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Authors(s)	Ruffing, Blair
Publication date	2020
Publication information	Ruffing, Blair. “Advisory & KT Tools and Processes to Support Potato Farmers and Agronomists to Assess Their Exposure to Risk of Cadmium.” University College Dublin. School of Agriculture and Food Science, 2020.
Publisher	University College Dublin. School of Agriculture and Food Science
Item record/more information	http://hdl.handle.net/10197/12844

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Advisory & KT Tools and Processes to support potato farmers and agronomists to assess their exposure to risk of cadmium

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Master's Thesis

Author: Blair Ruffing, BSc

to achieve the university degree of Master of Science (Agriculture)
Agricultural Innovation Support

submitted to

University College Dublin

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June 8th, 2020

AFFIDAVIT

I declare that I have authored this thesis independently, that I have not used other than the declared sources/resources, and that I have explicitly indicated all material which has been quoted either literally or by context from the sources used. The text document uploaded to UCD SISWeb is identical to the present master's thesis.

October 7, 2020 _____

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ACKNOWLEDGEMENTS

Firstly, I would like to thank all of my friends and family for keeping my head high throughout this two-year period. Your encouragement and belief in my ability means a lot. Thank you to everyone in the Drogheda Teagasc office for the laughs at teatime and the many unneeded but very much wanted biscuits. Thank you for giving me the space and the help needed to complete my research. To my main advisors, Dr. Monica Gorman and Mr. Shay Phelan, thank you for your advice and guidance along the way. I know I am only one mind of many you have and will mentor, but your help throughout these two years will stay with me for a lifetime. To all of the wonderful researchers at Teagasc Oak Park and beyond, thank you for sharing your work and working with me to bring this project to fruition. Thank you to my fellow MAIS students; without your confirmation, I really would not have been sure which way was up. Most importantly, I would like to thank all of the growers and agronomists who agreed to take part in this study. Your willingness to participate and be open with me means the world and will do a lot of good. Coming to Ireland from the USA was a major life decision for me, but everyone that I have met and everything I have done along the way has made it all worth it. Thanks again and best wishes to everyone.

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ABSTRACT

Cadmium (Cd) is a heavy metal found in soils all around the globe. This toxic metal accumulates in crops grown for consumption and is capable of causing harm to human health if consumed in high enough concentrations. There are several regions in Europe and across the globe with elevated levels of soil cadmium from a variety of sources, and the source of this cadmium determines the type of mitigation strategies needed to decrease levels of Cd in the soil. The source may be anthropogenic from use of phosphatic fertilizers or industrial contamination or geogenic from the weathering of soil and bedrock. There are maximum permitted levels of cadmium allowed in produce, as set by the European Union. Currently, there are discussions taking place in regard to lowering those maximum levels, making compliance a certain risk amongst growers in one of the most productive horticultural areas of Ireland. A mixture of methods was used to examine knowledge and attitudes of potato growers and agronomists in counties Meath, Dublin, and Kildare in Ireland where there are established elevated levels of available soil cadmium. The overall purpose of this study was to future proof the potato industry against this risk and provide insight into the effectiveness of advisory and knowledge transfer (KT) communication on farmer attitudes, knowledge, and intention to implement, particularly when dealing with an uncertain and unwelcome risk. Thirty-nine (39) growers and seven agronomists took part in one-on-one interviews and surveys regarding awareness of heavy metal contamination and intentions to mitigate. Themes from the interviews were established and analyzed in NVIVO, while quantitative statistical analysis was performed for the 39 grower surveys and seven agronomist surveys in SPSS. Qualitative analysis of the 39 one-on-one grower interviews and quantitative analysis of the 39 grower surveys revealed a very low level of

awareness around the Irish cadmium issue but a high level of intention to mitigate. Qualitative analysis of the seven agronomists and quantitative analysis of the seven agronomist surveys revealed a very high level of awareness and concern in regard to the cadmium issue with a low level of knowledge on possible mitigation strategies and low rate of advising clients with regard to same. This project has components dealing with themes of uncertainty, negative messages, and many others that are applicable to not only tillage but also dairy and drystock sectors. This research offers insights into understanding the best practice of communicating unpalatable messages to farmers in a way that allows them to see the best possible outcomes so that the message is at least somewhat welcomed, wanted, and accepted by the farmer.

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GLOSSARY OF ACCRONYMS AND TERMS

AKIS: Agricultural Knowledge and Innovation Support System

CREDIT: The "Cadmium: To Reduce, Evaluate, Detect, and Inform with Technologies" Project is a DAFM funded research project. This Masters research project is one of the tasks within this larger project.

Cd: Symbol for the chemical element cadmium

$CaCl_2$: The ionic compound, calcium chloride, of calcium and chlorine used to extract air-dried soil for purpose of soil analysis

DST: Decision Support Tools (DST) merge deep analysis with prediction capabilities to help individuals or companies improve the way they approach information in order to make better decisions

DAFM: The Department of Agriculture Food and the Marine (DAFM) is the Irish government ministry and regulatory body for the agri-food sector

EC: European Commission (EC) is the executive of the European Union

EFSA: European Food Safety Authority (EFSA) is the agency of the European Union (EU) that provides independent scientific advice on existing and emerging food-related risks

EU: European Union (EU) is a political and economic union of 27 member states located primarily in Europe

FBO: Food Business Operators (FBO) are individuals responsible for ensuring the requirements of food law are met within the food business under their control

FSAI: The Food Safety Authority of Ireland (FSAI) was established under the Food Safety Authority of Ireland Act, 1998, and works to protect public health and consumer interests in the area of food safety and hygiene

FW: Fresh weight (FW) is the weight recorded immediately after the plant or part of a plant is harvested

Ha: Hectare (ha) is a metric unit of square measure; one hectare is equal to 2.47 acres

MS: Shorthand version of mitigation strategies used throughout this thesis

ML: Maximum Levels (i.e. EU mandated maximum level standards for heavy metals like cadmium)

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Cadmium occurs naturally in soils across the globe and is able to accumulate in crops grown for public consumption. Maximum levels are established in legislation, and while current levels found in Irish produce do not present an unacceptable risk to the consumer, it is necessary to continually strive to reduce levels in produce. This study is one task that is part of a much larger Department of Agriculture, Food and the Marine (DAFM) funded research effort titled project CREDIT (Cadmium: Reduce, Evaluate, Detect, Inform with Technologies). The CREDIT project harnesses a range of scientific, knowledge transfer, farming, and policy and regulatory expertise to develop appropriate strategies to manage cadmium in crops. The various tasks that make up project CREDIT will support key stakeholders, including farmers, agronomists, the horticultural industry, and policy makers and regulators to combat these issues and preserve Ireland's horticultural industry and reputation as a producer of quality food into the future.

In 2011, another DAFM funded project, titled "Strategies for controlling cadmium contamination in Irish food production," aimed to use data from field surveys of animals and plants in the impacted area of the country to quantify the cadmium problem and highlight causal soil factors. These quantitative outcomes from the research undergone was then used to build a risk

assessment model and decision tree based on soil tests that would allow farmers to assess and avoid risk of cadmium accumulation in their crops.

From 73 field samples and 310 potatoes of the variety Rooster sampled over a period of four years in land both inside (58 fields) and outside (15 fields) of the impacted area, a complex model with several soil parameters (i.e. cadmium (Cd), zinc (Zn), potassium (K), magnesium (Mg), manganese (Mn), and phosphorus (P)) was developed to provide a good power of prediction for estimated tuber-Cd levels based on soil properties based in one laboratorial test (0.1 M (molar solution) of $CaCl_2$ (calcium chloride) extraction):

$$log(Cd_{Tuber}) = a + blog(Cd) + clog(Zn) + dlog(K) + elog(Mg) + flog(Mn) + glog(P) + hlog(Cd)^2 + ilog(Zn)log(Mn)$$

Figure 1.1 Equation that uses various soil parameters to predict estimated Cd level in the tuber (Alves, 2018)

Using this model, a single laboratory test will allow the grower or agronomists to receive an accurate prediction of the predicted cadmium content in the potato tuber in the form of a traffic light system rating as seen in the procedure found below in Figure 1.2.

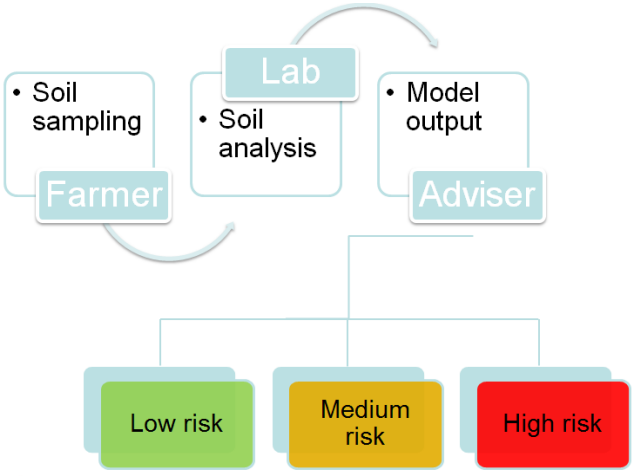


Figure 1.2 Procedure for providing traffic light system rating for potato growers and agronomists (Phelan, 2018)

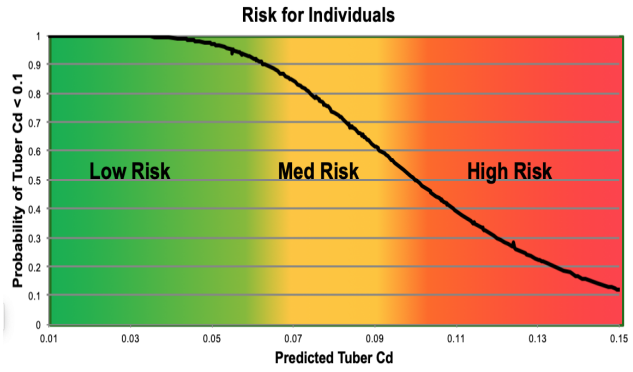


Figure 1.3 Graphical representation of cadmium risk assessment model (Phelan, 2018)

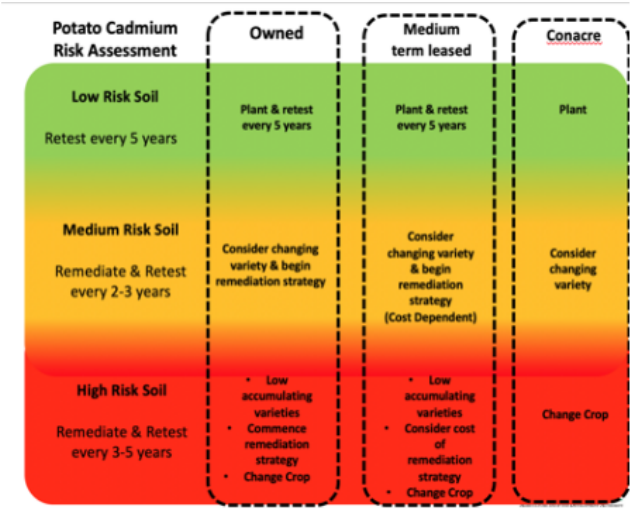


Figure 1.4 Continuation of cadmium risk assessment model that lays out mitigation strategy options based on tenure type (Phelan, 2018)

From the traffic light rating output generated from the model, the advisor is able to provide recommendations to the grower in terms of possible mitigation strategies. The mitigation strategies vary depending on the strength of the risk. These strategies and a thorough background on the context of cadmium in Ireland are discussed throughout the following sections.

1.1.1 Cadmium in Ireland

Cadmium (Cd) is a heavy metal that is potentially harmful to human health. Studies have shown that when consumed in high enough concentrations, normal kidney function may be compromised along with other health issues (Joseph, 2009; Waalkes, 1999; Honda et al., 2010; Satarug et al., 2010). Furthermore, Cd was classified as a human carcinogen in 1993 by the International Agency for Research on Cancer (IARC) and a class 1 carcinogen by the World Health Organization (WHO). Various food and non-food sources contribute to human intake of cadmium; fruit, vegetables, and cereal-foods contribute most in terms of public exposure along with smoking and industry. There are several regions in Europe with elevated levels of soil

cadmium. These sources may be anthropogenic such as use of fertilizers or industrial contamination. The difference in soil cadmium concentrations across Ireland, however, is the fact that the cadmium concentrations are mostly geogenic in nature from the weathering of soil and bedrock. A significant correlation has been found between regions in Ireland with an impure limestone bedrock type and high cadmium concentrations in the soil (Figures 1.5 and 1.6). Counties Dublin, Meath, and Kildare are the focus of this research project due to their high soil cadmium concentrations and that much of the horticultural industry of the island is based in these areas of north Leinster.

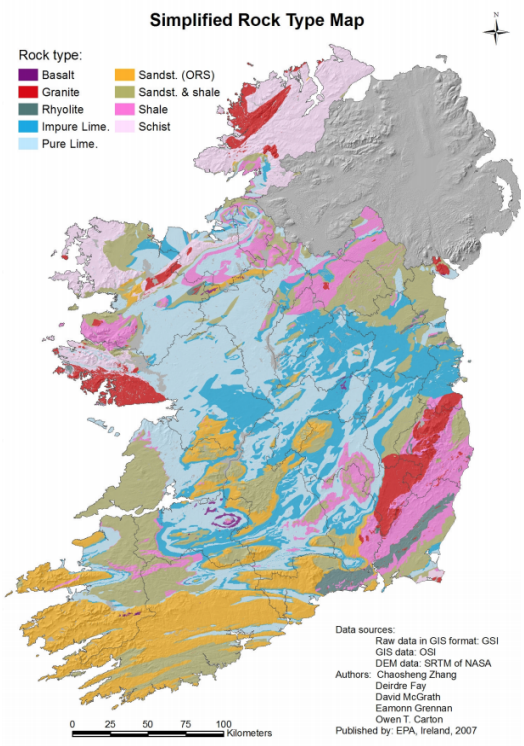


Figure 1.5 Map of Ireland displaying the various bedrock types found throughout the country (EPA Report, 2012)

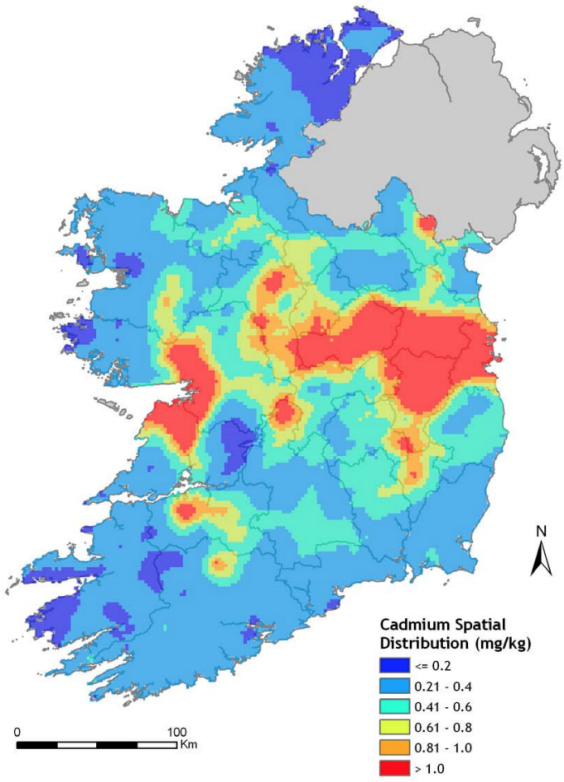


Figure 1.6 Map of Ireland displaying spatial distribution of cadmium throughout the country (EPA Report, 2012)

Geochemical pollution occurs in soils when the associated bedrock contains elevated levels of one or more metals. Rock weathering results in the release of such metals and their incorporation into derived soils. Certain geochemical and pedological factors are important when assessing the status of any particular trace element in the soil. The nature of the parent material provides a starting point and is indicative of likely contents in soils. For instance, it can be reasonably assumed that soils formed from acid igneous rocks will have low contents of a number of biologically important trace elements because minerals with which these trace elements are normally associated are not abundant in such rocks. Conversely, soils formed from fine-grained sedimentary rocks such as limestone shales or general clayey shales will, on average, have higher contents.

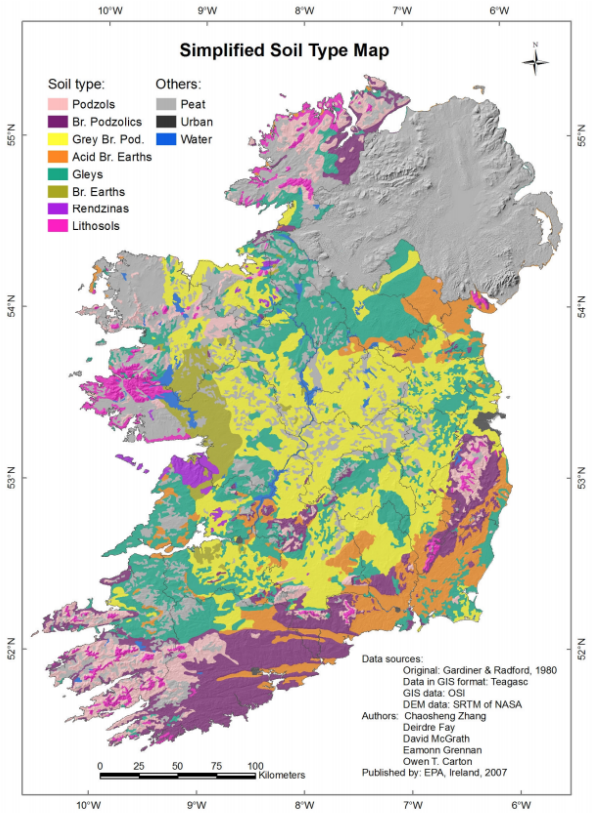


Figure 1.7 Map of Ireland showing the Great Soil Groups of the country (EPA Report, 2012)

As shown in Figure 1.7, the primary soil types of the impacted areas are Grey Brown Podzolics (yellow) and Gleys (jade). Grey Brown Podzolics are normally formed from calcareous parent material and are mostly underlain by pure and impure limestones. Gleys have a fairly high clay content, leading to poor drainage and permanent or intermittent water logging, making them unsuitable for cultivation or intensive tillage production in most cases. These soils are often associated with shale or sandstone.

From the point of view of plant nutrition and uptake of any particular trace element, it is important to mention that it is not so much the total but the available content which is of greatest importance. Soils may have relatively high total contents, yet the amounts available for plant uptake may be quite small. Factors such as soil pH, organic matter content, and drainage status all affect the availability of trace elements to plants. In the context of cadmium, a soil test for available cadmium is the only accurate measure of prediction for a grower's risk to cadmium being taken up by their crop. As previously mentioned, 0.1 M (molar solution) of $CaCl_2$ (calcium chloride) extraction is the suggested method for assessing available cadmium content in a soil sample. It is important to interpret the maps included above, particular Figure 1.4, correctly. Not all farms within areas designated as high cadmium zones will have a cadmium problem. With the intensity of sampling employed, the map can only highlight high-risk areas, but they serve to draw attention to the possibility of a particular problem arising

1.1.2 European Union Policy

The European Union (EU) sets maximum levels for certain food contaminants, including mycotoxins, metals, dioxins, nitrates, and more for the sake of ensuring the protection of public health. Contaminants are defined as substances that have not been intentionally added to food but

are present as a result of the various stages of production, packaging, and transport. Cadmium falls under the scope of metals along with lead, mercury, and inorganic tin. Under EU regulation, foodstuff that exceeds the maximum level requirement may not be placed on the market (EUR-Lex, 2015). According to the Commission Regulation (EC) No 1881/2006, countries within the EU have the responsibility to test for such contaminants and are obligated to send such results to the European Food Safety Authority (EFSA). While the maximum levels of cadmium in potatoes remains for the time being at 0.1 Cd/kg Fresh Weight (FW), there have been discussions between EU and EFSA stakeholders to lower said limit to 0.075 mg Cd/kg FW (FSAI, 2019). As it stands under the current maximum level regulations of 0.1 mg Cd/kg FW, it has been predicted that roughly 30% of potatoes grown for consumption in the impacted area would be found in exceedance of the maximum level while 70% would be found below the set maximum level. The impact of decreasing the maximum level from 0.1 to 0.075 mg Cd/kg FW would be that 50% of potatoes on the market would be found in excess of the maximum level and 50% would fall under the maximum level (Cd RED, 2018). Farmers and growers in the impacted area need access to high quality knowledge and advice if they are to make informed decisions about their enterprises. This research is focused specifically on the needs of potato growers and the agronomists who support them; however, the findings will have relevance to advisory services for all growers and indeed for supporting all farmers in addressing complex problems.

1.1.3 Cadmium and Possible Mitigation Strategies

Cadmium is concentrated in particular parts of the plants; leaves contain the most followed by storage roots and tubers (Mengist et al., 2018). Various mitigation strategies for cadmium exist, including but not limited to the application of organic matter, raising the pH, use of zinc, zinc

sulphate, and low cadmium fertilizers (Bolan et al., 2014). Cadmium in the soil readily attaches to clay particles in the organic matter, making it less available for uptake by the plants. Soil organic matter is generally built up by the retention of crop residues after harvest, use of green manure crops, pasture phases in crop rotations, and significantly reducing the number of crop cultivations. It should be noted that the build-up or breakdown of soil organic matter (SOM) is a slow process and significant changes only occur in the medium to long term, unless the organic matter is introduced externally from the likes of manures. The availability of cadmium to plants also decreases as soil pH increases. Zinc and cadmium uptake by plants occurs in a similar way, and it appears that if soil zinc levels are low, then more cadmium will be taken up by the plant. Addition of zinc sulphate (around 50-100 kg of zinc/ha) has proven to be successful in regions like Australia where cadmium is an issue. In their trials, applying zinc sulphate at planting significantly reduced tuber cadmium concentrations. Use of low cadmium content fertilizers is recommended; it is recommended that growers look for products that contain less than 150 mg cadmium per kg of phosphorus (Bolan et al., 2013; Mater et al., 2009; Lackovic et al. 2003; Wu et al., 2012; Izhevska, 2009). It is important to note that uptake varies considerably between different plant species and between varieties and/or cultivars. In Irish varieties, Cara and Maris Piper are the lowest Cd accumulators, while Rooster and Lady Rosetta are the highest Cd accumulators. A potential mitigation strategy for growers would be to change variety to a lower accumulator.

The topic of tenure type is also explored in this project as a component of the effectiveness of the mitigation strategies. The mitigation strategies for cadmium are unsuccessful in the short term; the inputs need time in order for results to be seen. In the Irish tillage sector, having solely long-

term leases or owning all of the farmed land is highly uncommon; however, there are a plethora of benefits to using the same land for more than the typical one-year lease. Crop rotations allow for further diversification of the grower's business along with increased benefits to soil health and fertility if planned and executed correctly (Dias 2014).

1.2 THEORETICAL FRAMEWORK OF THE STUDY

This study was guided by various theories and models based on and created with the complex aspects of agricultural extension services in mind (i.e. the elaboration likelihood model of persuasion (Petty and Cacioppo, 1986; Petty and Wegener, 1998), the R.E.S.E.T model (Van Woerkum et al., 1999; Leeuwis, 2004; Jansen, 2016), the theory of planned action/behavior (Fishbein and Ajzen, 1975; Ajzen,1985; Ajzen, 1991), and the theory of uptake and use of DST in agriculture (Rose et al., 2016; Venkatesh et al., 2012; Shibl et al. 2013)). Although these theories and models were not designed specifically for the case of cadmium and the Irish potato industry, the context of and variables contained in these ideas are relevant to the study and make it possible to measure the effectiveness of advisory and knowledge transfer tools to help potato growers and agronomists assess their risk of cadmium. Appropriate elements from each of the four theories and models are combined and used to guide the design, data collection, and data analysis of this study. A concise synthesis of how these theoretical models are distilled into the framework of this research will be offered after providing descriptions of each of the theories and models.

