others who possess some characteristics or requirements that are of interest to the research [18]. In the case of this research, the main requirement was that of being a farmer. While the snowballing method has its advantages it does not guarantee representation and possibilities of bias are present particularly since, when people nominate their acquaintances, it is likely that they share similar traits. In addition to the snowballing sampling method, other channels like village bars, online community forums, vegetable markets and the local vegetable brokerage site known as 'il-Pitkalija' was also visited (See Appendix B.2).

Specialised interviews involved the formulation of a set of open-ended questions which encourage the interviewees to give their own thoughts, opinions and experiences in relation to the subject at hand. In this research, specialised interviews were organised with the main stakeholders responsible for the management of waste and the attainment of sustainable development targets. These included the Environment and Resources Authority (ERA), WasteServ Malta Ltd (WSM) and the Ministry for the Environment, Sustainable Development and Climate Change (MECP). These entities play a crucial role in the product lifecycle of agricultural plastic waste, both as producers, influencers as well as waste generators.

In the final stage of the research, Geographic Information Systems (GIS) was used to map the frequency and location of the operation of the survey respondents. This reflected on the outcome of the areas being investigated and was relevant in the generalization and mapping of agricultural plastics being produced geographically.

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4. Results

4.1. Agricultural Holdings and Their Management in Malta and Gozo

Agricultural holdings in Malta are mostly located in the west of the island which agglomerates the western to north-western regions. Each region commends 2,541 ha and 3,252 ha of utilised agricultural area (UAA) respectively. In the western region 2,220 ha is arable land, while in the Northern region the figure reaches 1,825 ha. The presence of these holdings is lower in other regions particularly in the areas surrounding the harbour. Gozo agricultural holdings, on the other hand, are mostly located in the north-western region. The area has 2,449 ha of UAA.

Further information about the distribution of UAA can be found in Table 1.

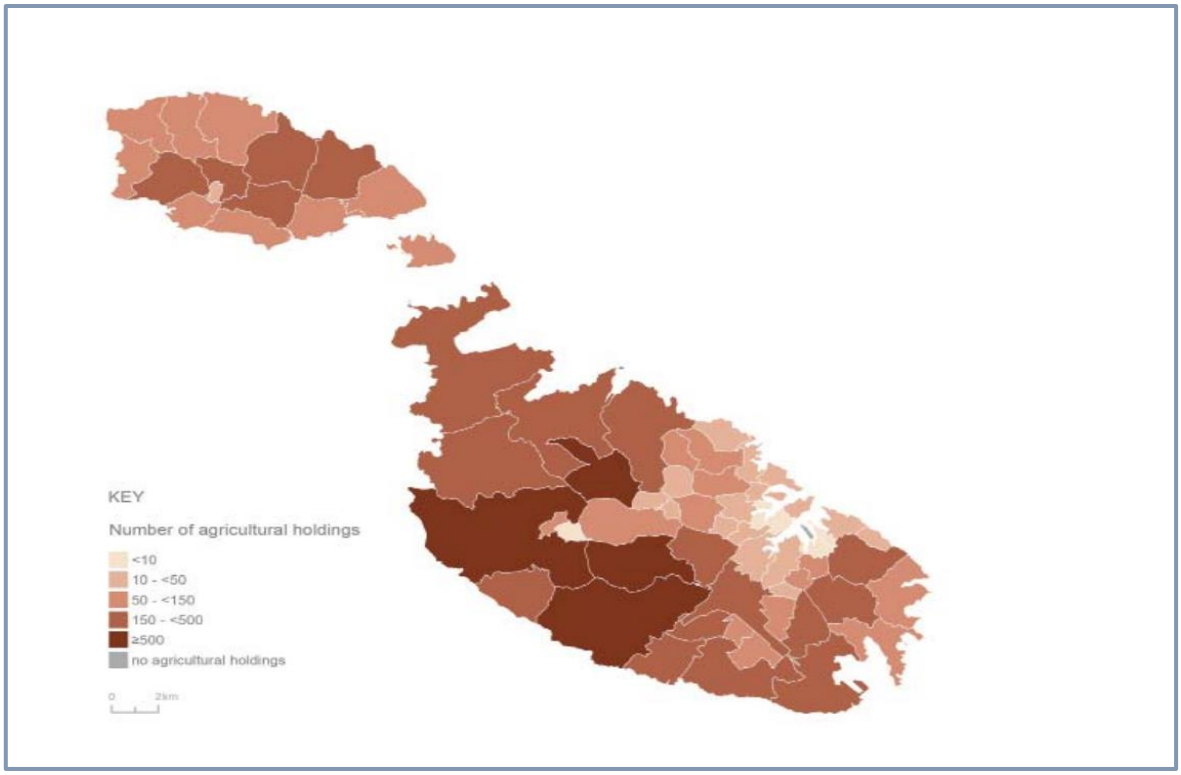

Figure 3. Distribution of agricultural holdings by locality in 2020. Source: National Statistics Office, 2022.

Table 1. Distribution of utilised agricultural area (UAA) by region/district and type for the year 2020. Source: NSO, 2022.

Type of UAA	MALTA	Malta	Southern Harbour	Northern Harbour	South Eastern	Western	Northern	Gozo & Comino
Total UAA (ha)	**10,730**	**8,281**	**410**	**243**	**1,834**	**3,252**	**2,541**	**2,449**
of which:								
Arable land	**7,782**	**5,891**	304	163	1,378	2,220	1,825	**1,891**
Permanent crops	**953**	**791**	12	11	58	404	306	**162**
Kitchen gardens	**1,995**	**1,599**	94	69	398	629	410	**396**

Note: Totals may not add up due to rounding.

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A concerning trend is the aging population of farmers. As can be noted in Figure 4, 31.8% of farmers are above 65+ with the second highest cohort (24.7%) being 55-64. With an already dwindling population, workers in this area are expected to go down further in the near future. It should be added that women farmers are a rare occurrence with the management of farms left mainly to males.

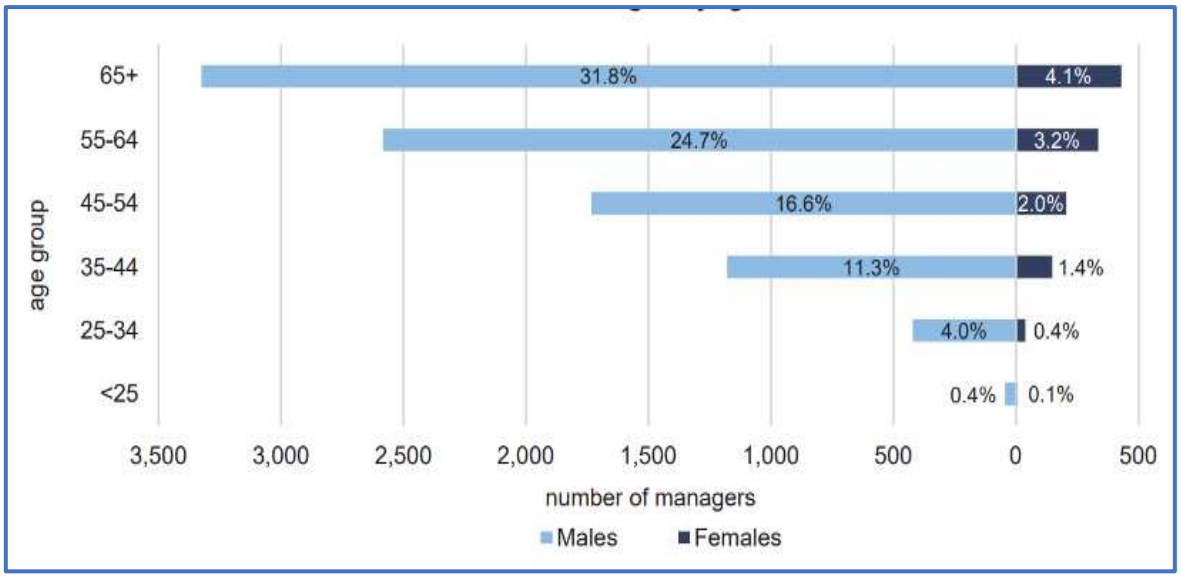

Figure 4. Distribution of managers by age and sex 2020. Source: National Statistics Office, 2022.

Agricultural plastic waste falls under the European Waste Code (EWC) 02 01 04 waste plastics (except packaging). Here packaging plastic waste is excluded. The figures listed under this code generated between 2016 and 2021 are provided in Table 2 below.

Table 2. Plastic waste registered under EWC 02 01 04 between 2016 and 2020.

EWC 02 01 04	Tonnes					
	2016	2017	2018	2019	2020	2021
Amount generated	33.8	217.02	100.9	61.42	301.42	54.16
Amount exported for R3*	68.78	48.6	21.28	--	12.28	8.36
Amount landfilled	33.88	32.85	79.62	61.42	41.56	45.8

Source: Environment and Resources Authority (ERA).

The EWC 02 01 04 refers to waste plastic (except packaging) generated under the Agriculture/Hunting/Fishing/Food processing. In both Table 2 and Figure 5, it can be noted that figures are not stable with spikes registered in 2017 and 2020 possibly since certain types of plastic are not replaced annually but take a longer time to deteriorate. Anomalies such as external elements, sun and heat also impact plastic tools on the field affecting their longevity [19].

The figures for landfilling export for recovery between 2010 and 2021 for EWC 02 01 04 are presented in Figure 5.

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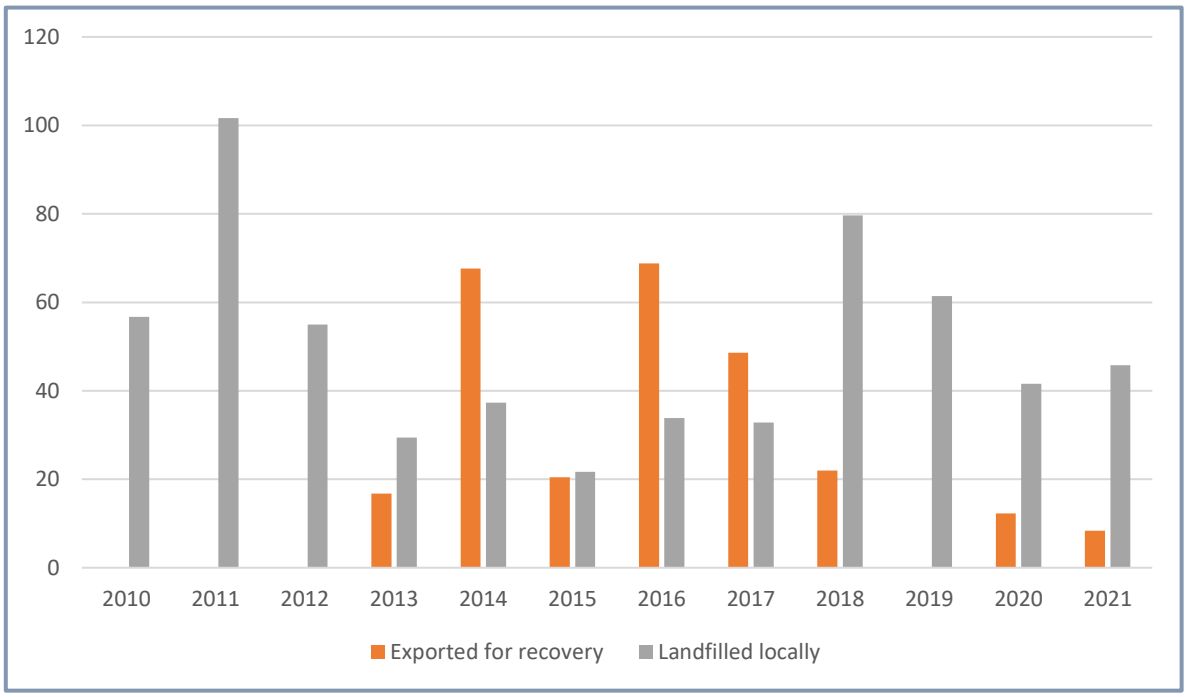

Figure 5. APW listed under European Waste Code 02 01 04 code landfilled locally and exported for recovery 2010 and 2021. Source: ERA, 2023.

4.2. Locality Mapping of Respondents

The localities from where respondents originated are provided in Figure 6 which was rendered with ARCgis after all responses to question five were analysed. Evidently, most questionnaires were obtained from localities with a significant agricultural footprint with the highest responses originating from Rabat, Mellieha, Zurrieq, Siggiewi, Dingli and Mgarr. No responses were obtained from the northern harbour region. The exact count is provided in Table 4.

