

CRANFIELD UNIVERSITY

CARLA PEGURARA GASPARIN

**AN EXPLORATORY STUDY INTO THE ACCEPTANCE OF ON FARM  
AUTOMATED TRACEABILITY SYSTEMS**

SCHOOL OF APPLIED SCIENCES

PhD THESIS

CRANFIELD UNIVERSITY

SCHOOL OF APPLIED SCIENCES

PhD THESIS

ACADEMIC YEAR 2006 – 2009

CARLA PEGURARA GASPARIN

**AN EXPLORATORY STUDY INTO THE ACCEPTANCE OF ON FARM  
AUTOMATED TRACEABILITY SYSTEMS**

SUPERVISORS:                    PROF. R.J. GODWIN  
   DR. D.W.K. BLACKBURN

2009

**THIS THESIS IS SUBMITTED IN FULFILLMENT OF THE REQUIREMENTS FOR  
THE DEGREE OF DOCTOR OF PHILOSOPHY**

## **Abstract**

The increasing pressure from retailers and consumers require that all farmers collect traceability data regarding the crops they produce and the name and application rate of the agrochemicals that they have used to produce them. In order to achieve this, automated traceability systems could be used to assist farmers in collecting the data required throughout the food chain to the market place. An Automated Agrochemical Traceability System (AACTS) was designed and developed at Cranfield University (Peets, 2009). This system is capable of automatically identifying and assisting in the precise weighing of the agrochemical loaded into a sprayer. The actual amount applied to crops growing in any given section of the field would then be recorded from the application maps obtained using precision farming methods. This work aims to identify the factors that inform the development of and the potential market uptake of the AACTS.

Interviews with representatives of the interest groups in the food chain were conducted in order to identify their perceptions regarding traceability systems. Moreover, ten farm sprayer operators were asked to judge the sprayer with AACTS against sprayer without AACTS in terms of ease of filling, data management, investment cost, operator safety and accuracy of the data. The food industry supports the need for the AACTS and will accept the new technology if it reduces cost, time, business risk and increases value of certified produce. It was found that the weighted ranking of the sprayer with AACTS was greater than the sprayer without the AACTS at 0.68 opposed to 0.32 respectively. Peets (2009) showed that the AACTS has a resolution within  $\pm 1$  g with the engine switched off and  $\pm 3.6$  g when it is not. Furthermore, there is no significant difference in speed of operation between the AACTS and the manual method including loading and record creation time at the 5% probability level. The system would also automatically create the record of the agrochemicals used, their application rate and field distribution pattern.

The price that a farmer would be willing to pay for the AACTS is positively related to the size of arable holding land, the cost of sprayer and the perception of the need towards the AACTS as found using an online questionnaire. Out of 119 respondents, 42% of the respondents perceived the need for the AACTS. This study estimated the

demand curve of the AACTS, according to this curve 4% of the farmers would buy the AACTS if it costs £3,500, 54% would buy if it cost £1,500 and 100% would buy it if it cost £200. According to the demand curve and production cost, the highest profit for the manufacturer of the AACTS could be obtained with retail price of £2,000 in Europe.

Twenty seven face to face interviews were conducted with farmers in England to identified the perceived main benefits, these were; the potential improvement of stock control in the chemical store, the avoidance of use of incorrect agrochemicals, the reduction of time in the office for record keeping and improved accuracy when filling the sprayer in terms of both the correct chemical and the dilution rate. However, in order to fulfil the farmers' requirements the AACTS should allow more rinsing space to wash out 10 and 20 litre containers. Furthermore the software and appropriate database should be programmed to enable the identification and loading of the corresponding generic agrochemical products.

The existing traceability systems of three different types of farm enterprise: fresh produce, onion production and a conservation grade cereal farm were analysed and suggestions for improvements were explored. It was demonstrated that the AACTS can avoid market and financial loss for relatively small cost. The operation cost of the AACTS for an area of 900 hectares is £1.29 per hectare. Furthermore, there is a potential time and financial saving if the agrochemical application records are received electronically. However, the savings will depend on the capability of the computer and its reliability. At Clements, the production manager spends around 600 hours per year typing the agrochemical application records into the computer.

A range of social science methods were used to estimate the market uptake of the AACTS. These included face-to-face semi-structured interviews with members of the food chain and farmers, the Analytical Hierarchy Process (AHP) to evaluate the prototype system of AACTS, and a Contingent Valuation (CV) questionnaire to estimate the farmers' willingness to pay for the AACTS. The information gathered from their collective use showed that they provided a valuable suite of methods for product development.



## Publications

The results of this research have been presented on European and International conferences on precision agriculture. The following papers were produced from this work:

Gasparin, C.P., Peets, S., Blackburn, D.W.K., Godwin, R.J. (2007) "Stakeholders Requirements for Traceability Systems", In: Proceeding of the 6<sup>th</sup> *European Conference on Precision Agriculture*, 3-6 June 2007, Skiathos, Greece, edited by J.V. Stafford. Netherlands: Wageningen Academic Publishers, p.793-799

Peets, S., Gasparin, C. P. and Blackburn, D. W. K. a. Godwin.,R.J. (2007), "RFID tags for identifying and verifying agrochemicals in traceability systems", In: Proceeding of the 6<sup>th</sup> *European Conference on Precision Agriculture*, 3-6 June 2007, Skiathos, Greece, edited by J.V. Stafford. Netherlands: Wageningen Academic Publishers, p.801-808

Gasparin, C.P., Angus, A., Cook, M., Peets, S., Blackburn, D.W.K., Godwin, R.J. (2008) "Measuring farmers' preferences for systems that improve agrochemical traceability", In: Proceedings of the 9<sup>th</sup> *International Conference on Precision Agriculture*, 20-23 July 2008, Denver, USA, edited by R. Kholsa. USA: Colorado State University

Blackburn, D. W. K., Peets, S., Gasparin, C. P. and Godwin, R. J. (2008), "Application for radio frequency Identification for agricultural traceability systems", In: Proceedings of the 9<sup>th</sup> *International Conference on Precision Agriculture*, 20-23 July 2008, Denver, USA, edited by R. Kholsa. USA: Colorado State University

Peets, S., Blackburn, D. W. K., Gasparin, C. P. and Godwin, R. J. (2008), "Development of an Automatic Agrochemical Recording System for Crop Sprayers", In: Proceedings of the 9<sup>th</sup> *International Conference on Precision Agriculture*, 20-23 July 2008, Denver, USA, edited by R. Kholsa. USA: Colorado State University

Peets, S., Gasparin, C. P. and Blackburn, D. W. K. a. G.,R.J. (2009), "RFID tags for identifying and verifying agrochemicals in traceability systems", *Precision Agriculture*. Online First (in press).

## Acknowledgments

Firstly, I am very grateful to AGCO Corporation for funding my PhD studies. Special thanks go to Mark Moore for all his support during the project.

I am deeply thankful to my supervisor Dick Godwin who gave me his entire support, dedication and time to carry out this research. I benefit from his invaluable professional capacity and his personal kindness.

I would also like to thank other people who gave me their time and knowledge to facilitate my work. I am indebted to Andrew Angus, Bob Walker, Joe Morris, Kim Blackburn, Matthew Cook, Pat Bellamy, Paul Burgess and Paul Jeffrey. Special thanks go to Sven Peets for a great teamwork during this period.

Furthermore, I appreciate the valuable inputs that the members of the thesis committee gave me: Peter Redman (Douglas Bomford Trust), Richard Price (Patchwork) and Paul Miller (TAG).

I am grateful to The Arable Group (TAG), which gave me the opportunity to announce the questionnaire on its newsletter. Finally I would like to thank all the people who participated in the surveys.

*I dedicate this work to my family for always being there and endless support.*

## Table of Contents

<b>Abstract.....</b>	<b>i</b>
<b>Publications.....</b>	<b>iii</b>
<b>Acknowledgments.....</b>	<b>iv</b>
<b>Table of Contents.....</b>	<b>v</b>
<b>List of Abbreviations.....</b>	<b>x</b>
<b>List of Figures.....</b>	<b>xii</b>
<b>List of Tables.....</b>	<b>xiii</b>
<b>1 Introduction.....</b>	<b>1</b>
1.1 Background.....	1
1.2 Aim.....	4
1.3 Objectives.....	4
<b>2 Literature Review.....</b>	<b>5</b>
2.1 Introduction.....	5
2.2 Standards.....	6
2.2.1 Codex Alimentarius.....	6
2.2.2 ISO 22000:2005.....	6
2.2.3 ISO 22005:2007.....	7
2.2.4 GLOBALGAP.....	7
2.2.5 EAN.UCC Traceability Guideline.....	8
2.3 Ongoing Research Involved with Food Traceability.....	10
2.3.1 The PETER - Promoting European Traceability Excellence & Research.....	10
2.4 Stakeholders.....	15
2.4.1 Consumers.....	15
2.4.2 The Food Industry.....	15
2.4.3 Legislative requirements.....	16
2.4.4 Quality assurance providers.....	17
2.4.5 Farmers and Growers.....	19
2.4.6 Farm Equipment Manufacturers.....	20
2.4.7 The Agrochemical Industry.....	21
2.4.8 Farm Software Providers.....	21
2.4.9 Agronomist.....	22
2.5 Agriculture Inputs.....	22
2.6 The Environment.....	24
2.7 Traceability Systems.....	24
2.7.1 Radio Frequency Identification systems.....	25
2.7.2 Cost of implementation of traceability systems.....	26
2.8 Automated Agrochemical Recording Systems.....	26

2.9	Innovation .....	28
2.10	Conclusions .....	32
<b>3</b>	<b>Methodological Approach.. .....</b>	<b>34</b>
3.1	Introduction.....	34
3.2	Research Design .....	34
3.2.1	Classification of social science research .....	34
3.3	Methodology .....	35
3.3.1	Chapter 4: Primary findings of the stakeholders' perspective towards traceability systems. ....	35
3.3.2	Chapter 5: Farmers' impression toward the AACTS .....	36
3.3.3	Chapter 6: Perceived Market Value.....	37
3.3.4	Chapter 7: Market Uptake .....	38
3.3.5	Chapter 8: Case studies .....	39
3.3.6	Discussion and conclusion .....	39
<b>4</b>	<b>Primary findings of the stakeholders perspective towards traceability systems.....</b>	<b>40</b>
4.1	Introduction.....	40
4.2	Interview with Stakeholders .....	40
4.2.1	Type of data collected.....	40
4.2.2	Data Collection and Type .....	40
4.2.3	Stakeholders .....	41
4.2.4	Data Analysis.....	44
4.2.5	Finding from the interviews .....	45
4.2.6	Summary of Findings .....	50
4.3	Workshop.....	50
4.4	Conclusion .....	52
<b>5</b>	<b>Farmer's Impressions towards the AACTS.....</b>	<b>54</b>
5.1	Introduction.....	54
5.2	The prototype – AACTS .....	54
5.3	Evaluation design.....	55
5.4	Multi-Criteria Decision Analysis.....	57
5.5	Analytical Hierarchy Process (AHP) .....	58
5.5.1	Questionnaire and data collection.....	59
5.5.2	Data Analysis.....	61
5.6	Results of the Analytic Hierarchy Process (AHP).....	65
5.6.1	Summary of the findings .....	71
5.7	Verification of the sample size power .....	74
5.8	Multiple choice questionnaire.....	76
5.9	Conclusion .....	76
<b>6</b>	<b>Perceived Market Value.....</b>	<b>79</b>
6.1	Introduction.....	79
6.2	Economic Valuation Techniques .....	79
6.3	Contingent Valuation (CV).....	80

6.3.1	The elicitation method .....	81
6.3.2	Survey Method .....	83
6.3.3	Sample population .....	83
6.3.4	Questionnaire design .....	84
6.3.5	Pilot survey .....	86
6.3.6	Bids amounts .....	87
6.3.7	Definition of the mean and median WTP .....	89
6.4	Results.....	91
6.4.1	Perception of need .....	93
6.4.2	Turnbull's self-consistency algorithm and Kaplan-Meier.....	93
6.4.3	Maximum Willingness to Pay .....	95
6.4.4	Bivariate probit model .....	99
6.4.5	The chi-squared test to determine the relationship within the independent variables.....	102
6.5	Attributes of the AACTS .....	103
6.6	Cost structure .....	103
6.7	Break-even analysis .....	104
6.7.1	New AGCO sprayers .....	106
6.7.2	New AGCO sprayers and retrofit for up to five years old AGCO sprayers.....	107
6.7.3	AACTS manufactured by a third party and available as a retrofit to the whole self-propelled sprayer industry in NA and EU .....	107
6.7.4	AACTS manufactured by a third party and available as a retrofit to the whole sprayer industry in EU .....	109
6.8	Conclusions.....	110
<b>7</b>	<b>Market Uptake.....</b>	<b>114</b>
7.1	Introduction.....	114
7.2	Receptivity .....	114
7.3	Selection of Research Technique.....	116
7.4	Sample Size.....	117
7.5	Pilot Questionnaire .....	118
7.6	Data Analysis .....	119
7.7	Synopsis of the main outcomes .....	119
7.7.1	Awareness.....	119
7.7.2	Association .....	120
7.7.3	Acquisition .....	124
7.7.4	Application .....	125
7.7.5	Further questions .....	130
7.8	Summary of findings .....	132
7.9	Conclusions.....	133
<b>8</b>	<b>Case Studies.....</b>	<b>136</b>
8.1	Introduction.....	136
8.2	Overview of potential improvement opportunities.....	136
8.3	Fresh Produce - T.H. Clements & Son Ltd.....	138
8.3.1	The existing traceability system .....	138
8.3.2	Opportunities for improvements.....	141

8.3.3	Potential benefits of the proposed system .....	145
8.4	Onion Production - F.B. Parrish and Son .....	146
8.4.1	The existing traceability system .....	146
8.4.2	Economic Analysis .....	150
8.5	Conservation Grade - Arable Farm.....	153
8.5.1	The existing traceability system .....	153
8.5.2	Analysis of potential financial savings.....	156
8.6	Conclusions.....	160
<b>9</b>	<b>Discussion.....</b>	<b>162</b>
9.1	Concept .....	162
9.2	Stakeholders' perceptions towards traceability systems.....	163
9.3	Practical evaluation of the AACTS.....	164
9.4	Farmers' attitudes towards AACTS.....	164
9.5	Willingness to Pay for AACTS .....	165
9.6	Analysis of the most profitable retail for AACTS .....	166
9.7	The application of AACTS at different type of farms .....	167
9.8	Critique of methods used .....	168
9.9	The role of the Agrochemical Companies .....	171
<b>10</b>	<b>Conclusions and recommendations.....</b>	<b>172</b>
10.1	Conclusions .....	172
10.2	Recommendations for future work.....	174
	<b>References.....</b>	<b>177</b>
	Appendix A - Interviews Transcripts, stakeholders .....	A-1
	Appendix B - Coding System – Stakeholders' interviews .....	B-1
	Appendix C - Multiple choice questionnaire.....	C-1
	Appendix D - AHP questionnaire.....	D-1
	Appendix E - Logic Decisions, results of the AHP questionnaire .....	E1
	Appendix F - Power Analysis.....	F-1
	Appendix G - CV Questions, Group A: Farmers who hire contractor to perform the spray application.....	G-1
	Appendix H - CV Questions, Group B: Farmers who do their own spray application or have a employee.....	H-1
	Appendix I - CV Questions, Group C: Spraying Contractors.....	I-1
	Appendix J - Alternatives bids for the AACTS, Group A.....	J-1