1.2.1 The Elaboration Likelihood Model of Persuasion

The elaboration likelihood model (ELM) of persuasion (Petty and Cacioppo,1986; Petty and Wegener, 1998) is a dual process theory that aims to describe attitudinal shifts and the various processes that occur throughout (Figure 1.8 below). In this theory, it is posed that there are two routes of persuasion: a central route and a peripheral route. The central route of persuasion results from the careful considerations that take place in one's mind about a certain decision. Examples include cost, reviews from others, return on investment, etc. Under this route, the message needs to be communicated in a way that catalyzes cognitive stimulation in the message receiver. The resulting attitude changes when using the central route are proposed to be enduring, resistant to counter persuasion, and relatively predictive of subsequent behavior. Alternatively, the peripheral route of persuasion results from the message receivers' association with the positive or negative cues in the prompt being discussed with a general disregard for logic. Examples include the credibility or attractiveness of the source of the message or the production quality of the message. The resulting attitude changes when using the peripheral route are proposed to be temporary, susceptible to counter persuasion, and unpredictive of behavior. The extent of the end results is determined on an individual basis based on the individual's motivation and ability to evaluate the argument being presented to them (Petty and Cacioppo, 1986; Petty and Wegener, 1998).

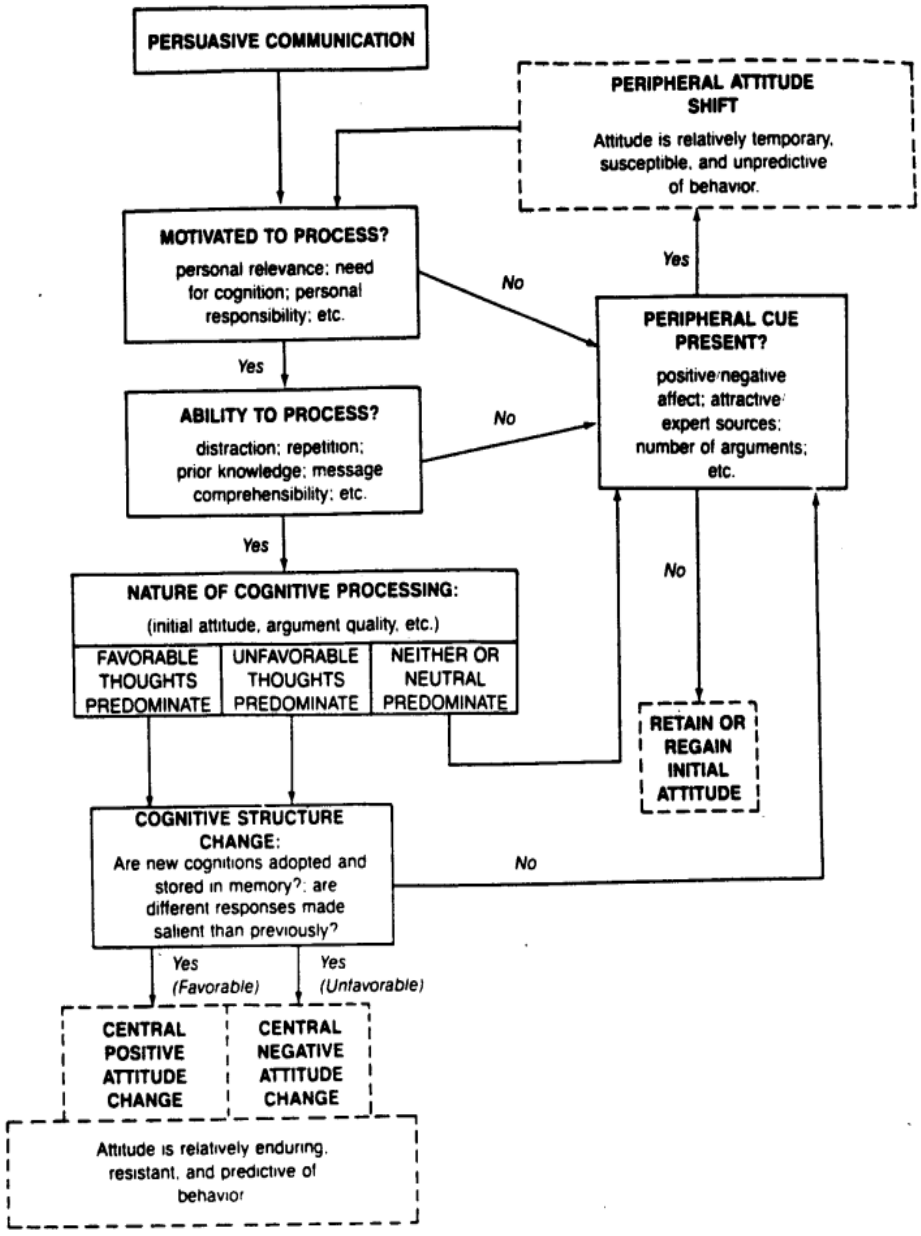


Figure 1.8 The Elaboration Likelihood Model (ELM) of Persuasion by Petty and Cacioppo, 1986 and Petty and Wegener, 1998

1.2.2 The R.E.S.E.T Model

Much of the literature regarding farmer risk perception state two factors that are important insights into the farmer mindset of risk control: the perceived threat and the perceived efficacy of preventive measures. These factors force the farmer to question whether they have a certain risk present on their operation and whether they are able to deal with the risk easily (Jansen et al., 2012). Woerkum *et al*. (1999) and Leeuwis (2004) developed the R.E.S.E.T model, which has since been adapted using some work by Shibl et al. (2013) and by Jansen *et al*. (2012) (Figure 1.9) for the purpose of assessing best practice for intervening in early mastitis detection in dairy cattle. The model combines a combination of positive and negative incentives that are used to facilitate a behavioral change when addressing a risk. Five main instruments are required to catalyze a change: R for Regulation, E for Education, S for Social Pressure, E for Economic Incentives, and T for Tools. The literature discusses the ways in which behavior can be changed and the positives and negatives of each method (Jansen et al., 2012). These routes will be explored thoroughly in the context of the cadmium issue in the three affected counties as part of this thesis.

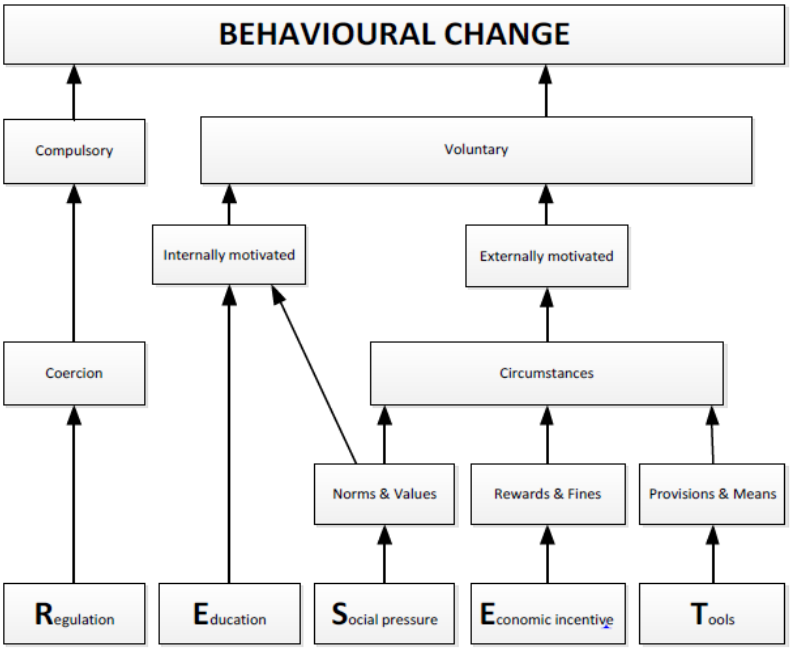


Figure 1.9 The R.E.S.E.T model adapted from Van Woerkum et al., 1990 and Leeuwis, 2004 by Jansen et al., 2012

1.2.3 The Theory of Reasoned Action & Theory of Planned Behavior

The Theory of Reasoned Action (TRA) is used to explain and predict behavior based on attitudes, norms and intentions (Fishbein and Ajzen, 1975). The constructs of TRA are behavioral beliefs, evaluations of behavioral outcomes which leads to attitude, then normative beliefs, motivation to comply which leads to subjective norms. Both the attitude and subjective norm lead to intention to perform the behavior, which results in the behavior. TRA does not account for people's perception of the power they have over their behavior. That is where the Theory of Planned Behavior (TBA) introduces control beliefs, perceived power which leads to perceived control, then intention to perform the behavior, after which then the behavior occurs (Azjen, 1991). In the context of this study, the agent is the risk of cadmium, the host is the potato grower, and the environment is the impacted area (Figure 1.10).

Behavioral belief produces in the host a favorable or unfavorable attitude towards a behavior. A potato grower may want to determine the level of available cadmium in their soil, but they are deciding whether to use the soil risk assessment tool or not. Evaluation of behavioral beliefs are the values attached to the outcome or behavior, or the positive or negative judgment a host has, for example, an evaluation on whether or not to use the soil risk assessment tool to determine the risk of cadmium being in the potato tuber. Attitude is a host's disposition to act in a certain way. The host, the potato grower, may decide not to use the soil risk assessment tool because they would rather remain ignorant about the agent, cadmium. Normative belief is when people close to the host agree or disagree over his or her behavior.

Motivation to comply is to agree with what the host's friends, family, neighbors, etc. think is the right behavior. Subjective norms are the host's perception of social norms or what his or her peers' beliefs are about the behavior. External factors such as demographics variables, attitudes towards targets, personality traits, and other individual difference variables also play a role in behaviors.

As mentioned previously, TRA does not take into account people's perception of the control they have over their behaviors. This is where the Theory of Planned Behavior (TPB) comes in with control beliefs. These are beliefs about factors that facilitate or impede the performance of the host behavior (Fishbein and Ajzen, 1975; Ajzen, 1991). Perceived power are factors that facilitate or impede performance of the behavior. The host has the control over his or her behavior, what may facilitate them to engage in the soil risk assessment model is his or her belief of being under the EU mandated maximum level of 0.1 mg CD/kg FW. Perceived control is the

individual's control over their behavior. With perceived control, the host is in control and can decide to perform the behavior.

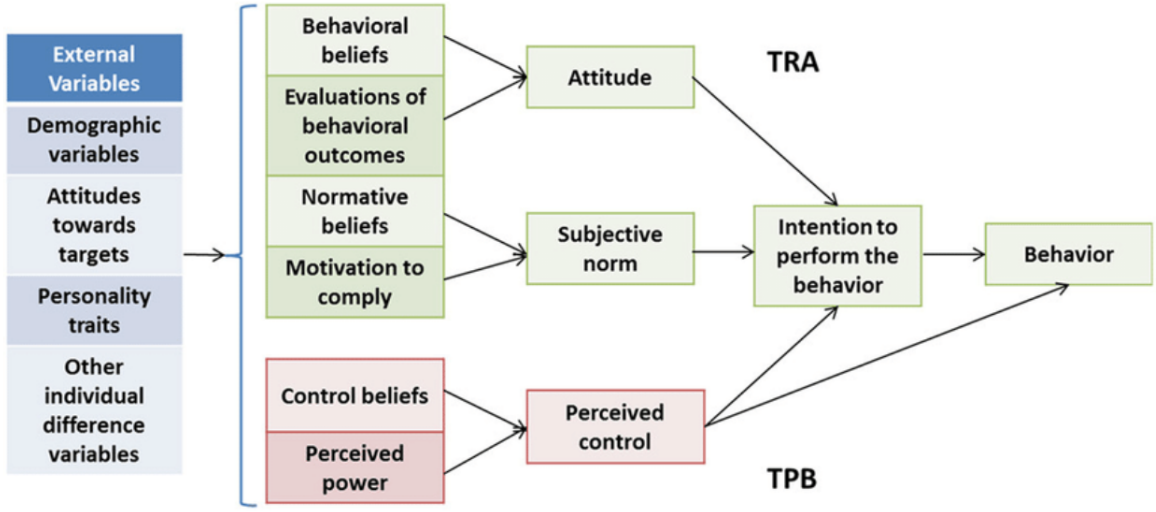


Figure 1.10 The Theory of Reasoned Action working alongside the Theory of Planned Behavior (Fishbein and Ajzen, 1975; Ajzen, 1991)

1.2.4 The Theory of Uptake and Use of DST in Agriculture

The Theory of Uptake and Use of Decision Support Tools (DST) in Agriculture uses the Unified Theory of Acceptance and Use of Technology (UTAUT) to develop a construct around the uptake of decision support tools in the agricultural sector. The four key elements of the theory are core factors of the DST, modifying factors of the user, driving factors, and the enabling factor (Figure 1.11). These elements interact throughout the model to predict likelihood of uptake and subsequent use of the DST (Rose et al., 2016; Venkatesh et al., 2012).

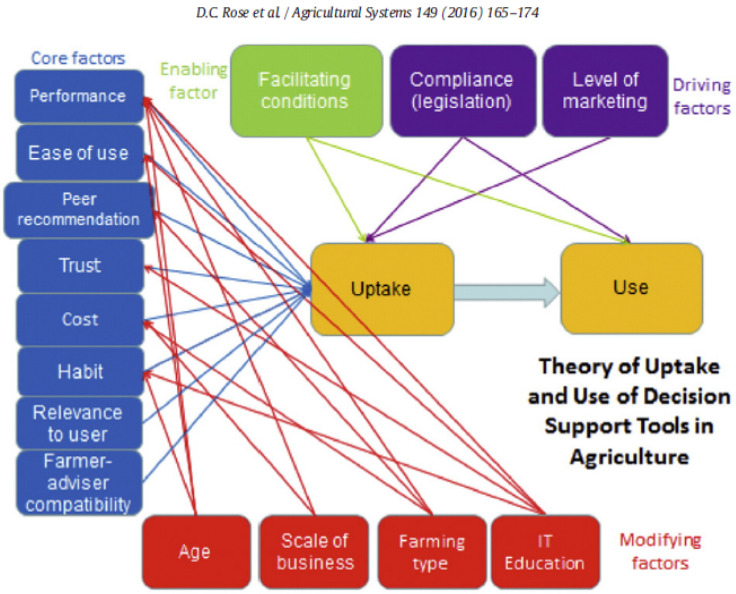


Figure 1.11 The Theory of Uptake and Use of DST in agriculture created by Rose et al. (2016), amended from the unified theory of acceptance and use of technology (UTAUT) from Venkatesh et al. (2012)

1.2.5 Summary

The Elaboration Likelihood Model of Persuasion was used as a guide for both data collection and data analysis. The model was used in order to classify the shiftability of a grower's attitude toward the message of engaging with the cadmium risk assessment model (i.e. the DST) after hearing the persuasive communication from the researcher in their one-on-one interviews. In order to do this properly, survey questions about the grower's prior knowledge, awareness, and proactiveness were necessary. The R.E.S.E.T model was used to inform both the research design and the data analysis of the study. The design of this study relied heavily on advisory knowledge transfer tools and processes, so the education and tools variables from the model were used to assess if they could lead to a voluntary behavioral change to interact with the cadmium risk assessment model. The variable of regulation was then used during data analysis to depict how compulsory actions could lead to a quicker route of uptake of the DST. From the Theory of

Reasoned Action, factors from the model like external variables were used to inform demographical survey questions along with questions relating to the individual's intentions to perform the behavior of interacting with the cadmium risk assessment model. Finally, The Theory of Uptake and Use of DST in Agriculture was used to inform the opinion-based survey given to those growers who chose to interact with the cadmium risk assessment model. The core factors included in this theory were used to guide the survey design.

1.3 RATIONALE

The issue of cadmium contaminated soils is an emerging risk in the Irish horticultural and arable sector, and it is believed that there is a very low level of awareness of the issue and its potential

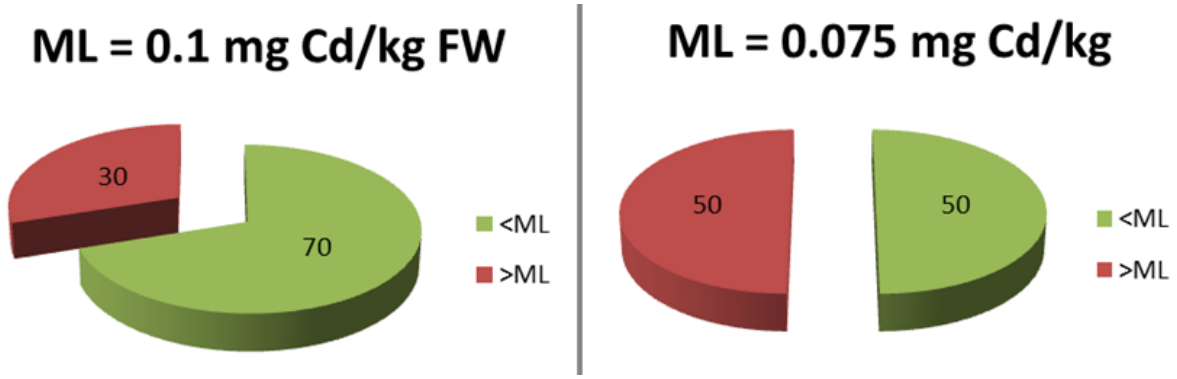


Figure 1.12 Pie graph representing estimated percentages of potato produce grown in the impacted area at risk of being rejected for exceeding the current maximum level requirement set for cadmium (on the left) and pie graph representing estimated percentage of potato produce grown in the impacted area at risk of being rejected for exceeding the proposed decreased maximum level for cadmium (on the right) (Griffin, 2018)

implications for farmers and agronomists (McGrath and Fleming, 2007). It is likely that the European Union (EU) may establish lower permissible maximum levels (MLs) for Cd than are currently legislated for. While a decrease in MLs would exacerbate the current issues, the current reality is that many growers may not be able to comply with the already existing MLs (*Ireland's Environment 2008*, 2008).

The potato is the third most important food crop in the world after rice and wheat in terms of human consumption. More than a billion people worldwide eat potatoes, and global crop production exceeds 300 million metric tons per year. In total, there are around 4,000 varieties of potatoes. In an Irish context, however, there are around 30 varieties being actively used and planted by Irish growers. The variety Rooster, which was released in 1991 is now the most popular variety in Ireland and occupies over 70% of total production in Ireland (Teagasc 2017).

Depending on the variety of the potato, the level at which cadmium is accumulated in the tuber will differ. As shown in Figure 1.13 below, the likes of Rooster and Lady Rosetta accumulate cadmium at the highest levels, while Maris Piper, Golden Wonder, and Kerr's Pink have a relatively low affinity for accumulating cadmium in the tuber of the potato. As stated above, the variety Rooster occupies over 70% of total potato production in Ireland and accounts for the majority of the total production in the cadmium impacted areas of Meath, Kildare, and Dublin. There is the risk that many growers are growing the high cadmium accumulating varieties on land that has high levels of available cadmium, leaving them vulnerable to batches of their crop getting rejected from being sold on the public market. Growers in the impacted area need access

to high quality knowledge and advice if they are to make informed decisions about their enterprises that cumulatively have a large impact on the nation's potato industry.

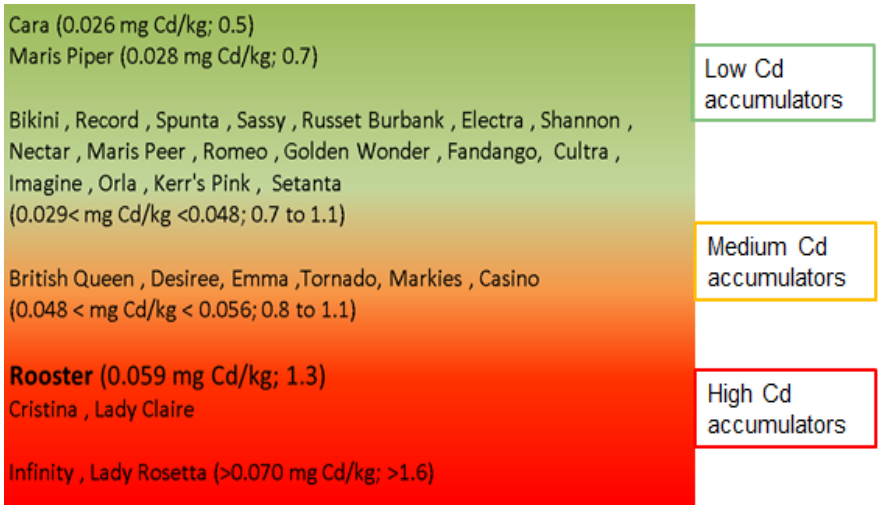


Figure 1.13 Ranking of common Irish potato varieties affinity for accumulating Cd (Griffin, 2018)

Following EFSA Scientific Opinion (EFSA, 2009), the European Commission investigated the possibility of reducing maximum levels (MLs) for cadmium; however, they concluded that an immediate reduction of MLs would be difficult to achieve as cadmium presence in foodstuffs is not uniform. A Commission Recommendation published in April of 2014 contained a list of requirements for the reduction of the presence of cadmium in foodstuffs.

The recommendation required the following:

- That available mitigation measures for reduction of cadmium in cereals, vegetables, and potatoes are progressively implemented by farmers and Food Business Operators (FBOs)
- That investigations and research is carried out to fill knowledge gaps

- That regular monitoring of the progress of the mitigation strategies is conducted by Member States by collecting data on cadmium levels in food

This recommendation covered a four-year period from 2014 to 2017 with a requirement of the Member States submitting final reports. Based on the collected information, the Commission was to reassess the situation by 31st December 2018 with a goal to decide on further and future measures. The decision by the Commission has yet to be released to date, leaving the Irish potato market still vulnerable to a possible decrease in maximum level requirements. There is an urgent need to fill the current knowledge gap in the potato growing community in regard to the cadmium issue in order to safeguard the industry. This study aimed to determine standard of and build engagement and commitment from growers in the affected areas; and to identify and understand what influences growers to engage in such an issue.

1.4 RESEARCH OBJECTIVES

1. Assess the influences affecting potato growers and agronomists' risk assessment of available soil cadmium and their adoption of the cadmium risk assessment model
2. Evaluate the effectiveness and uptake of the cadmium risk assessment model proposed for farmers and agronomists
3. Analyze extension tools and processes for both building engagement in the potato growing community and making an impact on the farmer decision making process

1.5 CONTRIBUTION OF THE STUDY

Various individuals, organizations, and companies will benefit from this research study as a large number of Irish potato growers and processors reside in the northeast where levels of cadmium are reaching concerning levels. In order to aid growers in assessing and managing their level of cadmium risk, the DST model that has been created is needed to demonstrate the farmers level of risk and the subsequent actions that are needed for mitigation. This study seeks to measure farmer engagement and attitudes toward this model and identify where any possible developments or changes could be made to increase its uptake. By working directly with the at-risk potato growers to adapt the established model, this study will help to ensure the adoption of the soil risk assessment model in order to further safeguard the potato industry from increased cadmium contamination.

Besides the commercial bodies that will benefit, other researchers seeking to understand farmer attitudes towards DSTs and their decision-making processes regarding managing risk will also gain from the findings of this study.

This project has components dealing with themes of uncertainty, negative messages, risk assessment, and decision support that are applicable to not only tillage but also dairy and drystock farming sectors. This research offers insights into understanding the best practice of communicating unpalatable messages to farmers in a way that allows them to see the best possible outcomes so that the message is at least somewhat welcomed, wanted, and accepted by the farmer.

1.6 ORGANIZATION OF THE STUDY

The study consists of a number of stages, which are systematically laid out in this thesis. The general approach adopted was to work from general to specific, with the early chapters providing the rationale and context of the study with the later chapters providing details on how the qualitative and quantitative data analyses were carried out as well as the key findings and conclusions.

This introductory chapter, while providing the background to the study, looks at the purpose and objectives of the research along with the practical value of a study of this nature. The next chapter will conduct a review of current literature dealing with topics such as risk management, adoption of DSTs, farmer decision making, message framing, and communication of unpalatable messages.

The remaining chapters provide the practical content of the study, including the empirical analysis, covering aspects such as the methodology used in conducting the surveys and in-depth interviews among potato growers and agronomists in the impacted areas of Meath, Kildare, and Dublin, the key findings from the investigation, what the results say about the current level of knowledge, intention to mitigate, and ability to handle the risk of cadmium, and the overall implications from a management and policy perspective both in the short and longer terms.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In this chapter, related literature is reviewed in order to identify the theoretical gaps that exist in the current body of knowledge. The specific purpose of this chapter is to review the theoretical and empirical literature on risk, information tailoring, message framing, trust, and importance of co-creation of decision support tools.