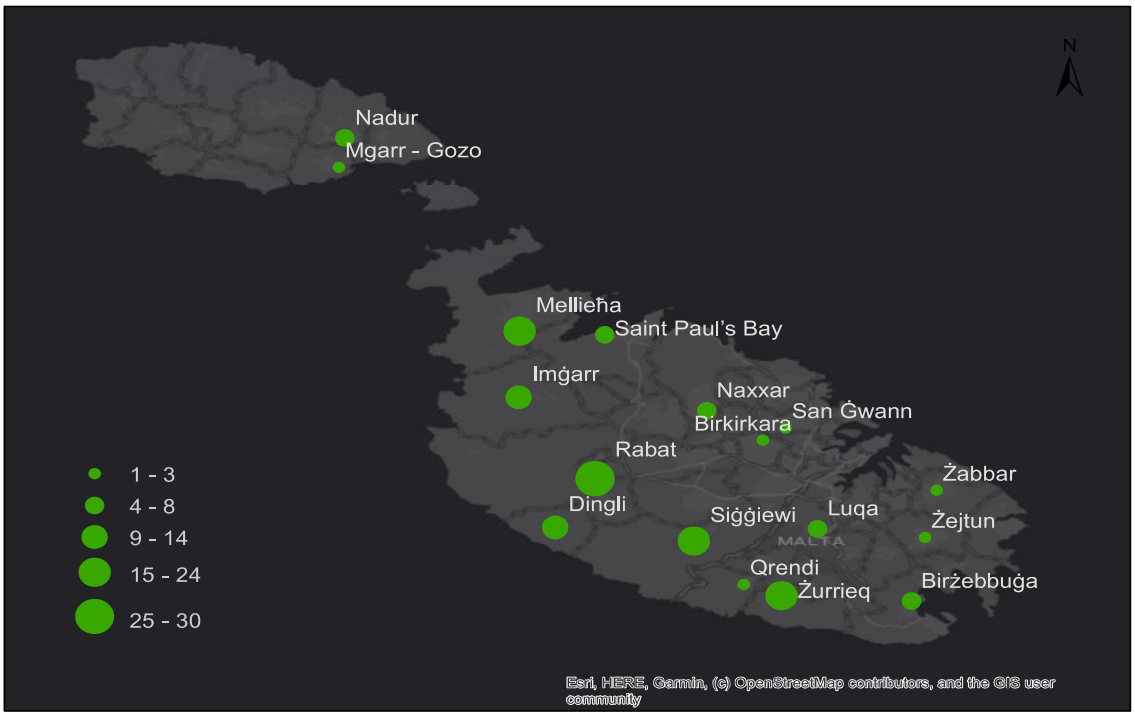

Figure 6. Mapping of respondents in relation to agricultural sites.

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Table 3. Localities from which questionnaires were collected and their frequency.

Locality	Latitude (°N)	Longitude (°E)	Count
Rabat	35.8826	14.3978	30
Mellieħa	35.9500	14.3667	24
Żurrieq	35.8292	14.4744	20
Siġġiewi	35.8542	14.4383	19
Imġarr	35.9197	14.3664	14
Dingli	35.8603	14.3814	12
Naxxar	35.9136	14.4436	8
Luqa	35.8597	14.4892	5
Nadur	36.0381	14.2950	5
Birżebbuġa	35.8267	14.5278	4
Saint Paul's Bay	35.9483	14.4017	4
Żabbar	35.8772	14.5381	3
Mgarr - Gozo	36.0247	14.2924	2
Birkirkara	35.9000	14.4667	1
Qrendi	35.8342	14.4589	1
San Ġwann	35.9056	14.4761	1
Żejtun	35.8556	14.5333	1

4.3. Hypothesis Testing Technique

The one-sample one parametric test was performed using the Statistical Package for the Social Sciences (SPSS). This test served to compare the observed probabilities to the hypothesis presented in Section 2. The null hypothesis was rejected when the asymptotic significant level was less than 0.5.

4.3.1. Hypothesis 1: Do Farmers Encounter Difficulties When Disposing of Plastic Waste?

The null hypothesis (H^o) stipulates that: farmers *do not* encounter difficulties to dispose of agricultural plastic waste.

The alternative hypothesis (H^a) states that: farmers *do encounter* difficulties to dispose of agricultural plastic waste.

N represents the total number of samples processed. The test statistic value is the numerical result of the test – the larger the number, the bigger the discrepancy between the survey replies. The degree of freedom parameter represents the number of possible survey replies minus one, for example, for yes/no questions (i.e., two possible observations), this parameter is one. This is because such a statistic first computes the mean of the data and therefore not all the information can be utilised for the actual test. The Asymptotic Significance, also known as the *p*-value of the test, indicates the significance of the tested relationship. If the value is less than 0.05 there is no difference between the mean values.

This hypothesis is tied with question 11 of the questionnaire. In Figure 4 it can be observed that a significant number of respondents answered 'yes' when asked whether they face difficulties to dispose of plastic waste. The outcome of the survey results in the alternative hypothesis being accepted and therefore the null hypothesis is rejected. This is also proven by the chi-square test summary presented in Figure 7. The total sample N reached 154 responses. The degree of freedom 1 refers to the number of variables provided by the researcher in the proposed hypothesis. A significance value of .024 was obtained when running the one-sample chi-square test resulting in the rejection of null hypothesis since the value did not exceed 0.5. The H^a was accepted.

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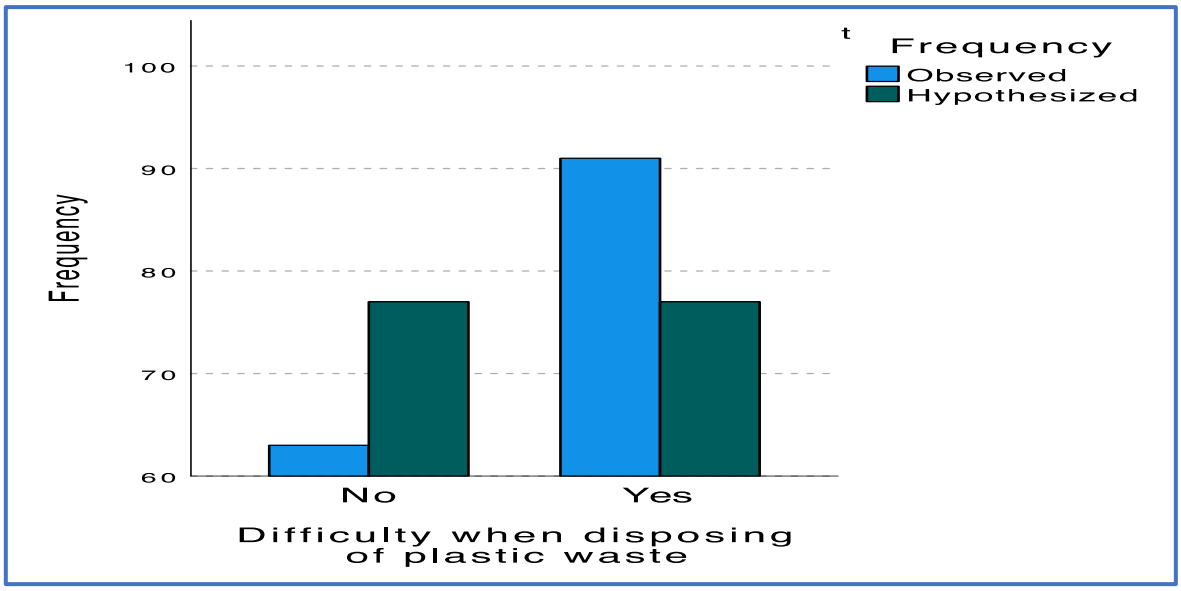

Figure 7. Difficulty to dispose of plastic waste.

4.3.2. Hypothesis 2: Do Farmers Need Information about How to Dispose of Plastic Waste?

The second hypothesis testing referred to whether farmers are sufficiently knowledgeable about how APW should be disposed of. The null hypothesis (H^o) stipulated that farmers are not knowledgeable on how to dispose of agricultural plastics, while H^a stipulated that farmers *are* knowledgeable of how to dispose of agricultural plastics.

This ties in with question 15 of the survey. The question asked respondents "Do you need any information about how you can dispose of plastic waste in an environmentally friendly manner?" In Figure 8 it can be observed that the majority of farmers responded 'yes' and therefore, as noted in the one-sample chi-square test summary, for sample N= 154 with a degree of freedom of 1 (since there were only two variables presented by the researcher), the level of significance was at .000. In view that this is below 0.5, the null hypothesis was rejected, and H^a was adopted.

One-Sample Chi-Square Test Summary

Total N	154
Test Statistic	5.091[a]
Degree Of Freedom	1
Asymptotic Sig.(2-sided test)	.024

a. There are 0 cells (0%) with expected values less than 5. The minimum expected value is 77.

Figure 8. One sample chi square summary.

4.3.3. Hypothesis 3: Are Farmers Willing to Change Their Disposal Patterns to Safeguard the Environment?

This hypothesis ties with question 14 of the survey. Here, the null hypothesis (H^o) stipulates that farmers are not willing to change their disposal patterns to safeguard the environment, while the alternative hypothesis (H^a) states that farmers are willing to change their disposal patterns regardless of the environment. In this case, respondents were allowed three possible replies – 'yes, no and maybe'.

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In Figure 10, the hypothesis testing for the willingness to change the disposal pattern is shown. The histogram notes the observed responses compared to those hypothesized. A large portion of respondents affirmed that they are willing to change their disposal patterns, followed by a 'maybe' response and the remaining responded 'no'. The hypothesized values were not met and therefore the null hypothesis is rejected.

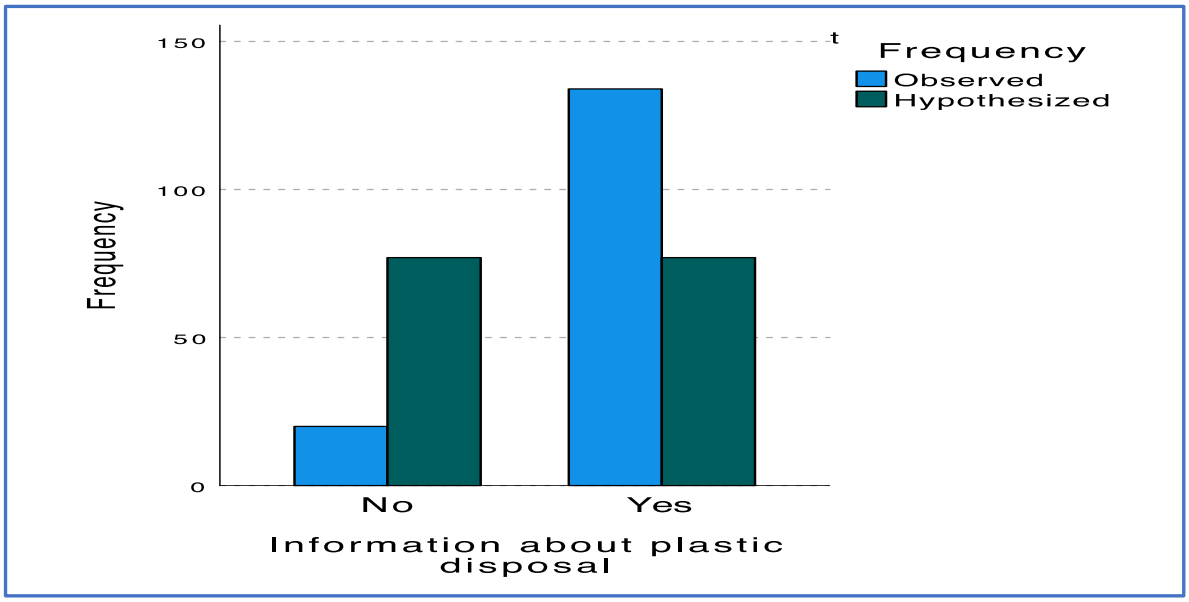

Figure 9. Hypothesis testing on farmers' knowledge to dispose of agricultural plastic waste.

One-Sample Chi-Square Test Summary

Total N	154
Test Statistic	84.390[a]
Degree Of Freedom	1
Asymptotic Sig.(2-sided test)	.000

a. There are 0 cells (0%) with expected values less than 5. The minimum expected value is 77.

Figure 10. The one sample chi-square testing for hypothesis on farmers' knowledge to dispose of APW.

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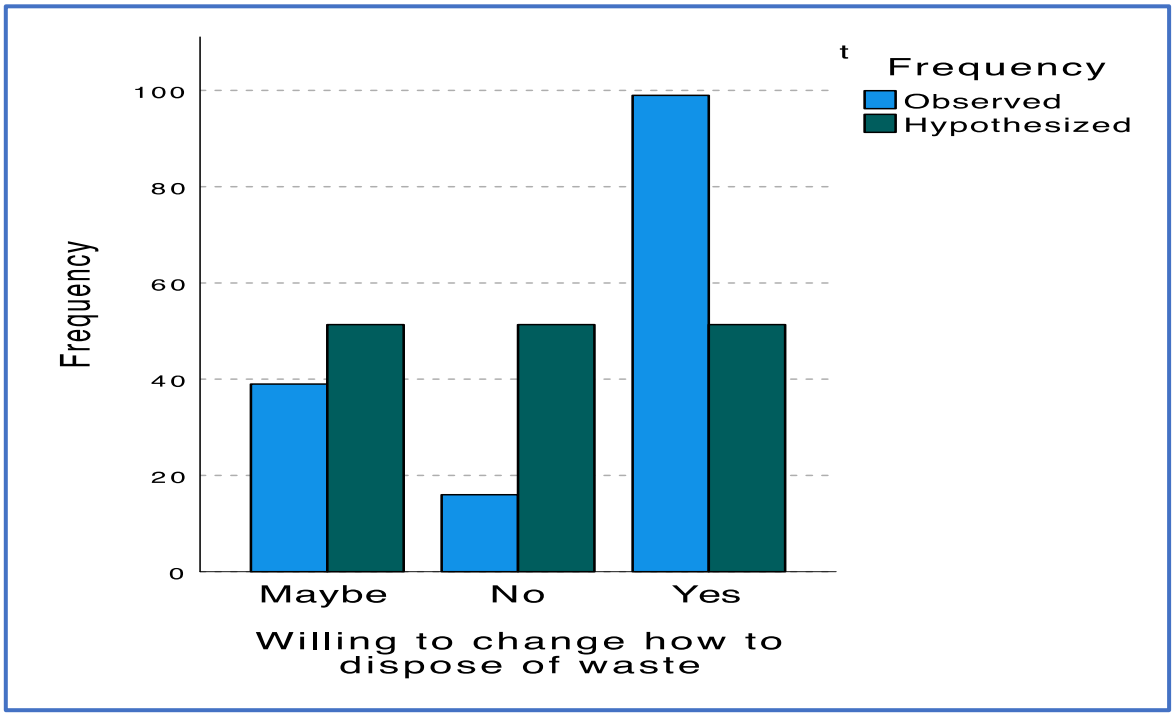

Figure 11. Willingness to change disposal pattern.