Appendix K - Excel spreadsheet model used to calculate the TSCA and to estimate the Kaplan-Meier..... K-1

Appendix L - The Chi squared test.....L-1

Appendix M - Receptivity Questionnaire.....M-1

Appendix N - Coding System – Farmers’ Interviews .....N-1

Appendix O - Interviews Transcripts, farmers .....O-1

Appendix P - Calculation of the Annual Cost of the AACTS.....P-1

## List of Abbreviations

AACTS	Automated Agrochemical Traceability System
ACCS	Assured Combinable Crops Scheme
AHP	Analytic Hierarchy Process
AI	Application Identifiers
CAP	Common Agriculture Policy
CG	Conservation Grade
CM	Choice Modelling
CR	Consistency Rate
CV	Contingent valuation
DBDC	Double-Bounded Dichotomous Choice
DC	Dichotomous Choice
EAN.UCC	European Article Numbering Uniform Code Council
EDI	Electronic Data Interchange
EU	Europe
FAR	Field Activity Report
FSA	Food Standards Agency
GLN	Global Location Number
GMO	Genetically Modified Organism
GPS	Global Positioning System
GTIN <sup>TM</sup>	Global Trade Item Number
ISO	International Organization for Standardization
IT	Information Technology
LPIS	Land Parcel Identification Systems
MAUT	Multi-Attribute Utility Theory
MCDA	Multi-Criteria Decision-Analysis
NA	North America
NFU	National Farmers' Union
OE	Open ended
PC	Payment Card



PSD	Pesticides Safety Directorate
RFID	Radio-frequency identification
RUT	Random Utility Theory
SP	Stated Preference Techniques
SSCC	Serial Shipping Container Code
TAG	The Arable Group
TSCA	Turnbull's self-consistency algorithm
WTP	Willingness to Pay
$\mu$	Mean
$\sigma$	Standard Deviation
t	Tonne

## List of Figures

Figure 1: Proportion of Production in UK under Farm Assurance Scheme (DEFRA 2008).....	18
Figure 2: Private brand label share of the total retail food volume sales for 13 non specified food categories. (KPMG, 2000).....	19
Figure 3: Modified induction hopper a) weighing system and b) RFID antenna (Source: Peets et al, 2008).....	55
Figure 4: Farmer conducting the experiment .....	57
Figure 5: The AHP model. ....	59
Figure 6: Example of the AHP question.....	61
Figure 7: Example of a 6 x 6 comparison matrix .....	62
Figure 8: Summary of the criteria weight from 10 farmers.....	73
Figure 9: Weighted mean scores of each attribute.....	74
Figure 10: Summary of response of 10 farmers .....	74
Figure 11: Kaplan-Meier analysis of mean and median WTP for AACTS .....	95
Figure 12: Maximum Willingness to Pay (£) – follow-up question.....	97
Figure 13: Demand Curve of AACTS within a sample of 48 respondents who perceived a need for AACTS .....	98
Figure 14: Modified induction hopper with a 20 litre container. ....	126
Figure 15: User Interface .....	131
Figure 16: Information and crop flow at Clements. ....	138
Figure 17: The harvest process of fresh greens, (a) fresh greens are placed in the “flower pots”, (b) a gang member collects the fresh greens and puts it into a bag, and (c) the bag is weighed and placed into the trays.....	140
Figure 18: Information flow at Parrish.....	147
Figure 19: Harvest at Parrish .....	148
Figure 20: Unloading area .....	149
Figure 21: 1t boxes of onion.....	149
Figure 22: Onions' store at Parrish .....	152
Figure 24: Trailer unloading the grains .....	155
Figure 25: Left image: 400t silo. Right image: 700t silo. ....	155

## List of Tables

Table 1: Weighing Platform specification, earlier and latest design.....	27
Table 2: Classification of research purpose (derived from Robson, 2002).....	35
Table 3: List of the interviewees .....	42
Table 4: Summary of findings from the interviews data.....	50
Table 5: Farm size (ha) for the ten sample farmers.....	56
Table 6: Scale Ranging.....	60
Table 7: Example of the output of a 6 x 6 AHP matrix.....	63
Table 8: C1 Matrix .....	64
Table 9 Priority ranking and weights for each criterion – Farmer A (CR = 0.092).....	66
Table 10 Priority ranking and weights for each criterion – Farmer B (CR=0.019).....	66
Table 11 Priority ranking and weights for each criterion – Farmer C (CR=0.038).....	67
Table 12 Priority ranking and weights for each criterion – Farmer D (CR=0.057).....	68
Table 13 Priority ranking and weights for each criterion – Farmer E (CR=0.093).....	68
Table 14: Priority ranking and weights for each criterion – Farmer F (CR=0.088).....	69
Table 15: Priority ranking and weights for each criterion – Farmer G (CR=0.080).....	69
Table 16: Priority ranking and weights for each criterion – Farmer H (CR=0.085).....	70
Table 17: Priority ranking and weights for each criterion – Farmer I (CR=0.092).....	70
Table 18: Priority ranking and weights for each criterion – Farmer J (CR=0.061).....	71
Table 19: Summary of criteria weight for 10 farmers - numeric data.....	72
Table 20: Alternative bids (£) for the AACTS (Groups B and C) .....	87
Table 21: Alternative bids (£/ha) for the AACTS (Groups A).....	88
Table 22: Summary statistics for demographic variables.....	92
Table 23: Summary of statistics for attitude variables .....	92
Table 24: Estimators according to Kaplan-Meier.....	94
Table 25: Maximum Willingness to Pay (£) – follow-up question - numeric data.....	96
Table 26: Statistic analysis of maximum WTP within the different groups .....	99
Table 27: Description of the variables tested in the probit model.....	100
Table 28: Bivariate Probit - Cost of the Sprayer .....	101
Table 29: Bivariate Probit: Need for the AACTS .....	101
Table 30: Bivariate Probit: Arable Farm size.....	102
Table 31: Chi-square analysis.....	102
Table 32: Annual production cost of AACTS (£) .....	104

---

Table 33: Break-even analysis – New AGCO sprayers .....	106
Table 34: Break-even analysis – New AGCO sprayers and retrofit sprayers .....	107
Table 35: Production Cost (£) - third party .....	108
Table 36: Break-even analysis – Europe (self-propelled sprayers).....	108
Table 37: Break-even analysis - North America (self-propelled sprayers).....	109
Table 38: Break-even analysis – Europe (self-propelled, mounted and trailed sprayers) .....	110
Table 39: List of Respondents .....	118
Table 40: Summary of the cost of precision farming equipment .....	151
Table 41: Gross Margin – £ per hectare .....	159
Table 42: Summary of the methods used, some key advantages and disadvantages and recommendations.....	169

## 1 Introduction

### 1.1 Background

In recent years traceability has become a necessary component of the food production process (Sarig, 2003). Traceability systems are an essential tool to efficiently record the history of a final food product or ingredient. At the outset it would be beneficial to state the legal and “standards” definitions of traceability, which are as follows:

- General Food Law Regulation, 178/2002/EC - “The ability to trace and follow a food, feed, food-producing animal or substance intended to be, or expected to be incorporated into a food or feed, through all stages of production, processing and distribution. Stages of production and distribution means any stage including import, from and including the primary production of food, up to and including its sale or supply to the final consumer and, where relevant to food safety, the production, manufacture and distribution of feed”
- ISO 8402:1995 – “ ability to trace the history, application or location of an entity by means of recorded identifications”

One issue that is currently influencing the development of food supply chains is the increasing regulatory demands for traceability. From 1 January 2005 in Europe, the General Food Law Regulation (EC) 178/2002 requires traceability to be established at all stages of the food chain. The aim of this regulation is to protect human health in relation to food and to promote free movement of food within the European countries. Similar requirements were introduced within the USA in June 2002, in the “The Bioterrorism Act 2002”. The EU Food Hygiene Legislation that applied from 1 January 2006 also had a traceability requirement. It is important to note that these regulations do not require a standardized form of data records.

The increasing number of independent traceability schemes for UK food products should give consumers additional confidence in food safety as these assurance schemes can result in quick and efficient withdrawal of products from the supermarket shelves. A major food retailer claims to have very effective systems in product recall, after Sudan 1 Dye in 2005 they were able to identify and recall the contaminated products within one

hour (Willgoss, P. Personal communication, 2005). However, there are examples of where existing traceability systems have been shown to be weak or absent and hence slow or unable to adequately assure consumers of the safety of their food, for instance, GMO StarLink maize (Anon, 2005), e.coli outbreak linked with fresh spinach (U.S. Food and Drug Administration, 2006), and salmonella outbreak linked with tomato, jalapeño and Serrano peppers all in the USA (U.S. Food and Drug Administration, 2008). According to Lupien (2005), all members of the food chain should have systems in place in order to guarantee food quality and safety.

The farm, as the primary producer, plays a key role in the production of safe food products passing through the food chain. Issues of product identification and records of process data begin on the farm. All subsequent product tracing relies on the accuracy and integrity of this data. A fresh produce farm in England was contacted at the beginning of the project in order to understand their traceability system and potentially identify constraints and opportunities for improvement. This farm is directly connected to a supermarket and needs to collect traceability data in order to comply with their quality assurance scheme. There are specific legal requirements covering on farm record keeping such as General Food Law Regulation 178/2002 in Europe in addition to market specific quality assurance schemes such as the GLOBALGAP and Assured Combinable Crops. At this farm the data collection is mainly manual and there is significant human interaction in order transfer the traceability information, set up the harvest and to label the trays of fresh produce after the harvest. Although a software product is used to record the traceability information, the farm manager has to spend time typing the relevant information into the computer and this is prone to human error. The data collected and recorded are the following: field/plot number, date of planting, variety of seed and batch number, agrochemicals used and rate, date of agrochemical application and date of harvest. There is an opportunity to improve the data collection and transfer using automated traceability systems.

Currently, most of the traceability data is manually collected and kept as paper based records. Consequentially the farmers deal with a large amount of paper work which they find time consuming and can cause a negative reaction to the traceability concept. However, there is an increasing uptake of IT systems at farm level, both in information gathering and management. It is the latter that is probably better developed as an

information management system start to implement technologies such as Geographic Information System (GIS) and electronic databases to reduce the overhead of managing and extracting useful information from the raw data. The use of electronic systems embedded in agricultural machinery allows monitoring of inputs and control of machinery to be guided by accurate and precise data, taking automatic records during process operation. McBratney et al. (2005) points out that “product tracking and traceability should be a major new focus of precision agriculture research, particularly to provide the tools on-farm to initiate the process”. Pierce & Cavalieri (2002) suggest that future machinery will be increasingly automated, capable of detecting crop quality at various points in the production system, and fully equipped for tracking information about the crop from field to the table. Specifically, agricultural machinery equipped with the ISO 11783 (ISOBUS) has the capacity to interconnect equipment to provide automatic recording of the field operations. The standard ISO 11783 aims to enable agricultural machinery (tractors and implements) from different manufacturers to communicate with one another and eliminate the need for separate controls and terminals. Auernhammer (2002) states that agricultural equipment with Global Positioning System (GPS) and the standardized communications by ISO 11783 opens possibilities for traceability. There is an opportunity to assist farmers in collecting data to satisfy legislative and business requirements through the provision of automatic recording systems. Following the earlier work of Watts et al. (2004), one specific development in the area is the further development of an Automated Agrochemical Traceability System (AACTS) by my colleague Peets (2009). This system automatically identifies both the agrochemical product and quantity being loaded into the sprayer. It will potentially improve the accuracy of the data gathered and reduce the time to transfer and manage the data. Benefits are therefore predicted for the traceability system at farm level. Although the benefits of improving traceability systems are clear, the uptake of such system is unknown. Several researches have been trying to understand what drives adoption of new technologies among farmers (see Feder and Umali, 1993; Ghadim and Pannell, 1999; Llewellyn, 2007). Risk and uncertainty has often been considered as a major factor reducing the rate of adoption of innovation.

The current development of the AACTS is considered by the parallel studies conducted in two PhD theses, where the engineering aspects of the system have been considered

by Peets (2009) and the author of this thesis has focused on the analysis of the factors related to the market requirements, farmers' willingness to pay for the AACTS and uptake of the concept. The overall aim of the combined research program funded by AGCO, Patchwork and Douglas Bomford Trust, was to investigate the requirements of the food chain stakeholders and to improve the design of the Automated Agrochemical Traceability System (AACTS). The detailed aim and objectives of this thesis are given below.

## **1.2 Aim**

To identify the factors that inform the development of, and the potential market uptake of the Automated Agrochemical Traceability System (AACTS) with a primary focus at the farm level.

## **1.3 Objectives**

1. To identify the stakeholders perceptions towards traceability systems, from the farm through to the supermarket.
2. To identify the user requirements and the product specification for an Automated Agrochemical Traceability System (AACTS).
3. To evaluate the reaction of the farmers and/or sprayer operators to the performance of the AACTS in comparison with the existing manual loading and recording systems.
4. To make recommendations for further development and acceptance of the prototype in the food chain with particular emphasis at the farm level.
5. To estimate the perceived market value, determine the demand curve and recommend the most profitable retail market price.
6. To identify the practical benefits of AACTS as applied to farms with a range of different types of product.
7. To suggest a combination of social science methods that can be used during the product development stage to pre-test the potential market acceptance.



## **2 Literature Review**

### **2.1 Introduction**

European consumers are becoming increasingly concerned with the origin and quality of the food they consume. Much of this has been caused by concern over Genetically Modified Organisms (GMOs), health risks associated with the increasing use of additives in processed foods, treatments used during the growing period of the crop and animals and by a lack of knowledge about the growing and processing conditions of food originating from less developed countries.

Traceability is defined by the General Food Law Regulation, 178/2002 as “the ability to trace and follow a food, feed, food-producing animal or substance intended to be, or expected to be incorporate into a food or feed, through all stages of production, processing and distribution.” The aim of traceability information is to ensure food safety and reliable practices in the food production and process and can be used by food industry, the public authorities and any other interested parties. The information is recorded by each member of the food chain and kept during the appropriate duration in a way allowing a rapid and easy retrieval.

The aim of this chapter is to review:

1. The existing standards and projects related to the development of traceability systems in the food chain.
2. The perceived stakeholders who may benefit from the use of traceability systems and play an important role on the development of future traceability systems.
3. The agricultural inputs that need to be recorded to comply with traceability systems.
4. The importance of traceability systems for the protection of the environment.
5. The literature concerning the identification of farmers’ adoption behaviours towards agricultural innovations.

## 2.2 Standards

In Europe, there are standards which address the use of traceability in the food chain. A number of standards relevant to the current study have been identified as follows.