2.2 RISK AND THE FARMER DECISION MAKING PROCESS

Risk is prevalent in the farming industry in the form of production, marketing, financial, human, and environmental risk (Tudor et al., 2013). Therefore, farmers must be equipped with the necessary knowledge and tools that allow them to properly assess, manage, and mitigate risks in order to retain stability and progress in their business (Meuwissen et al., 2001). Scientists and advisors working in the agricultural sector have the responsibility to provide support and knowledge in relation to the identification and management of risk. Such support will allow the farmer to properly mitigate against the issue at hand, not only for the benefit of environmental or human safety but also for the benefit of their business (Clostre et al., 2017). Explaining risk and risk assessment procedure is a challenge faced by all stakeholders involved in the agricultural sector.

2.2.1 Perception of Risk

Individuals perceive risk not only on the probability of the occurrence happening but also the personal impacts of the risk disrupting their enterprise and livelihood, causing destruction of personal property, or injury to self, family, or friends (Trumbo et al. 2016). People are not motivated to protect themselves from a risk based simply on awareness of the threat (Trumbo et al., 2016; Fox-Rogers et al., 2016; Janssen et al., 2014; Martin et al., 2007). Cognitive and affective processes of evaluating the risk contribute toward the perception developed by the individual. The cognitive processes involve the individual's perception of the likelihood the threat would happen, the severity of the threat, and their vulnerability to the threat. The individual also compares the threat to other known risks or evaluates the threat based on their, or someone else's past experience (Slovic & Peters, 2006). The affective processes involve an individual's concerns about the threat, their worry about the consequences, or the anticipated regret if the threat would happen (Jannsen et al., 2014).

The individual's perception of risk influences their motivation to mitigate the risk, protect themselves from the risk, or ignore the risk and any subsequent consequences. The threat of wildfires has been used to study the willingness, or unwillingness, of homeowners to engage in risk mitigation to protect their property and lives. The studies have found that the motivation to protect one's self is influenced by the cognitive perceptions of vulnerability, risk, severity, and efficacy. Strong beliefs in these areas will motivate the individual to change behavior to adopt risk mitigation measures (Martin et al., 2007).

The motivation for an individual to protect themselves from health risks such as smoking or sun exposure have been studied by measuring an individual's perception of risk and their motivation

to engage in behaviors to reduce their risk. The belief of an individual's efficacy to engage in the behavior to create a positive outcome was found to be critical to the individual's perception (Janssen et al., 2014)

2.2.2 The Farmer and the Risk

Better understanding how farmers perceive farm-related risks and behave in settings of uncertainty is critical for interpreting agricultural practices and designing policies, outreach programs, and decision support tools that effectively assist the farmer (Menapace, 2013). Variability exists between farmers across the globe. Due to this complexity, making general statements regarding farmer characteristics and farmer attitudes towards risk is difficult. Tudor et al. (2013) state that an individual utilizing the largest number of risk management tools on their farm was more likely to be a young male with a low tenure ratio, high gross farm income (GFI), and large farm size. Furthermore, the authors found a trend in the individual described above to be a risk taker, tenant of the land, and college educated. Overall, it can be concluded that a complete analysis of risk attitudes for farmers cannot be accomplished by looking at one single measure. Instead, a wide range of variables must be considered and studied in order to generate a well-rounded assessment of risk management and attitude for the farmer (Tudor et al., 2013). Advisors must remain objective and prepared to adapt on a case by case basis. Furthermore, there is room to expand on the idea of the farmer profile by adding more variables to consider. Including variables that consider factors such as farming experience, views on sustainability, farm type, family dynamics in relation to farm management, resource availability, etc., will expand the opportunities for characterizing how farmers choose to identify and manage risk. By

doing so, advisors will be able to tailor the conversation about risk to the individual in order to increase likelihood of understanding and adoption.

A study by Schemann et al. (2013) looked at horse farm managers' willingness to engage in behaviors to protect horses from equine influenza. This study identified the perceived vulnerability to equine influenza, coupled with prior experience with the disease and cost of response, as key to the motivation of the farm managers to engage in protective behaviors (Schemann et al., 2013). Keshavarz & Karami (2016) found that farmers faced with severe drought were less motivated to adopt conservation practices based on their perception of these practices not helping them cope with a sustained drought situation. Van Winsen et al. (2016) examined the influence of farmers' attitudes toward farming, characteristics like farm size and education background, and past experience on attitudes and perception toward risk. Their ultimate findings were that attitudes toward risk have a direct impact on farmers' strategy to cope with risk.

2.2.3 Farmer Decision Making

There have been multiple decision support tools in the past that have been developed with the best of intentions and capabilities to increase yields, cut down on costs, increase use of sustainable practices, etc., yet end up unused by the farmers they are intended for. One main issue that was found in various research papers on the subject matter was the idea that these tools did not fully consider the farmer decision making process. Jorgensen et al. (2007) focused on the decision support tool, Crop Protection Online (CPO), which was found to be unsuccessfully implemented on farms, even though it had the ability to reduce herbicide use by 40 – 50% if appropriately used. Jorgensen et al. (2007) concluded that the CPO decision support tool did not consider farmers' intrinsic motivations and the various farmer decision making styles that exist. The DST was used

and liked by user groups like agricultural advisors and students; however, decision making styles and ability to spend time conducting the assessments needed to inform the DST differ greatly for the farmer user group. Like Jorgensen et al. (2007), Farmar-Bowers and Lane (2009) ended with the same conclusion in regard to farmer decision making for biodiversity conservation policy. Farmar-Bowers and Lane (2009) determined that the type of intrinsic motivation for carrying out a particular effort (i.e. personal or monetary) is key to informing future successful policies and support tools. Focusing on what the farmer, the ultimate decision-maker, hopes to gain from said endeavor will shape how the policy or program is presented.

There is enough evidence to suggest that economic incentives or disincentives to implement good farming practice do not necessarily appeal to a farmer's decision processes. Floress et al. (2017) highlights the important role of pro-social variables in influencing decisions. These are actions, typically voluntary in nature, that have the intention to help or benefit other individuals (Eisenberg and Mussen 1989). Although traditional environmental policies, programs, and initiatives were heavily reliant on providing a monetary incentive or threatening a fine to increase uptake, Schwartz (1977) concluded from research that the intent of the individual was a critical factor in determining an individuals' behavior towards environmental problems. Similarly, Malawska et al. (2014) noted that financial incentives or disincentives to implement policy are not always going to be accepted by business orientated farmers. The findings of Foloress et al. (2017) would appear to support this argument, finding that farmers focusing on profitable business systems for optimal financial return did not overlook the need to protect the environment for the sake of their enterprise. The statistical analysis found a positive connection between environmental stewardship attitudes and financial

orientated farmers, however, it also acknowledged that this is an area where greater research is required.

2.3 TAILORING OF INFORMATION

Farmers are receiving generic advice from various sources with their advisor acting as a mediator in the middle, when advice should be "tailored to different farmer needs" (Rose et al., 2016; Jorgensen, 2007). Blackstock and Ingram (2010) concluded that there is a knowledge gap in the importance of how individual farmer participation influences the transfer of advice and information from farmer to farmer when it comes to controlling diffuse pollution. They highlighted that many farmers are not fully aware of whom, how, or when diffuse pollution is caused and who is responsible for decisions to alleviate the problem. Within the country of Ireland, there is a diverse community of individuals farming the land along with a diverse range of land tenure characteristics, hence Blackstock and Ingram (2010) reinforced the importance of tailoring advice to individual needs and guaranteeing that all stakeholders involved have consistent and parallel information. The proposed model for soil cadmium assessment seeks to reflect this idea by taking the soil samples from each unique farm and giving those farms a unique rating in order to help the farmer better understand their own risk to this issue and assess their management options accordingly. While the advice provided to the growers will be tailored, it is also critical to ensure that the information given in regard to the general issue is consistent in nature. If inconsistent advice is given to growers, this will mean that the risk of cadmium is not being dealt with properly and likelihood of effective actions being taken by growers and advisors alike will decrease.

2.4 TRUST AND THE ADVISOR-FARMER RELATIONSHIP

Trust has a critical influence on how individuals perceive a certain risk and respond to communications regarding that risk (Tateno and Yokoyama, 2013). Hansen et al. (2018) highlight the idea that some agronomist/advisor – farmer knowledge transfer encounters carry themes of imbalance of power, distrust, and variations of knowledge. The authors encourage the possibility for these encounters to facilitate both farmer and agronomist learning in their steps to increasingly sustainable farming practices (Hansen et al., 2018; Ingram, 2008). There is often a dichotomous nature of farm advisory services as being both a source of expertise and a facilitator of knowledge exchange. The advisor/agronomist is a representative of an institution that has set the agenda of the encounter; however, one would not be there without the other, and therefore, both parties have an opportunity to both educate and become educated (Bergea et al., 2008). By observing advisory visits on dairy farms in Norway and conducting interviews with both the farmers and the advisors, Hansen et al. (2018) were able to assess how advisor style, ability to empathize, farmer perception and the role of the advisory services affected the quality and acceptance of advice by the farmer. The authors expand upon the idea of how power dynamics between advisor and farmer can often inhibit the quality of service and recommend that advisors reexamine their role and adapt accordingly for each client. Instead of the job title providing the advisor with power, the inherent ability of the advisor to provide knowledgeable, adaptable, and relevant advice to the farmer will not only enhance the power of advisory services but also enhance the trust and relationship between farmer and advisor. By allowing the farmer to trust himself or herself and fostering confidence, it will make their trust in the advisor stronger. Subsequently, this will allow the relationship between farmer and advisor to grow stronger and

have a higher degree of professionalism, empathy and collaborative problem solving (Hansen et al., 2018; Ingram, 2008).

2.5 THE IMPORTANCE OF CO-CREATION

There has been much interest recently in the concept of co-creation of advisory and knowledge transfer tools and processes and its relevance in Irish agriculture. In relation to this study, the topic of risk assessment and decision-support are relevant in relation to the creation of user-friendly support tools. Ingram et al. (2017) point to the limited outreach and translation of the scientific results from funded research projects in agriculture and the challenge of translation, adaption, and valorization of research results so that they are responsive to farmers' needs and are made accessible. Many scholars agree on the need to directly involve farmers and other stakeholders at all stages of the innovation process in order to ensure relevance, applicability, and adoption, leading to a co-innovation process of change (Dogliotti et al., 2014).

To ensure that the risk assessment and decision support tools are user-friendly for both farmers and agronomists, this project involves the two in a co-innovation design and evaluation process of the advisory materials. This inclusion process is also essential to encourage confidence among growers that while the problem of Cd is serious and complex, there are options for mitigation if the risk is assessed systematically. For farmers to engage effectively, they need to be able to identify and prioritize problems as well as being willing to take certain risks and connect with other farmers and stakeholders to share knowledge (Botha et al. 2014). The approach in this project is collaborative with individual and small groups of growers and advisors in counties Meath, Kildare, and Dublin invited to take part in a cadmium working group which can liaise with research and policy institutions.

Many papers discuss the need for decision-support tools (DSTs) in relation to managing agri-environmental issues in order to progress the exchange of knowledge between stakeholders. By having active participation by the various stakeholders (i.e. scientists and decision-makers and/or farmers and advisors) throughout the process of creating and piloting the DSTs, the end result should include more well-rounded, relevant, and accessible tools for the end-user. Oliver et al. (2017) argue that a co-design and co-production strategy is an essential component of the DST design process as it not only instills a sense of ownership for the end-product by the farmer but it also increases the understanding of the product and likelihood of adoption (Oliver et al., 2017). The authors also argue that a stronger relationship and sense of responsibility to engage between scientist and decision-maker is needed in order to design DSTs that are not only effective in assessing the degree of risk but also user-friendly enough that acceptance and use by the farmer or end-user is likely. In this way, the authors argue for a more human-centric strategy when it comes to discussing the identification and management of risks to farmers. The authors suggest that creating more visual and interactive risk-management tools will capture farmer's interest. Furthermore, this type of design can help facilitate further discussion regarding improvements or alterations to the model along with continued engagement with the DST (Oliver et al., 2017).

Instead of having the creation of a DST as a research outcome, this project seeks to assess the existing DST that has been created for the purpose of assessing potato cadmium risk for farmers. The DST model can be referenced in figures 1.3 and 1.4. Multiple authors in the field of risk management and DST creation state that by turning a complex concept (i.e. heavy metal contamination) into a figure, a new universal language for communicating and thinking about complex decisions under risk can be created, understood, interpreted, and discussed between the

stakeholders (Hertzler, 2007). A benefit to using this type of model to identify and plan around risk is the universality and flexibility that it offers.

2.6 DELIVERING A MESSAGE

As the north Leinster region is one of the most productive agricultural regions of Ireland, this topic of study requires a degree of sensitivity as a disruption to the market could occur. It is important to note that there is a smaller safety margin in foods when it comes to levels of cadmium and regulatory health limits compared to other heavy metals such as lead and mercury. Because of this the matter becomes increasingly prominent if exceedances in potatoes are detected and testing by the retailers becomes more frequent.

Regionality of food products has become an important criterion for European consumers in their product evaluation and purchase decision (Verbeke and Roosen 2009). Environmental scandals occurring all over the world are raising a more general issue of food safety that is globally considered a prerequisite for both public health and market development (Cembalo et al 2019). As the issue of cadmium in Irish soil is so area specific, only affecting Counties Meath, Dublin, and Kildare, the idea of regional food safety comes into play and could play a major role in consumer purchasing decisions, especially as the research is showing a decline in potato consumption in Europe (Fernqvist et al 2015). The Irish National Food Consumption Survey conducted a North South Ireland Food Consumption Survey in 1997-1999 and a National Adult Nutrition Survey 2008-2010. From the data collected in this national survey, consumption of potatoes (boiled, mashed, baked, processed, chipped, fried, and roasted) since the 1997-1999 survey has decreased from 224 grams/day to 120 grams/day in the 2008-2010 survey. On the

other hand, consumption of rice and pasta has increased from 20 grams/day in the 1997-1999 survey to 35 grams/day in the 2008-2010 survey.

In the public media, increasing attention has focused on environmental damage connected to food scandals (Cembalo et al 2019). While the issue of cadmium contamination in northeast Leinster is not a food scandal as of today, the threat remains plausible. Furthermore, the risk of lowering maximum levels by the European Union and increased independent testing by supermarkets could force consumers to think twice about purchasing and consuming products grown in the affected area. Trust is a critical component of consumer purchasing decisions. Wim Verbeke from Ghent University in Belgium states that a consumers' food choices and dietary behavior can be markedly affected by communication and information (Verbeke 2019). From the demand side of information, consumers as well as retailers increasingly seek guarantees concerning food quality and safety, fueled at least partly by several consecutive food-safety incidents in Europe. Consumers seek information to help them know the origin, environmental, ethical, and technological conditions under which the food has been produced and processed (Verbeke 2019). Cadmium is a heavy metal that has been classified as a human carcinogen by the International Agency for Research on Cancer (IARC). This toxic metal is a major health concern due to its long half-life and persistence in the environment and in tissues (both plant and human) (Joseph 2009). The rationally ignorant consumer hypothesis states that even when information is free, consumers may refrain from acquiring such information due to the fact that the price of information and/or the expected opportunity cost of processing that information is too high in comparison with the marginal expected benefits from said information. These factors prevent the consumer's motivation to seek and process information (Verbeke 2006). This

hypothesis leaves room for the argument to be made that if news comes out about Irish vegetables containing a toxic metal that is linked to cancer, the consumer may take this statement at face value and choose to stop consumption and substitute with other products and/or ensure that said produce was grown in a region with no links to cadmium. This would have extreme negative effects on the growers and processors in the affected area who depend on the consumer to trust and purchase their produce.

2.6.1 Risk Communication

Risk communication is the flow of information and risk evaluations between individuals and groups involved in decision-making and judgement concerning the risk and benefit perceptions (Leiss, 1996). One objective of this study is to analyze extension processes for building engagement and commitment from potato growers and the agronomists that advise them. Risk communication provided a framework for this objective as a bridge between the perceptions of laypeople and the technical estimates of risk by the experts (Liu & Smith, 1990). Through the use of effective communication strategies, risk mitigation and protection behaviors can be encouraged for the farmers. Understanding the influences of the perceptions to the individual helps develop these effective strategic communications (Martin et al., 2009). Strategic communication is intentional communication with a purpose and a plan that is evaluated routinely to determine effectiveness (Smith, 2009). Because different individuals have varying perceptions of risk, self-efficacy, and response efficacy toward a situation, the risk communication needs to be strategic to provide messages salient to the audience (Martin et al., 2007). Risk communication should not preclude conflicts, but instead create situations where

conflicts can be productive as the dialogue can focus on facts with understanding of the perceptions that differ between groups (Fischoff, 1995).

2.7 CONCLUSION

Farmers need to be able to logically assess the various risks they encounter on a day to day basis. Some risks are nuanced and complex, thus requiring Decision Support Tools informed by reliable scientific data and tailored to the specific farmer it is intended to support. These components of a DST foster trust in the farmer for the decision support tool, increasing the likelihood of ongoing engagement and use.

CHAPTER 3

METHODOLOGY

3.1 BACKGROUND TO METHODS

This research was part of a wider study funded by the Department of Agriculture and Marine (DAFM) project, **CREDIT**, looking at advisory and technical techniques to **R**educe, **E**valuate, **D**etect, and **I**nform growers with **T**echnologies in regard to levels of soil **C**admium. Teagasc is the semi-state authority in Ireland responsible for research, advisory, and education services in the agri-food sector and it is the main partner in this funded research project. University College Dublin's School of Agriculture and Food Science is a partner in the project for the Task relating to advisory and knowledge transfer tools and this research project. The researcher was based in a Teagasc advisory office located in close proximity to the impacted areas for the duration of the research project.

This study was an exploratory, mixed-method design, which utilized both qualitative and quantitative data collection. The study explored farmers' and agronomists' knowledge and attitudes toward the issue of elevated available soil cadmium levels in three counties of Ireland: Dublin, Meath, and Kildare. The theoretical framework for the study utilized a variety of theories or models, most of which were originally designed with agricultural extension services in mind. These included, *inter alia*, the elaboration likelihood model of persuasion (Petty and Cacioppo, 1986; Petty and Wegener, 1998), the R.E.S.E.T model (Van Woerkum et al., 1999; Leeuwis,

2004; Jansen, 2016), the theory of planned action/behavior (Fishbein and Ajzen, 1975; Ajzen,1985; Ajzen, 1991), and the theory of uptake and use of DST in agriculture (Rose et al., 2016; Venkatesh et al., 2012; Shibl et al. 2013). With these theoretical frameworks in mind, variables such as perception of risk (including regulatory aspect of issue), level of familiarity (including knowledge and attitudes of issue), level of concern, proactivity (i.e. motivation to process and/or comply), and level of flexibility were selected as parameters to be measured to fulfill the objectives of this study.

Because the construct of these variables was not known, a qualitative method of data collection was needed to identify and describe the parameters listed above for potato growers in the impacted area and the agronomists who advise them. The qualitative method utilized in person, one-on-one interviews where growers and agronomists were able to provide in-depth descriptions of their perceptions regarding the risk of cadmium in their enterprises. The quantitative data collection was an in person, one-on-one survey, which was conducted during the same period of time as the qualitative method described previously.

This chapter will discuss the research design, objectives, sample populations, and methods used for data collection and analysis.

3.2 RESEARCH DESIGN

This study used a mixed-methods approach for the research on cadmium risk assessment for potato growers and agronomists in counties Dublin, Meath, and Kildare. The mixed method design included in-person interviews as the method for qualitative data collection and an in-person survey as the method for the quantitative data collection.

3.2.1 Mixed Method

Mixed method research design enables research studies to utilize both qualitative and quantitative data collection and analysis in order to provide a better and broader understanding of the research topic than a single method approach would provide (Cresswell and Clark, 2007). By using a mixed method design, the researcher was able to explore various nuances in farmer and agronomists' perceptions regarding the risk of cadmium with a qualitative method while also having the opportunity to conduct further statistical analysis on these identified perceptions with a quantitative method. Qualitative research was selected as a component of this study for its ability to examine the complexity and nuances within an issue under analysis. While there is definitive usefulness that lies in a quantitative research approach in the form of statistical, it presents some difficulty in capturing the depth of content that is desired. A mixed methods approach allows the researcher to take advantage of the varying benefits of analysis capabilities that lie in both qualitative and quantitative research methods.

3.2.2 Qualitative Method

A qualitative interview is a methodology that is frequently used to attain a deeper understanding of individual farmers' mindsets rather than attempting to solely quantify such factors with a general survey developed for a representative group of individuals (Marshall and Rossman, 2016). It is an explorative method that can be used to understand the relationships between different arguments used by farmers in conversations about the risk of cadmium and their enterprise. A major strength of qualitative research is the ability to explore novel populations and stimulate an environment for an exchange of knowledge between the study population and the researcher (Lincoln and Guba, 1995). This allows for a deeper understanding of the subjective

understandings and interpretations of the risk of cadmium in the lives of potato growers and the agronomists who support them. This study focused on perceptions towards the cadmium issue in Ireland and intention to interact with the cadmium risk assessment model. These perceptions include cognitive and affective thinking, identified in risk perception research as part of a layperson's (farmer's) assessment of risk that may differ from experts but still influences their attitudes and behavior (Slovic and Peters, 2006). The farmers' and agronomists' assessments of how they would handle and respond to the cadmium issue were explored through perceptions of self-efficacy and response efficacy. In-person, one-on-one interviews were chosen as the qualitative method to capture farmer and agronomists' perceptions regarding the threat of cadmium in the potato industry.

In-Person Interviews

The conducted interviews were semi-structured in nature, meaning that an unstructured interview and conversation took place prior to the in-person survey where the interviews turned more structured in nature. Depending on the farmer's answer to a survey question, more specific questions were asked afterward to further understand the farmer's reasoning and opinion on the question or subject matter being discussed. During the semi-structured interviews, the following topics were discussed:

1) description of the farm and the farmer (i.e. farm size, main crop type, primary potato variety grown, age, education level, etc.);

2) the farmer's familiarity with toxic metals, specifically cadmium in Northeast Ireland (if awareness of found to be low, a brief overview of the problem was provided by the interviewer)

3) the farmer's level of concern on owned and rented land,

4) the farmer's likelihood of using the soil risk assessment tool and possible mitigation strategies,

5) the farmer's familiarity with possible cadmium mitigation strategies/farmer's active use of mitigation strategy on farm in general /farmer's active use of mitigation strategy specifically for cadmium mitigation,

6) the farmer's historical use of decision support tools (DSTs),

7) the farmer's soil sampling protocol,

8) the farmer's opinion of testing for the purpose of regulation and sharing information with others (i.e. neighbors, advisor, governing bodies, etc.).

All farmers were interviewed during a period from March 2019 to September 2019 by the same individual (the author). The length of the interviews ranged from 16 minutes to 96 minutes, and all were digitally recorded with a mobile device. In order to protect each participant's identity, pseudonyms were assigned to each participant. The pseudonyms were used throughout the research process; farmer participants were referred as Interview 1-39 and agronomist participants as Agronomist A-G.

An in-depth interview that is audio recorded and transcribed word for word is one way of obtaining rich data as compared to "descriptive note taking" (Maxwell, 2005). Therefore, in order to secure "rich" and "unbiased" data, the researcher collected data using an in-depth interview, audio recorded and transcribed data word for word. Furthermore, Maxwell (2005)

indicated that not only does respondent validation significantly reduce the risk of misunderstanding respondents' responses, but it also helps researchers understand their biases.

Prior to data collection, participants were provided with an information and consent form outlining the following: (a) The participants' name will not be used; pseudonyms will be assigned instead; (b) Participants have a right to withdraw from the study at any time; (c) Study findings will be shared with others in a manner that protects the participants' identities; (d) And participants understand that the interview will be audio-recorded and transcribed (See Appendix A2).

3.2.3 Quantitative Method

Quantitative methods provide tools to identify how data fits into an existing theory or framework. The method routinely has numerical data and statistical analysis to provide external validity (Creswell and Clark, 2007). The addition of quantitative methods provided a statistical analysis of the descriptions obtained in the qualitative methods. A survey was developed for the quantitative methods for this study.