Figure 12 shows the results for the one-sample chi-square test. While respondents amount to 154, in this case the degree of freedom is 2 since 3 variables were provided. The level of significance reached .001. Since this was not greater than 0.5, the null hypothesis was rejected, and H^a was adopted.

One-Sample Chi-Square Test Summary

Total N	154
Test Statistic	71.545[a]
Degree Of Freedom	2
Asymptotic Sig.(2-sided test)	<.001

a. There are 0 cells (0%) with expected values less than 5. The minimum expected value is 51.333.

Figure 12. One sample chi-square test summary for hypothesis 3.

4.4. Survey Results

This section provides an analysis of the survey results which were originally assembled through Google Forms and then exported into SPSS to depict the histograms. The survey questions were presented both in Maltese and English (see Appendix B.2). The number of surveys conducted statistically adopted a 95 per cent confidence level and a confidence interval of 12, while adding two strata – full and part-time farmers as a representation of the target population. This made it possible for the researchers to calculate the required responses which summed up to 130. To offset the confidence interval a total of 154 responses were obtained.

The first four questions of the survey sought to obtain a demographic profile of the sampled group. As expected, the majority were male reaching 143, while female respondents reached 11 . Additionally, the majority of respondents fell between 51- 62 years (64), followed by the age cohort 36-50 (43) 63+ (25), 26-35 (17) and 18-25 (5). Therefore, together with being male dominated, the

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survey also confirmed that the farming population is an aging one and therefore set to retire in the coming years. This may affect both production quantities and crop types hence affecting the type and quantity of APW generated. Furthermore, the majority of respondents also proved to have been practicing agriculture on the site for more than 21 years (34 and 34 said that they had been practicing agriculture between 21 and 25 years and 26 and 30 years respectively). On the other hand, only 5 respondents said that have been working on the site between zero and 5 years, while 14 said they had been working on the farm between 6 and 10 years. This means that most respondents have ample experience and can therefore add depth to their responses. However, it also means that fewer farmers are entering the trade. Another concern is that most practicing farmers do so on a part-time basis. In the sampled population just over 60 farmers were full-time while the remaining were part-time. The discrepancy in the number of respondents is also significant to the sample size which was calculated through stratified sampling technique.

Questions five to ten seek to obtain feedback about the farm location, the type of crops grown and to connect the type of crops grown with the plastic waste generated. In addition to this, they aim to obtain a rough estimate of the type and quantity of APW generated on an annual basis.

The results of question five point out that most farms are located in Rabat followed by Mellieha, Zurrieq, Siggiewi, Mgarr, and Dingli sequentially, therefore confirming that most of the farm holdings are located in western and north-western regions of Malta. Respondents, in question six, pointed out that the most common crops grown consisted of potatoes, tomatoes, and olives, followed by strawberries and peppers. Question seven serves as a follow up question whereby respondents were asked to list, from highest to lowest, the crops that utilise most plastic material. The responses that were presented in a numerical grading system from the first to the last listed crop, were tabulated in a histogram provided in Figure 12. Figure 12 notes that tomatoes, followed by strawberries and potatoes, are the crops with the highest plastic requirements. This corresponds to the responses given in question 6. Olive trees, on the other hand graded much lower in terms of plastic requirements in comparison to tomatoes and potatoes even though they are equally cultivated. This may result from the fact that olive trees are more adaptable to the semi-arid climate prevalent in the Maltese Islands and therefore water usage is lower which in turn means a lower irrigational system. Additionally, since these trees are perennial and not seasonal the cultivation process is less intensive.

Question six sought to establish the type of plastic waste generated. Here respondents were provided with a set of options but could also input additional items. Results depicted in Figure 13 point out that the most common type of APW generated consisted of irrigation pipes followed by plastic mulching, packaging containers, plastic crates, fertiliser bags and low tunnels. The least generated items were nets and buckets while one respondent outlined that no plastic is used on his farm and therefore no waste is generated. The high disposal of irrigation pipes denotes high water consumption and distribution on the farm site.

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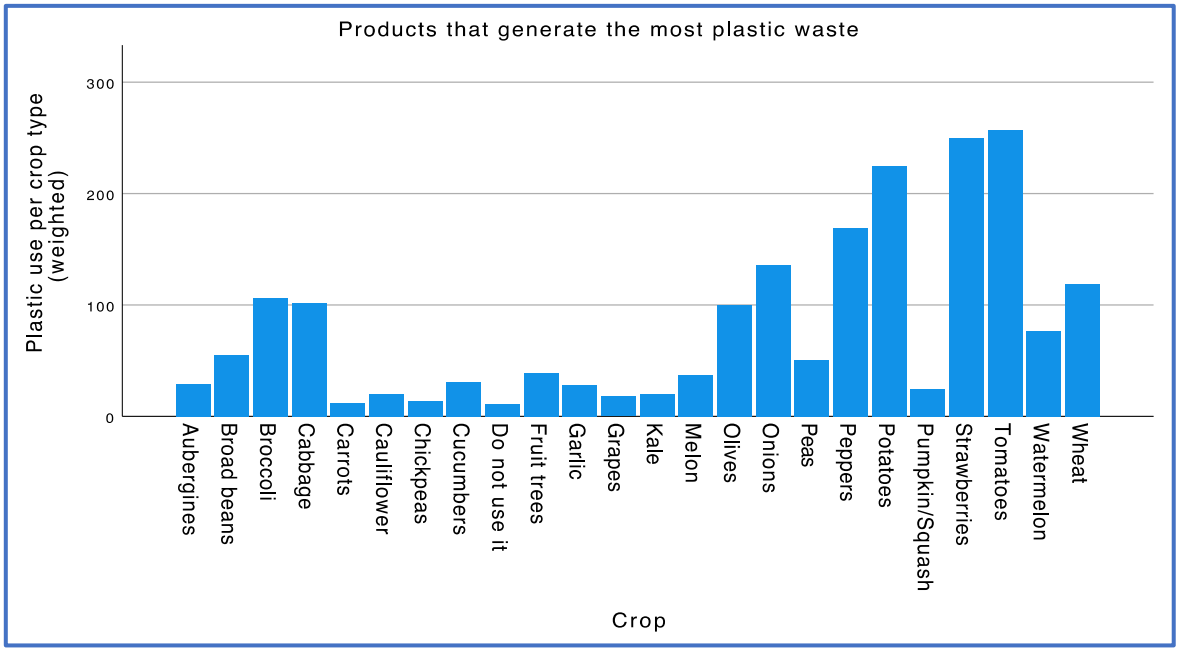

Figure 13. Crop products that require most plastic material.

An important feature of agricultural plastic is that usage tends to be on a longer scale. This can be noted in Question 9 whereby respondents were asked to establish the frequency with which plastic materials and tools are replaced. In their majority, respondents said that plastic materials were replaced every three years (78 responses). This is followed by annual replacement. However, the number of responses is much lower (34 responses). A total of 28 respondents said they replace it every two years. The results correspond to the waste disposal figures presented in Table 2 and Figure 5 whereby a spike in the waste generated was noted every three years. The responses are noted in Figure 14.

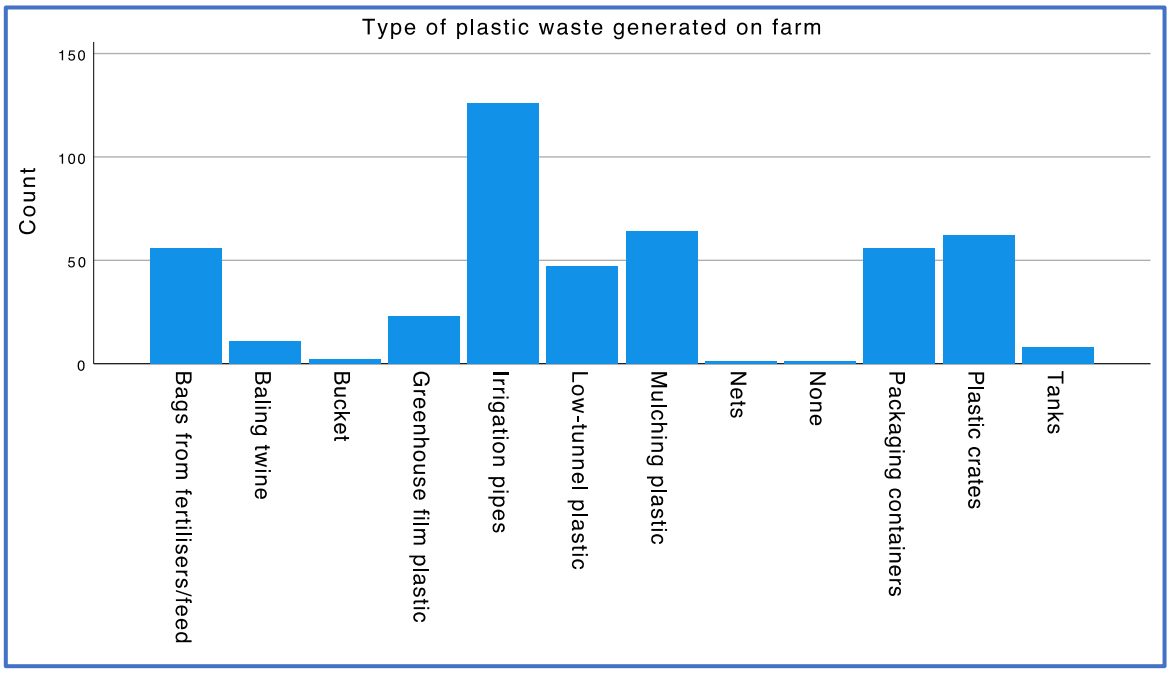

Figure 14. The main types of plastic waste generated.

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An attempt to quantify the plastic waste generated annually was made in Question 10. Here the majority of respondents said that they dispose of 0 to 20 kg, while less than 50 respondents stated that they generate between 20 – 50 kg per year.

Questions 11 to 19 aim to understand the difficulties and attitudes of respondents towards plastic waste. A total of 80 affirmed that they face difficulties when dealing with this type of waste.

Clearly the disposal system for agricultural plastic waste is not functioning adequately, and farmers do not have a clear-cut solution when disposing of this waste. The methods presently used by farmers to dispose of plastic waste are discussed in Question 12 and provided graphically in Figure 15. While most respondents (120) dispose of waste at the local civic amenity site and others make use of a local waste collector for recycling, it should be stressed that onsite incineration and ploughing are ongoing practices (38 and 21 respondents respectively said that they do these practices to dispose of their waste). Finally, a few respondents said that they transport waste in their own vehicle to the waste facility.

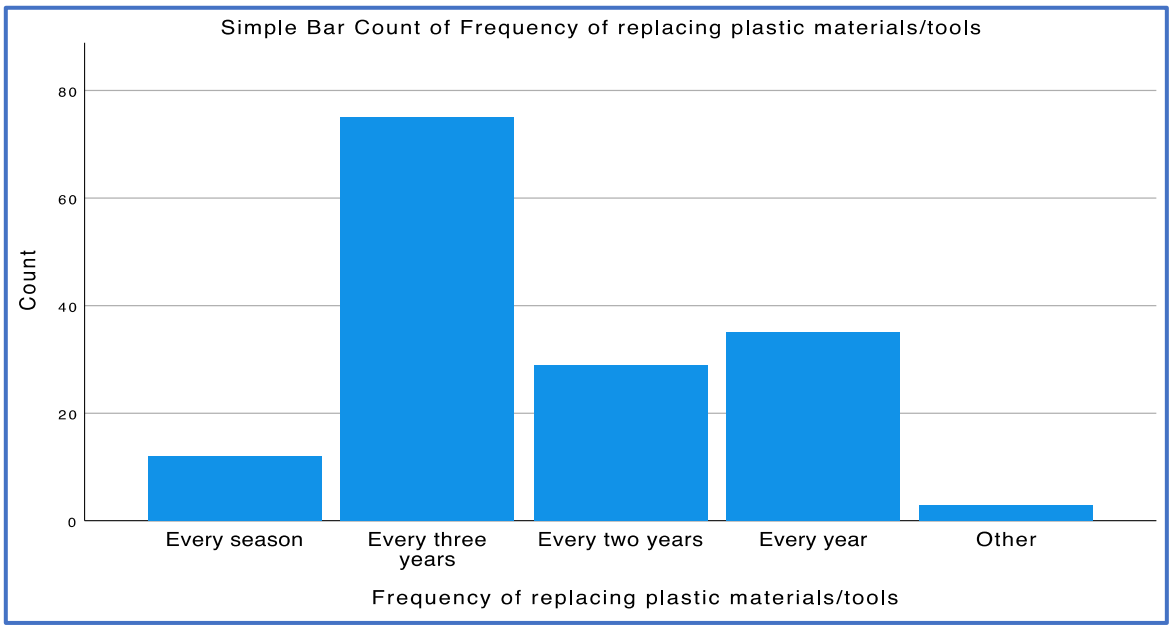

Figure 15. Simple bar count of the frequency of replacing plastic material/tools.