### 2.2.1 Codex Alimentarius

The Codex Alimentarius (2006) develops food safety standards which serve as a reference for the international food trade. It was set up in the 1960s as a joint instrument of the United Nations Food and Agriculture Organization and the World Health Organization. Its primary mission is to protect the consumer's health and to ensure fair practices in the international food trade. The Codex Alimentarius Commission adopts standards for commodities, Good Agricultural Practices (GAP) guidelines and defines maximum limits of additives, contaminants, pesticide residues and veterinary drugs to be found in food/feed. These are prepared by special committees and task forces.

### 2.2.2 ISO 22000:2005

The ISO 22000:2005 - *Food safety management systems – Requirements for any organization in the food chain* - is designed in order to create security by ensuring that there is no weak link in the logistic agro-food chain.

It integrates the 7 HACCP (Hazard Analysis Critical Control Points) principles. The HACCP suits any industry sector that manages risk; it is not an exclusive application to the food sector. The seven principles are:

- Conducting analysis of hazards;
- Identifying the critical control points;
- Defining and implementing the limits to the critical points;
- Establish and maintain the monitoring requirements;
- Take corrective action if critical limits are exceeded;
- Verify the effectiveness of the implemented HACCP;
- Keep data for analysis, improvement and objectively demonstrating responsible prudence.

The ISO 22000:2005 standard specifies requirements for a food safety management system when an organization:

- Needs to prove its ability to control food safety hazards in order to regularly produce reliable products which satisfy the client and the food safety regulations requirements;
- Tries to improve the clients' satisfaction by an efficient control of the food safety hazards, including the system update processes.

This standard does not specify the data format exchange but a set of information which needs to be available and exchangeable between the stakeholders as part of the protocols to control food safety.

### **2.2.3 ISO 22005:2007**

The ISO 22005:2007 - *Traceability in the feed and food chain – General principles and guidance for system design and development* - aims to help producers and processors to answer the main legal requirements in terms of crop production traceability. Its objective is to give the principles and basic requirements for the design and implementation of feed and food traceability system.

The principles of the traceability system according to this standard should be: verifiable; applied consistently and equitably; results oriented; cost effective and practical to apply.

### **2.2.4 GLOBALGAP**

GLOBALGAP (2009) is a private sector body that sets voluntary standards for the certification of agricultural products around the world. It is an equal partnership of agricultural producers and retailers which want to establish certification standards and procedures for Good Agricultural Practices (GAP). GLOBALGAP provides certification from before the seed is planted until it leaves the farm. It is a business-to-business standard, the logo can only be placed on the pallets that will not be visible to the end consumers.

GLOBALGAP developed an online data base called Field Passport where the farmer can keep information about the production during cultivation period of a crop. They can monitor the crop since the establishment by recording the seed information, soil, crop protection and fertilization details. The data is manually entered via the internet by the

farmer. There is an opportunity to provide this information electronically and to conduct the assessment based on Field Passport.

Van der Grijp et al (2005) point out that GLOBALGAP as a private governance system played an important role with three fruit production companies in Brazil. Over a period of 10 years, it became recognized for an improvement in social responsibility, environment protection and production methods.

### **2.2.5 EAN.UCC Traceability Guideline**

The GS1 System (formerly EAN.UCC System) is an international standard for identification and communication in any supply chain. The GS1 System is a set of global standards, which enable the unique identification of all trade items, processes, services, shipments, assets, companies and locations at any point in the supply chain. GS1 has developed a guideline (EAN.UCC, 2003) to provide a common methodology with global generic recommendations for users in all sectors to develop traceability solutions. It serves as a basis to start traceability projects by using EAN.UCC standards. The guideline sets four common principles of traceability, they are identification, data capture recording, links management and communication. Sections 2.2.5.1 to 2.2.5.4 are based on *EAN.UCC Traceability Implementation* (EAN.UCC, 2003).

#### **2.2.5.1 Identification**

The EAN.UCC system sets internationally unique identification numbers. The identification numbers identify an item; however, do not contain any information about it. The supply chain partners are responsible for deciding which information should be linked with each item.

There is a range of identification numbers depending on what has to be identified. The identification numbers provided by EAN.UCC are:

1. Global Location Number (GLN). Provides identification of location of each supply member. The supply member can also assign a GLN to all the relevant locations and functions of the process.

2. Global Trade Item Number (GTIN<sup>TM</sup>). Provides identification of the trade item or service and it is assigned by its brand owner. It has to be combined with a batch number in order to identify a specific item.
3. Serial Shipping Container Code (SSCC) is the identification of logistic units (i.e. pallets). The SSCC is exclusive to each logistic unit when linked to the GTIN<sup>TM</sup> and batch number.

#### 2.2.5.2 Data Capture and Recording

EAN.UCC system uses barcodes to encode information about the trade item or service. The identification numbers can be read by scanners and the information can be recovered. Two types of barcodes are used, EAN 13/UPC and UCC/EAN-128.

EAN 13/UPC is used to identify the trade units and/or consumers units. Examples of consumer units are individual breakfast cereal box; the trade unit is the pallet where a number of these boxes are transported. UCC/EAN-128 is used within supply chain to encode primary identification such as GTIN<sup>TM</sup> and SSCC and additional data such as batch number or weight.

EAN.UCC Application Identifiers (AI) defines the data structure to be exchanged between the members of the supply chain. The meaning of the data and data format are defined by the AI's.

#### 2.2.5.3 Links Management

The identification data is linked in each step of the supply chain. At the production site the SSCC is linked with production batches and GTIN<sup>TM</sup>. The data of the finished items for shipment with SSCC are identified with GLN. Consequentially, the history of the item can be traced.

#### 2.2.5.4 Communication

Electronic Data Interchange (EDI) provides exchange of information between computers of trading partners within a supply chain. The companies within the supply chain have to agree the type of data they will exchange, and how the data will be presented.

The FoodTrace project identifies the EAN.UCC as being the most suitable identification system available to be used in the food chain. The FoodTrace project is described on section 2.3.1.4.

## **2.3 Ongoing Research Involved with Food Traceability**

### **2.3.1 The PETER - Promoting European Traceability Excellence & Research**

Peter Project (Peter Project, 2006) is funded by the European Commission through the Sixth Framework Programme under the Food Quality and Safety Priority. The general objectives are to:

1. Provide an international forum for focussing and disseminating the results of European research on traceability.
2. Harmonize points of common interest, tools, content and strategies.
3. Improve collaboration between European projects.
4. Reduce potential duplication among ongoing projects.
5. Maximise the effectiveness of project activities with reference to shared objectives and results.
6. Recommend guidelines to the European Commission and stakeholders highlighting gaps, redundancies and research needs.

The overall goal of the project is to determine the most appropriate exchange information system for all types of stakeholders. The project will address the information exchange concepts and system guidelines prototypes (resulting for comparisons between the information systems used by the nine projects). The nine participating projects are detailed as follows:

#### **2.3.1.1 TRACE**

The aim of TRACE (TRACE, 2005) is to develop a Traceability Control Mechanism - methods and instruments for authentication and testing the produce to match with the information received.

It focuses firstly on mineral water, cereals, honey, meat and chicken but will have wider applicability to other commodities. It will also assess European consumer perceptions, attitudes, and expectations regarding food production systems and their ability-to-trace food products. Technology transfer activities will guide industry, regulatory bodies and analysts in the new systems and methods.

The project aims to correlate the commodity with the environment where they were produced. The criterion is to correlate the properties of the locally produced food with regional geochemical and bio-climatic factors. The objective is to reduce the need for a different set of data for each commodity.

#### 2.3.1.2 GeoTraceAgri

The GTA project contributed to the realisation of geotraceability (GeoTraceAgri, 2005). It is the association of geographical nature with the traditional data of traceability. The project has a role to show that it is possible to qualify the origin and the mode of production by geotraceability.

The purpose of the GeoTraceAgri project is to “define a methodology for the sampling, acquisition, utilization and processing of georeferenced data that will be used to generate agro-environmental indicators at various geographical scales that can be used by the members of the food chain”

The geotraceability indicators are interested in the existing relations between a product, a parcel and its environment (Incidences of the environment on the parcel production / Incidences of the agricultural practices of the parcel on the environment / Influence of the parcel characteristics on the production / Parcel historic). The geotraceability indicators have to answer various criteria such as: bring a synthetic view of a problem to facilitate the understanding of it, to be based on a reliable and easily accessible data, to be sensitive to waited changes and to be understood and accepted by all the users.

#### 2.3.1.3 GTIS-CAP – GeoTraceability Integrated System for the Common Agriculture Policy

The objective of GTIS-CAP project is to complete the information systems used by European and national bodies for the control and the management of the Common Agricultural Policy with geo-referenced traceability data and indicators (Oger, 2005).

The project aims to interface these information systems with agricultural management systems used by producers in order to provide them with added values for specific production methods based on precise specifications which are regulated by food chain actors and certifying bodies.

Within the framework of the Integrated Administrative and Control System (IACS) which forms the basis for managing subsidies allocated to producers as part of the CAP, complete digital Land Parcel Identification Systems (LPIS) have been implemented in the different member countries. LPIS are a key element of IACS for the management and control of area based subsidies: The identification of all the agricultural parcel permits cross checks of all applications make by farmers and ensure that the declared parcels exist and are eligible, as well as that any piece of land is subject to only one claim. LPIS are large scale (1:10000) digital maps used to reference agricultural parcels.

The GTIS should be a decentralized system based on web technologies, in which the main application (gate of access) is connected to various data servers (LPIS, remote sensing, traceability and other geographical data) in order to recover in real time information necessary to the implementation of the computerized decision-making system.

The integrated system is based on the three key components:

- Geo-Identifier (GEO-ID).
- Metacap – Metadata on resources in relation to the Common Agricultural Policy.
- Remote Sensing Imagery.

#### 2.3.1.4 FoodTrace

The aim of this project is, “to present a generic framework for traceability that can be applied to any food supply chain and accommodate the complexities of cross-supply chain interaction” (FoodTrace, 2004).

The core of the FoodTrace framework can be summarized in four requirements:

- Identification and item-attendant and item-associated data/information
- Item-attendant data carriers
- Data transfer and storage



- Data information communications

Identification is about being able to differentiate one item from another and any associated information. Item-attendant data relates to data that go along with an item within a suitable item-attendant data carrier.

FoodTrace identifies EAN.UCC as being the nearest system available of numbering and identification that allows fully open-system application. Although it was pointed out that issues including awareness, alignment with existing in-supply chain system, cost of membership and appropriateness of system provisions to meet their requirements need to be addressed.

A sixth framework project proposal, FoodTrace Plus, is designed to cover the areas in which further developments are required in support of process enhancement and traceability functions. These areas were identified in the FoodTrace generic framework.

#### 2.3.1.5 Co-Extra

The aims of this project are (Co-Extra, 2006):

- To develop comprehensive tools and methodologies and integrate them along with existing ones into embedded decision-support systems aimed at enabling co-existence between GMO and non GMO (conventional and organic) crops.
- To trace genetically modified organism (GMO) materials and derived products, along the food and feed chains.

Co-Extra studies and validates biological containment methods and provides tools and methods for implementing co-existence. In parallel, Co-Extra designs and integrates GMO detection tools and develops sampling plans.

#### 2.3.1.6 SEAFOODplus

The strategic objective of the SEAFOODplus (SEAFOODplus, 2003) is to reduce health problems and to increase well-being among European consumers by applying the benefits obtained through consumption of health promoting and safe seafood (wild and farmed fish and shellfish, both of marine and freshwater origin) products of high eating quality.

The research is divided into three projects:

- The main objective of the first project is to develop a traceability vocabulary and to develop a Good Traceability Practice guideline in order to define the requirements for management of operations in the seafood sector.
- The second project will integrate the information flow from primary producers to the others links in the chain.
- The third project will develop methods of validation of the developed and implemented traceability system.

#### 2.3.1.7 DNA-TRACK

The project concerns DNAs detection in raw materials and foods (DNA-TRACK, 2003). The project involves methods based on PCR (Polymerase chain reaction).

A new PNA-technology, actually aimed at biomedical diagnostics will be established as complementary to PCR, aimed at improving sensitivity, selectivity and increased detection limits in food. Validation of different methods will be performed, in order to provide updated criteria of choice in food control through the food chain. Application to genetically modified organisms (GMOs) will be performed.

#### 2.3.1.8 OLIV-TRACK

The main objective of this project is to apply molecular technologies based on genomic and metabolic information to the traceability of origin and authenticity of olive oil produced and sold within the European Union (OLIV-TRACK, 2004). The purpose of this is to ensure the production of reliable quality olive oil for the consumers' health and confidence, to protect sustainable cultivation of olive trees and to authenticate their European region of origin.

#### 2.3.1.9 ALCUE-FOOD

ALCUE-FOOD is an EU Specific Support Action which has been set up between four EU members states and four Latin American countries from the MERCOSUR region (ALCUE-FOOD, 2005). This project will promote a total food chain approach that will ensure that food export from Latin America comply with European safety and quality regulations. The aim is to enable products to be traced back from “European fork to Latin American farms” by developing EU-LAC partnership in food quality and safety.

## **2.4 Stakeholders**

### **2.4.1 Consumers**

Traceability may help the consumers to know where the food comes from, but the knowledge of the origin of the product does not make them safer according to the Food Standard Agency (2004). In the survey on consumer attitude, published by Food Standard Agency (2006), “chemicals in food” is the key area where consumers want more information from the FSA.

Research conducted by Nilsson et al. (2004) indicates that while small groups of consumers are satisfied with many different schemes, the mainstream group wants a reduced number of wide range credible schemes. An automated agrochemical recording system would be a benefit in this area where the certification bodies could certify the inputs on farm according to a robust system.

A robust traceability system is more likely to increase consumers’ choice based on product identity and origin. The consumers will gain confidence in food safety from quality assurance schemes of traceability and rapid withdrawal of products from sale, this information should be provided on-label.

### **2.4.2 The Food Industry**

Traceability systems are part of systems which enable the food industry (FSA, 2002):

- To comply with legislation
- To be able to take quick action to remove contaminated products from sale
- To protect brand reputation
- To minimize the size of any withdrawal
- To identify problems in production
- To maintain market and consumers confidence
- To differentiate in the market place

Golan et al (2004) points out that companies build traceability systems to improve supply-side management, to increase safety and quality control, and to market foods with credence attributes that difficult to be detected by the consumers, i.e. GMO. It is also stated that in the U.S. traceability systems tend to be motivated by economic

incentives, not government regulation. The decision relating to the implementation of traceability systems are often made with reference to business risk and to protect brand value.

Traceability may also improve the supply chain management between the businesses, including better integration of electronic data interchange and efficient consumer response systems. However, lack of synchronization of traceability and assurance protocols globally is a significant constraint preventing companies from implement protocols (Anon, 2004).

Which traceability data should be recorded and which data should be available to customers must be determined by food industry.

### **2.4.3 Legislative requirements**

From 1 January 2005, General Food Law Regulation 178/2002/EC required traceability in Europe. All the operators of the agro-food chain have to provide information about the origin and the destination of the agricultural products they deal with.