In-Person Survey

In an in-person, face-to-face survey, the interviewer is physically present to ask the survey questions and to assist the respondent in answering them by clarifying any confusion. This survey delivery mode can offer many advantages over mail, online, or telephone surveys in terms of the complexity and quality of the data collected (De Leeuw and van der Zouwen, 1988). These advantages, however, can come with increased logistical costs and increased risk of response bias. In-person surveys may limit the number of surveys and subsequent data collected compared

to a mail, online, or telephone survey as a convenient time must be agreed upon between the researcher and respondent and the researcher must travel to the respondent's location or vice versa (Groves and Kahn, 1979). A lower sample size, however, is made up for with the tendency for face-to-face interviews to last significantly longer than mail, online, and telephone surveys. The additional length allows the researcher the opportunity to gain further insight into particular questions and add clarity to any questions or answers posed by the respondent or interviewer (Fowler, 2002). Furthermore, the explanation of the cadmium issue in Ireland to the grower or agronomists being interviewed was aided by the use of graphic and visual aids. While the use of these resources would be difficult by telephone, costly by mail, and easily misunderstood online, maps, figures, etc. can be easily and economically incorporated into face-to-face surveys (Dillman, 2000). Finally, it is important to note the increased risk of interviewer or response bias when conducting face-to-face surveys. Since the researcher and respondent are not disembodied like they would be in the case of mail, online, or telephone surveys, nonverbal as well as verbal cues can be inadvertently introduced into the conversation, possibly influencing the respondents answer or even the interviewers' approach to the question at hand (Fowler, 2002).

3.3 RESEARCH OBJECTIVES

The objectives of this study were to:

1. Assess the influences affecting potato growers and agronomists' risk assessment of available soil cadmium and their adoption of the cadmium risk assessment model
2. Evaluate the effectiveness and uptake of the cadmium risk assessment model proposed for farmers and agronomists

3. Analyze extension tools and processes for both building engagement in the potato growing community and making an impact on the farmer decision making process

In person interviews and surveys were conducted with 39 potato growers and 7 agronomists in the impacted areas of Meath, Kildare, and Dublin. The structure of the interviews was focused around their current knowledge and attitudes in regard to the cadmium issue in Ireland, their sources of information and influence, as well as their palatability of possible mitigation measures.

3.4 METHODS OF SELECTION

3.3.1 Selection of Potato Growers

Selection of the potato growers who took part in this study occurred during a time of the year where farmers seek the aid of an agricultural advisor to carry out paperwork to receive the European Union (EU) funded Basic Payment Scheme (BPS). This scheme supports active farmers who are allocated payment entitlements as a means to supplement their main farming income. A major percentage of potato growers in the impacted area utilize Teagasc advisors during the application process, so the researcher was able to ask about the farmer's willingness to participate in the study as they came into the office for their appointment. Of the reported farmers, 23 were accessed during their visit to a Teagasc office for the purpose of a BPS appointment. The remaining farmers were purposely contacted using both information on the DAFM publicly posted National Potato Register and opinions of a Teagasc tillage and potato advisor based in the same office as the lead researcher. The Teagasc potato advisor was given the generated list from the DAFM National Potato Register and was asked by the researcher to

highlight possible willing and suitable participants for the study. One-hundred-and-twenty-five (125) potato growers based in the impacted areas of Meath, Kildare, and Dublin were sent information leaflets about the project, including a brief background of the cadmium issue, and an advance notice that the lead researcher would be contacting them for the purpose of requesting their time for an interview and survey (see Appendix Figure A1). All contact details were accessed using information posted on the public DAFM National Potato Register website. Cold calls and/or emails were used to select willing participants. Of the 125 growers contacted, 23 were accessed during their BPS appointment and 16 were willing to participate in the study after receiving a cold call and/or email. The remaining growers did not participate because they were either too busy, not interested, no longer growing potatoes, or unable to be contacted.

3.3.2 Selection of Agronomists

For the agronomist interviews and surveys, independent and commercial agronomists specializing in horticultural or other tillage crops (predominantly potatoes) and/or soil management were identified using recommendations from agricultural advisors working in the same Teagasc advisory office as the researcher, independent Google searches, and recommendations from the potato growers who were interviewed for the purpose of this study. After contact details were provided by an advisor or grower and/or discovered using publicly posted information from the web, the researcher carried out cold calls and cold emails to the identified agronomists working in the impacted area. Of the 15 agronomists identified by either one of the methods mentioned above, 7 agreed to be interviewed. The remaining 8 agronomists were either unable to be contacted, unable to find a suitable meeting time, or no longer working closely with potato growers in the impacted area.

3.5 METHODS OF ANALYSIS

After the researcher was confident that no new novel or substantial pieces of data were being collected from the surveys or interviews, and that the majority of the larger potato producers and their agronomists in the impacted area had all taken part in the study, the quantitative data was inputted into SPSS 26, and the qualitative data was transcribed by the researcher and inputted into NVivo 12. The quantitative data was analyzed and then used to augment the qualitative data in the analysis and create a richer description of the data.

3.5.1 Data Analyses of Qualitative Data

Interviews

All interviews were recorded and transcribed in full. NVIVO 12 was used to generate important themes and concepts that were found throughout all 39 grower interviews. Thematic analysis was chosen over other strategies of qualitative data analysis due to the added degree of flexibility that the approach offers (Braun and Clarke, 2006). This type of analysis allows the researcher to identify, analyze, and report patterns (i.e. themes) within the data while also allowing the researcher to apply any subsequent analysis to a variety of theoretical frameworks (Braun and Clarke, 2012; Roberts et al., 2019). Braun and Clarke (2006) state the importance of highlighting the researcher's active role in the identification of themes within the data. The authors state that a frequent mistake made by researchers analyzing qualitative data is simply stating in the methodology that "themes emerged" from the data. Instead, the literature suggests that researchers acknowledge one's own theoretical positions and values in order to be upfront about where the stated themes emerged from. The researcher has taken care when it comes to making

decisions in regard to the stated themes found in the research and understanding that said themes may have been influenced and developed from the researcher's personal thinking and understanding of the data.

A theme captures something significant about the data in relation to the research objectives and encapsulates some degree of patterned response or meaning within the data. As there is no hard-and-fast rule to identifying themes within a data set, and the number of instances the theme appears in the data does not necessarily signify importance, the researcher used judgement to determine what the themes within the qualitative data are (Firmin et al, 2017; Castleberry and Nolen, 2018). Finally, the researcher followed the guidance of Braun and Clarke's (2006) six-step process for carrying out a thematic analysis:

1) Familiarizing yourself with the data: Following the interviews audio recordings were transcribed. Transcriptions were read at least twice, and key notes added.

2) Generating initial codes: Notes and quotations formed initial codes.

3) Searching for themes: Each code was collated in relation to the research objectives, leading to the development of prospective themes.

4) Reviewing potential themes: These tentative themes were scrutinized across the data set, leading to the generation of five principal themes.

5) Defining and naming themes: Titles and summaries of each theme were then formulated.

6) Producing the report: Correspondingly, these themes will be presented briefly at this end of this chapter and in further detail in Chapter 4.

The qualitative data analysis process included the production of an initial coding framework developed through the independent coding of the full interview transcripts. The progression of analysis included using the coding framework while reading and rereading all transcripts. This process led to a reiteration of the coding framework and manuscripts were reanalyzed. Some themes were anticipated through the semi structured interview questions, yet other unexpected themes and associated sub themes emerged through this process. The researcher adopted an inductive, semantic and realistic approach to thematic analysis in line with a research aim of obtaining the subjective perspectives of participants. This approach allowed for exploration of individual experience and the meaning people attach to these.

Level of Familiarity

When an individual is not familiar about a certain topic, especially one that poses a risk to their business, the reaction to and assessment of said risk can vary dramatically from an individual who is familiar with the topic. During the interviews, the first objective of the researcher was to establish where the grower was in terms of level of awareness and knowledge on the topic of cadmium contamination and the risk is poses on the tillage sector.

Perceptions of Risk

An individual will assess a certain risk differently from another depending on a variety of factors such as past experience, personal traits and demographics, attitudes toward regulation and compliance, expected or perceived benefits, etc. Using risk literature to label the different types of risk assessment, the following terms were used to define the various perceptions of risk displayed by both the potato growers and agronomists: cognitive assessment, affective

assessment, and comparative assessment (Trumbo, 2016; Martin et al., 2007; Janssen et al., 2011). Cognitive assessment is an example of the risk being assessed thoughtfully and logically. The grower realizes the severity of the risk at hand and the possible implications. Affective assessment is an example of the risk assessment process being clouded by feelings or intuitive understanding. In this type, the grower may be hyper focused on the regulatory aspect of cadmium maximum levels and instinctually leaned toward an 'ignorance is bliss' attitude toward the risk. Finally, comparative assessment is an example of the cadmium issue being compared to a relative risk or other individual's experience and using either as an unconditional risk estimate. This means that the grower will assess the probability of the cadmium risk without considering ability to implement mitigation strategies or changes in existing behavior.

Level of Concern

Part of the risk assessment process is to determine the level of concern in regard to said risk. For each grower, the reason for concern will vary, whether it may be fear of the unknown, financial strain or loss, regulatory compliance, etc. Many of the potato growers in the impacted area utilize a conacre system where land is rented for a period of 11 months to grow their potato crop. If a grower is unable to get a soil cadmium analysis completed before taking the land, they would be running the risk of growing their crop in a high-risk soil.

Proactivity

This theme was used to determine the likelihood of the grower interacting with the cadmium risk assessment model. These responses were triggered by questions on the in-person survey which

aimed to assess the individual's likelihood of using the cadmium risk assessment model and any proposed cadmium mitigation strategies.

Flexibility

Some of the mitigation strategies proposed for managing the risk of cadmium require a certain degree of flexibility in terms of land management decisions, tenure type, variety type, and crop type. As seen in Figure 1.3, the advice for land found to have a high soil risk on a conacre tenure type is to change crop completely. While this would be an example of the most extreme measure suggested for cadmium mitigation, it may be the reality for some growers in the impacted area. Thus, the ability to be flexible in their business was assessed by asking questions about past changes in potato varieties or crops grown with follow up questions being asked about the reasons for such changes. Furthermore, questions about flexibility towards land renting decisions were asked, particularly ability to conduct soil testing prior to contract agreements being made. Ideally, the grower would be able to determine if the piece of land they are wanting to rent is a low, medium, or high risk soil for cadmium; however, this may not be an option for some growers in areas of Ireland like Dublin, where land is in such high demand.

Case Studies

Brief case studies were carried out for three growers that made the decision to interact with the soil risk assessment tool and obtain a soil cadmium analysis. While five growers out of the 39 participants got a soil cadmium analysis, only three of the five will be explained due to a delay in obtaining the final two grower's lab results due to the Covid-19 crisis. Their demographic information will be shared in the following chapter along with their responses from an online

survey provided to them after they had their soil samples analyzed by the lab for available soil cadmium and subsequent advice was provided to them based off of the cadmium risk assessment model described in Chapter 1 of this thesis. Their results and opinions of the process will be discussed in the next chapters.

3.5.2 Data Analyses of Quantitative Surveys

All responses were coded and inputted into SPSS 26 for analysis. A full description of the codes and values for each question can be found in Appendix Table A1. Statistical analysis was performed on the same platform and subsequent tables and graphs included in this paper were generated from the data.

Survey Questions

All surveys were conducted during the one-on-one interview with the grower or agronomist. The farmer survey consisted of 23 questions (some of which had sub questions), including a combination of open and closed format questions, including multiple-choice, Likert scale, short answer, and yes-no questions. The survey included questions concerning the same seven topics listed above in the qualitative interviews section. A copy of the grower survey can be found in Appendix Figure A3. The agronomist survey consisted of 21 questions (some of which had sub questions) that included a combination of short answer, Likert scale, and yes-no questions. A copy of the agronomist survey can be found in Appendix Figure A4. Many of the same questions appeared in both the farmer and agronomist survey; however, the agronomist survey was more directed toward the individual's technical knowledge of the subject matter and their current actions being taken in regard to advising clients on the issue. To be eligible to participate in the

survey, the farmer and agronomist had to be at least 18 years of age and sign a participant consent form (see Appendix Figure A2).

Grower Surveys

Some univariate analysis is used to analyze single variables such as age, farm size, education level. Multivariate statistical analyses are also used to emphasize correlation and explanation, and it will also be used to describe the possible factors influencing farmer behavior.

Although the sample size is small, it is still representative of the population. In the three counties, there is estimated to be around 80-100 potato growers. With some of those individuals renting or leasing out land instead of farming it themselves, it is possible that those numbers are even lower. As 39 potato growers were interviewed, it can be stated that in and around 50% of growers in the affected area were sampled. Furthermore, the researcher is confident that the majority of the larger potato growers and producers were interviewed as part of this study. However, because the sample size is small, the p-value that determines significance may or may not be completely reliable. A small sample size lacks power to test normality, so even when the p-value is significant (>.05), the test of assumptions is not possible, so the p-value is less credible.

Likert Scales were used throughout the in-person survey as a means to assess grower knowledge and perception of soil contaminant risks. All Likert questions were on a 5-point scale ranging from “not at all likely” or “not at all familiar” or “not at all concerned” to “very likely” or “very familiar” or “very concerned.” These scales were represented in numerical form and definitions were provided by the researcher to the participant as the surveys were conducted in-person.

When surveys are mailed out or sent out on an online platform for the interviewee to fill out independently, there can be variations in individuals' definitions of the Likert scale provided. One person's '1' could be another person's '2,' and vice versa. Since definitions of the Likert scale were provided to each grower during the survey, the risk of misunderstanding the scale is reduced.

Typically, because it is a 1-5 scale, Likert scales are considered to be ordinal data, meaning variables have natural, ordered categories, but the intervals between values cannot be presumed equal. As ordinal data, the mean and standard deviation and other parametric statistics like ANOVA cannot be taken (Wu et al., 2017). Instead, the median or mode is used as the measure of central tendency because arithmetical manipulations are required to calculate the mean and standard deviation, and this is considered inappropriate for ordinal data. This places a limit on how far the data can be analyzed in terms of determining significant correlations and the testing of relationships between variables in general. Many authors in a wide range of fields, however, suggest responses to single Likert Scale items with five or more item responses represent measures that can be appropriately viewed as interval in nature. Unlike ordinal data, interval data can use parametric statistics to analyze data, allowing for a deeper analysis of the results. As stated in the literature, parametric statistics can be used with Likert data with small sample sizes and non-normal distributions with no fear of coming to the wrong conclusion. These findings are consistent with empirical literature dating back nearly 80 years (Willits et al 2016; Carifio and Perla, 2008). Descriptive statistics were performed in SPSS 26 in order to test for the normality or the Likert scale questions, and the results revealed that the data did not follow patterns of a normal distribution.

Correlations were used and analyzed in SPSS to determine trends and attempt to make conclusions about grower perspectives on the cadmium issue and likelihood to adopt knowledge transfer packages. Spearman correlations, a measure of statistical dependence between the ranking of two variables, at various levels of significance were found and a few key correlations are summarized in the next chapter. A full list of variables, variable descriptions, and variable coding can be found in Appendix Table A1.

Agronomist Survey

As the sample size for the agronomist was only n=7, statistical analysis is limited. In this way, responses from the agronomist surveys are treated more like case studies. Basic descriptive statistics such as the analysis of single variables like education level, main potato variety of clients, etc., may be used; however, assuming any degree of significance or correlation from any other variables found in the agronomist quantitative surveys will be avoided due to the small sample size. A full list of variables, variable descriptions, and variable coding can be found in Appendix Table A2.

3.5.3 Validity of Data

Survey questions were reviewed by the researcher's primary advisors and the local Teagasc tillage and potato advisor working in the same office as the researcher. Suggestions and edits were subsequently made, and final drafts for both the grower and agronomist surveys were decided upon by the involved parties mentioned above. The researcher made the decision to not run pilot testing for the grower or agronomist surveys due to time constraints and the importance of collecting data from as many of the participants as possible. The researcher made the decision

to carry out data collection during the time of the year that would be considered to be less busy in comparison to other parts of the growing season.

3.5.4 Reliability of Data

Internal consistency needed to be measured for the Likert questions contained in the survey in order to confirm the reliability of the data. A reliability analysis was conducted in SPSS 26 for the 8 Likert questions in the survey, and Cronbach's Alpha was found to be 0.836. This indicates a good level of internal consistency for the scale with this specific sample as a Cronbach alpha coefficient of 1.0 would indicate perfect internal consistency (George and Mallery, 2003).

3.5.5 Limitations of Data

This study was only focused on potato growers and agronomists in three counties of Ireland with elevated levels of available soil cadmium. Future research is needed to build on the data presented in this study to seek out the perceptions, attitudes, and intentions of growers located in the impacted region producing other horticultural crops that are at risk of taking up high amounts of cadmium such as carrot, brassica, and leafy vegetable producers.

The in-person interviews and surveys may have been affected by power dynamics or lack of historical trust between the researcher and the grower and/or agronomist. Some participants could have been less inclined to share their opinion freely since the day the in-person meeting took place could have been the first time the grower or agronomist would have met the researcher. While the researcher does not believe this was an issue in this study and made every effort to help reduce this limitation, a point must be made to acknowledge the risk of such a limitation occurring.

3.6 BIASES

3.6.1 Historical Bias

The in-person interviews and surveys were held in the winter and early spring of 2019. A decision regarding the possible decrease in maximum levels of cadmium in horticultural produce (from 0.1 to 0.075 mg Cd/kg FW in the case of potatoes) was supposed to be made by governing bodies such as the EU and FSAI at the end of 2018, however, this never came to fruition. Instead, a decision was communicated by individuals working with the FSAI in late 2019 that the maximum level of cadmium in potatoes was going to stay at the current level of 0.1 mg CD/kg FW for the time being. As this decision was made after the grower and agronomist interviews and surveys were completed, perceptions of the risk of cadmium should not have been influenced as a result.

3.6.2 Research Bias

The researcher for this study has a background in soil science, natural resource management, resource economics, and small-scale organic farming in the United States prior to beginning the masters research. The researcher attained a Bachelor's of Science (BSc) degree in natural resources, with a specialty option in soil science, from Oregon State University's College of Forestry with first-class honors (i.e. Suma cum laude). As a duel citizen of the United States and Ireland, the research chose to carry out her post-graduate research in Ireland where the position for this master's research as part of the wider DAFM CREDIT project was being advertised. After being successful recruited for the research position, the researcher moved to Ireland to begin the research into the cadmium issue. The researcher's knowledge and passion for soil

science was the primary motivator to apply for the research position. The researcher did not have any prior experience working with Irish potato growers or Irish agronomists before carrying out data collection.

3.7 SUMMARY

This portion included the research question, data collecting instrument, procedures of participant selection, data collection, and data analysis in detail. It also included limitations and benefits of study method, the steps taken to ensure validation of the study, and to minimize potential bias. The following chapter presents the results of the study

CHAPTER 4

Results

This study was exploratory, mixed-method design, which utilized both qualitative and quantitative data collection. In person, one-on-one interviews were used for the qualitative data collection and an in person, one-on-one survey was used for the quantitative data collection. The research objectives of this study were to:

1. Assess the influences affecting potato growers and agronomists' risk assessment of available soil cadmium and their adoption of the cadmium risk assessment model
2. Evaluate the effectiveness and uptake of the cadmium risk assessment model proposed for farmers and agronomists
3. Analyze extension tools and processes for both building engagement in the potato growing community and making an impact on the farmer decision making process

This chapter will be broken up into four main sections: grower qualitative results, grower quantitative results, grower case studies, and agronomist qualitative results. Each section will go over demographic data of both groups and the various influences affecting adoption or engagement with the cadmium risk assessment model.

4.1 GROWER QUALITATIVE RESULTS

In the qualitative interviews, potato growers in the impacted area displayed a very low level of knowledge and awareness on the topic and risk of cadmium contamination in the soils of Northeast Leinster. Common themes were uncovered from the interviews that characterized the various influences of growers deciding whether or not to engage with the risk of cadmium. Demographic information of the growers who partook in this study along with the identified themes are described in the following subsections.

4.1.1 Demographics of Interviews

The participants completed a survey at the end of the interview that included demographic data as well as further quantitative data that will be discussed in a later section. Out of the 39 growers interviewed, 65.8% primarily farmed in Dublin, 28.9% in Meath, and 5.3% in Kildare. The largest number of participants claimed they farmed over 100 hectares (ha) at 44.7%, with 13.2% farming 61-80 ha, 34.2% farming 41-60 ha, and 7.9% farming 21-40 ha. In terms of main crop type, 63.2% stated that potatoes were their primary crop with 21.1% saying cereals were the main crop, 5.3% saying carrots, and 10.5% saying cabbage. When asked about tenure type, exactly 50% had a mixture of owned, medium term-lease, and/or conacre land. Only 13.2% had solely owned land, 2.6% had solely medium-term lease land, and 5.3% had solely conacre land. The majority of respondents (53.3%) grew the potato variety Rooster as their main variety. The next most stated main varieties of potatoes were Queens at 21.1%, Kerr's Pink at 10.5%, Markies at 2.6%, and Premiere at 5.3%. In terms of market types, the majority of respondents fell into the wholesale market type at 84.2%, with processing (i.e. chipping/crisping/etc.) making up 10.5% and yard (i.e. farmers markets) making up 5.3%. Many who claimed wholesale as their

primary market, stated that they utilized the other types of markets secondarily. Finally, age and education level information were gathered for the respondents. Many of the participants fell within the 51-59-year-old age, making up 41%, with 15.4% being between 21-40, 23.1% being 41-50, and 20.5% being older than 60 years of age. Many respondents (46.2%) held a Green Certificate[1] or some other type of Level 5 or 6 degree. The next most common responses were no qualifications at 25%, Leaving Certificate[2] only at 13.9%, Bachelor's Degree at 2.8%, Master's Degree at 2.8%, and a mixture of qualifications at 5.6%.

4.1.2 Research Objective 1: Influences Affecting Potato Grower Adoption of the Cadmium Risk Assessment Model

Familiarity

The topic of cadmium contamination can appear very complex when first mentioned to the grower, especially when knowledge level and awareness of the subject matter are low to begin with. When an individual is not familiar with a certain topic, especially one that poses a risk to their business, their reaction to and assessment of said risk can vary dramatically from an individual who is familiar with the topic. During the interviews, the first objective of the researcher was to establish what level of awareness and knowledge the grower had on the topic of cadmium contamination and the risk it poses to the tillage sector. Nearly all of the growers interviewed had a very low level of knowledge apart from one who had carried out independent

[1] A Green Certificate is Level 6 Specific Purpose Certificate awarded by the Further Education and Training Awards Council (FETAC); modules covered in the certificate course vary from Farm Business to Beef, Sheep, and Grass production and allow students to meet the requirements of a qualified farmer.
[2] The Leaving Certificate Examination is the university matriculation examination in the Republic of Ireland and the final exam of the Irish secondary school system.

research prior to the interview. The majority of growers interviewed stated they had never heard of the topic whatsoever or had only heard of it when they received the letter sent by the primary researcher (see appendix figure A1). The following will display a selection of quotes that characterize the three levels of familiarity exhibited from the in-person grower interviews.

Type 1: Low Level of knowledge and awareness (representative of most individuals interviewed): *"We only heard of it from your letter."* - Interview 24

Type 2: Low level of knowledge but some awareness (small number of interviewees fit this type)*: "I don't, ... to be honest with you. I really don't. It's in the soil? Sounds bad news."* - Interview 34

Type 3: High level of knowledge and awareness (only one interview displayed this type): *"Yeah, fairly familiar because we'd heard of it about 5 or 6 years ago and did a bit of research on it and asked a few people, but there was nobody with much information really at the time...We would have known that Meath, Dublin, Kildare was the area.* - Interview 9

When this grower was asked if they knew the source of the cadmium and that it came from the bedrock, they responded: Interview 9: *"Yeah, and that maybe fertilizers make it worse."*

Perception of Risk

An individual will assess a certain risk differently from another depending on a variety of factors such as past experience, personal traits and demographics, attitudes toward regulation and compliance, expected or perceived benefits, etc. Throughout the interviews, a variety of perceptions were identified in regard to the risk of cadmium for potato crops. While some growers were quick to say they would happily interact with the cadmium risk assessment model

after hearing the facts of the matter, others felt that interacting with the model would be a larger risk than having their potatoes found to be in exceedance of the established maximum level by a supermarket or governing body. Some growers took the stance that this risk was just another to add to a pile of risks facing the grower at this current moment and felt that it was not serious enough to be a top priority. Using risk literature to label the different types of risk assessment, extracts from interviews are used to present examples of cognitive assessment, affective assessment, and comparative assessment of risk (Trumbo, 2016; Martin et al., 2007; Janssen et al., 2011). Type 1, cognitive assessment, is an example of the risk being assessed thoughtfully and logically. The grower realizes the severity of the risk at hand and the possible implications. Type 2, affective assessment, is an example of the risk assessment process being clouded by feelings or intuitive understanding. In this example, the grower was focused on the regulatory aspect of cadmium maximum levels and instinctually leaned toward an 'ignorance is bliss' attitude toward the risk. Finally, Type 3, comparative assessment, is an example of the cadmium issue being compared to a relative risk or other individual's experience and using either as an unconditional risk estimate. This means that the grower will assess the probability of the cadmium risk without considering ability to implement mitigation strategies or changes in existing behavior. Type 1, cognitive assessment, is an example of the risk being assessed thoughtfully and logically. The grower realizes the severity of the risk at hand and the possible implications.