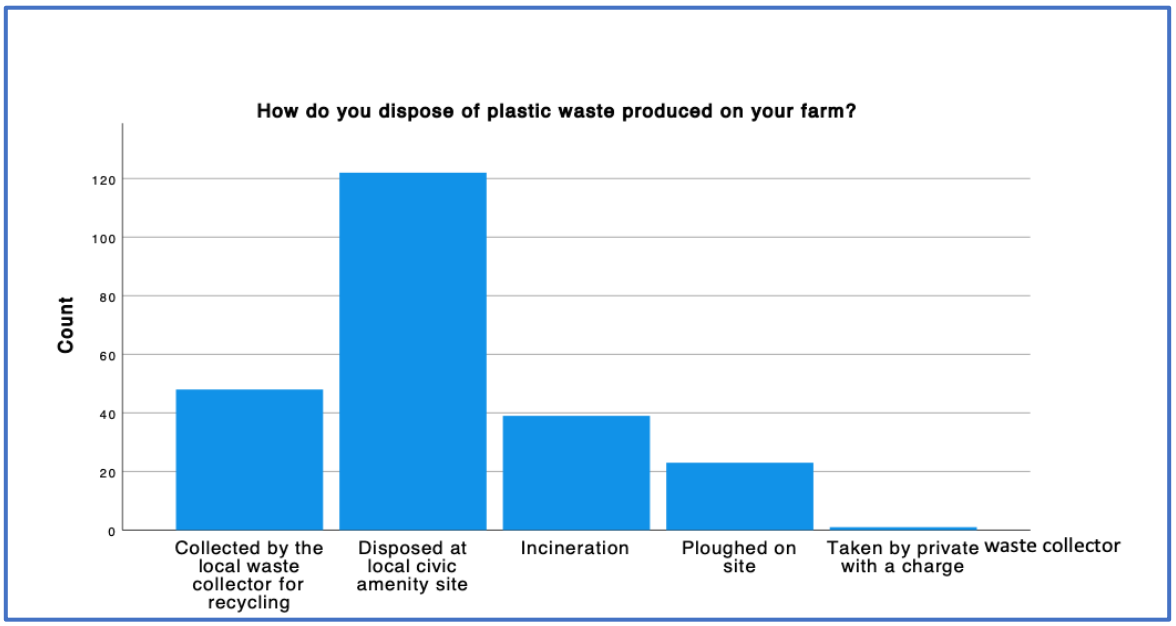

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Figure 16. Methods to dispose of agricultural plastic waste.

In question 13, the researchers sought to understand the attitudes of farmers towards recycling and/or sustainable disposal of agricultural plastic waste. An overwhelming majority strongly agree or agree with recycling and/or proposer disposal of this waste while less than 40 respondents were neutral. It is important to point out that no respondents disagreed with this question. The responses show that the farming community is cautious about the manner waste is disposed of. Environmentally harmful methods of disposal such as incineration and ploughing may result from barriers experienced by farmers. However, a number of respondents had a neutral stance on the importance of plastic waste to be disposed of adequately. The willingness of farmers to change their disposal practices is clearly expressed in the responses given to Question 14. Here almost 100 of respondents assert their willingness to change their disposal practices although misgivings remain causing thirty-nine respondents to tick the 'maybe' box and 17 to simply say 'no'. Therefore, while the trend outlines a willingness to change, this depiction also notes that some representatives remain hesitant.

The last five questions (questions 15 to 20) sought to highlight the barriers that farmers encounter when they need to dispose of plastic and their willingness to pay for an adequate collection scheme. In question 15, an overwhelming majority of respondents (128) stated that they need more information, with only 26 respondents responding no. Furthermore, when inquiring whether they encounter barriers related to material storage and collection (question 16), the majority said no (less than 100), while less than 60 said yes. This factor facilitates the possibilities to introduce a collection scheme since plastic would need to be stored before it is transferred to the treatment facility. It also reduces the possibility of weathering of the material which in turn facilitates recycling and reusing. However, some barriers are encountered particularly when farmers want to preserve the material for long term use. In fact, in question 17, it was noted that the provision of a store prior to collection would encourage farmers to divert the plastic waste generated to a recycling programme. Respondents, on the other hand, were less enthusiastic about transporting plastic waste to a collection centre themselves and proved to have a negative outlook towards the payment of a surcharge on agri-plastic to fund a recycling programme. The responses are tabulated in Figure 18.

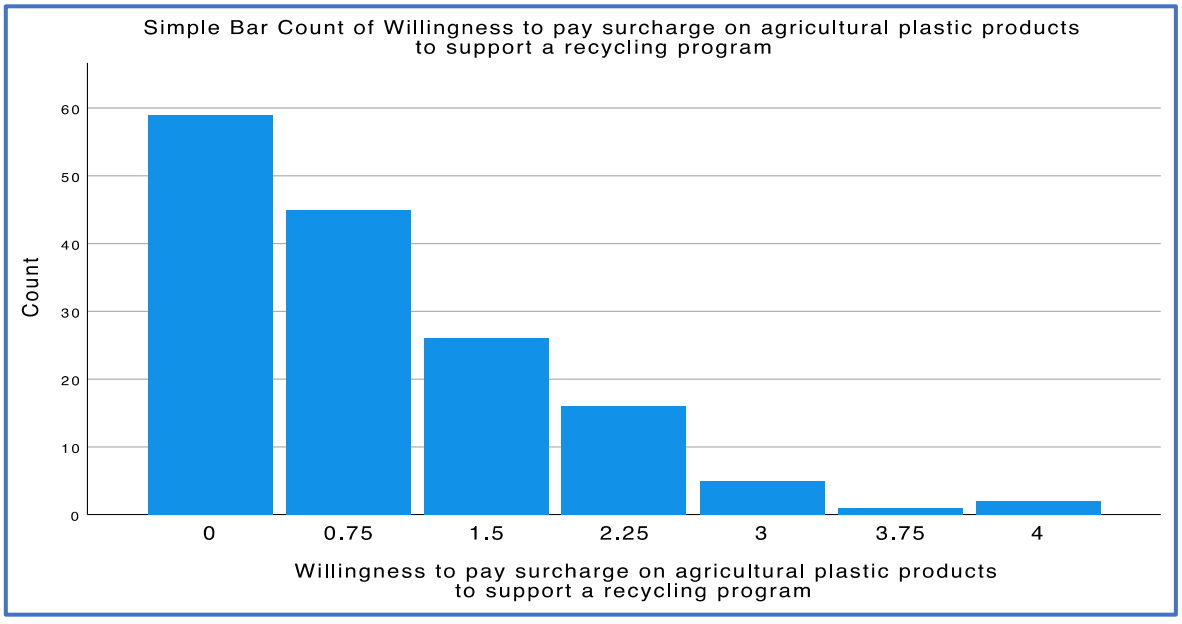

Figure 17. Simple bar count of willingness to pay surcharge on agricultural plastic products to support a recycling programme.

As can be noted, respondents were prevailingly negatively predisposed towards a surcharge. Following a zero surcharge, a 0.75€ surcharge was suggested. Immediately a drop is noted. This trend

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continues as the surcharge that is suggested increases. This makes the implementation of self-funding programmes difficult locally. More success would be guaranteed if a small sum is reimbursed to the farmers when they deliver the agricultural plastic waste to the collection centre. The overwhelming difference in the response is tabulated in Figure 19. Here more than 100 respondents replied favourably while the remaining were negative. The introduction of a deposit-refund scheme would also eliminate or reduce the adversity of farmers to transport the plastic waste to a collection centre which, as noted in question 17, could prove to be a problem.

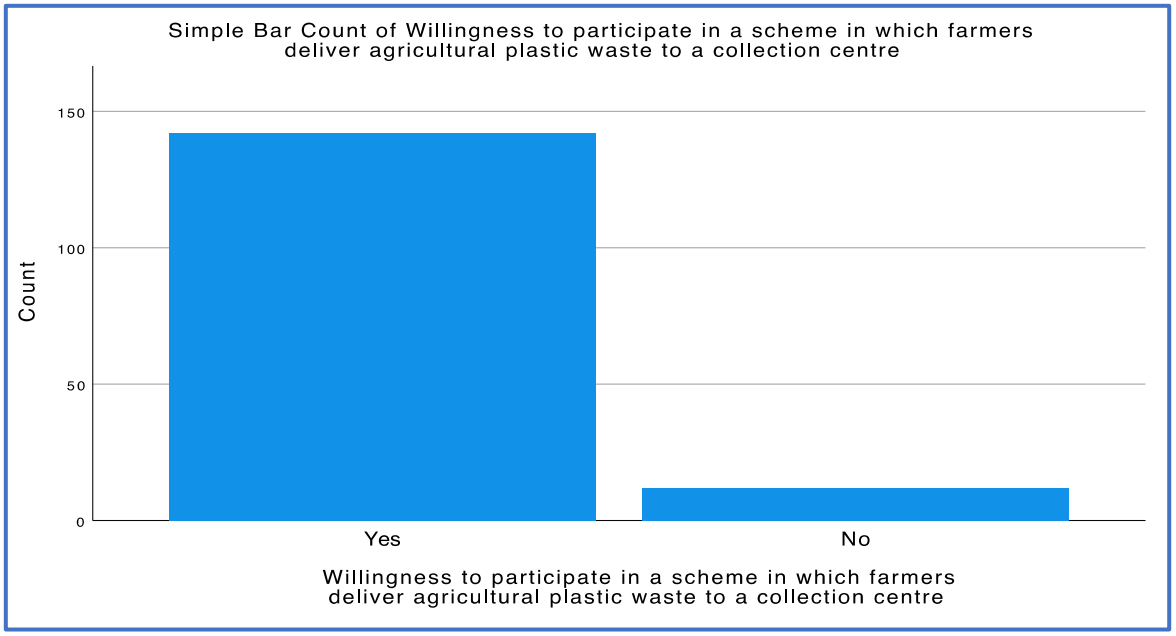

Figure 18. Willingness to participate in a scheme if a reimbursement is guaranteed.

Finally, question 20 is about governance. Respondents were asked their opinion as to who should be made responsible for overseeing the management of agricultural plastic waste in Malta and were provided with a list of stakeholders to choose from with the opportunity to add another field. Respondents were also allowed to select more than one stakeholder. Most respondents suggested Wasteserv Malta Ltd as the manager of the scheme followed by the Environment and Resource Authority (ERA) and the Ministry for Agriculture, Fisheries, Food and Animal Rights. The variable with lowest respondents was that of individual responsibility.

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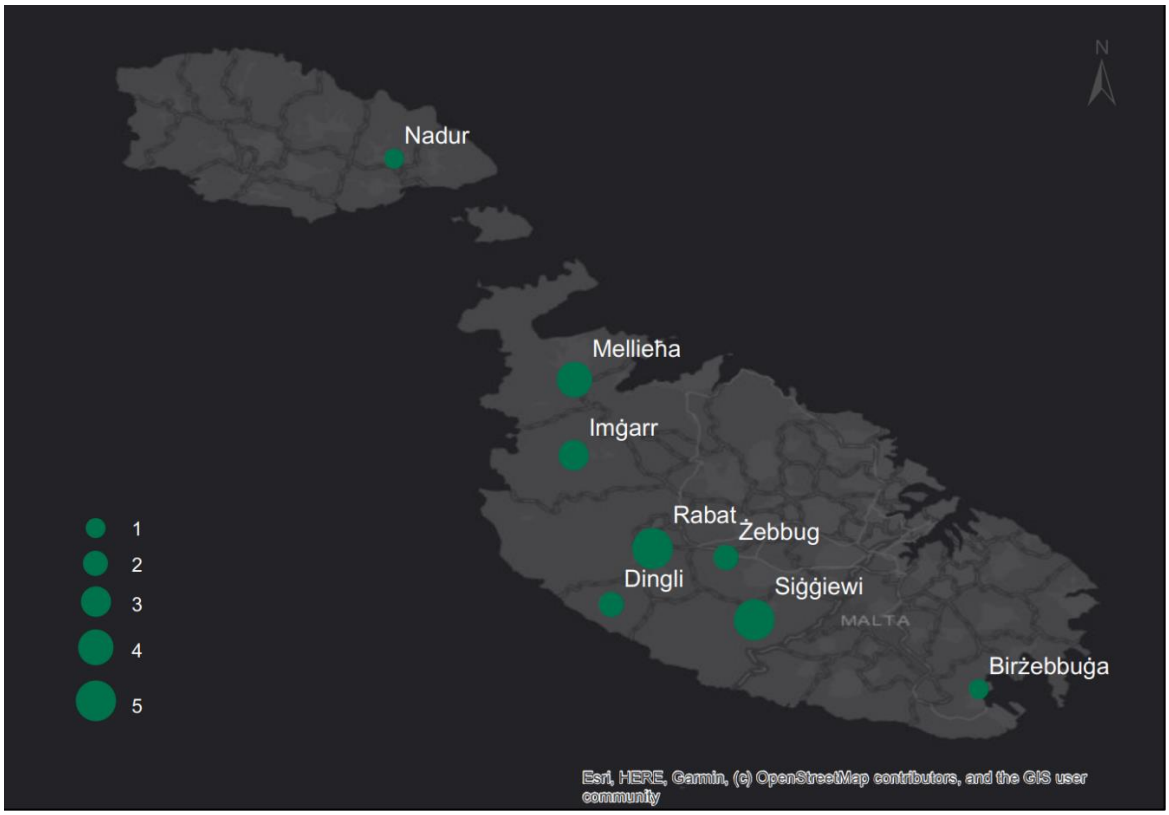

Figure 19. Distribution of localities where audits were carried out.