It applies to all the stages of production, processing and distribution of food and feed. The Article 18 of the General Food Law mandatory aspects on traceability in the food chain are fixed. In this article, operators are required to:

- Identify their suppliers of: food/feed and any other substance, for incorporation into food/feed.
- Identify the operators to which they have supplied products.
- Maintain appropriate records and ensure that such information is made available to competent authorities on demand.

The adoption of an internal traceability remains a business decision; the article 18 does not require it. According with the Regulation 178/2002/EC, importers and exporters of bulk goods don't have to demonstrate traceability back to the farm. FSA (2002) points out that the current market position is to obtain a contract agreement, which identifies both the buyer and seller, and for acceptance of goods to be dependent on analysis of quality at the point of delivery. This level of traceability would satisfy the requirements in the EU General Food Law Regulation.

#### **2.4.4 Quality assurance providers**

There are many different certification schemes. These different schemes involved the food industry and the final consumer demands for food safety, quality and environmental management.

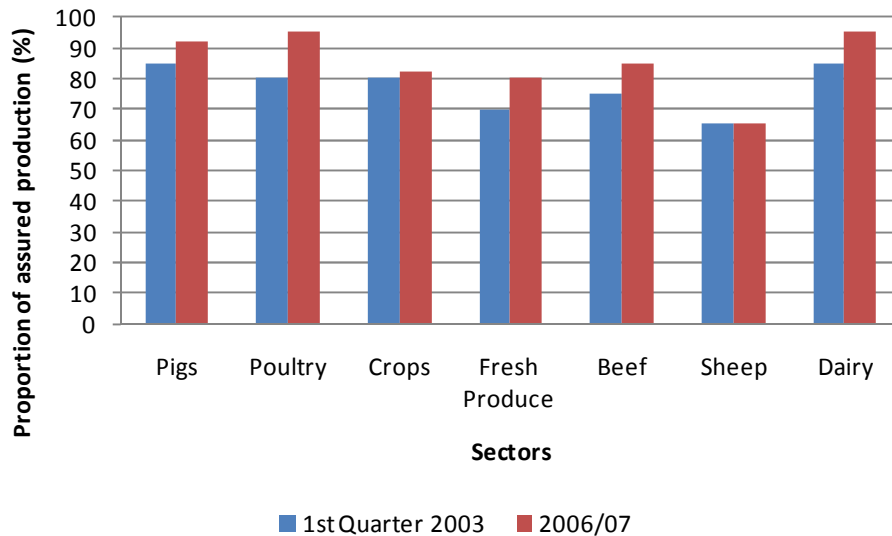
Farm assurance schemes have been developed as a result of both push and pull drivers throughout the food chain, as farmers seek to create added value for their products and consumers demand higher standards of environmental protection, animal welfare and food quality (FSA 2002). Fearne and Walters (2004) point out that the potential benefit of the farm assurance is the improvement of business management through the systematic monitoring of activities. The farm assurance schemes play a role to provide confidence to consumers that they are buying a produce being produced under good welfare conditions and an environmentally protected system (Bredahl et al., 2001).

Quality assurance schemes can require the food industry to have a traceability system in place. However, there is no scheme which sets down the guidelines for developing a traceability system, except in the case of the mandatory schemes in relation to cattle (FSA 2002).

Organic production systems can be considered as a legally enforceable farm assurance scheme, which operates throughout the food chain (FSA 2004). Within organic regulations, the focus has been verification of processes and maintenance of product integrity through the food chain.

A quality assurance scheme in use in Germany, QS Qualität und Sicherheit GmbH, offers a control system from field to the final retailers. This scheme provides certification across all stages of the food chain which enables the verification of a multi-level quality assurance system for consumers. For food quality it is essential to have all stages of the food chain certified, as if there is a problem in the early stage of the chain it will spread to the next members. The traceability system is only reliable if there is a consistent link through the whole chain. For example, one point in the chain can be confident from where they are buying products but must also guarantee that their supplier has the same confidence with their inputs. A certification from farm to retailer is an extra assurance that the whole chain is following quality assurance schemes.

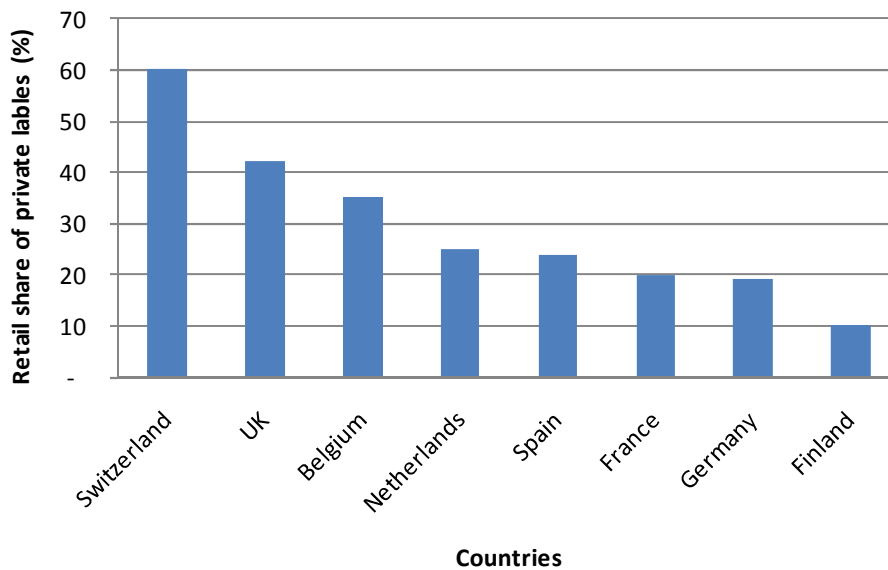
Figure 1 illustrates the proportion of food produced in UK which is covered by Farm Assurance Schemes.



**Figure 1: Proportion of Production in UK under Farm Assurance Scheme (DEFRA 2008)**

In 2006/07 all sectors apart from sheep, (which remained at 65%) had shown an increase in farm assured production compared to the baseline of 1<sup>st</sup> quarter 2003. The poultry and dairy sectors have the highest proportion of assured production at 95% with the pigs and beef sectors at 92% and 85% respectively. The crops and the fresh produce sectors have the proportion of assured production at 82% and 80% respectively.

In Europe, the retail private brands (e.g. supermarkets/retailers own brand) are associated with high quality assurance standards even higher than those existing standards (Bredahl et al., 2001). For instance, Tesco Choice standard requires higher quality standard than GLOBALGAP (Payne, personal communication, 2006). Figure 2 represents the retail share of private brand labels among 13 food categories in some European countries; it reaches 60% in Switzerland and 10%-40% in most other western European countries according to a publication released by KPMG (2000). The publication does not specify the types of food production that were taken into consideration.



**Figure 2: Private brand label share of the total retail food volume sales for 13 non specified food categories. (KPMG, 2000)**

In order to comply with quality standards, the farmers have to gather a number of pieces of information and keep the record of the operations, i.e. agrochemical application, seed treatment, crop storage and handling. This requirement is likely to increase the labour cost associated in collecting and managing the data.

#### **2.4.5 Farmers and Growers**

According to FSA (2002), the farmers are required to kept records of:

- the quantity of seeds and transplants brought in and their origin
- bought in fertilizing materials or manures
- management inputs on a crop basis
- pesticide applications
- manure exchanges with other holdings
- livestock purchases and sales
- crop sales with amount and destination
- veterinary products purchased and their use on an animal basis
- livestock feeds and feeding regime for each animal

The management of farm records raises a big workload onto the farmer, particularly with increasing legal demands on documentation for traceability of agricultural products.

The farm is the place where the primary traceability information is collected. The farmers/growers must be able to inform where the food product was grown, the agrochemical applied, the harvest date and all other information required to meet the traceability.

Market analysis (Watts 2004) showed that 95% of the farmer respondents thought that automatic record system would be a useful addition to a sprayer. A system for automatic data acquisition is very useful to the farmer to reduce the amount of error associated with manual entry of data into a computer and consequently less paperwork. Fernandez-Cornejo (2007) points out that time-saving benefits are driving the decisions of certain farm operator households to adopt new technologies and practices.

#### **2.4.6 Farm Equipment Manufacturers**

The use of electronic systems in agricultural equipment allows monitoring and controlling these machines and managing agricultural activities with precise data. The communication between the agricultural equipment becomes a fundamental requirement. The ISO 11783 (ISOBUS) is a common electronic standard, promoting the intercommunication and compatibility between machines from different manufacturers. This standard has been developed to meet the needs for electronic communication between tractor and implements, between components within tractors, within implements, and within other self-propelled forestry and agricultural machines.

Traceability only works if the input data is correct. The machines equipped with the ISO 11783 can provide the automatic registration of the information during the field operations. Auernhammer (2002) states that agriculture equipment GPS and the standardized communications by ISO 11783 opens possibilities for traceability.

To be globally competitive the country needs to produce high quality food at an affordable price. Pierce & Cavalieri (2002) point out that to achieve these we need to have technological innovation that improves crop quality and reduces the cost of production. They believe that the machinery of the future must be increasingly



automated, capable of detecting crop quality at various points in the production and processing system, and fully equipped for tracking information about the crop from field to the table. Bodria (2003) states that agriculture mechanization plays a key role in building a traceability system being appointed to monitor the first steep of food chain from the field to the processor.

#### **2.4.7 The Agrochemical Industry**

Watts (2004) has outlined the architecture to provide a full traceability system enabling the provision of the methodology for using RFID tag to transmit agrochemical data from the sprayer container to the on-board tractor computer and also an automated method of weighing the amount of active ingredient added to the sprayer tank.

The agrochemical industry has to standardize on the type of location of identifiers used on products delivered to the farm. This needs to include container manufacturers, chemical manufacturers, logistics companies and chemical distributors (Watts, 2004).

#### **2.4.8 Farm Software Providers**

The farm software and hardware providers can be an important partner in the food chain as they can support the industry by providing a system to hold the traceability information in an economic, easy to use form, and provide management tools. Record keeping is one of key points in the establishment of robust traceability system.

The industry provides a number of pieces of software to assist both the farmers and retailers to record and keep the information. For a robust traceability system the information flow is crucial then the necessity to have a standard data format for data exchange. However, most of farm software providers in UK (e.g. Farmade, Farmworks and Muddy Boots) have no standard data format for data exchange (Price, personal communication, 2007).

Kunisch et al. (2007) have described the agroXML, which is a data exchange language based on XML (eXtensible Markup Language) especially created to be used in the agriculture sector. The agroXML standardize the communication between agriculture software from different companies and online service providers. John Deere and Class are two of the large farm equipment companies which use agroXML as a data exchange

standard (Kunisch et al., 2007). Although AgroXML is very popular in Germany its use is not yet spread to other parts of the world.

#### **2.4.9 Agronomist**

A market research conducted by Watts (2004) with 41 arable farmers in England reports that 75% of the respondents rely on their agronomist to decide the spraying application. The crop management recommendation needs to be provided in a data format compatible with the traceability system place in farm. The professional relationship between the agronomist and farmers is essential to help the farmers to demonstrate good practices on field operations/applications.

### **2.5 Agriculture Inputs**

Traceability in the food chain starts with field inputs. Each different input is particularly significant in specific production systems. Water quality is particularly important for fresh produce and veterinary products are essential for use in livestock farms as are agrochemicals/fertilizers for arable and field vegetables and fruits crops. Soil data is particularly important for organic farming systems, where a key requirement is to identify that the produce comes from an organic field. Seeds records are essential for fresh produce and arable as these records are part of the traceability data required by farm assurance scheme in UK, i.e. Assured Combinable Crops Scheme (ACCS). The farmers/growers must to keep all the inputs records described above and make them available to the food chain whenever it is necessary.

The concern to differentiate the Genetically Modified Organism (GMOs) from the non-GMOs food products can be considered one of the drivers for the development of traceability system in the food chain. The rules concerning GMOs became legally compulsory in Europe in early 2004. The regulations are the Traceability and Labelling of GMOs (EC No. 1830/2003) and the GMO Food and Feed Regulation (EC No. 1829/2003) dealing with authorisation procedures and labelling issues.

In October 2000 the U.S. food industry was subjected to the Starlink GMO contamination of corn produce. StarLink was intended only for animal consumption as

it contains some characteristics of known allergens. It was estimated that the cost would reach \$500 million in payments to farmers, food producers and processors who had to withdraw food products (Anon, 2005). According to Vorman (2000) over 300 brands of taco shells, crisps and others corn products were withdrawn from shops, because of contamination. Consolidated Grain and Barge, a major grain handling company in the USA, justified the cost associated with implementing ISO certification based on the need of their overseas customers (Anon, 2004). As a management strategy this was successful in the result of the StartLink incident, since they could document and certify non-contaminated supplies of corn. This incident illustrates the potential damage in terms of confidence and cost caused by the absence of efficient food traceability systems. Traceability systems must to be able to provide clear and reliable product identification and the historic information of the food product being traded.

The pesticides are used in agriculture to protect crops from insect pests, weeds and fungal diseases while they are growing. The Pesticide Safety Directorate (PSD) maintains an updated list of the agriculture pesticides approved which farmers are allowed to use. The unregistered agrochemical can either be a counterfeited product, or an unapproved agrochemical such as withdrawn pesticide or a banned pesticide. In the UK, before a pesticide can be sold, supplied, stored, used or advertised it has to be approved under The Control of Pesticides Regulations 1986 (COPR) or the Plant Protection Products Regulations 2005 (PPPR). When appropriate, PSD will take prosecution action. A person who is found guilty under pesticides legislation is liable for a fine of up to £5000 per offence in the Magistrates Court and in the Crown Court there is provision for unlimited fines (Pesticide Safety Directorate, 2008). In addition to these controls, Cross Compliance inspections carried out by the Rural Payments Agency (RPA) check that only approved pesticides are used and that they are used in compliance with their conditions of use, good agricultural practice and where possible as part of an integrated approach to controlling pests and diseases. Failure to comply with these requirements may lead to reductions in a farmer's single farm payment. It is clear the farmer's responsibility over the pesticide application. This input is largely controlled in UK and the farmers must to keep the records of the application to prove compliance with the regulation.

## 2.6 The Environment

Sarig (2003) argues that in recent years, the development of large-scale commercial monoculture agriculture has contributed to environmental problems. He maintains that traceability has become an essential part of the food production. Having traceability system in place is a way to show good practice through production process and consequentially comply with quality assurance schemes and legislation. Legislation and quality assurance schemes have different rules, but both require records to be made regarding to environment compliance. This means that any actions which may fail to comply with environment protection can be controlled.

In 2006, the Environment Agency released the report *Good Farming, Better Environment*. In this report it is stated that the agency “will support new technologies, voluntary action, information exchange and adoption of good practice as alternatives to regulation where appropriate.” Traceability plays a key role in improving the environmental management. Furthermore, traceability data can be used to identify method of production, processing and impacts (land and water use and biodiversity).