Researcher: "*At the end of the day, it's a toxic metal. It does sound scarier than it is, yes, and it's everywhere. It's just the levels that it's at, and unfortunately we just have high levels in …"*

Interview 14: "*In a very big tillage area."*

Researcher: *"Exactly. And it just happens. It's just unfortunate. And obviously, it's just something to be aware of, because it can be a human, a public health issue. It might be spun into something."*

Interview 14: *"Yeah. That's what I'm saying. They could spin that into something serious. Potatoes in county Dublin are toxic.*

Researcher: *"Put a red mark on it. Yeah, don't buy from here, that kind of thing. And that's what we're trying to avoid."*

Interview 14: *"Well that's what's going to happen. We're all going to have our cadmium levels checked in our land and you'd be growing potatoes where the cadmium isn't there."*

Type 2, affective assessment, is an example of the risk assessment process being clouded by feelings or intuitive understanding. In this example, the grower was focused on the regulatory aspect of cadmium maximum levels and instinctually leaned toward an 'ignorance is bliss' attitude toward the risk.

Interview 7: *"Nobody's gonna really go and get the ground tested.*

Researcher: *"You think?"*

Interview 7: *"They would be hanging themselves, getting themselves in trouble and that's what I'm saying."*

Finally, Type 3, comparative assessment, is an example of the cadmium issue being compared to a relative risk or other individual's experience and using either as an unconditional risk estimate. This means that the grower will assess the probability of the cadmium risk without considering ability to implement mitigation strategies or changes in existing behavior.

Interview 9: *"No, no because there's a million other problems coming at you. And we're not going to focus all our time on that one. No, we just wouldn't be...We're just gonna chance it."*

It is also important to mention that although counties Meath, Dublin, and Kildare and considered the impacted area in terms of elevated soil cadmium levels, that does not mean that all fields are impacted. This is why getting a soil test with a cadmium analysis is critical for growers in the impacted area in order to inform their management strategies and land purchasing decisions. In order to get an accurate result for soil cadmium levels and be able to utilize the decision support tool developed by researchers at Teagasc Oak Park that produces an accurate prediction for cadmium levels in the potato tuber, a calcium chloride ($CaCl_2$) extraction process must be used. While expensive for the lab to run such a test, the cost to the actual farmer is minimal. That being said, price was determined to be a hindrance as to why growers in the impacted area have

never purchased such a test previously. One grower stated: *"I would just assume that if you need a special test, you would have to throw out loads of money."* This quote is representative of statements made by most of the 39 growers in the interviews.

Concern

Part of the risk assessment process is to determine the level of concern in regard to said risk. For each grower, the reason for concern will vary, whether it may be fear of the unknown, financial strain or loss, regulatory compliance, etc. A common trend found throughout the interviews was a difference in the level of concern between levels of cadmium on rented land and levels of cadmium on owned land. Many of the potato growers in the impacted area utilize a conacre system where land is rented for a period of 11 months to grow their potato crop. If a grower is unable to get a soil cadmium analysis completed before taking the land, they would be running the risk of growing their crop in a high-risk soil. As mentioned in Chapter 1, many of the possible mitigation strategies such as application of organic matter require a much longer time period than allowed in a conacre system to catalyze an effective decrease in available soil cadmium. The research showed that many of those using a conacre system or other type of short-term lease, especially those > 41 years old, would be less concerned about the risk of cadmium being on the rented land than their owned land. This is represented in a quote by interview 5 shown in Figure 4.1 below. Another trend, as exhibited by the quote from interview 14 in Figure 4.1, was lower concern of the risk of cadmium if the grower's predicted tuber cadmium levels (found by running their available soil cadmium levels through the cadmium risk assessment model) were found to be high but still under the regulation mandated maximum level of 0.1 mg Cd/kg FW. Finally, the fear of the unknown, exhibited in a quote from interview 39

shown in Figure 4.1, was commonly expressed and linked to the low knowledge and awareness level of the issue of cadmium amongst potato growers in the impacted area. In this way, many were concerned about the regulatory aspect of this issue and the fact that they do not have any idea what kind of levels are present in their land since they were unaware of the special laboratory extraction process required.

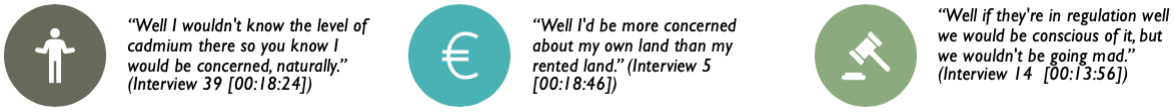


Figure 4.1 Quotes from in-person interviews displaying relationships between uncertainty and concern level, tenure type and concern level, and regulation compliance and concern level

Proactivity

This theme was linked to the likelihood of the grower interacting with the cadmium risk assessment model. These responses shown in Figure 4.2 below were triggered by the survey questions which aimed to assess the individual's likelihood of using the cadmium risk assessment model and any proposed cadmium mitigation strategies. The research showed a wide range of intentions to be proactive and interactive with this issue. As shown in Figure 4.2 below,

some extracted quotes were put in order from high intention of proactivity (green) to low intention of proactivity (red).



Figure 4.2 Color coded representation of proactivity levels displayed by potato growers

Flexibility

Some of the mitigation strategies proposed for managing the risk of cadmium require a certain degree of flexibility in terms of land management decisions, tenure type, variety type, and crop type. As seen in Figure 1.3 of Chapter 1, the advice for land found to have a high soil risk on a conacre tenure type is to change crop completely. While this would be an example of the most extreme measure suggested for cadmium mitigation, it may be the reality for some growers in the impacted area. Thus, the ability to be flexible in their business was assessed by asking questions about past changes in potato varieties or crops grown with follow up questions being asked about the reasons for such changes. For the most part, respondents had all displayed a degree of flexibility when it came to the type of variety being used; nearly all stated that the reason for said change was because of market demands.

Other growers, however, felt that while changing varieties for market reasons was a valid response, changing varieties or crop type for the sake of minimizing their risk to cadmium was

not something they would currently contemplate e.g. *"Well yeah we'd change to the market needs but not for this perspective."*- Interview 25

Questions about flexibility towards land renting decisions were asked, particularly ability to conduct soil testing prior to contract agreements being made. Commonly, respondents do conduct a soil test to know the soil fertility of fields they are considering renting. Ideally, the grower would also be able to determine if the piece of land they want to rent is a low, medium, or high-risk soil for cadmium; however, many growers stated that as land is in such high demand, especially in County Dublin, this would not always be possible. One interviewee explained this dilemma:

> "*Yeah, that's not the way it works because yeah you rent the land and then you do the soil sampling and then you do everything else. You have the land rented; you have the money paid. If the soil sample comes back and it's high in cadmium, well you rented it, I'm not giving you back your money. It's the same thing whether you own it, or you rent it...if someone rings you, the field is set, you need to go with your checkbook and take that field, here's the money. Because if I don't, there's a guy right behind me with a bigger checkbook."* - Interview 9

4.2 GROWER QUANTITATIVE RESULTS

The research discovered that 92.3% of the 39 potato growers surveyed had never purchased a soil test that included a cadmium analysis and therefore are uncertain of the levels of cadmium in the soil they grow their produce in even though the area is one of high risk. As initial understanding and knowledge of the risk is low, further investigation is needed into how farmer reasoning is formed, what beliefs are held, and how they influence farmer behavior and choice of response. This study has the capacity to add to the current body of literature in regard to risk assessment and response behavior by farmers when it comes to complicated risks like heavy metal contamination that have deep roots in scientific explanation.

Table 4.1 Summary of the mean data from various 5-point Likert scale questions on the potato grower survey in relation to farm size (ha)

Farm Size (ha)		Familiarity with toxic metal contamination in Northeast Ireland	Level of concern on owned land	Level of concern on rented land	Likelihood of using soil risk assessment model	Likelihood of using mitigation strategies if risk of cadmium is high but within current maximum level	Likelihood of using mitigation strategies if risk of cadmium is high and exceeding the current maximum level
21-40	Mean	1.67	2.33	2.67	3.67	3.00	4.67
41-60	Mean	2.08	3.08	2.50	4.08	3.75	4.50
61-80	Mean	2.20	3.60	4.00	3.40	3.60	4.40
≥ 100	Mean	2.12	3.29	3.18	4.24	3.65	4.41
Total	Mean	2.08	3.18	3.06	4.03	3.62	4.46

Some important conclusions derived from Table 4.1 above include that there was found to be a low level of concern for both owned and rented land for those with smaller farm sizes, a high likelihood of using mitigation strategies across all farm sizes, and a lower likelihood of using mitigation strategies if Cd levels were found to be high but still within the current maximum level (ML) of 0.1 mg Cd/kg potatoes FW [i.e. in the yellow/orange zone].

Other important findings from Table 4.2 include that the likelihood of using mitigation strategies (MS) is high amongst all age groups but highest amongst younger farmers, the level of concern in regard to the risk of cadmium is the same for young farmers on both owned and rented land, and the likelihood of interacting with the cadmium risk assessment model is highest amongst the oldest and youngest categories of age groups

Table 4.2 Summary of the mean data from various 5-point Likert scale questions on the potato grower survey in relation to farmer age (years)

Age (years)		Familiarity with toxic metal contamination in Northeast Ireland	Level of concern on owned land	Level of concern on rented land	Likelihood of using soil risk assessment model	Likelihood of using mitigation strategies if risk of cadmium is high but within current maximum level	Likelihood of using mitigation strategies if risk of cadmium is high and exceeding the current maximum level
21-40	**Mean**	2.67	3.83	3.83	4.33	3.83	4.50
41-50	**Mean**	1.78	3.00	2.67	3.89	3.56	4.00
51-59	**Mean**	2.31	3.00	3.00	3.94	3.73	4.60
≥ 60	**Mean**	1.75	3.25	3.00	4.25	3.38	4.75
Total	**Mean**	2.13	3.18	3.06	4.05	3.63	4.47

When looking at the total mean responses, growers had a marginally higher concern level of the risk of cadmium on their owned land compared to the land they rent. Despite the slightly higher mean value for the level of concern on owned land, both categories (i.e. concern on owned land and rented land) have a mean value corresponding to the 'neither/nor' value on the 5-point Likert scale provided to the grower on the survey. For the survey question corresponding to the grower's likelihood of using the soil risk assessment tool for the risk of cadmium, the total mean response was found to be 4.05; this correlates to the 'very good chance' value on the 5-point Likert scale provided.

Significant correlations at the 0.05 level (2-tailed) were found between variables, including a positive correlation between likelihood of using mitigation strategies (MS) if available Cd levels were found to high but still within the maximum level (ML) of 0.1 mg Cd/kg potatoes FW and level of concern on rented land as seen in Figure 4.3.

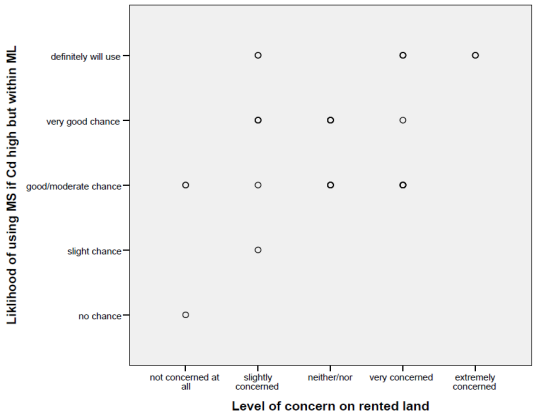


Figure 4.3 Scatter plot displaying a positive correlation at the 0.05 level between level of concern on rented land and likelihood of using mitigation strategies (MS) is Cd risk was found to be high but within the current ML

Significant correlations at the 0.01 level (2-tailed) were also found, including positive correlations between the 1) likelihood of using the cadmium risk assessment model and the likelihood of using mitigation strategies of risk of cadmium is found to be high and exceeding the current maximum level of 0.1 mg Cd/kg FW as seen in the scatter plot Figure 4.4, 2) likelihood of using the cadmium risk assessment model and the likelihood of using mitigation strategies if cadmium risk is high but still under the current maximum level of 0.1 mg Cd/kg FW as shown in Figure 4.5, and 3) level of concern on owned land and the likelihood of using mitigation strategies if cadmium risk is found to be high but still under the current maximum level as seen in Figure 4.6.

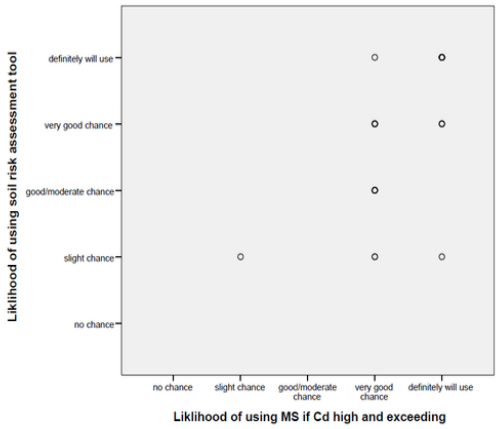


Figure 4.4 Scatter plot displaying a positive correlation at the 0.01 level between likelihood of using the cadmium risk assessment model and likelihood of using mitigation strategies if cadmium risk is found to be high and exceeding the current ML

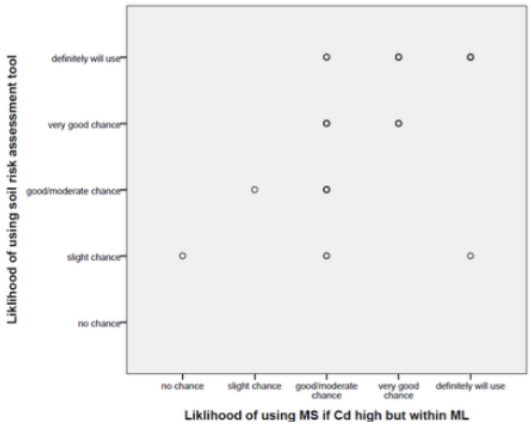


Figure 4.5 Scatter plot displaying a positive correlation at the 0.01 level between likelihood of using the cadmium risk assessment model and likelihood of using mitigation strategies if cadmium risk is found to be high but within the current ML

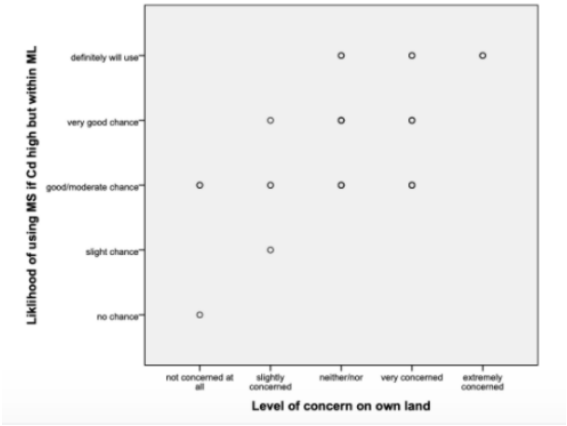


Figure 4.6 Scatter plot displaying a positive correlation at the 0.01 level between level of concern on owned land and likelihood of using mitigation strategies if cadmium risk is found to be high but within the current ML

The research showed that 18% of the 39 surveyed potato growers, some of whom are involved in the production of other vegetables such as leafy brassica, leafy vegetables, and/or other root vegetables, were completely unaware (a value of 1 out of a possible 5 on the Likert scale provided for the grower) of the cadmium issue before speaking with the researcher who was also charged with educating growers on the topic. From the data collected in the one-to-one

interviews and surveys of the 39 potato growers, 48% (value of 2 out of a possible 5 on the Likert scale) stated that they have at least heard of the issue beforehand while 32% (value of 3 on the 5-point Likert scale) claimed passable knowledge of the subject. None of the 39 growers were able to claim enough knowledge to explain the topic to someone else (value of 4 on the 5-point Likert scale) or proficient knowledge (value of 5) in the subject matter.

4.3 GROWER CASE STUDIES

4.3.1 Research Objective 2: Evaluating the Effectiveness and Uptake of the Cadmium Risk Assessment Model

Although the survey and interview responses from the growers implied a high intention to engage with the cadmium risk assessment model, only five of the 39 growers actually took action to conduct a soil cadmium analysis for the purpose of receiving an estimated risk assessment of tuber-Cd exceeding the current ML of 0.1 mg Cd/kg FW. Three of those five potato grower's cases, including results, demographic information, and personal opinions of the process obtained from a brief online survey are presented here and they illustrate the thinking and decision process.

4.3.2 Case I

This grower was the first of the 39 participants to get an available soil cadmium analysis completed. This potato and cereal grower, farming owned and medium-term leased land in both Dublin and Meath, falling in the 51-59 age group, and having a Leaving Certificate and Green Certificate, is known as an 'influencer' in the potato industry of the Northeast amongst both growers and advisors in the region. After receiving the results shown in Figures 4.5 and 4.6, the

grower was asked to complete a brief online survey regarding his experience with the entire process.

Table 4.3 Copy of sample result summary provided to grower after running lab results through the cadmium risk assessment model

Sample Label		Estimated tuber-Cd (mg/kg)	Probability of tuber-Cd exceeding the current ML (0.1 mg Cd/kg FW)
SS-483613	EED/220	0.147	Very high (> 80%)
SS-483614	EED/221	0.114	High (60%)

Table 4.4 Copy of grower's soil risk index rating for the tested samples and associated mitigation strategy advice

Soil Risk Index	Implement remediation strategies?	Use low-Cd varieties?	Start soil remediation?	Change crop?	Estimated tuber-Cd (mg/kg)	Probability of complying (%)	Tested sample SS-483613	Tested sample SS-483614
Low	No	-	-	-	<0.05	>99%		
Low-Medium	Yes	-	Yes	-	0.05-0.070	78%-99%		
Medium	Yes	Yes	Yes	-	0.071-0.099	50%-78%		
High	Yes	Yes	Yes	Yes	0.01-0.12	30%-50%		X
Very High	No	-	-	Yes	>0.121	<30%	X	

When asked what had influenced his decision to send soil samples off for a cadmium analysis, the grower chose 'general curiosity' out of the list of eight possible influences as seen in Appendix Figure A5. The grower stated that the cadmium results were 'probably needed' for his business but added in an available comment box that they would only be needed "if it becomes law." When asked if he would avail of the test again in the future, he chose 'not so likely' and went on to add that he would get the test done again "only if I have to." Furthermore, he stated that he was 'not so likely' to recommend the test to another grower since the results "are only giving bad news in my area." When asked directly about interpreting his results using the cadmium risk assessment model, he felt they were 'extremely easy' to understand and that the

results were “well explained to me.” As for any changes to management decisions on land being used to grow potatoes, the grower stated that ‘additional organic matter’ would be used. Finally, the grower noted that ‘timeliness’ was the most disliked aspect about the delivery of results. The grower had to wait several months for his samples to be processed by the lab despite the lead researcher and other advisors’ attempts to make contact with the lab to expedite the process.

As the cadmium results for this grower came back with high and very high probabilities of potatoes grown in those fields having tuber-Cd levels above the current ML of 0.1 mg Cd/kg FW, the associated advice for this grower included the most extreme mitigation strategy of changing the type of crop from potatoes to something else for those fields.

4.3.3 Case II

This potato and cereal crop grower primarily farms conacre and owned land in Dublin. He falls in the ≥60 age group and holds no formal education qualifications. After receiving the results shown in Figures 4.3 and 4.4, the grower was asked to complete a brief online survey regarding his experience with the entire process. An important note is that Case II and Case III both received a different format of results from Case I. In Case I, the grower only received results pertaining to cadmium levels instead of all of the necessary parameters used in the model to produce an estimated tuber-Cd level. After Case I, it was decided that the grower should receive all relevant results along with the color-coded table displaying their soil risk index. This is why the format of these next two case studies differs from Case I.

Table 4.5 Copy of sample results from laboratory prior to running results through the cadmium risk assessment model

Sample ID	Unit	Cadmium	Potassium	Magnesium	Manganese	Phosphorus	Zinc
SS-533258	ppm	0.371	169	93	39.9	5.61	1.93

Table 4.6 Copy of grower's soil risk index rating for the tested samples and associated mitigation strategy advice

Soil Risk Index	Implement remediation strategies?	Use low-Cd varieties?	Start soil remediation?	Change crop?	Estimated tuber-Cd (mg/kg)	Probability of complying (%)	Tested sample SS-533258
Low	**No**	**-**	**-**	**-**	**<0.05**	**>99%**	
Low-Medium	**Yes**	**-**	**Yes**	**-**	**0.05-0.070**	**78%-99%**	
Medium	**Yes**	**Yes**	**Yes**	**-**	**0.071-0.099**	**50%-78%**	**X**
High	**Yes**	**Yes**	**Yes**	**Yes**	**0.01-0.12**	**30%-50%**	
Very High	**No**	**-**	**-**	**Yes**	**>0.121**	**<30%**	

When asked what influenced his decision to send soil samples off for a cadmium analysis, the grower also only chose the option of 'general curiosity' out of the list of eight possible influences as seen in Appendix Figure A5 like the previous case. The participant felt 'neutral' towards his overall experience of getting a soil test with a cadmium analysis and added that the process was "easy to do and cheap." This grower also stated that the cadmium results were 'probably needed' for his business and added in an available comment box that he "will need to do it anyway." When asked if he would avail of the test again in the future and if he would recommend this soil test to another grower, he chose 'somewhat likely' for both questions. He stated that his fellow growers "need to do it to find out what's there." When asked directly about the results he was provided after putting his available soil cadmium results into the cadmium risk assessment model, he felt they were 'very easy' to understand and that he would be "adding chicken pellets

this year" as a source of organic matter. This case had the fastest turnaround time for results with results received in a few weeks and interpreted through the cadmium risk assessment model.

This grower was provided with the following statement to help understand his results:

> Planting potatoes in this field carries a medium risk of the harvested tubers exceeding the cadmium (Cd) values. Even though the model predicts the Cd level to be lower than the maximum level (0.1 mg Cd/kg tuber) it is at the upper end of the scale. The estimated tuber value has a high confidence value however as with all model estimates there is always a degree of uncertainty. Remediation strategy needs to consider the type of land access (owned land, leased land, Conacre) as remediation on short term rental is virtually impossible, and only mitigation actions such as crop change and cultivar selection are possible.

4.3.4 Case III

This participant is the farm manager of a large vegetable growing and packing business in the impacted area. While the main crop of this business is potatoes, this participant also grows carrots, onions, and cereal crops. This participant primarily farms conacre and short-term leased

land in Meath, falls in the 21-40 age group, and has the qualifications of a Leaving Certificate and Green Certificate.