4.5. Agri-Plastic Waste Audits

To carry out the audit, stratified sampling was employed based on the working status of the farmers, i.e., full- or part-time. The sample size was determined by calculating the percentage of full-time and part-time farmers divided against the total population. This led to a result of 23 audits.

$$Plastic\ audit\ sample = \frac{Fulltime\ farmers\ per\ cent\ /\ partimefarmers\ per\ cent}{\text{Total population}}$$

The localities targeted in the audit are shown in Figure 18.

The result of the audits is tabulated in Table 4. The audits on the selected sites were conducted by the researchers together with the farmer or person responsible for the cultivation of crops. These individuals were also requested to provide any records in relation to the plastic materials that were purchased within the last year. In addition to this, a detailed account of the purchasing and disposal trends for each plastic material are listed in Appendix B.1. The values obtained from each farm were tabulated in a separate table, where eventually the values were averaged with the results shown in Table 4.

The most prevalent waste originated from greenhouse plastics, followed by irrigation pipes and plastic mulching. This can be noted in the table below where greenhouse plastics reached 23.33 kg for the year under examination, Irrigation pipes on the other hand, amounted to 22.71 kg followed by plastic mulching with 19.35 kg. Items like plastic crates and IBC tanks are listed as non-available due to their long-lasting feature which makes their disposal patterns both irregular and infrequent as opposed to other types of materials. Further observations outline that the most frequently disposed material consists of soft, flexible plastic such as LDPE, while HDPE material have a much lower disposal frequency.

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Table 4. Plastic waste generated in farms.

Plastic Materials	Types of Plastic Polymers	Per Year (Kilograms)	Per Season (Kilograms/3 Months)
Plastic mulching	LDPE	19.35	4.838
Low tunnels	LDPE, EVA, LLDPE, PVC	14	3.5
Greenhouse plastics	LDPE, LDPE.IR, LLDPE, EVA	23.33	5.833
Irrigation pipes	LDPE, HDPE, PVC, PRFV	22.71	5.677
Plastic containers for produce	PET, PP	3.71	0.929
Plastic crates	HDPE	N/A	N/A
Buckets	HDPE	0.600	0.150
Fertiliser bags	LDPE, HDPE	1.02	0.255
IBC Tanks	HDPE	N/A	N/A

Onsite discussions and investigations revealed that the annual disposal for certain plastic materials such as greenhouse plastic is financially unsustainable. However, another variable which that influences disposal patterns is the weather which can cause irreversible damage thus offsetting any savings made in the previous years. In the case of irrigation pipes, disposal is more frequent since weather conditions make the material more brittle and difficult to manage without damaging the system. Generally, irrigation pipes have a 3.5-year cycle. In the case of plastic mulching and low tunnels disposal patterns are similar. However, variations exist due to the severity of the weather together with the harvesting methods. Site managers pointed out that harsh weather conditions can cause irreversible damage resulting in the need for the items to be replaced. This material would therefore last for an average of about one or two seasons. Finally, in the onsite discussions it also emerged that farmers who utilise machinery for harvesting purposes outlined a higher disposal rate of plastic mulching as it becomes damaged during this process.

Plastic containers were noted to be used by farmers to sell foraging plants, fruits and berries. It was highlighted that such sales typically spike around spring and summer when berries and other fruits are more in demand. However, the disposal of the containers is left to the customer since they are sold as an integral part of the product and are not considered as single-use plastic due to their composition, as described by the EPR compliance and enforcement officer in the stakeholder interview in Appendix B.3 Interviewee 2.

In scenarios where intermediate bulk container (IBC) plastic tanks were used; their main scope was water storage and the integration of an irrigation system. The use of such material was predominantly observed in agricultural sites which were used for kitchen gardens or by part-time farmers, hence the frequency of IBC tanks was much lower.

4.6. Stakeholder Interviews

Several interviews were held with stakeholders which are critical in the management of plastic waste within the Maltese Islands including the formation of policies, enforcement of illegal waste disposal and the upkeep and compliance of policies. These included an environment protection officer on waste policy, the team manager in compliance and enforcement (waste schemes and exports), the compliance and enforcement officer on illegal management of waste from ERA and the Director of Environment at the Ministry for the Environment, Climate Change and Sustainable Development (MECP).

The ERA officials were asked about the feasibility of a collection and recycling programme for plastic waste generated from agriculture. It was outlined that formation of policy required data from within the industry which is presently unavailable. This is in view of the perception that the limited data presented on APW signifies that presently the sector generates low quantities as compared to other sectors. The inclusion of APW in an EPR scheme could be a possibility to manage the waste and

bind the importer. However, issues with its feasibility might arise since EPR costs are reflected on products which in turn would add pressure to the farming community. Policy personnel outlined that that prior to the formation of any policy on agriculture, it is crucial to ensure that the sustainability of the farming practice and the affordability of food prices are kept in mind.

Discussions about a possible EPR scheme were initiated by the ERA representative on compliance and enforcement of policies and schemes, whereby it was pointed out that in Malta this scheme was solely tied to packaging waste. This means that EPR involves *solely* the packaging of the plastic materials rather than the material itself. Further to this, new policies focused on single-use plastic target materials with certain polymers that are not reusable. In the context of APW, none of the polymers are listed as single-use plastic, not even fruit containers since they contain polymers which make the reuse of material possible. He also pointed out that in discussions concentrated on the introduction of EPR schemes solely on APW it was concluded that they would not be economically feasible due to the market value of the product and the low quantities, as opposed to other products like batteries. However, APW can be potentially included in other schemes.

Illegal disposal of waste was discussed with the responsible officer within ERA. The researchers questioned the frequency of reports concerning the burning of waste plastics and cases of illegal waste disposal in agricultural sites. The main illegalities encountered, the officer noted, concerned illegally dumped or incinerated waste but cases were not limited to this. Generally, between four and ten cases are reported on an annual basis. These reports mostly concerned plastic incineration which is evidenced by foul odours or black plumes – common indicators of plastic burning. The most incinerated plastics are irrigation pipes, plastic mulching and sampling containers. Fines are issued if the contravener admits to the illegality or is intercepted while incinerating the material. Very few cases of ploughing on site are reported since this is more likely to go unnoticed. However, if caught red handed, contraveners are fined and ordered to clear the site.

The officer representing the MECP highlighted that presently no obligations or schemes targeting APW are present. However, international agreements, like for example, the EU Green Deal are binding for Malta. The targets set in this agreement include the agricultural sector particularly in reducing the environmental and climate footprint and ensuring a sustainable food system. The United Nations Sustainable Development Goals (UNSDGs) were also highlighted as a key measure to guide the development of such industries. Therefore, although agricultural plastic wastes are not directly targeted, international commitments bind the Maltese authorities to improve food security and ensure the sustainability of the industry.

5. Discussion

This research was a first step to gather primary data directly from the generators in Malta. While the study is focused on the island, the agricultural practices and crops nurtured are common for the region, making the results more widely applicable. As was noted in the audits, the three main types of APW generated are greenhouse plastics, irrigation pipes and plastic mulching. All types of plastics are meant to be long term however weather conditions can result in severe damage leading to the need to have them replaced. Various efforts have been enacted to increase the sustainability of agricultural practices including the Common Agricultural Policy 2023 – 2027 (CAP 2023 -2027) and the Biodiversity Strategy 2030. However, in the former, the emphasis made on soil conservation is primarily concentrated on pesticide and fertiliser used [20]. The Biodiversity Strategy 2030, on the other hand, aims to build on societies' resilience to future threats one of which refers to food insecurity whereby challenges emanating from soil pollution including plastics are mentioned [21]. The European strategy for plastics in a circular economy [COM (2018) 28] - although in a brief, fleeting comment - mentions the possibility of introducing an EPR scheme for the recycling of agricultural plastics [22]. On a local basis, the document guiding agricultural waste management in Malta, namely, "Agricultural waste management in the Maltese Islands (2015-2030)" does not account for this type of waste but turns its primary focus on manure and slurry while looking for energy generation options. Therefore, the deficiency in policy measure to tackle APW persists both at local and international level. This is despite early warnings from influential institutions like the United

Nations Environment Programme (UNEP) are already documented with statements that emphasise the present "increasing evidence that degraded plastics are contaminating the soil and impacting biodiversity and soil health [23].

To this end, of critical concern are the replies given in question twelve of the questionnaire (see Figure 15) whereby thirty-eight and twenty-one respondents affirmed that they incinerate and plough plastic in the soil respectively. This means that for thirty-eight per cent of respondents these two practices are an ongoing exercise. While the agricultural industry consumes smaller quantities of plastics as compared to other industries[2], their erratic release into the environment is directly injected into the soil affecting its health and therefore is closely connected to the food chain. The latter is of crucial importance particularly in the current quest for the achievement of the SDGs especially SDG 12 – sustainable consumption and production and SDG 15 – Life on land, together with the targets set in the CAP 2023 – 2027, the Farm to Fork Strategy and the Biodiversity Strategy 2030. It should be emphasised that in the stakeholders interviews it emerged that only about four to ten cases of incineration on site are reported annually while the cases of ploughing often go unnoticed. When confronted, farmers often reply that they were not aware that these practices are harmful and illegal. This resonates with the motivations behind the LabelAgriWaste Scheme project which was launched to develop a collection system with the aim of to reducing or eliminating the erratic disposal methods of APW within Europe.

However, until recently, collection schemes of APW within EU continues were almost absent. FAO, in their recent report, 'Assessment for agricultural plastics and their sustainability: A call for action" notes that within the EU only *four* countries have a system in place for the collection of APW, three of which are voluntary[3] [page 83][5]. A main reason for the almost absence of policy initiatives is the sparse availability of data, a sentiment which was also emphasised in the stakeholders' interviews. All interviewees referenced to the absence of data, as the lead cause for APW to be overlooked in policy interventions. This shortcoming is evident not only in Malta but on an international level, to the extent that FAO, in the same report, points out that figures of plastic use in agriculture are not conclusive particularly since they "do not specify the agricultural value chains that had been included in their assessments" [Page 16]. In view of this, the report uses the figure of ten million tonnes as an estimate of the quantity of plastics used in terrestrial crop and agricultural production [5].

The results of hypothesis questions 1 and 2 (see Sections 4.3.1 Hypothesis 1: Do farmers encounter difficulties when disposing of plastic waste? and 4.3.2 Hypothesis 2: Do farmers need information about how to dispose of plastic waste?), highlight the difficulties that farmers face when they need to dispose of APW. In fact, the responses were strongly skewed towards the 'yes' answer with farmers expressing their frustration when they need to dispose of this waste and stressing that additional information would be beneficial. Furthermore, in Section 4.3.3 (Hypothesis 3: Are farmers willing to change their disposal patterns to safeguard the environment?), the respondents also express an overwhelming willingness to change the present methods of disposal. This corresponds to the case study presented in Section 2.2 which focused on Nova Scotia, Canada whereby respondents also revealed a strong desire for farm plastics to be recycled or disposed in a sustainable manner and that the disposal of APW in a public landfill is not an adequate method.

Therefore, a clear first step should be the introduction of information sessions for farmers that provide the necessary guidance about the available solutions to dispose of APW. These initiatives will guide farmers to avoid erratic practices that impart harm on their own resources while at the same time assist in improving the soil conservation necessary to ensure sustainable food production systems.

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[2] According to Plastics Europe, in 2021 the agricultural, farming and gardening industry consumed four per cent of the 390.7Mt of plastics produced [2].

[3] France, Germany, and Spain have a voluntary system while Ireland is the only country with a mandatory collection scheme.

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While the present figures for APW display limited quantities, they can be expected to intensify as the use of plastic diffuses itself further into agricultural practices. Therefore, the introduction of a collection scheme for appropriate disposal offers an opportunity to provide a preventative measure before these figures escalate further. This would prevent a reactive system which is applied as a bolt-on approach. Malta, in view of the geographical constraints and the relative concentration of farms, could be used as a case study for the application of a holistic collection,recycling and recovery scheme for this type of waste. Lessons learned from the LabelAgri Waste scheme as regards to necessary setup for the management of the scheme could be utilised.

The results of this research stress that an overwhelming majority of the farmers strongly agree (63 respondents) or agree (62 respondents) with the proper disposal and/or recycling of APW. However, the introduction of a fee to finance a recycling scheme (Figure 16) was met with less enthusiasm with the majority stating (58 respondents) that they would not be willing to pay anything. The next highest cohort stated that a nominal fee of €0.75 is acceptable. Furthermore, the majority of farmers also stated that storage of plastic until it is collected can also be accommodated however the scheme would also need to cater for those who are unable to store the APW. As discussed in Section 4.4 (see Figure 19), a more successful implementation of the scheme is guaranteed if plastic collection takes the form of a deposit refund system since farmers would need to take back their waste to receive a reimbursement of the nominal fee paid upon purchasing. This would also encourage more farmers to transport their waste since this was reported as a barrier. Similar findings were noted in the Nova Scotia case study.