## 2.7 Traceability Systems

The Food Standard Agency (2002) defines the basic characteristic of traceability system as the identification of units/batches of all ingredient and products; the information on when and where they are moved or transformed and a system linking these data.

The Food Standard Agency (2004) point out that “traceability system are record keeping procedures that show the path of a particularly unit or batch of product or ingredient from suppliers, through all the intermediate steps which process and combines ingredients into new products and through the supply chain to customers and perhaps ultimately to consumers.” The information carried in a traceability system varies and depends on the nature of the product, on farm and manufacturing and requirement in law.

The cost of implementation of traceability systems is likely to vary between business and sectors depending on the type of technology adopted, the amount of information required to be stored and the complexity of the food chain.

The basis of all supply chain technology is the ability to identify the logistic units: pallets, packages, and units of product. Machine readable labels are being developed to enable the scanning of goods in and out of suppliers in order to track products and improve logistics, reduce errors of paper records and manual data entry and finally set up electronic ordering and payment system which reduce errors and increase efficiency (FSA 2004). RFID is an example of product identification and is described below.

### **2.7.1 Radio Frequency Identification systems**

A RFID (Radio Frequency Identification) system consists of a transponder (RFID tag), reader/writer and antenna. The data transfer from the transponder to the reader is achieved by a radio frequency link. RFID operates on five principal frequencies: 0–135 kHz, 13.56 MHz, 433 MHz, 900 MHz (UHF), and 2.4 GHz (microwaves) (Blackburn et al., 2008). According to Blackburn et al. (2008) the HF (High Frequency) tags have practical advantages such as better penetration through water and relative insensitivity to electromagnetic noise. High Frequency tags are generally considered to be from 3 MHz to 30 MHz, typically operate at 13.56 MHz. High Frequency tags can be read from less than 1 metre away and transmit data faster than low frequency tags.

There are two types of transponders, the passives and the actives (Watts, 2004). Passive systems are activated by a remote energy source. The read range of these systems dependent on frequency and they have very limited data carrying capacity. The active systems contain their own energy source. When they are activated by a remote signal, the internal power source then used to broadcast the stored information. They have greater storage capacity than passive systems and a greater read range.

RFID solutions have been quickly adopted by the food industry. In January 2005, Wal-Mart mandated its top 100 suppliers to adopt RFID, since then they are gradually requiring all suppliers to adopt the technology (Roberti, 2005). Well's Dairy Milks adopted RFID technology to meet Wal-Mart's mandate, they recognized that extending the technology beyond the tagging pallets they could improve inventory management, quality control and gain insights into its production and supply-chain practices (Greengard, 2007).

RFID Journal gathers a range of case studies on RFID adoption. Wholesale food distributor SYSCO, stated that using RFID-enabled temperatures sensors they reduce the track spoilage (Collins, 2005). KiMs, a snack Food Company in Denmark, stated that the using RFID to track shipments within its supply chain has decreased the inventory holding cost and workforce (Khan, 2004). Wang et al. (2006) argue that deployment of RFID and wireless sensors in agriculture traceability systems will increase in the future. Consequentially it will contribute to the development of automated traceability system at farm level.

### **2.7.2 Cost of implementation of traceability systems**

The cost of implementing traceability systems varies between business and sectors depending on the type of technology adopted, the amount of information required to be stored and the complexity of the food chain. Golan et al. (2004) states that traceability costs include the cost of recordkeeping and product differentiation. Decisions need to be made according with the level of traceability required and this also affect the cost of the system. According to Golan et al. (2004) the factors which affect the cost of traceability system are the following: a) amount of information to be recorded, b) number of transactions, c) tracking unit size, d) degree of product transformation, e) number of new segregations or identify preservations activity and f) technologies difficulties.

Traceability systems come with a cost. But the costs of not having it, or having inefficient systems in place, may be the lost of the consumer's confidence in case of a food scare. Companies have to weigh the cost of complying with a customer's request against possible loss of future business (Jorgenson et al, 2003).

According with Toyryla (1999) traceability can be justified economically using the same techniques that are used to justify any other capital investment, he also refers to Feigenbaum (1991) that the cost of traceability in comparison to the estimated benefits, determine the desirable level of traceability.

## **2.8 Automated Agrochemical Recording Systems**

The study undertaken by Watts (2004) showed that the barcodes are not suitable for a farm environmental because the surface contamination affect the performance of the

readers. The RFID has been identified as an appropriated method of data transfer, achieving >99% reliability under operational conditions. The prototype automatic chemical inputs recording systems, was designed, and built using a commercially available RFID reader, load cells and a portable computer, running specially written software and mounted near chemical induction hopper of the sprayer. The RFID reader is encased in a steel box, one side being clear plastic in the direction of the chemical container.

Code of Practice for Using Plant Protection Products (Defra, 2006) requires a significant amount of data to be written by the sprayer operator in order to generate a spraying record. Watts (2004) states that to generate the complete spraying record it is necessary to give the sprayer knowledge the amount and properties of the products loaded.

Watts (2004) designed a prototype that permits the agrochemicals to be loaded and recorded before going to the sprayer tank. It was designed to be able to weigh loads in the range of 0.2-30 kg with an accuracy of 1 g, but the best accuracy achieved was 20 g due the mechanical vibration from the tractor/sprayer unit. The weighing platform was reconfigured by Peets (2009) to provide much improved resolution (Table 1).

**Table 1: Weighing Platform specification, earlier and latest design**

<b>Feature</b>	<b>Watts ( 2004)</b>	<b>Peets (2009)</b>
Range	200-30,000 g	36-1,600 g
Resolution	20 g	1 g* / 3.6 g**
Resolution %	0.067%	0.0625%* / 0.225%**
Speed	68.5 s	34 s

\* With engine switched off.

\*\* Sprayer fully operational.

Watts (2004) has conducted an experiment in order to compare the conventional and the automatic recording system. The results shows that the loading time including the record creation was decrease by 4.3 seconds per container when using the automatic device. However, the loading cycle was increased by 15 seconds per container in comparison with the conventional method. The more recent development of the automated agrochemical recording system reconfigured by Peets (2009) has proven that

there is no statistically significant difference between the loading and record creation time between the automatic and manual system.

## **2.9 Innovation**

Diederer et al. (2003) classifies agriculture as a supplier dominant sector which depend on the suppliers industries for its innovation and technical progress. Rogers (2003) makes reference to earlier work which investigate the nature of innovation. Gabriel Tarde (1843-1904), propounded the theory that social movements were fundamental forces arising out of combination of individual decisions made by a population connected by awareness of peer action. Schumpeter (1883-1950) pointed out that those who created technical innovation were the generators of economic growth and that the difficulties of the entrepreneurial cycle were in effect drivers of the creative process. He concluded that innovation has been the driver for all the major advances in society.

The process of adoption involves information gathering, investment in research, risk assessment and learning process to use the new technology (Diederer et al. 2003).

Rogers (2003) concentrated on the method by which innovations were disseminated. His study was based on agriculture at the time of the “Green Revolution”, which some innovations became popular practice very quickly and others with great value to the market failed completely. In order to study facts surrounding the rate of adoption of different innovations Rogers (2003) designed a classification, which would allow a comparative study to be made. He defined the characteristics of innovation, which affect the ease of adoption as the following:

1. Relative advantage: developers are likely to have an uncritical belief on the valued of their innovation, but potential customers will have a widely differ understanding of this factor. “The degree of relative advantage is often expressed as economic profitability, social prestige, or other benefits.”
2. Compatibility: “Is the innovation consistent with the values, and needs of the people who adopt it?” Innovations may address need of which the customers considers unimportant or which they may not be aware.



3. Complexity: complexity is one of the most obvious areas of difficulty. Will the potential users find it easy to use and understand? The adoption of new technologies requires initial financial investment as well investment in learning new skills.
4. Trial-ability: Is the innovation available to experiment before they adopt? If the farmers are able to “try before they buy” without a major investment then this reduces the factors of risk in an initial involvement.
5. Observability: Rogers (2003) identify that an important factor which affect the easy of adoption is how ease is for people to see the result of the use and action of the technology. Many new technologies which may solve problem may fail because neither the problem, nor the solution, nor the means of the solutions are visible.

Favourable classification in all these attributes has significant influence on the rate of adoption of a given innovation. If an innovation fails to comply in any of the above measures then it will be more difficult to introduce.

Rogers (2003) proposed that adopters of any idea could be categorised as innovators, early adopters, early majority, late majority and laggards. Each adopter’s willingness to participate would depend on their awareness, enthusiasm and willingness to either lead/follow or take risks. He summarises these groups are following:

1. Innovators: they are the technology enthusiasts who like to be the first to adopt any development. They are happy to tinker for hours to make their technology work. They are a great help to the developers as they are willing to try out new ideas. “The innovator plays a gatekeeping role in the flow of new ideas into a system.”
2. Early Adopter: They are a group who will get involved with technology. They can often see practical applications for new technology way in advance of the developers and are willing to pay well for any innovation which they feel put their business ahead of their market competitors. They are characterised as the risk takers who will progress technologies that work and who will abandon those which don’t work.
3. Early Majority: They will monitor the activities of more adventurous group and when a system appears to be reliable and useable, it becomes worthwhile to adopt it. The sales rise sharply at this stage since new group see proven utility for the

technology and start to make part of the adoption. It worth noting that rise in sales also allows unit cost to be reduced.

4. Late majority: This group will wait and see for longer. Usually they adopt a technology because it has become so common on the market that they buy by default. This group will buy into a technology by responding to incentives like trade-ins on their old systems.
5. Laggards: This group are not considered worth marketing to and they will only invest in a technology when there is no alternative. They have great resistance to change and are usually suspicious of innovation.

The innovators and the early adopters are the leaders for the early majority to who will get involved when they see that the development has some value for their own business.

Gray et al. (2004) refers to Cooper (2001) who believed that the innovations which are more likely to succeed are those who are strongly customer-oriented. Furthermore, he argued that it is essential to identify what costumers perceived as beneficial and valuable to assessing the likelihood of success for a new innovation. When conducting the customers' analysis it is important to target the right customers. Gray et al. (2004) suggest that the customers who have limited budget and those with lacking of technical knowledge about the innovation should be included on the analysis as they represent potential customers. However, those who don't need the product should not be included. Furthermore, Gray et al. (2004) argued that opportunities to create a new innovation can come from the understanding of benefits and features of existing products that the customers either like or dislike or place value.

Understanding the perception and attitudes of farmers can help to understanding why farmers adopt technologies beyond the economic benefit, and what industry and researches could focus on to influence adoption of these technologies. Adrian et al. (2005) argued that the farmers which are more likely to adopt precision agriculture technology and understand its potential benefits are those that are more confident about learning and using this technology. Adrian et al. (2005) also make reference to Daberkow and McBride (2003) work, which indicated that age, farming experience, education level of farm managers/owners, off-farm employment, farm size and crops grown influence the adoption of precision agriculture technologies. Furthermore,

Jockinke et al. (2007) indicated that the initial cost of the technology can be a barrier to the precision farming adoption.

An analysis conducted by Douthwaite et al. (2001), suggests that the success of agricultural innovation depends on the partnership between the researchers and the “key stakeholders” (those who will use and put innovation into practice, such as farmers). He argued that the “key stakeholders” play a key role to learn how to use the technology and based on its own experience they are able to suggest improvements. The researchers, those who have the scientific knowledge of the technology, will then be able to employ the necessary changes. Furthermore, Douthwaite et al. (2001) pointed out that a macro-invention, which is a completely new technology never seen on the society, only requires the “key stakeholders” participation when a functioning prototype has been built. Finally, Douthwaite (2002) stated that “the successful technologies were the one which manufacturers and users had modified the most”.

Research conducted by Dierderen et al. (2003) has identified the adoption behaviour in Dutch agriculture. The results show that innovations are positively related to farm size, market position and farmer’s access to information. Additionally, Llewellyn (2007) also pointed out the importance of the information quality and availability in adoption decision by farmers.

It has not been found in the literature review papers which address the adoption of automated traceability system. However, in the early stage of the development of the automated agrochemical recording system, Watts (2004) conducted a pre-market research with farmers in UK. The results show that 50% of the farmers interviewed believed that the automatic recording system is very useful, 45% believe that it useful and only 5% believe that it is not very useful. Watts (2004) argued that the adoption of the automated agrochemical recording system would be slow because of the reliance on comprehensive machine electronics.

Although no previous research on adoption of automated traceability system has been found, the need for automated traceability system is clear. The 13<sup>th</sup> Club of Bologna (Nov, 2002) meeting has published the conclusions and recommendations of the meeting which the general subject was: Mechanisation and Traceability of agricultural

production: a challenge for the future. In this document the following made the key points given below:

1. Pierce and Cavalieri (2002) pointed out that smart agriculture machines with tracking capabilities will be increasingly important to meet the consumers demand and to be competitive in the global market.
2. Auernhammer (2002) argued that there is a need to make agriculture machines more intelligent and able to collect real time information from every stage of the food production. This would enable the monitoring of the food production from field to distribution.
3. Zaske (2003) reminded the reader of the importance to have continuous documentation of the product flow and off all steps of the food chain. An automated traceability system would automatically collect data and generate the required documents to comply with farm assurance schemes and legislation.

The previous studies on adoption behaviours towards agricultural innovations were based on technologies which were already being used and known by the farmers. However, the AACTS is unknown amongst the farmers and its development is in a prototype stage. The receptivity model can be used to identify the market uptake of a product that is not yet in the market. This model identifies if the potential adopters are willing and able to absorb, accept and utilise innovation options (Clark et al. 2000). More details regarding the receptivity model are given in Chapter 7.

## **2.10 Conclusions**

Traceability systems have been primarily implemented in the food chain to comply with the legislation and quality assurance providers' requirements. Traceability systems play an important role on the improvement of environment management. The traceability records could improve the identification of methods of food production, process and impacts. There are nine ongoing projects in Europe, under the umbrella of Peter Project, to help the food chain to achieve traceability, but none of these projects will provide a guideline for product handling, from field to processor. Product handling guidelines should be developed in order to help the farmer to provide a product differentiation. The food industry has identified other benefits delivered by traceability systems such as

recall containment, and market share. Finally, the decision to invest in traceability is based either on comparison of the cost and benefits of traceability or on market requirements.

In the UK, there are a number of farm assurance schemes and legislations which required data to be collected and recorded at farm level. It is clear from the literature review that automated traceability system would assist the farmers to collect traceability data and generate the required reports in order to comply with legislation and quality assurance schemes. However, there is no evidence of how much the farmers would pay for such a system and their perceptions towards automated traceability systems.

Two PhD researcher students were involved in the development of the Automated Agrochemical Traceability System (AACTS). The first, Peets (2009) focused in the development of hardware and software to link automated recording and data transfer units to the hardware and software capabilities of agricultural machinery and farm computer systems. Furthermore, the analyses of the factors related to the market were conducted by the author of this thesis. The following section describes the actions taken by the author.

1. Interviews with food chain stakeholders in order to indentify theirs perceptions towards traceability systems.
2. To identify farm sprayer operators' impressions towards the AACTS in comparison with conventional manual loading system.
3. To identify farmer's willingness to pay for the AACTS.
4. To conduct detailed research with farms owners and/or managers in order to identify their attitudes towards the AACTS.