Table 4.7 Copy of sample results from laboratory prior to running results through the cadmium risk assessment model

Sample Name	Customer Ref	unit	Cadmium	Magnesium	Phosphorus	Potassium	Manganese	Zinc
SS-532249	4	ppm	0.116	81.1	3.88	334	55.9	2.21
SS-532253	8	ppm	0.365	148	2.38	82.9	31.1	2.2
SS-532254	9	ppm	0.27	111	2.49	116	36.7	2.09

Table 4.8 Copy of grower's soil risk index rating for the tested samples and associated mitigation strategy advice

Soil Risk Index	Implement remediation strategies?	Use low-Cd varieties?	Start soil remediation?	Change crop?	Estimated tuber-Cd (mg/kg)*	Probability of complying (%)	Tested samples		
							SS-532249	SS-532253	SS-532254
Low	No	-	-	-	<0.05	>99%	X		
Low-Medium	Yes	-	Yes	-	0.05-0.070	78%-99%		X	X
Medium	Yes	Yes	Yes	-	0.071-0.099	50%-78%			
High	Yes	Yes	Yes	Yes	0.01-0.12	30%-50%			
Very High	Yes/No**	Yes**	Yes**	Yes	>0.121	<30%			

When asked what influenced his decision to send soil samples off for a cadmium analysis, the grower chose the options of 'wanting to safeguard my business for the future,' 'general curiosity,' 'wanting to ensure my produce is of the best quality for consumers,' and 'to help inform my management decisions' out of the list of eight possible influences as seen in Appendix Figure A5. The participant felt that his overall experience of getting a soil test with a cadmium analysis was 'somewhat negative' as it "took way too long to get results sorted out." The grower stated that the cadmium results were 'probably needed' for his business but added in an available comment box that he "thinks they are needed, but because the results came back so late, they were useless" to him. When asked if he would avail of the test again in the future, he chose 'not so likely' and went on to add that the test is a "waste of money if the results don't come in time." When asked directly about the results he was provided after putting his available

soil cadmium results into the cadmium risk assessment model, he felt they were ‘very easy’ to understand and that “additional applications of spent mushroom compost” would be used as a means of increasing organic matter content. Like the first case, this participant also had to wait several months for his samples to be processed by the lab despite the lead researcher and other advisors’ attempts to make contact with the lab to expedite the process.

Along with the results shown above, the grower was also provided with the following statement to help understand his results:

> Planting potatoes in the field corresponding to sample SS-532249 carries a low risk of the harvested tubers exceeding the Cd values. No remediation strategies need to be considered at the present. Planting potatoes in the fields corresponding to samples SS-532253 and SS-532254 carries a low-to-medium risk of the harvested tubers exceeding the Cd values. Even though the model predicts the Cd level to be considerably lower than the maximum level (0.1 mg Cd/kg tuber), soil remediation should be considered to maintain those conditions.

4.4 AGRONOMIST QUALITATIVE RESULTS

As stated previously in the methods chapter of this thesis, a majority of the quantitative data collected from the seven agronomist surveys will not be presented in this chapter of results. The small sample size of seven would not provide a reliable statistical analysis; therefore, only descriptive statistics collected from the surveys and qualitative data collected from the interviews will be used.

4.4.1 Demographics of Interviews

From the seven agronomists who were interviewed for this study, two of them (28.6%) classified themselves as independent or private agronomists with four (57.1%) of them working for some type of agriculture merchant company, and one (14.3%) being an in-house agronomist for a large vegetable produce supplier in the impacted area. Three of the agronomists (42.9%) stated that the main crop type they dealt with was potatoes, with the remaining four (57.1%) stating that cereals were the primary crop they advised on with potatoes falling second. All seven agronomists had potato growers with whom they worked with in at least one of the impacted counties of Meath, Dublin, or Kildare. The average age of the seven agronomists was 54.6 years old with 40 being the youngest age and 68 being the oldest. The majority (57.1%) held some type of Level 5 or 6 degree from an agricultural college with two (28.6%) holding a BSc in an agricultural field and one (14.3%) holding a Leaving Certificate only.

4.4.2 Research Objective 1: Influences Affecting Agronomist Interaction with Cadmium Risk Assessment Model

During the interviews carried out with agronomists working with potato growers in the impacted area, participants were asked about the risk of cadmium and their own perceptions and current actions toward said risk. Various quotes gathered from the seven transcribed interviews will be shown in relation to the main topics covered in the agronomist interviews: familiarity of risk, perception of risk, and proactive response toward the risk.

Agronomist Familiarity

The agronomists discussed their previous encounters with the risk of cadmium, and many stated that they had been made aware of the risk by Teagasc staff members or other sources as far back as 10 years before this research project was carried out. An independent agronomist described how the issue had come up at different times but that:

> *"there's been nothing done."* - Agronomist A

Another agronomist working for a leading agricultural merchant company discussed how they had attended meetings in the past directed towards advisors and agronomists and how they should be dealing with the risk of cadmium. In their experience, however, little information was transferred and/or exchanged, so little action was implemented as a result:

> ***"****Because it was so vague, we really did nothing about it."* - Agronomist D

Another agronomist working for one of Ireland's leading potato packaging company emphasized their familiarity with the topic of soil cadmium contamination in the impacted area but admitted that little action toward remediation or general risk assessment had been made.

Agronomist Perception of Risk

Agronomist participants were asked about their personal perceptions toward the risk of cadmium for their potato clients along with the risk's farmers with elevated levels of cadmium could encounter when navigating through the supply chain. When asked their opinion on farmer response efficacy, the majority of agronomists stated that the growers would engage with a decision support tool for this risk if they had an engaged point of contact who they can direct queries to and the right information. Many pointed out that the lack of clear information flowing through the potato growing community with regard to the cadmium risk is a source of concern and fear for some growers as illustrated by this quote:

> *"They were saying, what's going on? They weren't saying anything to each other, they were just saying it to me. It's all low key but they were saying what the hell are we going to do?"* - Agronomist F

The agronomists discussed the perceived risks involved in the cadmium issue, with many arriving at a similar conclusion i.e. the problem is not going to go away and that sooner or later it will be a critical issue. Some felt that the supermarkets could start to exclude growers from the area and that there is a big marketing risk for potatoes and other produce from the area. They were also fearful of the consequences for the growers if they are, for example:

"digging 24 tons an acre into boxes and sending them off to wherever and the test comes back, cadmium, rejected. It's cattle feed, but it can't actually be cattle feed cause that's human consumption as well, you have to dump them at 4000 euro an acre. That's a very real thing." - Agronomist B

When discussing the risk of cadmium on short-term leased land or conacre systems, there were varying opinions. Many agronomists took the stance that their clients would and should be able to take soil samples for an available cadmium test prior to purchasing of land, eliminating the risk of getting into a contract for a piece of land with a high cadmium risk. Another private agronomist realized the issue in discarding the risk of cadmium for rented land by stating:

"It would be the issue of finding land that would be of concern" - Agronomist C

Other agronomists stressed the importance of fresh land in the potato growing industry, and how an overall competition for fresh land in the most productive tillage area of Ireland would only increase the risk for growing potatoes on land with high levels of available cadmium:

"the Dublin growers and the North Meath growers are going into the red now to try and get fresh land because they're being pushed out from the other places."- Agronomist A

Fewer participants were familiar with the policy side of the cadmium risk. Some were aware of the current ML of 0.1 mg CD/kg FW, but few were aware of the possibility of the ML decreasing to 0.075 mg CD/kg FW. One agronomist expressed quite negative views about European regulation:

"It's not as if it's contamination...it's naturally occurring in one of the earliest farming areas in the world...the Boyne Valley and so I think that it's created a heap of hassles

which is typical of Europe, creating a heap of hassles when I think there shouldn't be hassle...Having said that, the reality is when they introduce new regulations, we either have to say no we're not having that and then there would be a showdown but we have to try and do what you're doing now. I do think that Europe generally needs to be a little bit more understanding. Things like this make me see why the British voted to leave Europe."- Agronomist G

Agronomist Proactivity

The agronomists discussed their perceived ability to deal with the cadmium issue along with any current actions being taken amongst their potato growing clients. Some participants were upfront about the fact that they had not discussed this risk with their clients seeing as though they had little information and did not feel comfortable approaching their growers with a subject matter, they did not feel equipped enough to handle or communicate.

Others seemed hesitant to focus their efforts on the cadmium problem, while some of the agronomists were confident in their ability to engage with their clients on this issue. A participant responded to a question prompted by the interviewer dealing with current plans of actions on cadmium mitigation. They said:

"Going organic, organic fertilizer, zinc. I haven't gotten into the field testing yet because I think that even though they know this is coming down the line, I think it's easier to drip them bit by bit rather than slap that through [the model], that's a failure. That would just be trouble...whereas if we go bit by bit by bit as they are becoming more aware of the fact that people are testing for cadmium all the way that it would be a varietal selection based

on a field assessment and field results and then minimize the results by using a half ton an acre of chicken pellets. That's my plan."- Agronomist B

While most of the participants seemed prepared to engage with the cadmium risk assessment model, a few took to the opinion that this was not an issue for the agronomists. One participant stated:

"Well I would be able to do it but I would not be at all willing to do it because we don't tend to as a company to get involved. We leave that to be the other guy's problem."- Agronomist G

The results displayed in this chapter will now be discussed in terms of significance, implication, utility in the next chapter.

CHAPTER 5

DISCUSSION AND CONCLUSION

5.1 INTRODUCTION

This study explored advisory and knowledge transfer tools and processes to support potato growers and agronomists assess their exposure to the risk of cadmium so that they can make good decisions based on any remedial action needed. Descriptions of farmer efficacy including familiarity of risk, perception of risk, concern toward risk, proactivity about risk, and flexibility to adapt to risk were identified. Furthermore, descriptions of agronomist efficacy including familiarity of risk, perception of risk, and proactivity about risk were identified. In both groups, possible influences affecting interaction with the cadmium risk assessment model were explored.

The study was a mixed-methods research design and utilized qualitative data collection through in-person interviews and quantitative data collection through in-person surveys. The objectives of this study were:

1. Assess the influences affecting potato growers and agronomists' risk assessment of available soil cadmium and their adoption of the cadmium risk assessment model

2. Evaluate the effectiveness and uptake of the cadmium risk assessment model proposed for farmers and agronomists

3. Analyze extension tools and processes for building engagement in the potato growing community to assess the risk of cadmium and making an impact on the farmer decision making process

The theoretical framework for this study, discussed in section 1.2, provided a structure and roadmap for meeting the research objectives. The following chapter will explore and discuss the interesting results of the study. The discussions will be broken down into separate sections for the potato growers and the agronomists with the final section including overall implications and conclusions.

5.2 FARMERS AND RISK ASSESSMENT

5.2.1 Research Objective 3: Analyzing Extension Tools and Processes for Building Engagement and Impacting Farmer Decision Making Process

The study findings show that the majority of potato growers displayed a low level of awareness and knowledge surrounding the current cadmium problem in the impacted region. The elaboration likelihood model (ELM) of persuasion, described in Chapter 1 of this thesis, posits that prior knowledge and message comprehensibility play a major role in one's ability to process a communicated message and subsequent attitudinal shifts. According to the model, if ability to process is not exhibited, a peripheral cue (i.e. expert sources, positive/negative affect, etc.) is necessary to cause an attitudinal shift; however, that shifted attitude is likely to be temporary and non-predictive of future behavior. If a peripheral cue is not present, the individual is likely to retain their initial attitude toward the message. As the majority of growers displayed an inability to process the communication, peripheral cues, like the researcher's presentation on the risk of

cadmium, were the main method of persuasion to get the growers interested in interacting with the cadmium risk assessment model. Fear of the unknown was an emotion displayed by many of the growers, and this is another example of a peripheral cue in the form of negative affect. If a grower is afraid of the risk of cadmium having a negative effect on their business, a peripheral attitude shift can take place. Unfortunately, with either of the peripheral cues presented for this case, the end result, according to the ELM of persuasion, is unpredicted of the grower's future behavior (Fishbein and Ajzen, 1975; Ajzen, 1985; Ajzen, 1991).

The R.E.S.E.T model also contains an educational factor in predicting the likelihood of a behavioral change taking place. In this model, the individual must be internally motivated to change their behavior. In this way, the action of engaging with the cadmium risk assessment model would be entirely voluntary in nature (Jansen et al., 2012). A major goal of this research project was to increase the level of awareness and knowledge of growers in regard to the risk of cadmium in their business. That being said, even if the grower's knowledge and awareness levels were increased after the in-person meeting with the researcher, these models suggest that any decision made by the grower to engage or not would be voluntary, susceptible to change, and heavily dependent on external variables (i.e. demographics, evaluations of behavioral outcomes, motivation to comply, etc.) (Ajzen 1991; Jansen et al., 2012; Petty and Wegener, 1998). Furthermore, the research would agree with the literature review presented in Chapter 2, particularly with Trumbo et al., 2016, Fox-Rogers et al., 2016, and Janssen et al., 2014 who state that people are not motivated to protect themselves from a risk based simply on awareness of the threat. The interviews and surveys increased awareness regarding the threat of cadmium;

however, only five out of the 39 growers were motivated to proactively protect themselves from the risk.

When asked about their likelihood of using the cadmium risk assessment model, 43.6% of the 39 growers stated that they definitely would use the tool with the mean response falling at 4.05 out of a 5-point Likert scale. While this was an optimistic prediction of grower behavior, the reality is that only five of the 39 growers actually did use the cadmium risk assessment tool throughout the duration of this study. An explanation for why intention did not align with end behavior can be offered on an opinion basis by the researcher; however, no follow up data was taken in order to provide an explanation based on research findings. One possible explanation is the period of time between when the in-person survey took place and when annual soil sampling by the grower normally takes place. On average, the growers in the impacted area conduct soil testing between the months of November and February. With most of the grower interviews being completed by the month of August, this left a significant length of time for the importance of getting an available soil cadmium test to be lost on the grower despite various follow up strategies. The researcher was aware that follow up reminders would be required in order to ensure grower follow through; these reminders were completed in the form of telephone calls, emails, and sections about cadmium testing in the monthly Teagasc Potato Newsletter. While many were grateful for the reminder and gave further statements of intention to engage with the cadmium risk assessment model, it is clear from the actual participation numbers that the intentions were not as strong as they appeared. It is possible that since the maximum level limits for cadmium in potatoes did not end up decreasing from 0.1 mg Cd/kg FW to 0.075 mg Cd/kg

FW, the growers did not feel that the risk of cadmium posed an urgent and/or imminent risk to their enterprise.

There were three types of risk assessment processes exhibited by the growers: cognitive assessment, affective assessment, and comparative assessment. Understanding how the grower perceives the risk of cadmium will not only help in understanding more of the farmer decision making process but also how the type of process used will determine the end behavior. In the example of cognitive risk assessment, the grower realized two very possible routes that the cadmium issue could take in the future. First, the grower was able to grasp that consumer behavior could be affected or marketing tactics of competitors could be used to deter consumers from buying potatoes grown in the high cadmium areas. Secondly, the grower was able to assess that in the near future, it will be possible that regulation will mandate that all growers have their cadmium levels measured in order to ensure that potatoes are not being grown on high risk soil. The second type of risk assessment behavior exhibited by the growers was affective assessment in which the grower took on an 'ignorance is bliss' attitude, and their assessment was clouded by the intuitive understanding of preemptive testing leading to consequences if cadmium levels were found to be exceeding the current minimum level. As it is not currently mandatory by EU regulation for growers to get their soil or end-product tested for cadmium, any action taken to do so would be considered voluntary. In the eyes of some growers, however, a voluntary action would be leaving their business vulnerable to penalties if a governing body were to uncover they had been growing produce destined for human consumption on a piece of land with known elevated levels of available cadmium. The example for the final type of risk assessment, comparative assessment, showed a grower who equivalated the current cadmium issue with any

other type of risks one may face on the farm, therefore, discarding any need for proactive action. In this way, the risk is not realized and yet another type of 'ignorance is bliss' attitude is displayed. When looking at the R.E.S.E.T model in Figure 1.9, one can see that there are five routes to behavioral change: regulation, education, social pressure, economic incentive, and tools. One way to get growers to view the risk of cadmium in a more serious light would be to change the regulation and to make getting a soil test with cadmium analysis done compulsory. However, this is not the current situation, so instead, we must rely on the other four routes to lead to behavioral change. The cadmium risk assessment model exists as the tool for growers to determine their risk level for cadmium. According to the R.E.S.E.T. model, to make progress towards the next step to behavioral change, one must have the provisions and means to attain such a tool. Provisions and means are needed to afford getting a soil test with an added cadmium analysis via a $CaCl_2$ extraction process. The cost of such a test is €23.90 before VAT[3] per soil sample at the laboratory where the researcher referred all participating growers. This is a low price to pay when considering a few fields, where one soil sample is taken per field; however, the research showed that 44.7% of the participating growers farmed over 100 hectares. This could mean that some growers will not justify the high price of a voluntary soil cadmium analysis unless they have sufficient means to do so along with many other costs associated with growing potatoes. Even if a grower does have the means to get their land tested for available cadmium, circumstances such as tenure type, time of year, potato variety being grown, etc. still need to be considered before reaching the final steps of the grower being externally motivated to carry out the behavior of engaging with the cadmium risk assessment model and volunteering to

[3] VAT (Value Added Tax) is a tax charged on common goods and services that are provided in Ireland

do so. In this study, only a handful of growers made it through this voluntary route with only five of the 39 growers deciding to engage with the cadmium risk assessment model.

The mean level of concern on grower's owned land and rented land were found to be only marginally different from the in-person surveys, however, the qualitative data from the in-person interview revealed a larger difference between concern level and tenure type. There was a very strong, positive correlation (at a 0.01 significance level) between the level of concern a grower had on their owned land and their perceived likelihood of using mitigation strategies if cadmium levels were found to be high but still under the current ML of 0.1mg Cd/kg FW potatoes. In other words, if a grower had a high degree of concern for their owned land, they would be more likely to begin mitigation strategies even if their soil risk index came back elevated (i.e. the light orange and dark orange indexes) but still estimated to be under the current ML. A similar correlation was found between concern on rented land and likelihood of implementing mitigation strategies if estimated tuber Cd levels were high but still within the current ML; however, it was at a 0.05 significance level. These are very important findings because the medium soil risk index category is the most difficult to provide advice for. One can either view the medium category with a 'glass half full' or a 'glass half empty' attitude, seeing as though it is equidistant from both the higher soil risk indexes (i.e. dark orange and red) and the lower soil risk indexes (i.e. dark green and light green). The results have shown that the majority of the potato growers interviewed for this study would rather error on the side of caution when it comes to dealing with the risk of cadmium on both their owned and rented land. Nevertheless, there will still be growers that take on the 'glass half full' opinion. It is very important to help growers avoid this type of 'in the clear' attitude. The estimated tuber Cd value has a high confidence value;

however, as with all model estimates, there is always a degree of uncertainty. This degree of uncertainty along with the known variability of cadmium at the field level could mean that the grower's risk for cadmium could actually be higher than the model predicts.

Finally, a main source of concern for many of the growers was fear of the unknown. Before the in-person interview with the researcher, a few of the growers had never even heard of the cadmium issue, while most had maybe heard of the issue in the past but could not claim any passable knowledge on the subject. Without the knowledge to allow for a full understanding of the risks involved, there is a greater chance of one either overestimating or underestimating the possible implications. Therein lies the importance of consistent knowledge transfer messages in regard to this issue along with ongoing follow through to ensure that growers stay engaged and receive the most up to date information

There was a wide range of proactivity levels identified in both the qualitative and quantitative data. During the in-person interviews, there were many growers that expressed great intentions to be proactive and interact with the cadmium issue, but there were also a few that did not want the possible risk of cadmium to influence their decision to use an otherwise perfectly good field. Proactivity is negatively influenced by the grower's inability to recognize the real risks involved in growing potatoes in a field with high levels of available cadmium.

Grower proactivity was evidenced through the very strong positive correlation (at the 0.01 significance level) between a grower's likelihood of using the cadmium risk assessment model and their likelihood of using mitigation strategies if the model came back with a medium soil risk index that was at the upper end of the scale (i.e. reaching close to the high soil risk index). This result shows that if a grower is willing and able to be proactive in one matter of this risk, they are

likely to be proactive in other ways as well. Engaging with the cadmium risk assessment model is already a form of proactiveness due to its current voluntary nature. Likewise, a grower is being proactive when they are taking actions to lower their soil cadmium levels to reduce their risk of cadmium even further even though they are technically following all ML requirements.

According to the Theory of Reasoned Action (TRA) in Figure 1.10, an individual's intention to act on a certain behavior can be a good measure of predicting whether that individual will act on that behavior or not (Fishbein and Ajzen, 1975; Ajzen, 1991). In this case, the strong correlation between two proactive behaviors indicates that the intention to act is present. Even still, one must factor into account the various external variables (i.e. demographic), beliefs (i.e. normative and behavioral), and attitude of the individual to gauge the planned behavior accurately.

Other than remediating the soil with treatments like applications of organic matter in the form of spent mushroom compost, brown bin waste, or chicken manure, the mitigation strategies for cadmium require a large degree of flexibility in terms of management strategies. For many of these farmers, growing potatoes has been a part of their family's history for generations. Furthermore, many choose to grow a popular variety like Rooster for its consistent market demand. As shown in Figure 1.14, Rooster is one of the highest cadmium accumulators out of the other varieties grown in Ireland. If a grower were to receive results like the results displayed in Table 4.6, the only advice given to the grower is to change the crop completely for that field. If a grower were to continue to plant potatoes in that field, they would be willingly taking on the risk of their potatoes having levels of cadmium that exceed the current ML. Other more serious mitigation strategies include changing to a variety that uptakes cadmium less readily like other popular Irish varieties such as Cultra and Maris Piper (reference Figure 1.14). Many growers had

changed varieties previously in response to market demands; however, a few communicated that the issue of cadmium would not be a compelling reason to switch to a different variety. According to data analyzed in 2019 by Kantar Worldpanel Ireland[4], Rooster makes up 59.9% of sales in the Irish market. According to that same set of data, however, other whites such as Cultra were also performing strongly at 19.3% of market demand. When looking at the domestic potato market report published in May 2020 by the Irish Farmers' Association (IFA), showed that a box of Rooster (equivalent to about 100 kg) could be sold for the same average price of a box of Cultra or another white variety at an average price of €350. At the 2020 National Potato Conference that took place in Dublin, the Consumer Insight Director of Kantar Worldpanel presented that while Roosters are still growing in the market in terms of number of trips consumers take to purchase the variety and price, the variety Maris Piper has been the variety winning new shoppers. This all goes to show that while growers might not change the primary variety they grow for the sake of mitigating their risk to cadmium, they will respond to market changes. From recent market data, it shows that growers stand to profit from growing other varieties like Cultra and Maris Piper, which just so happen to be low cadmium accumulating varieties.

Another mitigation strategy is considering the land and tenure type when planning where the potato crop will be planted in any given season. Case Study II illustrated that soil remediation on short term rental is virtually impossible, and only mitigation strategies such as a crop change or cultivar selection are possible. The majority of growers stated that they have at least some type

[4] Kantar Worldpanel Ireland uses advanced analytics and continuous monitoring of a consumer panel made up of 5,000 Irish households that together provide a representative source of consumer behavior toward fast-moving consumer goods in the market.

of short-term rental. In this way, it is very important that the growers find land that they intend on renting on a short-term basis that has naturally low levels of available cadmium already. Getting a soil test with a cadmium analysis done prior to purchase is the only way a grower can ensure that the land is low risk. While a few of the growers who primarily farm in Counties Meath and Kildare stated that this would be possible if the turnaround time for results was expeditious, others, primarily those who farm in Dublin, stated that this would not be possible due to the heavy competition for land.

Making the Decision to Engage with the DST

Engagement from the 39 potato growers with the cadmium risk assessment model was disappointingly low. That being said, the case studies of the three growers who did end up engaging with the cadmium risk assessment model can be viewed as the piloting stage of the decision support tool for all intents and purposes. As these were the first growers in the impacted area to not only interact with the cadmium risk assessment model but also get a soil test with an added available cadmium test, their experiences hold crucial narratives to help better understand farmer attitudes and their decision-making process. Their opinions on what worked and what did not throughout the process will be useful for future marketing of the tool to other growers in the future.