6. Conclusions

This research sought to examine the current use of plastics within the agricultural industry and the present disposal practices. A literature examination outlined the impacts that plastics usage has on the environment including their connection with agriculture. Given that the local context exhibited a data gap for the two facets, the researchers utilised the information from the reviewed literature to adopt adequate research approaches and address the data gaps. Together with a qualitative and quantitative study conducted with farmers, the researchers took into consideration the stakeholders that influence the decision making within the industry and presented questions to delve deeper into the aim of the study.

The Maltese farming sector is characterised by an individualist approach which sets the notion of a self-abiding mentality. This approach surfaced during the waste audits as various disposal patterns emerged some of which cause harm to the environment and the very land they depend on. In addition to this, an extensive knowledge gap on topic was observed during the audits including on-site discussions with site managers. The issue came to light also in an interview held with the ERA enforcement officer – farmers are clearly uninformed about measures or efforts to properly dispose of waste that minimise environmental impacts. Researchers also noted increased focus on producing fruits and vegetables associated with least costs due to the ever-increasing expenses of raw materials like seeds, saplings, plastic and fuel. While figures also suggest that the predominant disposal method is that of delivering plastics to the civic amenity sites, instances of waste incineration or plastic ploughing still take place. This is mainly due to the limited number of deposition frequencies or the lack of knowledge about the impacts this entails.

It can be concluded that additional research is a necessity to further investigate what is happening to the plastics used in agriculture. Table 2 already indicates a gap as to the quantity of wastes generated and what happens to them. The same is true in other European countries. To this end, FAO reports that "data from five European countries with an established national collection and recycling schemes indicates a collection between fifty and eighty-four percent of end-of-life APW which means that the balance remains either uncollected, disposed on farms or sent directly for disposal elsewhere" [page 31] [5]. This therefore call for additional examination of the flows followed by the plastics purchased for agricultural purposes, their usage and ultimate disposal and/or recycling or recovery.

Together with shedding light on the disposal practices of APW, the research also disclosed that farmers feel the need to be more aware of the impacts of their actions and therefore set forth a clear path for authorities which starts with education, possibly followed by schemes that cater for the collection of these items. The necessity of these actions is becoming more pressing with the requirements set by international policy documentation towards increased sustainability of food production processes. An aspect that was not examined in this research is the possibility of using alternative materials instead of plastic which can prove to be longer lasting and does not entail the disintegrating qualities of plastic. This can be a preventative initiative that guarantees financing possibilities, lowers replacement and disposal expenses, ensures the benefits generated by plastic use for agricultural output while preventing the degradation of soil and biodiversity therefore allowing an improvement of sustainability infrastructure.

Author Contributions: This research emanates from the M.Sc. by Research in Sustainable Development carried out by Mr Ranier Borg during 2020 and 2021 at the Institute for Climate Change and Sustainable Development within the University of Malta under the supervision of Dr Margaret Camilleri Fenech. Mr Ranier Borg carried out the data collection including the data conceptualisation and preparation of the first draft. The adaptation of this research, including the drafting, reviewing and editing of research into the document presented here, was carried out by Dr Margaret Camilleri Fenech. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study. The form is available in Appendix A.1.

Data Availability Statement: Data collected during the waste audits is presented in Appendix B.1 while the transcripts of the interviews are provided in Appendix B.3.

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Conflicts of Interest: The authors declare no conflict of interest.

Acronyms

APW – Agricultural Plastic Waste, CA sites – Civic Amenity Sites, CAP – Common Agricultural Policy, EPR – Extended Producer Responsibility, ERA - Environment and Resources Authority, EU – European Union, EWC – European Waste Code, EWC – European Waste Code, FAO – Food and Agricultural Organisation, GIS - Geographic Information Systems, IBC - intermediate bank container, MECP - Ministry for the Environment, Sustainable Development and Climate Change, NSO – National Statistics Office, SDGs – Sustainable Development Goals, SPSS - Statistical Package for the Social Sciences, UAA – Utilised Agricultural Area, UNEP – United Nations Environmental Progamme, WSM - WasteServ Malta Ltd.

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Appendix A

Application of plastics in agriculture

Protected cultivation films: • Greenhouse and tunnel • Low tunnel • Mulching • Nursery films • Direct covering • Covering vineyards and orchards	**Nets:** • Anti-hail • Anti-bird • Wind breaking • Shading • Nets for olives and nut picking **Piping, irrigation /drainage**: • Water reservoir • Channel lining • Irrigation tapes and pipes • Drainage pipes • Microirrigation • Drippers	**Packaging:** • Fertilizer sacks • Agrochemical cans • Containers • Tanks for liquid storage • Crates **Other:** • Silage films • Fumigation films • Bale twines • Bale wraps • Nursery pots • Strings and ropes

Source: Scarascia-Mugnozza, Sica & Russo, 2011.

Appendix A.1. Consent Form

Dear Participant,

Thank you for accepting to participate in this research study. The title of this research is "Investigating the use of plastic in the agriculture industry in the Maltese Islands" and is conducted by Mr Ranier Borg with the supervision of Dr Margaret Camilleri Fenech. Below please find the main conditions regulating your participation.

- I……..voluntarily agree to participate in this research study whilst representing ……
- I understand that even if I agree to participate now, I can withdraw at any time or refuse to answer any question without any consequences of any kind.
- I understand that I can withdraw permission to use data from my interview within two weeks after the interview, in which case the material will be deleted.
- I have had the purpose and nature of the study explained to me in writing and verbally and I have had the opportunity to ask questions about the study.
- I understand that participation involves a set of questions related to the research subject and the company/authority/ entity I represent.
- I understand that I will not benefit directly from participating in this research.
- I agree to my interview being audio-recorded.
- I understand that all information I provide for this study will be treated confidentially.
- I understand that in any report on the results of this research my identity will remain anonymous. This will be done by changing my name and disguising any details of my interview which may reveal my identity or the identity of people I speak about.
- I understand that disguised extracts from my interview may be quoted in a dissertation or presentation.

As a participant, you have the right under data protection legislation, and in particular the General Data Protection Regulation (2016/679) to access, rectify and where applicable ask for the data concerning you to be erased. If you choose to have your responses attributed to the organisation that you represent, you will be provided with a transcript of the interview that given the opportunity to review and modify this before any attributable information is included in the research outputs.

_____ _____

Signature of Participant Date

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Appendix B

Appendix B.1. Plastic Waste Template and Workings

Farm number	Plastic tools	Manner of disposal	Frequency of disposal	Type of storage
	Plastic mulching			
	Irrigation pipes			
	Plastic containers for produce			
	Plastic crates			
	Buckets			
	Fertilizer bags			

Farm number/ Produce	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Lettuce													√	√									
Potatoes	√	√	√		√		√			√		√		√			√		√	√	√	√	√
Onions	√		√																				
Tomatoes		√			√	√	√	√	√			√	√		√	√	√	√	√	√	√	√	√
Garlic	√		√																				
Kale		√			√	√	√	√	√			√			√			√	√	√	√	√	√
Olive trees	√		√	√							√						√						
Strawberries			√										√										
Grape vines				√																			
Chickpeas	√																						
Peas	√																√				√	√	
Broad beans	√		√																				
Peppers	√	√	√		√	√		√	√	√			√		√	√	√	√	√	√	√	√	√
Cherry tomatoes																			√	√			√
Aubergine		√			√		√	√	√	√		√	√	√	√	√	√	√	√	√	√	√	√
Zucchini		√			√	√	√	√	√	√		√		√	√	√		√	√	√			√
Melon		√	√		√	√	√	√	√	√		√		√	√	√		√	√	√			√
Watermelon		√	√		√	√	√	√	√	√		√		√	√	√		√	√	√			√
Cabbage		√			√	√	√	√	√	√		√		√	√	√		√	√	√			√
Pumpkin		√			√	√	√		√	√		√		√	√			√	√	√			√
Squash							√		√														
Fruit trees		√		√	√	√	√	√	√	√		√			√	√	√	√	√	√	√	√	√
String beans			√														√				√	√	

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	Plastic tools	Manner of disposal	Frequency of disposal	Type of storage
Farm 1	Plastic mulching	Ploughed / CA Site	3 months	N/A
	Irrigation pipes	CA Site	4 Years	Outside
	Plastic containers for produce	N/A	N/A	N/A
	Plastic crates	Taken to *Pitkalija*	6 years	N/A
	Buckets	CA Site	3 years	Outside
	Fertilizer bags	CA site	1 year	N/A

	Plastic tools	Manner of disposal	Frequency of disposal	Type of storage
Farm 2	Plastic mulching	CA site, ploughing	4 months	Agriculture store
	Low tunnels	CA site	6 months	Agriculture store
	Greenhouse plastics	Taken by installer	3 years	Agriculture store
	Irrigation pipes	CA site, Incineration	2 years	Agriculture store
	Plastic containers for produce	Disposed by customer	N/A	Agriculture store
	Plastic crates	Taken to Pitkalija	6 years	Agriculture store
	Fertilizer bags	CA Site	1 year	N/A

	Plastic tools	Manner of disposal	Frequency of disposal	Type of storage
Farm 3	Plastic mulching	Ploughed / CA Site	3 months	Agriculture store
	Low tunnels	CA Site	6 months	Agriculture store
	Irrigation pipes	CA Site	3 Years	Outside
	Plastic containers for produce	N/A	N/A	N/A
	Plastic crates	Taken to Pitkalija	6 years	N/A

	Plastic tools	Manner of disposal	Frequency of disposal	Type of storage
Farm 4	Irrigation pipes	CA Site	6 years	Outside
	Plastic containers for produce	N/A	N/A	N/A
	Plastic crates	N/A	6 years	N/A
	Fertilizer bags	CA Site	1 year	Agricultural storage

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	Plastic tools	Manner of disposal	Frequency of disposal	Type of storage
Farm 5	Plastic mulching	CA site, ploughing	4 months	Agricultural storage
	Low tunnels	CA site	6 months	Agricultural storage
	Irrigation pipes	CA site, Incineration	2 years	Agricultural storage
	Plastic containers for produce	Disposed by customer	N/A	Agricultural storage
	Plastic crates	Taken to Pitkalija	6 years	N/A
	Fertilizer bags	CA Site	1 year	Agricultural storage

	Plastic tools	Manner of disposal	Frequency of disposal	Type of storage
Farm 6	Plastic mulching	CA site, ploughing	4 months	Agricultural storage
	Low tunnels	CA site	6 months	Agricultural storage
	Greenhouse plastics	Taken by installer	3 years	Agricultural storage
	Irrigation pipes	CA site, Incineration	2 years	Outside
	Plastic containers for produce	Disposed by customer	N/A	Agricultural storage
	Plastic crates	Taken to Pitkalija	6 years	N/A
	Fertilizer bags	CA Site	1 year	Agricultural storage

	Plastic tools	Manner of disposal	Frequency of disposal	Type of storage
Farm 7	Plastic mulching	CA site, ploughing	4 months	Agricultural storage
	Low tunnels	CA site	6 months	Agricultural storage
	Irrigation pipes	CA site, Incineration	2 years	Agricultural storage
	Plastic containers for produce	Disposed by customer	N/A	Agricultural storage
	Plastic crates	Taken to Pitkalija	6 years	N/A
	Fertilizer bags	CA Site	1 year	Agricultural storage

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	Plastic tools	Manner of disposal	Frequency of disposal	Type of storage
Farm 8	Plastic mulching	CA site, ploughing	4 months	Outside
	Low tunnels	CA site	6 months	Agricultural storage
	Greenhouse plastics	Taken by installer / Farmer to CA Site	3 years	Agricultural storage
	Irrigation pipes	CA site, Incineration	2 years	Agricultural storage and Outside
	Plastic containers for produce	N/A	N/A	N/A
	Plastic crates	Taken to Pitkalija	6 years	N/A
	Fertilizer bags	CA Site	1 year	Agricultural storage

	Plastic tools	Manner of disposal	Frequency of disposal	Type of storage
Farm 9	Plastic mulching	CA site, ploughing	4 months	Agricultural storage
	Irrigation pipes	CA site, Incineration	2 years	Agricultural storage
	Plastic containers for produce	Disposed by customer	N/A	Agricultural storage
	Plastic crates	Taken to Pitkalija	6 years	N/A
	Fertilizer bags	CA Site	1 year	N/A

	Plastic tools	Manner of disposal	Frequency of disposal	Type of storage
Farm 10	Plastic mulching	CA site, ploughing	4 months	outside
	Low tunnels	CA site	6 months	outside
	Irrigation pipes	CA site, Incineration	2 years	outside
	Plastic containers for produce	Disposed by customer	N/A	N/A
	Plastic crates	Taken to Pitkalija	6 years	N/A

	Plastic tools	Manner of disposal	Frequency of disposal	Type of storage
Farm 11	Plastic mulching	CA site, ploughing	4 months	N/A
	Irrigation pipes	CA site, Incineration	2 years	Outside
	Plastic containers for produce	N/A	N/A	N/A
	Plastic crates	Taken to Pitkalija	6 years	N/A
	Fertilizer bags	CA Site	1 year	N/A

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	Plastic tools	Manner of disposal	Frequency of disposal	Type of storage
Farm 12	Plastic mulching	CA site, ploughing	4 months	Outside
	Low tunnels	CA site	6 months	Outside & agricultural store
	Irrigation pipes	CA site, Incineration	2 years	Outside
	Plastic containers for produce	Disposed by customer	N/A	Agricultural store
	Plastic crates	Taken to Pitkalija	6 years	N/A
	Fertilizer bags	CA Site	1 year	N/A