### **3 Methodological Approach**

#### **3.1 Introduction**

This chapter introduces the different research methods used to address the aim and objectives of this research. It explains the different classifications within the social science methods used to identify the purpose of the research. The sections within the thesis, and how they relate to the objectives, are then outlined.

#### **3.2 Research Design**

##### **3.2.1 Classification of social science research**

According to Neuman (2003), depending upon the objectives of the research this can be organised into three groups namely: 1) explore a new topic, 2) describe a social phenomena or 3) explain why something occurs. Whilst an early work by Robson (2002) defines a fourth stage to the classification of the purpose as shown in Table 2 with deals with “Emancipatory” issues. Yin (1994) suggested that “what” questions can be exploratory and can be used in any research strategy. According to him a “what” question can also mean “how much” or “how many”, in these cases it is more likely to be used for surveys or archival strategies. He also points out that “how” and “why” questions are more explanatory and likely to lead to the use of case studies, histories and experiments.

Table 2: Classification of research purpose (derived from Robson, 2002).

Purpose of study	Description
<b>Exploratory</b>	<ul style="list-style-type: none"> <li>• To find out what is happening, particularly in the little-understood situation.</li> <li>• To seek new insights.</li> <li>• To ask questions.</li> <li>• To assess phenomena in new light.</li> <li>• To generate ideas and hypotheses for future research.</li> <li>• Almost exclusively of flexible design.</li> </ul>
<b>Descriptive</b>	<ul style="list-style-type: none"> <li>• To portray an accurate profile of person, events or situation.</li> <li>• Requires extensive previous knowledge of the situation to be researched or described</li> <li>• May be flexible and/or fixed design.</li> </ul>
<b>Explanatory</b>	<ul style="list-style-type: none"> <li>• Seeks an explanation of situation or problem, traditionally but not necessarily in the form of casual relationships.</li> <li>• To explain patterns relating to the phenomenon being researched.</li> <li>• To identify relationships between aspects of phenomenon.</li> <li>• May be flexible and/or fixed design.</li> </ul>
<b>Emancipatory</b>	<ul style="list-style-type: none"> <li>• To create opportunities and the will to engage in social action.</li> <li>• Almost exclusively of flexible design.</li> </ul>

### 3.3 Methodology

The following sections describe the methodology used to address the objectives of the research within the respective chapters.

#### 3.3.1 Chapter 4: Primary findings of the stakeholders' perspective towards traceability systems.

This chapter aims to address the objective number one: *To identify the stakeholders' perceptions towards traceability systems, from the farm through to the supermarket.*

This chapter is predominantly exploratory, with the objective to explore the feasibility of future traceability systems' concepts with some descriptive elements. A total of seventeen members of the food chain were interviewed in order to identify their

perceptions towards traceability systems. The individual face-to-face semi-structured interviews were designed in order to collect qualitative data.

This was the first stage of the project, starting in March 2006 and finished in February 2007. The stakeholders interviewed were supermarket, farm software providers, quality assurance providers, manufacture of agriculture equipment, agrochemical industry, an agronomist, one arable farmer, one fresh produce farmer, National Farmers' Union, and the UK government Food Standards Agency. This group is considered to be the main members of the food chain playing an important role in the development of future traceability systems to be used at farm level. At this stage only two farmers/growers were interviewed in order to identify their current practice towards traceability systems and their perceptions towards traceability systems. However, as there was little information regarding the development of AACTS, no further interviews with farmers were conducted at this stage. It was sufficient that a more in depth farmers/growers studies should be conducted in the later stages when more detailed practical information could be provided.

### **3.3.2 Chapter 5: Farmers' impression toward the AACTS**

This chapter aims to address the objective number three: *To evaluate the reaction of the farmers to the performance of the AACTS in comparison with the existing manual loading and recording systems.* This part of the research is mainly descriptive with the objective to describe how different farmers judge the attributes of the AACTS and also how they rank the sprayer with the AACTS in comparison with the sprayer without AACTS.

Multi-criteria decision analysis (MCDA) was used to identify how individuals make decisions by combining the use of qualitative and quantitative data. Within the MCDA, the Analytical Hierarchy Process (AHP) was used for the prioritisation of the sprayer with and without AACTS. Ten farmers were invited for the evaluation and they were all familiar with the spraying operation and data management process. The first five farmers evaluated the prototype in February 2008. Another group of five farmers conducted the evaluation in April 2008, to ensure a sufficiently large statistical sample.



To achieve better ranking for the options (sprayer with and without AACTS), there is a need to use a combination of qualitative and quantitative criteria based on which the comparative judgments are made. The AHP is a method which combines both types of data, qualitative and quantitative, which for this research comprises of three quantitative criteria (minimise the investment cost, minimise time taken to fill the sprayer and accuracy of the data gathered) and three qualitative criteria (ease of retrieval of agrochemicals input data, avoid use of unregistered agrochemicals and operator safety). The criteria were chosen according to the main perceived differences between the sprayer with and without AACTS. As a result of the AHP, it was possible to identify how the farmers perceive the attributes of the AACTS and also how they rank the sprayer with the AACTS in comparison with the sprayer without AACTS.

### **3.3.3 Chapter 6: Perceived Market Value**

Based on the results of experiments conducted by Peets (2009), the benefits of the AACTS in terms of accuracy and speed in comparison with the manual loading process were now known. This data was used to illustrate an online questionnaire with the objective of identifying how much the farmers were willing to pay for the AACTS. This chapter aims to address objective number five: *To estimate the perceived market value, determine the demand curve and recommend the most profitable retail market price.* This part of the research is mainly descriptive with the objective to describe different farmers' profile and identify how this related with their willingness to pay (WTP) for the AACTS.

A contingent valuation (CV) questionnaire was used to identify farmers' WTP for the AACTS. This type of questionnaire aims to identify individuals' economic value for a new product which is not currently available in the market. Therefore, it can be used to pre-test the market of a product under development. In order to reach a higher number of farmers it was chosen to announce the link of the questionnaire to The Arable Group (TAG) newsletter and to offer a prize for the firsts 100 respondents. The questionnaire was announced in the newsletters of April 28<sup>th</sup> and May 15<sup>th</sup>, 2008.

The results of the CV questionnaire were used to construct a potential demand curve of the AACTS in the European market. Although the demand curve was constructed based

on answers of farmers in England it was extrapolated to European market, which is not ideal but only practical method in this situation.

The demand curve allowed the prediction of the most profitable retail price and required production level for Europe and could assist the company who will produce the AACTS to make judgment about investment risks.

### **3.3.4 Chapter 7: Market Uptake**

A more detailed analysis of farmers' perceptions and attitudes towards the AACTS was necessary to address the objectives number two and four as follows:

- *To identify the user requirements and the product specification for an Automated Agrochemical Traceability System (AACTS).*
- *To make recommendations for further development and acceptance of the prototype in the food chain with particular emphasis at the farm level.*

Semi-structured face-to-face interviews with 27 farmers in England were conducted during October and November 2008. The interviews were recorded on a voice-recorder and the transcriptions are available in Appendix O. As the results of the CV questionnaire found no evidence between the level of current technology (use of GPS and spatial variable application) and the decision to buy the AACTS, it was decided to choose respondents with similar attitudes towards technology in order draw out common and interconnectivity factors. The majority of the respondents chosen to participate in the questionnaire were motivated by the use of this technology. The face-to-face semi-structured interviews allowed the collection of more detailed data regarding the farmers' reaction towards the AACTS.

The questionnaire was designed based on the Receptivity model. This model aims to identify if the individual is willing and able to absorb, accept and use innovation options. As a result of that, it can be identified the issues which influence the new technology uptake. This chapter is exploratory, with the objective to explore the future feasibility of farmers to accept and use the AACTS.

### **3.3.5 Chapter 8: Case studies**

This chapter aims to address the objective number six: *To identify the practical benefits of AACTS as applied to farms with a range of different types of product.*

The results of previous chapters allow the understanding of the different aspects of AACTS and how this system could benefit different types of farm enterprises. This chapter describes the existing traceability systems of three different types of farm enterprise according to different type of final product's handling: fresh produce, onion production and a Conservation Grade cereal farm and explore ways to improved it. All these farm enterprises are focused on high value and quality production.

In this study the researcher carried out face-to-face unstructured interviews in each farm. It opened with one question "Please tell me about the traceability system at this farm, how the data is collected/recorder and how it is transferred from one stage to the next" and then let the interviewee narrate the process. Further information was collected during the harvest season in 2008, by observing and talking with people responsible for the harvest. Two days was spent in each farm to collect the relevant data. The data analysis was conducted during December 2008, February and March 2009.

### **3.3.6 Discussion and conclusion**

The detailed information regarding the use of the above methods described are given in their respective chapters. The section 9.8 in the Discussion chapter discusses the advantages and disadvantages of the various techniques used. This addresses objective number seven: *To suggest a combination of social science methods that can be used during the product development stage to pre-test the potential market acceptance.* The overall conclusion of the methodology used is given in chapter 10.

## **4 Primary findings of the stakeholders perspective towards traceability systems**

### **4.1 Introduction**

This chapter presents the main results and findings of the interviews with representatives from different interest groups of the agri-food chain. The aim of the interviews was to identify the stakeholders' perspective towards traceability systems. The list of the stakeholder types is given in section 2.4 and the detailed list of the interviewees is given in Table 3.

The chapter describes the methods employed to facilitate the data collection and the application of these methods in relation to this particular study. The primary data collected by way of semi-structured interviews was then analysed using coding and clustering methods. Following the interviews the stakeholders were invited to attend a workshop to discuss the results of the individual interviews.

### **4.2 Interview with Stakeholders**

#### **4.2.1 Type of data collected**

This study is predominantly exploratory, with the objective to explore the feasibility of future traceability systems' concepts. This study is in some extent descriptive as well. The study is not explanatory because it is not considering explaining why something happens as stated by Neuman (2003). For the exploratory purpose of this study, qualitative data was collected. This permits a higher degree of detail to be obtained and to identify the requirements of each member of the food chain. There is no quantitative data to be collected in this study.

#### **4.2.2 Data Collection and Type**

A semi-structured interview was selected as being the most appropriate to gain a range of insights and also to obtain the richness of details required. Individual interviewees were selected to represent a wide range of the agri-food industry. A semi-structured interview process was identified as most suitable – as described by Robson (2002), this

format allows the interviewer to modify questions during the interview, give explanation and include or exclude questions as necessary. This flexibility allows the interviewee to share further information as necessary. The “predetermined question with fixed wording” as Robson (2002) describes the structured interview does not allow flexibility in this type of research where the interviewee is welcome to share some other information as necessary.

In total, seventeen interviews were conducted. It was intended to obtain a representative sample of those who are in some way involved in traceability in the food chain. Individual questionnaires were developed for specific industry sectors. Specific questions highlight individual aspects of each step of the chain and identify the requirements of each stakeholder. The interviews transcriptions are available in Appendix A.

#### **4.2.3 Stakeholders**

The seventeen stakeholders interviewed were the food industry, quality assurance providers, manufacture of agriculture equipment, agrochemical industry, farm software providers, an agronomist and the UK government Food Standards Agency. Table 3 provides the list of the interviewees.

**Table 3: List of the interviewees**

<b>Participant</b>	<b>Description</b>	<b>Industry Role</b>
Respondent A	T H Clements & Son Ltd	Vegetable Grower
Respondent B	Muddy Boots	Software Provider
Respondent C	Cmi plc	Certification Body
Respondent D	The Arable Group (TAG)	Agronomic Service
Respondent E	FARMADE	Software Provider
Respondent F	Farm Works	Software Provider
Respondent G	Food Standard Agency	UK Government department
Respondent H	LW Vass	Agrochemical Dealership
Respondent I	Linking Environment and Farming - LEAF	Quality Assurance Scheme
Respondent J	National Farmers' Union	Farmer Association
Respondent K	Organic Farmers & Growers	Quality Assurance Scheme
Respondent L	Arable farmer	Farmer
Respondent M	Syngenta	Agrochemical Industry
Respondent N	Frontier Agriculture	Grain Dealer
Respondent O	Jordans / Conservation Grade	Food Processor & Quality Assurance Scheme
Respondent P	AGCO	Agriculture Machinery Manufacture
Respondent Q	Waitrose	Supermarket

The stakeholders interviewed play an important role in the food chain and is familiar with traceability systems. They are described below.

TH Clements, grows, harvests, packs and delivers brassica to supermarkets throughout the UK. The company owns 400 hectares and works with an additional 52 others growers around UK. In 2006/2007 Clements was one of Tesco's largest cauliflower, broccoli, sprouts and cabbage suppliers. In order to supply Tesco, Clements has to comply with Tesco's Nature Choice (quality assurance scheme) which requires high level and detailed traceability data to be collected and recorded.

Muddy Boots, Farmade and Farmworks are all farm software providers. These three companies focus on different sectors of the agribusiness. Farmade focuses on farmers that use software to manage the farm data; they claim to have 65% of this market. Muddy Boots focuses on software which helps the agronomist to provide recommendations, they claim to have 70% of this market. However, Farmworks focuses on software to assist users that use precision farming technologies (e.g. variable

application rate and yield maps). The greatest numbers of their customers are contractors working with large areas of usually more than 400 hectares.

CMi plc provides consulting, certification and technical services in the food supply chain and it is the market leader for UK agriculture and retail audit. According to the operations manager, CMi plc has approximately 70% of the combinable crop market, 95% of the fresh produce market and 30% of the livestock market.

The Arable Group (TAG) works close to arable farmers by providing consulting and agronomic advice. TAG is the UK's largest independent agronomy service. It has 23 trial centres around the UK and a total of 2,044 farmers registered. There are also a further 50 independent consultants who are members.

Food Standard Agency is an independent UK Government department created to protect the public's health and consumer interests in relation to food.

LW Vass is an agrochemical dealership that provides agronomic advice and agrochemical products to around 1,500 farmers located an area of 40 miles radius from their depot in Maulden, Bedfordshire, UK. Its annual turnover is £8.5 million.

Linking Environment and Farming (LEAF) is a farm assurance scheme. Its products can be found at Waitrose, Whole Foods Market, Burts Chips, Farrington's mellow yellow and Heritage Potatoes. LEAF Marque certification is complementary to existing farm assurance schemes. The farmers need to be a member of assurance scheme to join LEAF and need to have traceability system in place. Currently, LEAF has approximately 500 members.

The National Farmers and Union (NFU) is a trade association which represents the interest of the farmers and growers in UK. The NFU's Farmers and Grower membership has approximately 55,000 members.

Organic Farmers and Growers (OF&G) is a certification body qualified by DEFRA to provide organic certification. The number of farmers and growers registered are 1,750; it is the second largest in term of number of operator organic certification in UK.

Syngenta is a large global agribusiness which markets pesticides and seeds. According to the *Syngenta Annual Review 2007* the crop protection sales revenue was \$7.3 billion.

Syngenta plays an important role on the food chain by giving the growers the support to comply with the supermarket requirements.