The Theory of Uptake and Use of DST in Agriculture (Figure 1.11) shows that a dynamic relationship between modifying factors (i.e. age, scale of business, and farming type), core factors (i.e. peer recommendation, trust, cost), driving factors (i.e. compliance and marketing) and the enabling factor of facilitating conditions all play a role in not only the uptake of the DST but the actual use of the tool. The most interesting of the elements involved in this theory for this

specific case would be the enabling factor facilitating conditions. Engaging with the cadmium risk assessment tool entails engaging with a process. The process begins with the grower or advisor collecting samples of soil that will be analyzed for available cadmium. The grower or advisor will then appropriately label each box and include contact information before mailing off the samples to the only lab in Ireland that has agreed to work with the overall CREDIT project and has the capability to accurately test for available cadmium. It is at this point that the process falls almost entirely into the laboratories hands and timing of results depends heavily on the laboratories capacity. After the samples are testing for available cadmium along with the other elements required to run the cadmium risk assessment model (i.e. K, Mg, Mn, P, and Zn), the results should be sent to both the farmer and a researcher at Teagasc Oak Park in County Carlow, Ireland who is the sole individual in charge of running the model and producing a soil risk index for the grower. In all of the case studies, the process failed at two critical points: the samples being run by the lab and the raw results being sent to the researcher in possession of the model. Both of these collapses in the process resulted in significant time delays of delivering the results of the grower's cadmium risk assessment. Some of the samples taken by the growers involved in the case studies were from already purchased or in the process of being purchased short term rentals that they planned on planting potatoes in for the 2020 growing season. The delay in the delivery of results, sometimes upwards of several months, defeated the purpose of the grower getting the test done in the first place. In other words, the results provided no benefit to the grower as short term remediation is ineffective and/or the grower would have been forced to purchase the land seeing as though they had no reason not to at the time. Other tasks within the wider CREDIT Project have the ability to solve this issue by providing rapid detection technologies for heavy metals. Project teams at Technological University Dublin (TUD) in Co.

Dublin, Ireland and Letterkenny Institute of Technology (LyIT) in Co. Donegal, Ireland are in the process of developing spectroscopic tools for heavy metal detection and electrochemical sensors for the detection of cadmium. If successful, this would allow for the rapid detection of cadmium and reduce the need for long wait times for lab results.

The modifying factors included in the Theory of Uptake and Use of DST in Agriculture does not add much insight in the context of this study. There was a good range of ages and farm sizes across the individuals who engaged with the cadmium risk assessment model. This finding disagrees with studies like ones conducted by Tudor et al. (2013) and Van Winsen et al. (2016) that state that individuals most likely to utilize risk management tools would be young males with large farm sizes. Furthermore, the farming type would have been the same for all participants since the focus of the research was on potato growers. Finally, IT education would be irrelevant seeing as though no IT is required for the use of this DST. All of that being said, core factors can be discussed in relation to the uptake and use of the DST.

Trust is a core factor involved in a grower's pathway to the uptake and use of a DST. As discussed in section 2.4, trust influences how an individual perceives and responds to a risk. As this was the first set of potato growers in the impacted area to engage with the cadmium risk assessment model, a large degree of trust was placed by those growers in both the research and researchers involved with the model. The growers did not have peer recommendations to base their decisions off of. Instead, their experiences will now act as the peer recommendation factor for the next growers who choose to engage or not engage with the model. Unfortunately, most of the growers in the case studies were either adamant about their intentions to not recommend the process to another grower or only somewhat likely to provide a positive peer recommendation.

This will likely have a significant impact on the level of uptake and use from other growers in the future. Alas, this goes against Foloress et al.'s (2017) statements that pro-social variables can have a stronger influence on the farmer-decision making process than economic incentives or disincentives. With the majority of the growers who interacted with the DST having negative experiences, pro-social variables cannot be relied on to promote the use of the DST, so it is likely that economic incentives or disincentives will be required to increase uptake and use. It should be of note, however, that some literature warn against the use of economic means of persuasion due to the decreased likelihood of them being accepted by business-oriented farmers (Malawska et al., 2014; Foloress et al., 2017).

In the in-person interviews and surveys, most growers were surprised to learn how cost effective the soil test with a cadmium analysis is. In the survey, the majority of respondents stated that they would have thought a cadmium analysis would be significantly more expensive than a generic soil test. Furthermore, none of the growers in the case studies stated that the price of the test was anything but fair. That being said, the cost effectiveness of the test becomes an irrelevant benefit when seeing how long the process of getting end results took. If a grower is having to wait months to receive their cadmium risk results and possibly be put in a situation where they have to move ahead with rental decisions or even planting, the results lose their value. This failure in the system is going to cause a lack of trust with the grower and make them less likely to get the test done again in the future and/or recommend the test to another grower in the impacted area. The process must be expedited in the future to justify cost, increase trust, and improve the likelihood of peer recommendation.

5.3 AGRONOMISTS AND RISK ASSESSMENT

Interviews with the agronomists working in the impacted area revealed a low level of familiarity around the cadmium issue and its possible implications for the potato industry. Many revealed that there has been no action taken due to their low level of familiarity surrounding the entire subject matter. If the agronomist does not have enough knowledge to address the issue and risk with their clients appropriately and do not feel equipped to offer associated advice, little or no action will be taken by that agronomist. That being said, many of the agronomists stated that they were aware of what cadmium is and the sources of the element in Ireland. This means that while they had the knowledge to address the issue and risk with their clients, they have chosen not to do so. This could be due to a lack of understanding in regard to the regulatory aspect of the risk or a lack of information surrounding any mitigation strategies for soil remediation, cultivar selection, or tenure type decisions. Differences in education levels between the agronomists was observed, with only two of the seven agronomists holding Ordinary Bachelor's degrees in an agricultural field. Education level did not correlate to a higher degree of familiarity, however, so there is a need to implement learning material on heavy metal contamination, EU regulatory aspects of this issue, and soil remediation practices in third-level agricultural education in Ireland. It would also be useful to incorporate lessons on emerging problems in the tillage sector along with changes in policy and legislation into Continuous Professional Development (CPD) programs for agronomists and advisors working closely with the horticultural sector. Making these courses mandatory or providing incentives for added qualifications or certifications would encourage those that might not be interested otherwise. Extending and perfecting the agricultural knowledge and innovation support system (AKIS) to the agronomists whose advice is taken

seriously by the potato growers in the impacted area will improve the communication pathways and ensure that all stakeholders are on the same page.

This lack of knowledge or lack of confidence on the topic can speak to why there has been very little action and advice given by agronomists working with the potato growers in the impacted area in regard to cadmium mitigation. While there is room for some degree of collaborative learning between farmers and agronomists in this situation as Hansen et al. (2018) and Ingram, 2008) recommend, the agronomist still needs to be a source of expertise for the grower. This is a perfect example of the agronomist having the opportunity to provide knowledgeable, adaptable, and relevant advice to the grower that will boost the power of their advisory services while also fostering a relationship of trust and collaboration with their client.

The researcher observed in the agronomist's interviews that some individuals, much like some of the growers, took an 'ignorance is bliss' stance to the risk of cadmium in the potato growing industry. By placing the blame on the regulatory bodies and ignoring the real possible implications that this risk poses to those working and relying on the industry for a livelihood, these agronomists are possibly exacerbating the risk by downgrading the danger of cadmium to their clients. This is especially concerning as these agronomists are regarded as experts and trustworthy sources of information to their clients, so their opinions hold a great deal of weight in the potato growing community.

5.4 UTILITY

Various individuals, organizations, and companies will benefit from this research study as a large number of Irish potato growers and processors reside in the Northeast where levels of cadmium

are reaching concerning levels. By using a reliable model informed by quality research, growers can feel confident about the standard of results they receive. This study has also worked one-on-one with the majority of the at-risk potato growers in order to safeguard the potato industry from increased cadmium contamination. While initial uptake and use of the cadmium risk assessment model was low, the study ensured that growers working in the impacted area are aware of their options and how they can determine their risk of cadmium in the future.

Besides the commercial bodies that will benefit, other researchers seeking to understand farmer attitudes towards DSTs and their decision-making processes regarding managing risk will also gain from the findings of this study. This project has components dealing with themes of uncertainty, negative messages, and many others that are applicable to not only tillage but also dairy and drystock sectors. This research offers insights into understanding the best practice of communicating unpalatable messages to farmers in a way that allows them to see the best possible outcomes so that the message is at least somewhat welcomed, wanted, and accepted by the farmer. Previous Knowledge Transfer (KT) messages were delivered to help farmers increase production, efficiency, and profitability. In this case of cadmium, farmers are being asked to undertake risk assessment and mitigation methods to remain standing still in a way. While some of the mitigation strategies such as addition of organic matter may lead to increased soil fertility and possible increase in yields, these results cannot be confirmed. Furthermore, these methods may not be easy or convenient at the farm level.

While this case is very much focused on the potato industry, it is important to note the broader impact that this research has in the agriculture sector. Uncertainty and negative messages are found not only in the tillage sector but also the dairy and drystock industries. This research can

be used as a guide for further research into those themes in those sectors along with other recommended future research that will be discussed in the next section.

5.7 FUTURE RESEARCH

There is a need for studies to be conducted on the risk of cadmium for other tillage crops, especially in the horticultural sector. Potatoes are not the only crop that readily uptakes cadmium into the part of the plant grown for consumers. Leafy brassicas and leafy greens are some examples of crops that uptake cadmium at an even higher rate than some of the higher risk potato varieties. While there are not a large number of these types of growers in Ireland, especially in the impacted area, they have a right to know their risk of cadmium and the possible implications it could have on their businesses.

More research is also needed on negative knowledge transfer messages in the agricultural sector. Most knowledge transfer or exchange efforts are focused on positive messages such as increasing yields and profits. In these ever-changing times, negative messages like the risk of cadmium will become more frequent. The agricultural sector must be equipped with the knowledge and understanding of how to communicate the message to the growers in a way that is coherently received and logically assessed.

5.8 SUMMARY & FINAL RECOMMENDATIONS

From the research, it is clear that there is a knowledge gap within the potato growing community about the severity and possible implications of high cadmium levels in soils. The findings also raise the question of whether using the ‘carrot’ or ‘stick’ approach is the best way to farmer or agronomist’s usage of a DST. These groups will use a DST if they are required to by legislation

or market requirements, such as complying with EU maximum level requirements. This would mean that mandating the use of the cadmium risk assessment model is the quickest route to uptake. However, such methods are extreme and risk alienating a set of end users that already feel the strain of adhering to the many regulations found in the tillage sector. An alternative is to incentivize use, perhaps through financial incentives, such as grants or subsidies to help the growers cover the cost of the soil analysis necessary to engage with the DST. This researcher recommends a combination of the strategies found in the R.E.S.E.T model in Figure 1.9. This would mean the use of a suite of supports including regulation, education, social pressure, economic incentives/disincentives, and tools to catalyze a behavioral change and support the adoption of a best practice. The risk of cadmium is not leaving the potato sector; it cannot be ignored and will impact the industry in one way or another in the very near future. Growers and agronomists can either make the choice to be proactive and make decisions to mitigate the risk or they can choose to ignore the risk until it is too late. Knowledge transfer and exchange efforts must continue within the potato growing community and beyond in order to ensure that consistent and up-to-date information is being disseminated as changes in legislation continue to be discussed and effective mitigation strategies continue to be trialed and tested at the farm level.

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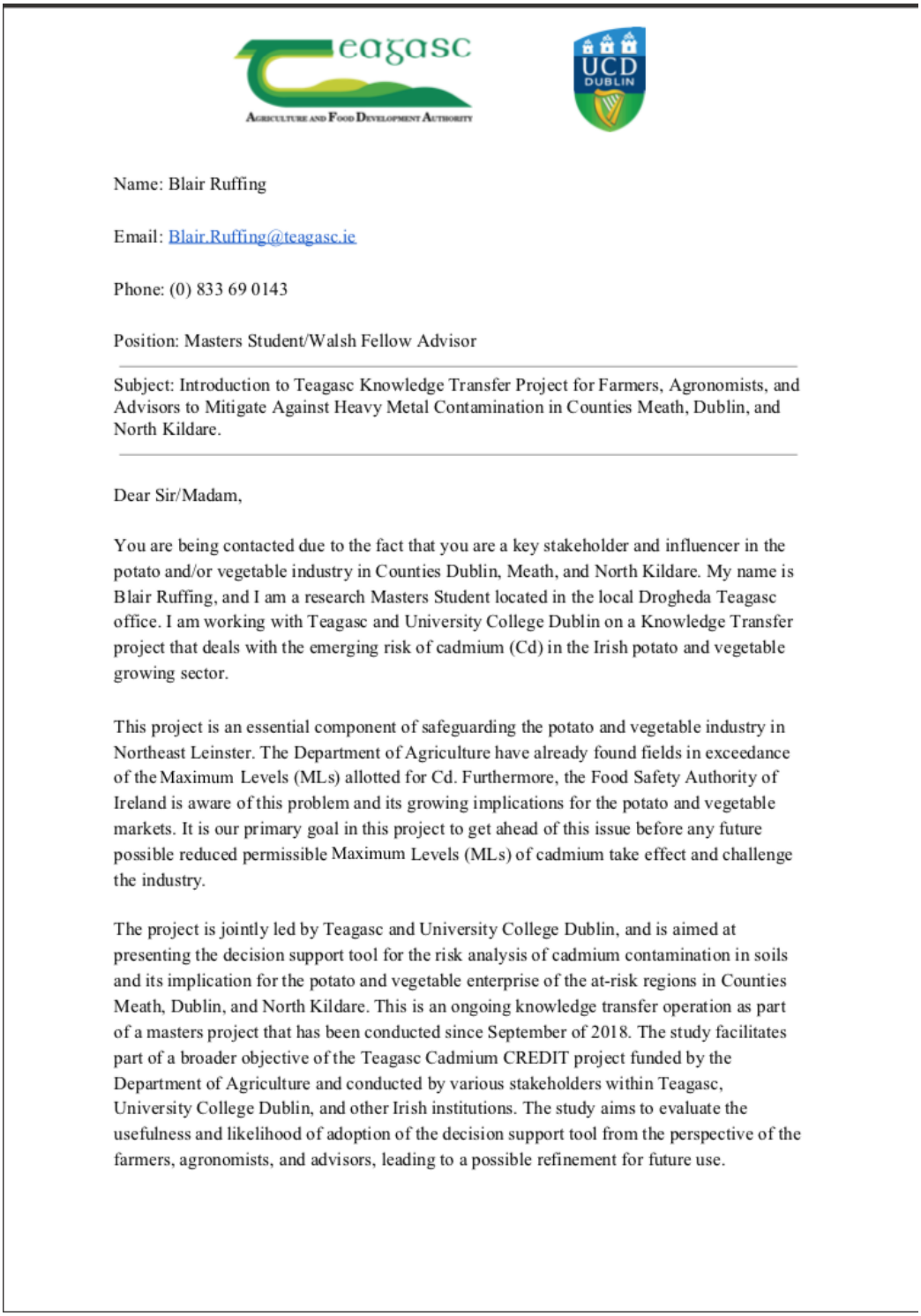
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APPENDIX



Name: Blair Ruffing

Email: Blair.Ruffing@teagasc.ie

Phone: (0) 833 69 0143

Position: Masters Student/Walsh Fellow Advisor

Subject: Introduction to Teagasc Knowledge Transfer Project for Farmers, Agronomists, and Advisors to Mitigate Against Heavy Metal Contamination in Counties Meath, Dublin, and North Kildare.

Dear Sir/Madam,

You are being contacted due to the fact that you are a key stakeholder and influencer in the potato and/or vegetable industry in Counties Dublin, Meath, and North Kildare. My name is Blair Ruffing, and I am a research Masters Student located in the local Drogheda Teagasc office. I am working with Teagasc and University College Dublin on a Knowledge Transfer project that deals with the emerging risk of cadmium (Cd) in the Irish potato and vegetable growing sector.

This project is an essential component of safeguarding the potato and vegetable industry in Northeast Leinster. The Department of Agriculture have already found fields in exceedance of the Maximum Levels (MLs) allotted for Cd. Furthermore, the Food Safety Authority of Ireland is aware of this problem and its growing implications for the potato and vegetable markets. It is our primary goal in this project to get ahead of this issue before any future possible reduced permissible Maximum Levels (MLs) of cadmium take effect and challenge the industry.

The project is jointly led by Teagasc and University College Dublin, and is aimed at presenting the decision support tool for the risk analysis of cadmium contamination in soils and its implication for the potato and vegetable enterprise of the at-risk regions in Counties Meath, Dublin, and North Kildare. This is an ongoing knowledge transfer operation as part of a masters project that has been conducted since September of 2018. The study facilitates part of a broader objective of the Teagasc Cadmium CREDIT project funded by the Department of Agriculture and conducted by various stakeholders within Teagasc, University College Dublin, and other Irish institutions. The study aims to evaluate the usefulness and likelihood of adoption of the decision support tool from the perspective of the farmers, agronomists, and advisors, leading to a possible refinement for future use.

Figure A 1 Invitation letter to participate in potato grower survey (page 1 of 2)

As a key stakeholder in the industry, your opinions are considered to be crucial to the discussions on the outcomes of the assessment study and the way forward. In the coming months, it is likely you will be invited to participate in one-on-one interviews and Knowledge Transfer workshops relating to the cadmium issue. Your decision whether or not to participate will not prejudice your future relationships with other growers or members of the industry. If you decide to participate, you are free to discontinue participation at any time without prejudice. Furthermore, any information that is obtained in connection with this study and that can be identified with you will remain confidential and will not be disclosed.

Please feel free to contact me, Blair Ruffing, at Blair.Ruffing@teagasc.ie if you require or desire any additional information.

I very much look forward to collaborating with you on this project and working together to future proof this important industry.

Yours Sincerely,

Blair Ruffing

Blair Ruffing
Teagasc | Walsh Fellow | Drogheda
UCD School of Agriculture and Food Science MAIS Student
T: 0833690143
E: Blair.Ruffing@teagasc.ie

Questionnaire Ref. No: ____

Participant Consent Form

"Advisory & KT Tools and Processes to support potato farmers and agronomists to assess their exposure to risk of cadmium"

• I ..... voluntarily agree to participate in this research study.

• 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 I have had the opportunity to ask questions about the study.

• I understand that participation involves providing answers and opinions relating to general and specific topics in relation to the agriculture sector and my own enterprise.

• 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 the following platforms: thesis, conference presentations, published papers.

• I understand that if I inform the researcher that myself or someone else is at risk of harm they may have to report this to the relevant authorities - they will discuss this with me first but may be required to report with or without my permission.

• I understand that signed consent forms and original audio recordings will be retained in the primary researchers private desktop that is protected by a unique username and password that is only known by the primary researcher until the exam board confirms the results of the primary researchers thesis.

Figure A 2 Participant Consent Form (page 1 of 2)

Questionnaire Ref. No: ____

• I understand that a transcript of my interview in which all identifying information has been removed will be retained until the exam board confirms the results of the primary researchers thesis.

• I understand that under freedom of information legalisation I am entitled to access the information I have provided at any time while it is in storage as specified above.

• I understand that I am free to contact any of the people involved in the research to seek further clarification and information.

Contact details:

Primary Researcher: Blair Ruffing

Degree: MAgrSc Innovation Support Programme

Affiliations: UCD and Teagasc

Primary Researcher Email: Blair.Ruffing@teagasc.ie

Primary Researcher Mobile: 0833690143

UCD Supervisor: Dr. Monica Gorman
Phone: 017167768
Email: monica.gorman@ucd.ie

Teagasc Supervisor: Shay Phelan
Phone: 0877985195
Email: shay.phelan@teagasc.ie

Teagasc Supervisor: Stephen Alexander
Phone: 0876273888
Email: Stephen.Alexander@teagasc.ie

Signature and **date** of research participant

_____/_____/2019

Signature and **date** of researcher

I believe the participant is giving informed consent to participate in this study

---

_____/_____/2019

Table A 1 Coding Key for Grower Survey

Question Number	Variable Name	Variable Description	Value Labels
	ID	Questionnaire number	Enter number
1	Var001	County where farm is located	1= Dublin, 2= Meath, 3= Kildare, 4= Other
2	Var002	Farm size	1= ≤20, 2=21-40, 3=41-60, 4=61-80, 5=81-99, 6= ≥100
3	Var003	Main Crop Type	1= Potatoes, 2= Carrots, 3= Spinach, 4= Lettuce, 5= Cabbage, 6= Broccoli, 7= Celery, 8= Cereals, 9= Cauliflower, 10= Other
4	Var004	Secondary Crop Type	1= Potatoes, 2= Carrots, 3= Spinach, 4= Lettuce, 5= Cabbage, 6= Broccoli, 7= Celery, 8= Cereals, 9= Cauliflower, 10= Other
5	Var005	Tenure Type	1= owned, 2= medium term lease, 3= conacre, 4= all of the above, 5= mixture
6	Var006	Main Variety Grown	1= Rooster, 2= Lady Rosetta, 3= British Queen, 4= Markies, 5= Maris Piper, 6= Kerr's Pink, 7= Cara, 8= Premiere, 9= Casa Blanca, 10= Cultra, 11= Saturna, 12= Other

7	Var007	Secondary Variety	1= Rooster, 2= Lady Rosetta, 3= British Queen, 4= Markies, 5= Maris Piper, 6= Kerr's Pink, 7= Cara, 8= Premiere, 9= Casa Blanca, 10= Cultra, 11= Saturna, 12= Other
8	Var008	Primary Market Type	1= Chipping, 2= Crisp, 3= Salads, 4= Wholesale 5= Processing, 6= Yard
9	Var009	Secondary Market Type	1= Chipping, 2= Crisp, 3= Salads, 4= Wholesale 5= Processing, 6= Yard
10	Var010	Age range	1= ≤ 20 years old, 2= between 21-40, 3= between 41-50, 4= between 51-59 years old, 5= ≥ 60 years old
11	Var011	Education Level	1= Leaving Certificate, 2= Bachelor's Degree, 3= Green Cert and/or Level 5/6, 4= Master's Degree, 5= Doctorate Degree; 6= Other
12	Var012	Familiarity with toxic metal contamination	1= not familiar at all, 2= have heard of the issue, 3= passable knowledge of the subject, 4= enough knowledge to explain to someone else 5= proficient knowledge
13	Var013	Familiarity with toxic metal contamination in Northeast	1= not familiar at all, 2= have heard of the issue, 3= passable knowledge of the subject, 4= enough knowledge to explain to someone else 5= proficient knowledge

14	Var014	Level of concern on own land	1=not concerned at all, 2= slightly concerned, 3= neither/nor, 4= very concerned, 5= extremely concerned
15	Var015	Level of concern on rented land	1=not concerned at all, 2= slightly concerned, 3= neither/nor, 4= very concerned, 5= extremely concerned
16	Var016	Likelihood of using soil risk assessment tool	1= no chance, 2= slight chance, 3= good/moderate chance, 4= very good chance, 5= definitely will use
17	Var017	Likelihood of using mitigation strategies if Cd contamination high	1= no chance, 2= slight chance, 3= good/moderate chance, 4= very good chance, 5= definitely will use
18	Var018	Likelihood of using mitigation strategies if Cd is high but within ML	1= no chance, 2= slight chance, 3= good/moderate chance, 4= very good chance, 5= definitely will use
19	Var019	Likelihood of using mitigation strategies of Cd is high and exceeding	1= no chance, 2= slight chance, 3= good/moderate chance, 4= very good chance, 5= definitely will use
20	Var020	Regularly conduct soil testing	1= Yes, 2= No
21	Var021	Purchase of soil test with soil Cd level	1= Yes, 2= No

22	Var022	Presume that Cd test is expensive	1=Yes, 2= No
23	Var023	Use of DST in past to aid in risk management	1= Yes, 2= No
24	Var024	Knowledge of OM as MS	1= Yes, 2= No
	Var025	Use of OM on farm in general	1= Yes, 2= No
	Var026	Use of OM for Cd mitigation	1= Yes, 2= No
	Var027	Knowledge of lime as MS	1= Yes, 2= No
	Var028	Use of lime on farm in general	1= Yes, 2= No
	Var029	Use of lime for Cd mitigation	1= Yes, 2= No
	Var030	Knowledge of zinc fertilizer as MS	1= Yes, 2= No
	Var031	Use of zinc fertilizer on farm in general	1= Yes, 2= No
	Var032	Use of zinc fertilizer for Cd mitigation	1= Yes, 2= No

	Var033	Knowledge of low cadmium fertilizers as MS	1= Yes, 2= No
	Var034	Use of low cadmium fertilizers on farm in general	1= Yes, 2= No
	Var035	Use of low cadmium fertilizers for Cd mitigation	1= Yes, 2= No
	Var036	Knowledge of zinc sulphate as MS	1= Yes, 2= No
	Var037	Use of zinc sulphate on farm in general	1= Yes, 2= No
	Var038	Use of zinc sulphate as Cd MS	1= Yes, 2= No
	Var039	Knowledge of changing varieties as MS	1= Yes, 2= No
	Var040	Use of changing varieties on farm in general	1= Yes, 2= No
	Var041	Use of changing varieties for Cd mitigation	1= Yes, 2= No
	Var042	Knowledge of changing crop as MS	1= Yes, 2= No