	Plastic tools	Manner of disposal	Frequency of disposal	Type of storage
Farm 13	Plastic mulching	CA site, ploughing	4 months	N/A
	Low tunnels	CA site	6 months	Agricultural store
	Irrigation pipes	CA site, Incineration	2 years	Outside
	Plastic containers for produce	Disposed by customer	N/A	Agricultural store
	Plastic crates	Taken to Pitkalija	6 years	Agricultural store
	Fertilizer bags	CA Site	1 year	N/A

	Plastic tools	Manner of disposal	Frequency of disposal	Type of storage
Farm 14	Greenhouse plastics	Taken by installer	3 years	Agricultural storage
	Irrigation pipes	CA site, Incineration	2 years	Outside
	Plastic containers for produce	Disposed by customer	N/A	Agricultural storage
	Plastic crates	Taken to Pitkalija	6 years	N/A
	Fertilizer bags	CA Site	1 year	Agricultural storage

	Plastic tools	Manner of disposal	Frequency of disposal	Type of storage
Farm 15	Plastic mulching	CA site, ploughing	4 months	N/A
	Low tunnels	CA site	6 months	N/A
	Irrigation pipes	CA site, Incineration	2 years	Outside
	Plastic containers for produce	Disposed by customer	N/A	N/A
	Plastic crates	Taken to Pitkalija	6 years	N/A
	Fertilizer bags	CA Site	1 year	N/A
	IBC tanks	CA Site	8 years	Outside

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	Plastic tools	Manner of disposal	Frequency of disposal	Type of storage
Farm 16	Greenhouse plastics	Taken by installer	3 years	Agriculture store
	Irrigation pipes	CA site, Incineration	2 years	Agriculture store
	Plastic containers for produce	Disposed by customer	N/A	Agriculture store
	Plastic crates	Taken to Pitkalija	6 years	N/A
	Fertilizer containers	CA Site	1 year	Agriculture store

	Plastic tools	Manner of disposal	Frequency of disposal	Type of storage
Farm 17	Plastic mulching	CA site, ploughing	4 months	Agriculture store
	Low tunnels	CA site	6 months	Agriculture store
	Irrigation pipes	CA site, Incineration	2 years	Agriculture store
	Plastic containers for produce	Disposed by customer	N/A	Agriculture store
	Plastic crates	Taken to Pitkalija	6 years	N/A
	Fertilizer bags/containers	CA Site	1 year	Agriculture store

	Plastic tools	Manner of disposal	Frequency of disposal	Type of storage
Farm 18	Plastic mulching	CA site, ploughing	4 months	Agriculture store
	Greenhouse plastics	Taken by installer	3 years	Agriculture store
	Irrigation pipes	CA site, Incineration	2 years	Agriculture store
	Plastic containers for produce	Disposed by customer	N/A	Agriculture store
	Plastic crates	Taken to Pitkalija	6 years	N/A
	Fertilizer bags	CA Site	1 year	Agriculture store

	Plastic tools	Manner of disposal	Frequency of disposal	Type of storage
Farm 19	Plastic mulching	CA site, ploughing	4 months	Agriculture store
	Low tunnels	CA site	6 months	Agriculture store
	Irrigation pipes	CA site, Incineration	2 years	Agriculture store
	Plastic containers for produce	Disposed by customer	N/A	Agriculture store
	Plastic crates	Taken to Pitkalija	6 years	N/A
	Fertilizer bags	CA Site	1 year	N/A

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	Plastic tools	Manner of disposal	Frequency of disposal	Type of storage
Farm 20	Plastic mulching	CA site, ploughing	4 months	Agriculture store
	Low tunnels	CA site	6 months	Agriculture store
	Irrigation pipes	CA site, Incineration	2 years	Agriculture store
	Plastic containers for produce	N/A	N/A	N/A
	Plastic crates	Taken to Pitkalija	6 years	N/A

	Plastic tools	Manner of disposal	Frequency of disposal	Type of storage
Farm 21	Plastic mulching	CA site, ploughing	4 months	Agriculture store
	Irrigation pipes	CA site, Incineration	2 years	Agriculture store
	Plastic containers for produce	Disposed by customer	N/A	N/A
	Plastic crates	Taken to Pitkalija	6 years	N/A
	Fertilizer bags	CA Site	1 year	N/A

	Plastic tools	Manner of disposal	Frequency of disposal	Type of storage
Farm 22	Plastic mulching	CA site, ploughing	4 months	N/A
	Irrigation pipes	CA site, Incineration	2 years	Outside
	Plastic containers for produce	Disposed by customer	N/A	N/A
	Plastic crates	Taken to Pitkalija	6 years	N/A
	Fertilizer bags	CA Site	1 year	N/A

	Plastic tools	Manner of disposal	Frequency of disposal	Type of storage
Farm 23	Plastic mulching	CA site, ploughing	4 months	N/A
	Irrigation pipes	CA site, Incineration	2 years	outside
	Plastic containers for produce	Disposed by customer	N/A	N/A
	Plastic crates	Taken to Pitkalija	6 years	N/A
	Fertilizer bags	CA Site	1 year	N/A

Appendix B.2. Questionnaire in the English and Maltese Languages

The below pages provide the questionnaire that was distributed to farmers forming part of this research. The questions are available in both English and Maltese.

English

1. Specify your gender.
   - Male
   - Female
   - Other
2. What is your age?
   - 18-25

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- 26-35
- 36-50
- 51-62
- 63+

3. How long have you been practicing agriculture on the site?
   - 0-5 years
   - 6-10 years
   - 11-15 years
   - 16-20 years
   - 21-25 years
   - 26-30 years
   - 31 years +
4. Are you a full-time or part-time farmer?
   - Full-time Farmer
   - Part-time Farmer
5. In which locality is your field located?
6. What crops do you mostly grow in your field.
   - Tomatoes / Cherry Tomatoes
   - Cucumbers
   - Bell peppers
   - Onions
   - Aubergine
   - Squash
   - Strawberries
   - Melon
   - Watermelon
   - Broccoli
   - Cabbage
   - Potatoes
   - Wheat
   - Other:
7. List, from most to least, the products that generate the most plastic waste.
8. What type of plastic waste is generated at your site?
   - Baling twine
   - Bags from fertilisers/feed
   - Low-tunnel plastic
   - Mulching plastic
   - Greenhouse film plastic
   - packaging containers
   - Irrigation pipes
   - Plastic crates
   - Other:
9. How often do you replace plastic materials/tools?
   - Every season
   - Every year
   - Every two years
   - Every three years
10. On average, how much plastic waste do you generate per year?

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- None
- 0 - 20Kg
- 20Kg - 50Kg
- 50Kg-100Kg
- 100Kg+

11. Do you find any difficulty when disposing of plastic waste?
    - Yes
    - No
12. How do you dispose of plastic waste produced on your farm?
    - Incineration
    - Ploughed on site
    - Disposed at local civic amenity site
    - Collected by the local waste collector for recycling
    - Other:
13. It is important for me that farm plastics are recycled or disposed of in a sustainable manner
    - Strongly agree
    - Agree
    - Neutral
    - Disagree
    - Strongly disagree
14. Would you be willing to change the way you dispose of waste?
    - Yes
    - No
    - Maybe
15. Do you need any information about how you can dispose of plastic waste in an environmentally sound manner?
    - Yes
    - No
16. Do you encounter barriers which prevent you from collecting and storing plastics in your field?
    - Yes
    - No
17. What actions would encourage you to divert the plastic waste produced from your activity into a recycling program?
    - Collect and deliver to collection centre (self)
    - Store for collection by waste collector
18. How much would you be willing to pay in terms of a small surcharge on agricultural plastics in order to support of a recycling program?
    - €00.00
    - €0.75
    - €1.50
    - €2.25
    - €3.00
    - €3.75
    - €4.00

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19. Would you be willing to participate if a scheme were to be introduced, granting a small sum back when the farmer delivers agricultural plastic waste to a collection centre?
    - Yes
    - No
20. In your opinion who should be made responsible for overseeing the management of agricultural plastic waste in Malta?
    - Farmer's association
    - The Environment and resources authority
    - Ministry for Agriculture, Fisheries, Food and Animal Rights
    - Ministry for the Environment, Sustainable Development and Climate Change
    - Wasteserv
    - Local Council
    - Other plastic brokers
    - Other:

Maltese:

1. Speċifika s-sess tiegħek
    - Raġel
    - Mara
    - Oħra
2. X'inhi l-età tiegħek?
    - 18-25
    - 26-35
    - 36-50
    - 51-62
    - 63+
3. Kemm ilek tipprattika l-agrikoltura fis-sit?
    - 0-5 snin
    - 6-10 snin
    - 11-15-il sena
    - 16-20 sena
    - 21-25 sena
    - 26-30 sena
    - 31 sena+
4. Int bidwi fuq bażi full-time jew part-time?
    - Full-time
    - Part-time
5. F'liema lokalità tinsab il-għalqa/għalieqi tiegħek?
6. Liema huma l-prodotti l-aktar li tkabbar fil-ghalqa/ghalieqi tiegħek?
    - Tadam
    - Basal
    - Patata
    - Bżar
    - Hjar
    - Brunġiel
    - Qara ħamra
    - Brokkoli

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- Frawli
- Kaboċċi
- Qamħ
- Other:

7. Ikteb, mill-iktar għall-inqas, il-prodotti li jiġġeneraw l-iktar skart tal-plastik fl-opinjoni tiegħek.
8. X'tip ta' skart tal-plastik huwa ġġenerat mill-attività tieghek fis-sit?
   - Spag tal-imballaġġ
   - Basktijiet tal-qamħ/fertilizzant
   - Plastik mill-mulching
   - Plastik minn serer
   - Plastik minn low tunnels
   - Kontenituri tal-plastik
   - Pajpijiet tal-irrigazzjoni
   - Kaxxi tal-plastik
   - Other:
9. Kull kemm tibdel materjali/għodda tal-plastik?
   - Kull staġun
   - Kull sena
   - Kull sentejn
   - Kull tliet snin
   - Other:
10. Bħala medja, kemm tiġġenera skart tal-plastik fis-sena?
    - Xejn
    - 0-20Kg
    - 20Kg - 50Kg
    - 50Kg - 100Kg
    - 100Kg+
11. Issib diffikultà meta tiġi biex tarmi skart tal-plastik?
    - Iva
    - Le
12. Kif tarmi l-iskart tal-plastik li jiġi ġġenerat fis-sit tiegħek?
    - B'mogħod ta inċinerazzjoni
    - Huwa maħrut fuq il-post
    - Meħuda lejn civic amenity site
    - Miġbura mill-kollettur tal-iskart lokali għar-riċiklaġġ
    - Other:
13. Huwa importanti għalija li l-plastiks tal-agrikoltura jiġu riċiklati jew jintremew b'mod sostenibbli
    - Naqbel ħafna
    - Naqbel
    - Newtrali
    - Ma naqbilx
14. Tkun lest li tibdel il-mod ta' kif tarmi l-iskart?
    - Iva
    - Le
15. Għandek bżonn xi informazzjoni dwar kif tista' tarmi l-iskart tal-plastik b'mod li ma jagħmilx ħsara lill-ambjent?

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- Iva
- Le

16. Issib ostakli li ma jħallukx tiġbor u taħżen il-plastik fis-sit tiegħek?
    - Iva
    - Le
17. Liema azzjonijiet iħeġġuk li tiegħu l-iskart tal-plastik li joriġina fl-għelieqi tiegħek għal dak ta' programm ta' riċiklaġġ?
    - Jinġabar u jigi trasportat lejn iċ-ċentru tal-ġbir (mill-bidwi)
    - Jinħażen u jinġabar għall-ġbir minn kollettur tal-skart
18. Li kieku kellek tħallas soprataxxa, kemm int lest tħallas fuq plastiks agrikoli b'appoġġ għal skema ta' riċiklaġġ?
    - €00.00
    - €0.75
    - €1.50
    - €2.25
    - €3.00
    - €3.75
    - €4.00
19. Li kieku tigi introdotta skema li tagħti somma żgħira lura lil min jieħu l-iskart tal-plastik agrikolu tiegħu f'ċentru tal-ġbir, tkun lest li tipparteċipa?
    - Iva
    - Le
20. Fl-opinjoni tiegħek, min għandu jkun responsabbli li jissorvelja l-immaniġġjar tal-iskart tal-plastik mill-agrikoltura f'Malta?
    - Assoċjazzjoni tal-bdiewa
    - Environment and Reosurces Authority
    - Il-Ministeru għall-Ambjent, it-Tibdil fil-Klima u l-Ippjanar
    - Il-Ministeru għall-Agrikoltura, Sajd u Drittijiet tal-Animali
    - Wasteserv
    - il-Kunsill Lokali
    - Sensara oħra tal-plastik
    - Other:

Appendix B.3. Stakeholder Interview Transcripts

Interviewee 1: Environment and Resources Authority- Waste Policy Interview – Environment Protection Officer on Waste Policy

1. Research suggests that there is little to no policy which addresses agricultural plastic waste in the Maltese islands. Do you think this should be addressed in future policies?