Frontier Agriculture is a UK grain dealer. It has over 600 employees based across 35 regional offices and stores. Its annual turnover is more than £750 million.

Jordans Cereals produces specialist cereal products in UK. The company contracts a restricted number of suppliers to produce the grains to comply with the Conservation Grade quality scheme. This quality scheme was created to protect the environment and wildlife. Jordans Cereals is supplied by 79 farmers, representing approximately 60,000 acres of UK farmland.

Waitrose supermarket represents 4% of the UK market share, and 16% share of organic food. The company emphasis is food quality rather than low prices.

AGCO is a large global agriculture machinery manufacture and distribution. Their brands are sold in more than 140 countries. The main brands are Massey Ferguson, Valtra, Challenger and Fendt. In 2006, AGCO had 23.2% of the market share in UK and 40% in Europe.

#### **4.2.4 Data Analysis**

All raw data from the interviews were analysed using a coding system. Similar topics were clustered to facilitate the identification of related themes and then to conduct the final analysis. Miles and Huberman (1994) describe the technique as follows: “Codes are tags or labels for assigning units of meaning to the descriptive or inferential information compiled during a study”. They suggest that these codes are linked to “chunks” related to a similar topic. The codes are then used to retrieve and organize the “chunks”. The “chunk” is described as a “word, sentence, phrases, or whole paragraphs connected or unconnected to a specific setting”. The codes were used to analyze the transcriptions of the interviews from which the clusters were derived. The coding system developed for this research is given in Appendix B and the transcriptions of the interviews are given in Appendix A.



#### 4.2.4.1 Summary of Research Design

The research in this study is a flexible design, being mainly exploratory. The qualitative data was collected in the form of semi-structured interview. The data was analysed using a coding system, similar topics were clustered to facilitate the identification of similar themes and then to conduct the final analysis.

#### 4.2.5 Finding from the interviews

Results from the interviews have been separated by stakeholder sector and written to draw out the common and inter-connectivity factors. In total five sectors were identified, each is explained below.

##### 4.2.5.1 Farmers and Growers

Fourteen of the seventeen respondents highlighted that traceability information is currently and should remain within the management system of the farmer or grower. The retailers currently assume that their suppliers have traceability systems in place and they only request all the data if there is a specific problem.

Respondent A noted that they have been requested to submit the list of chemicals that were used prior to application in order that the retailer can identify any perceived risk in the final market.

This group state that an effective traceability system needs to help farmers to comply with farm assurance standards and legislative regulations. The regulations are very strict and the farmers are required to have traceability systems in place to meet the requirements. The system should be low cost, time efficient, and offer both competitive advantage and differentiation in the marketplace.

The farmers interviewed see traceability as the ability to provide assurance, prove the farm records and demonstrate good practice in environmental protection and agrochemical inputs. Respondent L noted that *“Traceability records are seen as a market tool and as a competitive advantage over those in the market that don’t have traceability records.”*

The three software providers, two agronomists and the machinery company state that traceability data from field operations should return to the farm computer to improve

subsequent management decisions. The management system would hold a database which describes what happened with each field and associate this with the yield registered post-harvest. This robust data will aid management decisions season after season.

Seven of the respondents believe that the relationship between agronomist and farmer could be enhanced by implementing an automated agrochemical recording system. Farmers can use such systems to demonstrate good practice. In the event of an issue, such a system would allow the detail of the original agronomist's recommendation to be verified against actual application practice, eliminating any ambiguity in responsibility. Respondent D mentioned that usually the agronomists try to eliminate all the possible reasons, i.e. checking that the farmers have followed the recommendations of professionals in using the prescribed chemical products for their crops and the correct application rates and weather conditions. The agronomists then could transfer the responsibility to the farmer if the recommendation has not been followed properly or the farmer could prove that the recommendation was incorrect or misleading.

In organic systems, fewer types of inputs are used and the focus has been on the verification of processes and maintenance of product integrity through the food chain. However, there exists a list of permitted pesticides that can be used in organic crops/systems. Therefore an automated agrochemical recording system that would retain the information in detail would provide extra assurance to the farmer. Respondent K noted that *"For us, the most important aspect of traceability is to be able to identify if the produce came from one of our certified organic farms, and identify this produce all the way through the food chain."*

In the UK, examples of farm schemes are LEAF Marque, Assured Combinable Crops and Conservation Grade. Respondent C stated that *"The farm is currently certified against standards as a whole system, the next step would to certify each individual lorry to pass individual material traceability up the chain"*. This is a step-change from "certified source" level. Usually the farmers have the traceability data, but when produce transfers to the merchant the information is usually lost because the goods delivered with batch identification may be emptied into a single silo and mixed with earlier deliveries. This is especially an issue with combinable crops. How such

information could be transferred, stored and assessed further along the food chain needs to be identified. The respondent C also stated that *“Farmer will invest in better traceability according to the market demand. If the market demands to have the grains separated by field they will do it. They need to see the benefits.”*

#### 4.2.5.2 Automated Recording System

An over-application with the prescribed agrochemical product or an application of the wrong agrochemical product are both considered as contamination in the field. Thirteen of the respondents believe that an automated recording system which records in detail the agrochemical inputs would be seen as a system for damage limitation. This could most obviously be at the point of application, warning the operator to not overdose. It can also operate subsequently, allowing the farmer to be able to identify a specific affected area and hence isolate any affected produce and not be required to withdraw more than necessary. The respondent G noted that *“If there is any problem of contamination then the farmer will be able to identify the specific area and hence produce contaminated and not withdraw more than necessary”*.

All three software providers interviewed (respondents B, E, F) believe that operational decisions should be pre-planned and the field operator should not be solely responsible for the decisions. Usually an automated recording system is not editable by the users, however in their past experience the farmers wanted to be able to edit the information. This presents a key dilemma, since if changes are made, then the system must be able to retain or register the changes and must be able to allocate the person responsible. For example, if a farmer changes the agronomist's recommendation, the agronomist is no longer responsible for the new application. Some flexibility in the system would however, be advantageous by allowing the information to be changed and recorded by users. This would mean that the chain of responsibility is broken and the final report would show the changes and the reasons for them. The system available to the field operator must be as simple as possible to use in order to improve the reliability of the information gathered. The respondent F stated that *“It can't be too tight. The information will be more accurate, more valuable and more honest the easier you make for the operator to record. It needs to help the operator and not control him.”*

The system needs to carry on the crop approval details. Respondent E noted that *“if the operator has to read the label to check if it is approved every time he loads the sprayer tank, there is no difference”* Respondent E also noted *“It would be a tremendous advantage if the system could identify the equivalent product recommended. If the agronomist recommends a product, and the farm has the generic, the system could identify and allow the operator to go ahead.”* After the application the information would go back to the farm system then the data base would be updated with the product that was actually applied.

#### 4.2.5.3 Food Industry

An automated traceability system which can record, in a demonstrably robust manner, the precise history of agrochemical inputs is generally felt to provide valuable extra assurance for the industry. Eleven of the respondents stated that for the traceability system to gain broader acceptance in the field there must be demand from retailers who have engaged in such a system and are interested in it.

One respondent states that supermarkets have their own systems for residue testing. Their main concern for the business is the risk of contamination. If high levels of agrochemical products are detected in the product chain, and if the industry cannot identify who has supplied the product, then precise withdrawal of the contaminated product might be difficult. In such cases the withdrawal of more material is necessary in order to prevent the contamination of the healthy material.

Currently, retailers perceive that they have strong traceability systems with their direct suppliers in the later stages of the food chain. The supermarket interviewed states that they are able to rapidly identify and recall the contaminated products due to efficient traceability systems with the supplier. However, they see issues at the on-farm level. Their system controls the flow of information coming into the company, but it cannot guarantee the accuracy of the information. Any technology that makes that system more efficient, quicker and more cost effective would be beneficial.

#### 4.2.5.4 Consumers

Eleven of the respondents believe that the traceability information does not need to be available directly to the final customers. However, respondent G noted that *“The*

*consumers would be interest to know if the traceability system exist and the product could be withdraw if there is any problem*". The information of certification/approval to the industry standard levels should be provided on product labels. This is supported by the one supplier of specialised products (respondent O) who believes that presenting the data to consumers would be an advantage to the market.

Ten of the respondents agreed that the consumers wouldn't check the traceability information of each product if it were available. If the industry has a suitable electronic database in place internally then the presentation of data can be addressed independently using technologies such as; internet, short message service etc. The industry needs to identify the benefits in terms of consumer confidence to justify publication cost. Respondent C suggested that they could hold this database centrally on behalf of the industry as they already work with different certification schemes.

#### 4.2.5.5 Product database

The farm assurance schemes (respondent C and I) are looking to move to electronic systems. Respondent C states that the assessment checklist is on paper. The auditor goes on-farm and manually enters the information and then the form goes back to the office to be graded. If there is any non-conformity, another form is sent back to the farmer and he can submit the backup evidence of compliance. The assessment checklist and the non-conformities form are scanned in the certification office. The electronic system would replace the scanning process. They also want to be able to have a central database where each member of the food chain could have access to it and update the information according to the process. Such a database would facilitate the monitoring of the products through the food chain. The database would need to be held together by agreed industry standards and maintenance of the required data.

## 4.2.6 Summary of Findings

The results from the interviews are summarized in the Table 4.

**Table 4: Summary of findings from the interviews data**

- 
- An automated traceability system, which can record in a demonstrably robust manner the precise history of agrochemical inputs, is generally felt to provide valuable extra assurance for the industry.
  - The industry generally feels that information does not need to be available directly to the final customers.
  - There are many different quality assurance schemes, but only one data base could be sufficient.
  - Currently, retailers perceive they have generally strong traceability systems with their direct suppliers in the later stages of the food chain, however they see issues at the on-farm level.
  - Justification for system acceptance / perceived added value through:
    - reduced costs / time (automatic records)
    - increased value of certified produce
    - reduced business risks
  - For the system to gain acceptance in the field there must be a demand from retailers who have engaged and interested in it.
  - The traceability information is and should remain within the management system of the farmer or grower, the retailers currently assume that their suppliers have traceability systems and they only request all the data if there is a specific problem.
  - The farm is currently certified against standards as a whole system, the next step would to certify each individual lorry load.
  - Operational decisions should be pre planned (The operator shouldn't be solely responsible for the decision).
  - The system should be editable (i.e. capacity to correct both technical and human mistakes).
  - Simple, easy to use, quick, cost efficient and reliable – Practical issues of on-farm technology.
- 

## 4.3 Workshop

Following the interviews, all the interviewees were invited to attend a workshop, which was organized in order to present the summary of findings and conclusions from the interviews and attempt to incorporate the perceptions into a logical process for all stakeholders in the food chain. The workshop took place at Silsoe campus on 30<sup>th</sup> January 2007. Sixteen people attended the workshop including representatives of Patchwork, AGCO, Douglas Bomford Trust, FarmWorks, Muddy Boots, Farmade, CMI plc, Frontier and also the Cranfield University members involved in this research. First, the conclusions from Table 4 were presented by the author. The group members were

asked if they agreed with the conclusions from the interviews and if there were any controversial or missing issues. After the discussion, a report of the early stages of the development of the automated agrochemical recording system was presented by Peets (2009). The group was also asked for their opinion regarding the development. Following this, the main conclusions were written during the meeting and briefly read at the end by the chairman who called for members' opinion. After the workshop, the conclusions were sent to the stakeholders in order to ensure that all the important information was accurately recorded together with a request for any modifications (none were subsequent received).

The presentation and discussion took 4 hours all together. The main conclusions are the following:

1. Traceability should be more than record keeping, it should include job planning. The numbers of management decisions are increasing and traceability records help the farmers to run their business and to manage the farm.
2. Traceability systems need to comply with the environmental protection schemes as environmental protection is one of the major concerns of the market, especially retailers, alongside those of food safety and quality.
3. There are a range of different quality assurance schemes on the market as the retailers want to:
  - a. Differentiate how they handle different levels of details and
  - b. Differentiate the products from one retailer to another.
4. Although there are many different quality assurance schemes, only one industry wide data base should be sufficient. There should be one central database, such as AFS (Assured Food Standard). The discussion highlighted that this database should hold further details such as the agrochemical inputs.
5. There should be a standard data exchange format.
6. The availability of the traceability information to the final consumers depends on the value that the end users put on having traceability system on different food chains (fresh produce, animal and grains).
7. The information does not need to travel with the product, however, the consumers should have access to the traceability information.

8. Traceability has different values in different points in the chain and this depends on both the product and the process. Some traceability records need to go to the final consumers (e.g. beef labelling at TESCO) and in other cases it stops earlier in the chain (e.g. pasta and bread).
9. The main concern is what to do for bulk grains as it loses identity (traceability records) by the time it goes into the processor. The separation of the grains by quality or GMO would depend on the food industry vision for the benefits in doing so.
10. The concept of an automated agrochemical recording system was considered good for a genuine honest farmer to improve the business, to identify errors, and to assure better use of pesticides. It is a practical management tool for farmers; however it can not be considered as a policing tool because there are a number of ways to corrupt the information. The system will not work as a totally foolproof traceability system if it relies too much on trust.

#### **4.4 Conclusion**

Generally, it is felt that increasing commercial pressures from retailers (and their customers) and legislation (e.g. General Food Law Regulation 178/2002 in Europe) make effective traceability systems an essential part of a modern farm business. Farmers and growers are concerned about the perceived cost and paperwork time requirements of implementing effective systems.

From the analysis of the interviews, it has been shown that the industry believes an automatic traceability system, which will record agrochemical usage electronically, will be of wide benefit to the agri-food industry. The inputs should be combined with other general information from the farm business to form the basic input data to traceability systems. Ultimately there are aspects of trust with the operator, and data from such a system can help demonstrate good practice, and make falsification of records considerably more difficult, however it will not work as a foolproof system.

An electronic system that could improve the performance of paper driven systems would be well accepted if the cost/benefit ratio is favourable. It is likely that the early



adopters would be the specialist farmers who grow high value crops, where quality is one of their main concerns.

The industry will accept new technology if it reduces cost, time, business risk and increases value of certified produce. Traceability can provide a competitive advantage and add value to farm products.

## **5 Farmer's Impressions towards the AACTS**

### **5.1 Introduction**

This chapter presents the evaluation of the AACTS conducted with farmers. The evaluation was designed to measure some engineering parameters of the AACTS (Peets, 2009) and to obtain the farmers' impression towards the AACTS. The later is presented in detail in this chapter. The aim of the experiment was to identify how each individual farmer judges the sprayer with the automated agrochemical traceability system (AACTS) in the context of the ease of filling, data management, investment cost and operator safety in comparison to conventional manual loading system. The comparison was made using Analytical Hierarchy Process (AHP) as a decision making tool. The AHP is one of the multi-criteria decision-analysis (MCDA) models, which can be used to identify stakeholders' priorities. A multiple choice questionnaire was also used to collect further options regarding the ACCTS's performance.