	Var043	Use of changing crop on farm in general	1= Yes, 2= No
	Var044	Use of changing crop for Cd mitigation	1= Yes, 2= No
25	Var045	Participate in Cd workshop	1= Yes, 2= No
26	Var046	Press satisfaction buttons	1= Yes, 2= No
27	Var047	Trust in scientific data	1= Yes, 2= No
28	Var048	Which statement agree with most	1= Dep should regularly test farms, 2= Dep should communicate with Teagasc advisors when exceedances, 3= Dep should trust farmer to manage land, 4= Dep should never test
29	Var049	Which statement agree with most	1= my business is a private matter, 2= share information with competitors, 3= only share if competitor has shared issue, 4= share with advisor
30	Var050	Where do you get majority of information	1= Teagasc advisor, 2= private advisor, 3= agronomist, 4= family, 5= internet, 6= other
31	Var051	Mark all DSTs used in last 5 years	1= E-Profit Monitoring, 2= NMP Online, 3= Seed Rate Calculator, 4= Weed Spotters, 5= Crop Yield Calculators, 6= Other

32	Var052	3 sources of information	1= Weather Reports, 2= advisor, 3= agronomist, 4= neighbors, 5= family, 6= other

Table A 2 Coding Key for Agronomist Survey

Question Number	Variable Name	Variable Description	Value Labels
	ID	Questionnaire number	Enter number
1	Var001	Organisation	Enter Value
2	Var002	Age	Enter Value
3	Var003	Highest level of education completed	Enter value
4	Var004	Main County Advised	Enter Value
5	Var005	Secondary Counties	Enter Values
6	Var006	Main crop type dealt with	Enter Value

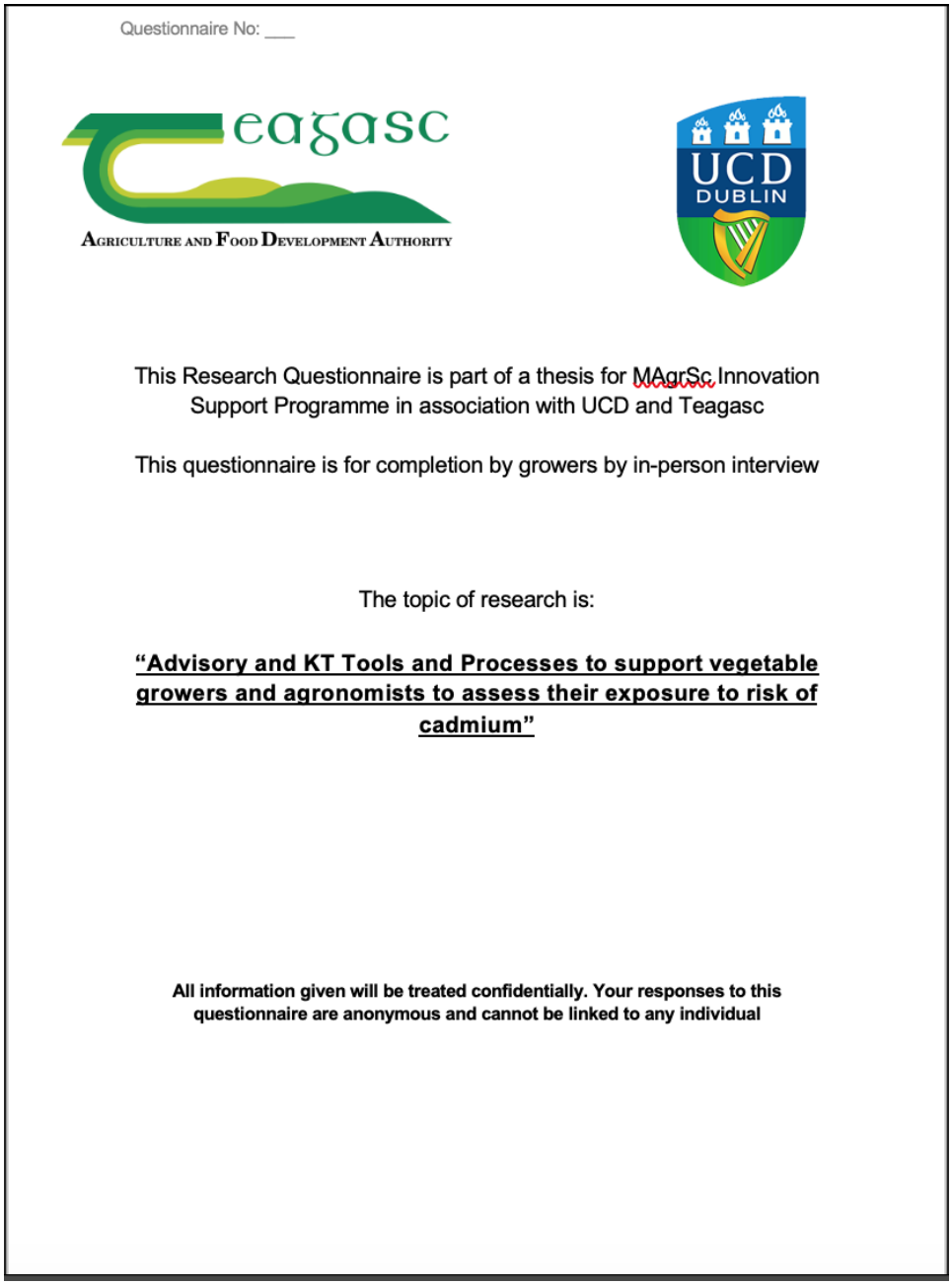
7	Var007	Secondary crops dealt with	Enter Value
8	Var008	Main variety of potatoes dealt with	Enter Value
9	Var009	Secondary varieties dealt with	Enter value
10	Var0010	Primary market type of clients	Enter value
11	Var011	Secondary market types of clients	Enter value
12	Var012	Familiarity with toxic metal contamination	1= not familiar at all, 2= have heard of the issue, 3= passable knowledge of the subject, 4= enough knowledge to explain to someone else 5= proficient knowledge
13	Var013	Familiarity with toxic metal contamination in Northeast	1= not familiar at all, 2= have heard of the issue, 3= passable knowledge of the subject, 4= enough knowledge to explain to someone else 5= proficient knowledge

14	Var014	Level of concern on client's owned land	1=not concerned at all, 2= slightly concerned, 3= neither/nor, 4= very concerned, 5= extremely concerned
15	Var015	Level of concern on client's rented land	1=not concerned at all, 2= slightly concerned, 3= neither/nor, 4= very concerned, 5= extremely concerned
16	Var016	Likelihood of using soil risk assessment tool for clients	1= no chance, 2= slight chance, 3= good/moderate chance, 4= very good chance, 5= definitely will use
17	Var017	Likelihood of recommending mitigation strategies to clients if Cd contamination high	1= no chance, 2= slight chance, 3= good/moderate chance, 4= very good chance, 5= definitely will use
18	Var018	Likelihood of recommending mitigation strategies to clients if Cd is high but within ML	1= no chance, 2= slight chance, 3= good/moderate chance, 4= very good chance, 5= definitely will use
19	Var019	Regularly conduct soil testing on clients land	1= Yes, 2= No
20	Var020	Conducted a soil test with soil Cd level	1= Yes, 2= No
21	Var021	Presume that Cd test is expensive	1=Yes, 2= No
22	Var022	Use of DST in past to aid in risk management for clients	1= Yes, 2= No

23	Var023	Past history of recommending mitigation strategies on client farms	1= Yes, 2= No
24	Var024	Knowledge of OM as MS	1= Yes, 2= No
	Var025	Past recommendation to clients for OM for Cd mitigation	1= Yes, 2= No
	Var026	Knowledge of lime as MS	1= Yes, 2= No
	Var027	Past recommendation to clients for use of lime for Cd mitigation	1= Yes, 2= No
	Var028	Knowledge of zinc fertilizer as MS	1= Yes, 2= No
	Var029	Past recommendation to clients for use of zinc fertilizer for Cd mitigation	1= Yes, 2= No
	Var030	Knowledge of low cadmium fertilizers as MS	1= Yes, 2= No
	Var031	Past recommendation to clients for use of low cadmium fertilizers for Cd mitigation	1= Yes, 2= No

	Var032	Knowledge of zinc sulphate as MS	1= Yes, 2= No
	Var033	Past recommendation to clients for use of zinc sulphate as Cd MS	1= Yes, 2= No
	Var034	Knowledge of changing varieties as MS	1= Yes, 2= No
	Var035	Past recommendation to clients for use of changing varieties for Cd mitigation	1= Yes, 2= No
	Var036	Knowledge of changing crop as MS	1= Yes, 2= No
	Var037	Past recommendation to clients for use of changing crop for Cd mitigation	1= Yes, 2= No
25	Var038	Participate in Cd workshop	1= Yes, 2= No
26	Var039	Client's awareness of issue	Enter value
27	Var040	Client's concern of issue	Enter value

28	Var041	Agronomist or organisation's current actions towards issue	Enter value
29	Var042	Current advice given to clients about issue	Enter value
30	Var043	Intention to provide advice given on issue	Enter value



Questionnaire No: ___

Teagasc

AGRICULTURE AND FOOD DEVELOPMENT AUTHORITY

UCD DUBLIN

This Research Questionnaire is part of a thesis for MAgrSc Innovation Support Programme in association with UCD and Teagasc

This questionnaire is for completion by growers by in-person interview

The topic of research is:

"Advisory and KT Tools and Processes to support vegetable growers and agronomists to assess their exposure to risk of cadmium"

All information given will be treated confidentially. Your responses to this questionnaire are anonymous and cannot be linked to any individual

Figure A 3 Copy of grower survey given to potato growers during in-person interviews (page 1 of 5

Questionnaire No: ___

Preliminary Survey for Vegetable Growers in Northeast Leinster

County where farm(s) is located (Check all that apply): ☐ Meath ☐ Kildare ☐ Dublin ☐ Other: _____

Farm size (ac): _____

Main crop type: _____

Secondary crop type: _____

Tenure type (check all that apply): ☐ owned ☐medium term lease (1-3 years) ☐long term lease (3+ years) ☐conacre ☐mixture ☐other _____

Main Variety Grown: _____

Secondary Variety? _____

Primary Market Type: _____

Secondary Market Type: _____

Age of Interviewee: _____

Highest level of education completed by interviewee: _____

Rate yourself for the following questions on a scale of 1-5 (1 meaning not at all and 5 meaning extremely)

3. How familiar are you with the topic of toxic metal contamination in soils?

1 2 3 4 5

4. How familiar are you with the topic of cadmium contamination in soils in the Northeast of Ireland?

1 2 3 4 5

5. How concerned are you regarding the risk of cadmium contamination in regards to your production on your owned land (if applicable)?

1 2 3 4 5

Questionnaire No: ___

6. How concerned are you regarding the risk of cadmium contamination in regards to your production on your rented land (if applicable)?

1 2 3 4 5

7. How likely would you be to use a Decision Support Tool (DST) like the soil risk assessment tool to help assess your risk to cadmium?

1 2 3 4 5

8. How likely would you be to begin mitigation strategies if the soil risk assessment tool determined that your risk for cadmium contamination was high?

1 2 3 4 5

9. How likely would you be to begin mitigation strategies if the soil risk assessment tool determined that your risk for cadmium contamination was high but still within existing EU Maximum Limits (MLs)?

1 2 3 4 5

10. How likely would you be to begin mitigation strategies if the soil risk assessment tool determined that your risk for cadmium contamination was high and exceeding EU MLs?

1 2 3 4 5

Provide a yes or no answer to the following questions

11. Do you regularly conduct soil testing (regular testing is considered at least every 3-5 years)? Y N

12. Have you conducted a soil test that includes **available** soil cadmium levels in the past 5 years? Y N

13. Would you presume that a soil test that includes a cadmium analysis would be more expensive than a generic soil test? Y N

14. Have you used a Decision Support Tool of any type in the past to aid in risk management on your farm (some examples of DSTs include Nutrient Management Plan (NMP) online, EProfit Monitoring, crop yield calculators, etc.)? Y N

Questionnaire No: ___

15. Have you and/or are you currently using cadmium mitigation strategies on any of your farms:

Mitigation Strategy	Knowledge of being a possible cadmium mitigation strategy	Active use on farm in general	Active use on farm for cadmium mitigation specifically
Organic Matter	Y N	Y N	Y N
Lime	Y N	Y N	Y N
Zinc Fertilisers	Y N	Y N	Y N
Low cadmium fertilisers	Y N	Y N	Y N
Zinc Sulphate	Y N	Y N	Y N
Changing Varieties	Y N	Y N	Y N
Changing Crop	Y N	Y N	Y N

16. If invited, would you participate in a facilitated workshop on adaptation of the soil risk assessment tool? Y N

17. Do you intend on taking soil samples for the purpose of a cadmium analysis?
Y N

18. Do you normally take soil samples prior to any purchasing/leasing/etc. of land?
Y N

19. Do you tend to trust science and scientific data? Y N

20. When you notice the traffic light colored satisfaction buttons at locations such as Lidl, Dublin Airport or Heuston Station, do you provide input and press a button?
Y N

21. Which of the following statements would you agree with most?

A. Testing of farmland and produce for elements that are a potential public health risk should be common practice and those found in violation should be reprimanded (i.e. given a fine, deemed ineligible to sell that crop, etc.)

Questionnaire No: ___

B. Testing of any kind should never happen on my farm
C. Governing bodies, retailers and the public should trust farmers to manage the land appropriately and testing should occur on rare occasions
D. Testing of farmland and produce for elements that are a potential public health risk should be common practice and efforts should be made by those found in violation to work with their advisor, governing bodies, and the retailer (if appropriate) on solutions without fear of repercussions

22. Which of the following statements would you agree with most?
A. My business is a private matter and should not be shared with anyone
B. I view my competitors as allies and share information with them regularly
C. I will only share information with my competitors if I know they have the same issue on their land
D. I share information with my advisor and trust that if they discuss overarching topics that apply to my farm, they will anonymize my enterprise

23. Where do you get the majority of the information that helps you make management decisions on your farm?
A. My Teagasc Advisor
B. My Private Advisor
C. My Family
D. My Neighbors
E. The Internet
F. Other: _____

Questionnaire No: ___





This Research Questionnaire is part of a thesis for MAgrSc Innovation Support Programme in association with UCD and Teagasc

This questionnaire is for completion by agronomist by in-person interview

The topic of research is:

"Advisory and KT Tools and Processes to support potato farmers and agronomists to assess their exposure to risk of cadmium"

All information given will be treated confidentially. Your responses to this questionnaire are anonymous and cannot be linked to any individual

Figure A 4 Copy of survey given to agronomists during in-person interviews (page 1 of 4)

Questionnaire No: ___

Preliminary Survey for Agronomists in Northeast Leinster

Organisation: _____

Age: _____

Highest Level of Education Completed: _____

Main county you advise in: _____

Secondary counties: _____

Main crop type you deal with?: _____

Secondary crop type (if applicable)?: _____

Main Variety you deal with: _____

Secondary Varieties? _____

Primary Market Type of Clients: _____

Secondary Market Type: _____

Rate yourself for the following questions on a scale of 1-5 (1 meaning not at all and 5 meaning extremely)

3. How familiar are you with the topic of toxic metal contamination in soils?

1 2 3 4 5

4. How familiar are you with the topic of cadmium contamination in soils in the Northeast of Ireland?

1 2 3 4 5

5. How concerned are you regarding the risk of cadmium contamination in regards to production on client's owned land (if applicable)?

1 2 3 4 5

6. How concerned are you regarding the risk of cadmium contamination in regards to your production on your client's rented land (if applicable)?

1 2 3 4 5

Questionnaire No: ___

7. How likely would you be to use a Decision Support Tool (DST) like the soil risk assessment tool to help assess your client's risk to toxic metals?

1 2 3 4 5

8. How likely would you be to recommend mitigation strategies if the soil risk assessment tool determined that your client's risk for cadmium contamination was high?

1 2 3 4 5

9. How likely would you be to recommend mitigation strategies if the soil risk assessment tool determined that your client's risk for cadmium contamination was high but still within existing EU Maximum Limits (MLs)?

1 2 3 4 5

10. How likely would you be to recommend mitigation strategies if the soil risk assessment tool determined that your client's risk for cadmium contamination was high and exceeding EU MLs?

1 2 3 4 5

Provide a yes or no answer to the following questions

11. Do you regularly conduct soil testing on your client's land (regular testing is considered at least every 3-5 years)? Y N

12. Have you conducted a soil test that includes **available** soil cadmium levels in the past 5 years? Y N

13. Would you presume that a soil test that includes a cadmium analysis would be more expensive than a generic soil test? Y N

14. Have you used a Decision Support Tool of any kind in the past to aid in risk management on your client's farm? Y N

15. Have you and/or are you currently recommending cadmium mitigation strategies on any of your clients' farms:

Questionnaire No: ___

Mitigation Strategy	Knowledge of being a possible cadmium mitigation strategy?	Recommended for cadmium mitigation specifically?
Organic Matter	Y N	Y N
Lime	Y N	Y N
High zinc content fertilisers	Y N	Y N
Low cadmium-content fertilisers	Y N	Y N
Zinc Sulphate	Y N	Y N
Changing Varieties	Y N	Y N
Changing Crop	Y N	Y N

16. If invited, would you participate in a facilitated workshop on adaptation of the soil risk assessment tool? Y N

Open ended questions:

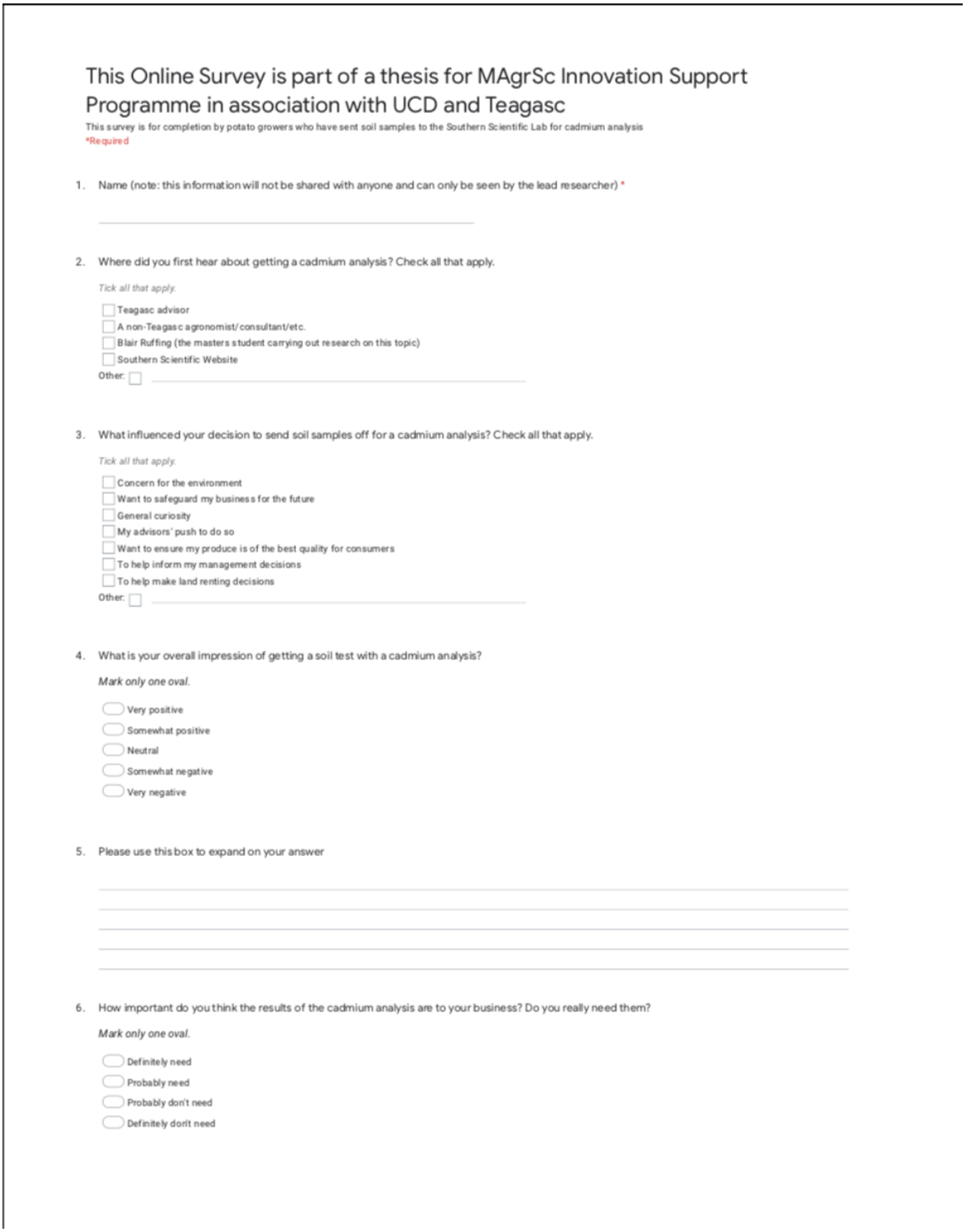
Would you say your clients are aware of this issue?

Would you say your clients are concerned about this issue?

What are you or your organisation currently doing (if anything) about this issue?

What is the current advice you are giving to your clients about this?

Will you begin to advise your client on this if you haven't done so already?



This Online Survey is part of a thesis for MAgrSc Innovation Support Programme in association with UCD and Teagasc

This survey is for completion by potato growers who have sent soil samples to the Southern Scientific Lab for cadmium analysis

*Required

1. Name (note: this information will not be shared with anyone and can only be seen by the lead researcher) *

2. Where did you first hear about getting a cadmium analysis? Check all that apply.

Tick all that apply.

- Teagasc advisor
- A non-Teagasc agronomist/consultant/etc.
- Blair Ruffing (the masters student carrying out research on this topic)
- Southern Scientific Website
- Other:

3. What influenced your decision to send soil samples off for a cadmium analysis? Check all that apply.

Tick all that apply.

- Concern for the environment
- Want to safeguard my business for the future
- General curiosity
- My advisors' push to do so
- Want to ensure my produce is of the best quality for consumers
- To help inform my management decisions
- To help make land renting decisions
- Other:

4. What is your overall impression of getting a soil test with a cadmium analysis?

Mark only one oval.

- Very positive
- Somewhat positive
- Neutral
- Somewhat negative
- Very negative

5. Please use this box to expand on your answer

6. How important do you think the results of the cadmium analysis are to your business? Do you really need them?

Mark only one oval.

- Definitely need
- Probably need
- Probably don't need
- Definitely don't need

Figure A 5 Copy of online survey given to potato growers who engaged with the cadmium risk assessment model (page 1 of 3

7. Please use this box to expand on your answer

8. How likely are you to get the test done again in the future for any new and/or existing untested land?

Mark only one oval.

- Extremely likely
- Very likely
- Somewhat likely
- Not so likely
- Not at all likely

9. Please use this box to expand on your answer

10. How likely are you to recommend this soil test to another grower?

Mark only one oval.

- Extremely likely
- Very likely
- Somewhat likely
- Not so likely
- Not at all likely

11. Please use this box to expand on your answer

12. How easy was it to understand the results and associated advice?

Mark only one oval.

- Extremely easy
- Very easy
- Somewhat difficult
- Very difficult
- Extremely difficult

13. Please use this box to expand on your answer

14. Did you make any new management decisions based on the results? Check all that apply.

Tick all that apply.

- [ ] Adding organic matter
- [ ] Extending lease contract to greater than 1 year
- [ ] Changing variety grown
- [ ] Changing crop grown
- [ ] Getting more frequent soil tests with cadmium analysis

Other: [ ] _____

15. Please use this box to expand on your answer (eg. what type of organic matter do you use now? How long is your lease contract now? Etc.)

16. What are the things that you liked most about the delivery of your Cadmium Risk Assessment Results? Check all that apply.

Tick all that apply.

- [ ] Timliness
- [ ] Easiness to understand
- [ ] Quality of advice
- [ ] Layout
- [ ] Color coded results

Other: [ ] _____

17. What are the things that you disliked most about the delivery of your Cadmium Risk Assessment Results? Check all that apply.

Tick all that apply.

- [ ] Timeliness (or lack there of)
- [ ] Understandability
- [ ] Advice offered
- [ ] Layout
- [ ] Color scheme

Other: [ ] _____

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