As you said specific policy for this kind of waste is quiet limited. . Of course, this does not mean that this type of waste is not regulated in any way. As such from a policy point of view, policy is the thing to create a policy I need to have some kind of information on which the policy itself is based. Now of course, unfortunately, even the information we have about plastic from agriculture is quite limited, which means that with this information I am talking about how much data is generated. I'm not saying I don't have data, but its accuracy has never been questioned so well that we can determine how much it actually reflects reality. This type of waste is classified under a particular code referring to plastic from agriculture, some kind of input is recorded under this type of waste but they are not large amounts that sometimes again question a sector like agriculture where the use of -plastic is

what it means to be used in the greenhouse also irrigations in short how to record such a small amount compared to the amount to be expected, apart from that there is no policy, even the information so that we can actually be developed in policy is quite limited. I think that's one of the main reasons why maybe it never came, there were never put forward policies or else there was an intention to have a specific policy on that. Not only in Malta, but also on the part of the EU institution, there has never been a push for a specific policy on this type of waste.

2. **When you say it's already being recorded to an extent these by means of Malta is this type of data being recorded?**

Obviously in Malta when it comes to waste, when it comes to environmental reporting mainly we capture data from especially when it comes to waste we are discussing about, from waste management facilities which are main actors when it comes to waste management, where they report the amounts of waste they accept on site, the origin of the waste as well as the faith of the waste, in this case it is recorded under specific EWC codes and of course we know that it is this type of plastic waste that comes from agriculture . In addition, there will be some recorded data, facilities, facilities whatever I am talking about waste management facilities which are covered by environmental permit, and these have the requirement to report thin data, especially data on waste mainly reporting off site transfer of waste. In addition, then there are exports of some waste where if there is a transport of this type of waste, it is obviously recorded through un-access before the export. Those are mainly the sources of how such waste can be recorded.

3. **Part of the question, do you think there is a need for some kind of policy in the future and do you want to check the data before saying that it is necessary or not necessary?**

I understand this in the sense that if you first create a policy to see exactly what is needed you need to have a clear picture of the current situation. That is to say, once you have a clear picture, it will be easier to see what kind of processes are needed so that all kinds of waste can be handled in the best possible way and apart from that if it can be this type. Waste is not generated in the first place. Now of course it is not always possible due to the industry itself and the sector but of course you need to have a clear picture of what waste is being generated and the amounts that are being generated so that you can create a policy based on actual facts.

4. **Given your experience on environmental policy, what kind of policy tool or scheme would be ideal to tackle agriculture plastic waste in terms of reduction and accountability? Again of course we are saying if there is enough data and action will be taken in terms of a policy or a scheme. In your experience, what do you think would be ideal to reduce plastics in the industry or increase accountability, from the producer himself would have more responsibility perhaps?**

Of course, when it comes to waste, it will always be based on the principle of the producer pays, ideally the one who generates the waste is responsible for the management and treatment of waste as well as other waste streams that are perhaps more visible during everyday life. This type of waste is being managed under EPR where the producer who is putting this type of waste on the market remains responsible even after this material becomes waste, therefore I think the responsibility of the producer is important even when it comes to the management of waste, and I think policies to be as effective as possible must be given a certain responsibility even to the producer himself. We obviously need to determine what we mean by a producer because it may be how you are selling the product in the first place, it may be how you are using it, obviously it needs to be determined to understand exactly how it is being used and what type of process is there before it is placed on the market whether it is being manufactured in Malta or even being imported, these are all variables which of course one then decides if exactly how the material producer is defined.

5. **So the term producer changes depending on the industry in a way or?**

To some extent this is the case. For a example the construction and demolishing waste strategy identifies developers as producers. The EPR scheme under packaging or WEEE identifies the

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importer placing on the market as the producer as such unless there is a definition at EU level, the producer can be defined according to the sector and the industry you are talking about.

6. **So it looks like there has to be some kind of EPR scheme or policy tailored to the agricultural.**

Yes, exactly. To better implement the producer pays principles or even policy to encourage reuse of certain items.

7. **If I'm not mistaken there is a concept of reuse for the green plastic crates ?**

Yes, the *Pitkalija* usually have a washing process so that they can keep on reusing but at the end of the day they deteriorate or become too brittle with the sun, In fact many farmers mentioned that most of them try to reuse as much as possible because the costs is of the material is huge in fact the first to start with how much money they spend on plastic pipes, mulching etc. In fact, the intention to reuse them maybe not for environmental reasons but for economic reasons.

Often when we talk about reuse and these kinds of best practices there are often economic reasons behind them, but it does not mean that there are no environmental benefits that are paired through the same systems. There is also another example of plastic crates made from a certain type of plastic which has a much higher recyclability than for example the plastic film used in greenhouses. The options of not reusing after that are they are limited even on plastic pipes for irrigation so PVC will probably be those.

In fact, that is an example because you have a lot of mulching which is heat resistance or UV resistance. Their recyclability rate of being malted down and reused is difficult because you have two different resins mixed together not as much as one resin that its melted and remelted into something else. And I mentioned accountability obviously because I'm tackling disposal patterns. If people who currently have the sticker of the middleman enter the Civic Amenity sites of *Ta' Qali.* But those who are part-time farmers who do not sell middlemen do not have this accessibility. So, what becomes of it? It's not being accounted for; it's not being disposed probably in illegal disposal sites so what happens? Will it burn? Will it be ploughed in the field? There are these questions that I'm addressing slowly of course there's a scheme that in a way it accounts for these loopholes. That's why I mentioned accountability schemes. At first it seems to entice the farmer that they become more transparent, because of course if you say listen to it you need to become transparent and I will increase the cost no one would want to be part of that.

Interviewee 2: ERA EPR Compliance and Enforcement –Team Manager (Waste Schemes and Exports)

1. **With the ERP scheme for the Maltese islands, was agriculture plastic ever considered to be implemented within the scheme? And if no what was the reason?**

Agricultural waste plastic when it comes to EPR for plastics we are only talking about packaging. To explain myself better - if you have a mobile, you have the mobile in a box the outer plastic usually the mobile phone boxes come in a bigger box and the pallet and shrink wrap around that is all packaging i.e., here we are talking about packaging related to products that are put on the market, i.e., the plastic we are talking about; The fields that look like a small tent for you to grow produce are not in the EPR. They are not considered, they are not packaging material of products that will end up with the consumer, but that plastic is good to be collected and recycled if it is obviously of recyclable quality. Perhaps you can get into the scheme, as you said, for example, pallets or plastic that are rolled up with pipes, for example, but not plastic. So, it was never included in the EPR scheme because it is not packaging.

2. **Do you think the involvement of agriculture plastic waste within the EPR scheme would deter importers from putting on the market as much plastic related products?**

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If we have products that are related to agricultural use fall under EPR if they are produced but, we are not talking about that plastic that makes tents with it to be able to grow vegetables in it or irrigation pipes. Like strawberry plastic containers, plastic sometimes comes in this soil: weed peat and be in a bag, that's plastic, it's surrounding the product itself. The plastic that grows to make the grass in it is the product its loan, that is, there may be things related to agriculture that are in the EPR, as long as it is packaging, for example, the tanks; The little ones come with pesticides, that's packaging. That comes in a bigger box. Comes on a pallet. That's all packaging.

3. **If we were to do something similar to the EPR for agricultural plastics. Do you think that is possible? Do you think it is feasible? Or at least nothing?**

Well, most of the amounts from the these plastic products and packaging is are also probably catching agricultural items. I'm not saying that the thin plastic that is used to wrap crops and or those used to grow vegetables in it, those are not trapped in the scheme. Let's start with the fact that this type of material is usually very dirty because when you put it in the soil, even though it is very large, it is dirty and unfit for recycling. Though It can be washed, one to see if it is viable to wash it.

4. **Are these types of plastics exported, in your experience?**

Yes, plastics are exported.

5. **So, since farmers can enter Wasteserv's civic amenity site at *Ta' Qali*, Does this means that Wasteserv then exports the waste abroad?.**

Yes, every material that can be exported is exported abroad to be re-purposed.

6. **So to conclude; do you think that it is viable to have for instance, a scheme to register or control the producer of agriculture plastic waste? i.e. if I am selling plastic pipes or mulching do you think there should be a type of scheme to gives more accountability for its collection or reuse?**

Well, the scheme, is aimed for packaging plastics so they target general products and not on just one sector because it is difficult. If focus on one sector you would leave the other sector out. So, they made it as packaging plastics so that it ends up at the consumer. I think if one would focus just on agricultural it would be problematic. Even to have a scheme to only target one sector. Even though there is one for just batteries, the scheme is catching a large amount as it extends to various industries. Moreover, batteries also have a lot of profits in them, plastic has more to undergo more work and it doesn't contain the same amount of profit. I don't think it's feasible to go for an agricultural-only scheme.

7. **Do you think it should be included with some other scheme?**

It can be included when the kind plastics that are present are determined but currently the law here in Malta is on packaging.

8. **In the case of single use plastic regulations, would fruit and vegetables sold in a container fall under this classification?**

Single use plastic containers are classified as single use and unusable. The bag must be biodegradable and less than 15 microns or more than 50 microns to be used. They can be sold in bags for example, but the bags must be biodegradable and less than 15 microns. The transparent strawberry box is not sideways so it can still be used, in fact one of the guidance we give people is if you have a strawberry box obviously the box is not closed that can be put back in a bag because the bag to use the purpose of the bag is to avoid contamination.

Interviewee 3: ERA Illegal Disposal Compliance and Enforcement –Officer (Illegal Management of Waste)

1. **How do you tackle cases of illegal management of waste? What is the process?**

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Well to explain better this question, first one has to understand how we tackle cases and reports. We get reports from the general public or entities through our website, telephone or media channels. With the details provided such as location, time and type of incident. For example; someone is burning plastic and there are bad fumes in the area. As compliance and enforcement officer we gather as much info as possible to find the area. We take photos of the site and search for any evidence of the material which was burned. The owner or responsible person is confronted on the matter. They are ordered to clear the waste and warned that this carries hefty fines. The case remains active and monitored until the area is cleared. In cases with enough evidence of who incinerated the material and if the material is considered as toxic, a fine is issued. Cases are also opened if ERA officers encounters the event.

2. What do you mean when you mentioned, considered as toxic?

Well, the legislation allows for organic/agricultural waste to be burnt, particularly 1 ton per day from the site of production. So if a farmer is seen burning dry vegetation or crops we do not have the remit to intervene. Anything other than that, for example: white goods, plastics, packaging waste, furniture, metal, we can intervene.

With farmers we usually encounter a bit of both. For instance, farmers burning dry vegetation with some packaging waste from agricultural activities, or most commonly plastic pipes. Burning of plastics is usually identified by dark plumes of smoke and heavy odours. In most cases a fine is issued. Most of the time the person is not aware that this is not permitted. Usually, it is a case by case basis where the degree of waste, type and if it was the first infringement are taken into consideration.

3. What action do you take on the person responsible following the episode?

Following an episode, we stay in contact with the person, we give a time frame so that they clear the site from the burnt debris and any other waste. As I mentioned before, some cases we issue a fine and if the person doesn't comply we issue an enforcement order. This carries daily fines until the area is remediated. To be honest, this is not as frequent as most people comply.

4. On average how many cases related to farmers or agricultural sites do you encounter per year?

With regards to agricultural sites we mostly received complaints related to dumping of material. However they turn out to be engineering works for soil replenishment. Cases related to waste management on agricultural sites would probably be around 10 to 20 cases per year. Usually there is a seasonal spike, before and after summer where the crops are removed to make way for other seasonal crops.

Interviewee 4. Director at Ministry for Climate Change and Sustainable Development (MECP)

1. Are there any policies, schemes or any form of initiatives targeting agricultural plastic waste in any form?

There are agreements set in place at all levels, not in agriculture only. Such as, in transportation, in culture, waste management, climate change i.e., all these things. So, Malta at EU level has signed the European Green Deal, which means we are agreeing to adopt it throughout the sectors. On the agricultural side there is the farm to fork strategy, which is more based on food, arable farming and types of farming practices, in essence the whole industry, of course this has the side effects on consumables such plastic so there we can't go into farm to fork strategy without touching on the European Green Deal. In essence they go hand in hand. As the director of sustainable development, we are not doing anything about this, because it is not within our remit. However, at the moment I am doing a strategy on sustainable development that will covers up to 2050, of course I will consult with the various ministries, and they obviously take various initiatives in into considerations. Now with regards to plastic waste and other materials, the farmer should know that he is not supposed to burn in tanks or any other area. As they are supposed to take the waste to Wasteserv with the

incentives register their vehicle and go as many times as one needs to the CA site. Now how often this is done I do not know, but the possibility is there. What are more effective are for example, certain policies aimed to control the pesticide use in agriculture. However, the policies address security rather than consumables. I do think that your research is highlighting an issue, as no one knows how much waste each farmer produces, for instance plastic waste.

2. Circling back to the green deal which you mentioned earlier, how can it help or impact the industry?

Degradable plastic is very expensive. Now an option is to get aid from the government. To go green, even on a personal level. Disregard farmers, it is very expensive, for instance to install solar panels; buy an electric car, buy AAA + appliances. One can purchase these materials but when you take all of these into consideration, you have a huge expense. This may save money in the long run because that's the way it is, but for example a normal white good can cost a normal amount of about 150 euros while a AAA+ can costs about 250 euros. In essence, to go green it's expensive, this means that if we did not have subsidies on solar panels, very few people would opt for it. So, if we want to go green in the sector, one has to adopt something similar to the solar panels approach. I think we can go for a green approach for the farming sector. Just as the approach in installing solar panels in our community, we can do the same for the thing for the farming community and on different schemes.

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