### **5.2 The prototype – AACTS**

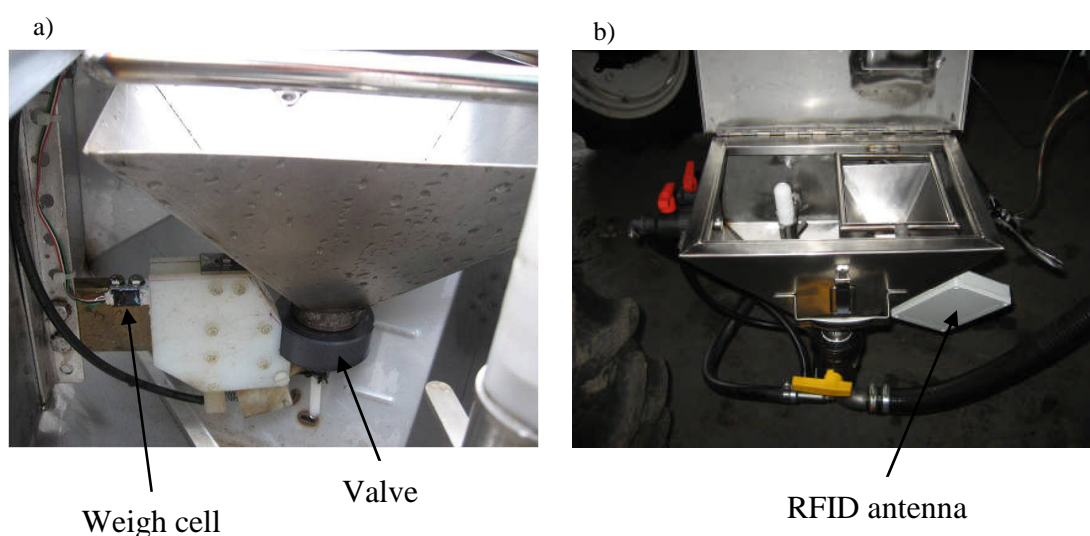
As described in the literature review the first prototype system was designed by Watts (2004) and the more recent development of the system reconfigured by Peets (2009). The AACTS consists of a weighing system (integrated in the standard induction hopper), RFID reader and antenna, and user interface (Peets et al., 2008). This system automatically identifies and records the quantity and the name of agrochemicals being loaded into a sprayer, decreasing the scope for human error. Additionally, the information regarding the application will be stored electronically so it can be downloaded directly into a computerised system. This will potentially minimise the time required to input spray data in order to satisfy environmental and traceability scheme regulations. Furthermore the AACTS will ensure that the sprayer has the correct product and rate as prescribed by the agronomist.

The operator together with ACCTS identifies, weigh and record the precise amount of the agrochemicals loaded into the sprayer. For this to work the agrochemical containers have to be labelled with a RFID label. The following information is encoded on the RFID labels as suggested by Peets et al. (2007): country of registration, chemical type

(e.g. herbicides, fungicides, and adjuvants), national registration number, container size, specific gravity, unit of measure (g, kg, ml, l) and a check sum.

By the use of the RFID reader the agrochemical will be identified and the operator will pour the chemical into the induction hopper in order to weight the required amount. The weighing system is constructed within a standard induction hopper as shown in Figure 3. It is a stainless steel measuring hopper with a volume of ~1.4 litres and nominal capacity of 3 kg (Peets et al., 2008).

**Figure 3: Modified induction hopper a) weighing system and b) RFID antenna (Source: Peets et al, 2008)**



The ACCTS will potentially minimise the chance of contamination associated with pouring the agrochemical into the measuring jug and washing it out. The operator will load the agrochemical straight into the sprayer.

### 5.3 Evaluation design

The total of 10 farmers evaluated the AACTS. The farmers have the certificate of competence as required by the Food Environmental Protection Act (FEPA) and issued by National Proficiency Test Council (NPTC). They are all mainly arable farmers and are familiar with the spraying operation and data management process. The farm size of each farmer is given on the Table 5.

**Table 5: Farm size (ha) for the ten sample farmers**

<b>Farmer</b>	<b>Farm Size (ha)</b>
A	67
B	100
C	219
D	485
E	200
F	558
G	142
H	202
I	161
J	303

The experiments were conducted on the Silsoe campus of Cranfield University in different days; therefore each farmer evaluated the prototype separately. The practical engineering experiment was designed by Peets (2009). The aim of this part of the evaluation is to compare the time to load the chemical requested and the accuracy of recording and dispensing using the conventional and the prototype system. For this experiment the engine of the sprayer was running, and the modified induction hopper was mounted next to the sprayer and connected to the tank. The experiment involved the sprayer loading process of six different tasks. On each task, the farmers were asked to load a set of three products into the sprayer. The products used at the experiment were water, sugar, and gluupy (mix of wall paper paste and water) to simulate different agrochemicals. After loading the sprayer using the prototype, another six different tasks were conducted using the conventional induction hopper. Following are the summary of the performance's evaluation result found by Peets (2009):

- “In terms of accuracy there is no significant difference between dispensed and recorded amount at 5% probability level using the automatic recording system. This means that the required amount was dispensed and recorded. However, with manual method the dispensed amounts are significantly smaller than prescribed and recorded amounts”. The data shows that the operator using the AACTS dispensed 100.66% of the target amount and the AACTS recorded 100.54%, whilst the manually dispensed system was only 92.56% of the target with a least significant difference (5%) of 2.17%.
- “There is no significant difference in speed of operation between the AACTS and the manual method including loading and record creation time at 5%

probability level. However, considering only the loading time on manual method there is significant difference. The mean time to complete task using automatic recording system was 211.8 s, manual method including loading and recording 201.3s, and manual loading time 181.2 s”.

After the loading process the farmer answered the AHP questionnaire and the multiple choice questionnaire. The multiple choice questionnaire consists of five questions regarding the performance of the system in terms of risk of contamination to the operator, risk of spillage, chemical identification, measuring system and rinsing system. The Likkert (Bateman et al., 2002) scale was used. In this scale, the respondents are asked to indicate a degree of agreement or disagreement with statements about the prototype. The multiple choice questionnaire is shown in Appendix C and the results in section 5.8. Figure 4 shows one of the farmers conducting the experiment.



**Figure 4: Farmer conducting the experiment**

#### **5.4 Multi-Criteria Decision Analysis**

The use of the multi-criteria decision analysis (MCDA) is addressed in many papers. Linkov et al. (2006) states that MCDA provides supported techniques for the comparison of project alternatives based on decision matrices, and it also provides structured methods for the incorporation of project stakeholders' opinions in the ranking of alternatives.

The MCDA methods are multi-attribute utility theory (MAUT) and the Analytical Hierarchy Process (AHP). The MAUT theory is used in order to find a simple expression for the net benefits of a decision (Linkov et al., 2006). In this method the attributes must have relative weights assigned to them. For instance, a sprayer can be evaluated based on cost, engine, speed range, boom width, liquid tank capacity and clearance. Each of these attributes are assigned weighting, for instance: cost (£), engine (hp), speed range (mph), boom width (m), liquid tank capacity (L) and clearance (mm).

The MAUT was not selected for this research because it requires measurable attributes. Some of the attributes to be judged by the farmers do not have values, such as “ease of retrieval of agrochemical input data” (C3), “avoid use of unregistered agrochemicals” (C5) and “operator safety” (C6). The attributes chosen to be judged are shown on Figure 5. The Analytical Hierarchy Process (AHP) was chosen to identify the farmers’ impression towards the AACTS. The method is explained in the following section.

### **5.5 Analytical Hierarchy Process (AHP)**

Saaty (1980) describes the AHP as a method for formulating and analyzing decisions. The AHP was developed to solve a specific class of problems that involves prioritization of potential alternate solutions. This is achieved by evaluation of a set of criteria elements and sub-criteria elements through a series of pairwise comparisons. Numerous applications of the AHP have been made since its development and it has been applied to many types of decision problems (Zahedi, 1986).

In general, models defined using AHP can be used for two purposes: to support ranking of decision alternatives as part of a specific individual or a group of decision makers to build a decision support systems to assist repetitive decision making activities (Naas et al., 2005). Bolloju (2001) addressed the application of AHP for the purpose of solving a specific category of decision problems that involves different decision makers solving similar questions independently.

Naas et al. (2005) demonstrated the value of AHP in selecting the best traceability system in pig production. The research compares the manual, electronic and manual/electronic traceability system. The electronic data recording presented the best

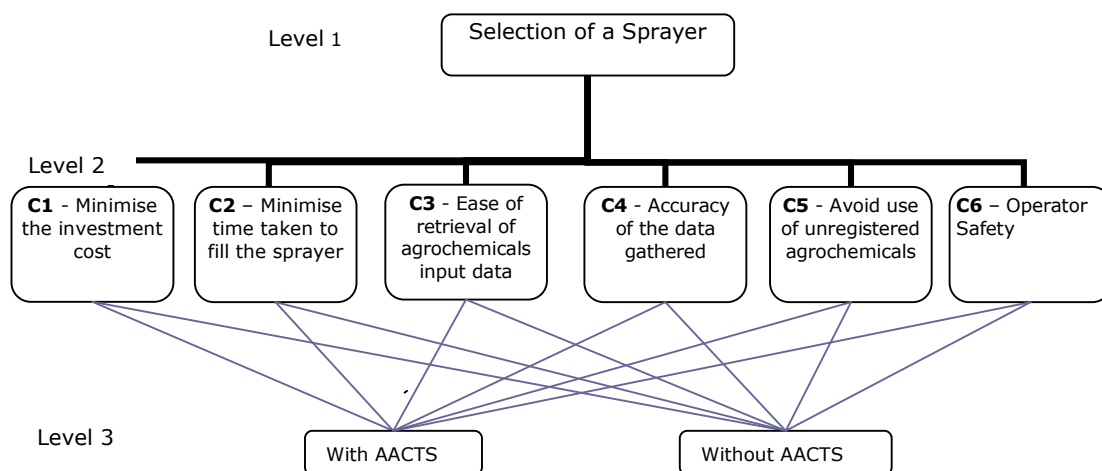
alternative in terms of security and reliability as well practice and fastness in both recording and data processing.

Grandzol (2005) describes the AHP as a “hierarchy of criteria and sub-criteria cascading from the decision objective or goal”. The interviewee can develop relative weights (called priorities) by making pairwise comparison at each level of the hierarchy; this will distinguish the importance of the criteria (Grandzol 2005). The final step is to combine the priorities calculating a composite weight for each alternative based on the preference derived from the comparison matrix (Figure 7). Detailed information regarding the AHP is given in sections 5.5.1 and 5.5.2.

### 5.5.1 Questionnaire and data collection

The criteria were defined according to how the automatic system differentiates from the conventional system, in terms of data management, investment cost, filling performance and operator safety. Since the project related to this research is unique, the criteria selection reflects the perceived advantages and disadvantages of the system in comparison with the conventional system. A senior technical officer who is expert on agrochemical application and a senior researcher scientist on spray application were consulted in order to make the research model as realistic as possible.

The AHP model shown in Figure 5 consists of three levels. Level 1 is the goal of the analysis - selection of a sprayer. The selection of sprayer (Level 1) is influenced by the certain criteria C1-C6 as seen in Level 2.



**Figure 5: The AHP model.**

1. **C1 - Minimise the investment cost:** The objective of minimising the investment cost.
2. **C2 – Minimise time taken to fill the sprayer:** This refers to the time spent filling the sprayer machine with the agrochemicals inputs.
3. **C3 - Ease of retrieval of agrochemicals input data:** This refers to how easily the data can be retrieved; the data can be held on paper or electronically.
4. **C4 - Accuracy of the data gathered (agrochemicals inputs):** This refers to the accuracy of the data that have been collected on agrochemical use on the farm.
5. **C5 - Avoid use of unregistered agrochemicals:** This refers to the use of registered agrochemicals, according to the Pesticides Safety Directorate (PSD).
6. **C6 – Operator Safety:** This refers to the risk of spillage of agrochemicals when filling up the induction hopper using measuring jugs.

The third and last level is the alternative choices that are sprayer with and without the Automated Agrochemical Traceability System (AACTS).

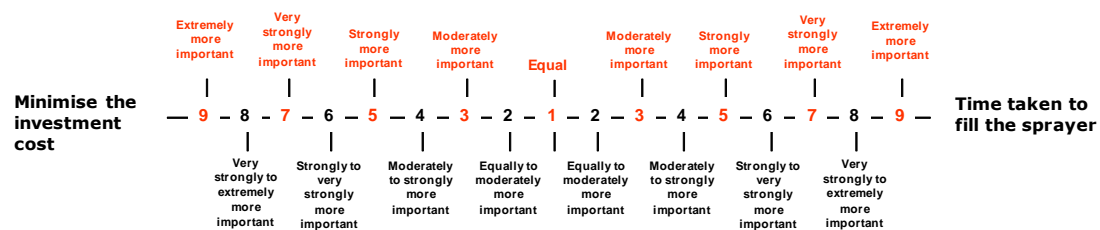
The next step of the process is to differentiate the relative importance of the criteria by completing a pairwise comparison for each set of criteria. A scale of values ranging from 1 (equal) to 9 (extremely more important) was used to express farmer's preference. The Table 6 shows the scale presented to the farmers when interviewed. The same scale was used by the farmers to score how well each of the alternatives (sprayer with or without AACTS) performs against each criterion.

**Table 6: Scale Ranging**

<b>Scale</b>	<b>Description</b>
1	Equal
2	Equally to Moderately more important
3	Moderately more important
4	Moderately to Strongly more important
5	Strongly more important
6	Strongly to Very Strongly more important
7	Very Strongly more important
8	Very Strongly to Extremely more important
9	Extremely more important



The full AHP questionnaire is shown in Appendix D, however, an example of the question is demonstrated below. Respondents were asked how important are each criteria relative to the other criteria in spray application. If ‘minimise the investment cost’, was more important than ‘time taken to fill the sprayer’ then the respondent circle a number on the left hand side of “1”. However if the respondent thinks that “time taken to fill the sprayer” is more important than “minimise the investment cost” then he circles a number on the right hand side of “1”. If both criteria are equally important the number “1” is circled.



**Figure 6: Example of the AHP question**

### 5.5.2 Data Analysis

In this research The Logical Decisions<sup>®</sup> software was used to analyse the data. However an explanation of how to calculate the priority weight will be presented.

The consistency of the interviewees’ judgment is considered an issue which requires special attention when using the AHP process. As the originator of the method (Saaty, 1980) described the method as a redundant comparisons to improve validity recognizing that interviewees may be uncertain or make poor judgments in some of the comparisons. This redundancy leads to multiple comparisons that may lead to numerical inconsistencies. Saaty (1980) suggested the error in these measurements is tolerable only when it is of a lower order of magnitude (10%) than the actual measurement itself. If the Consistency Rate (CR) is less or equal to 0.10 then the analysis can proceed. Otherwise, the respondents should review their answers until the CR is less or equal to 0.10.

In this study the CR of each respondent was checked using The Logical Decisions<sup>®</sup> software after the farmer completed the AHP questionnaire. A laptop with the software

was used to input the respondents' answers. None of the farmers has CR higher than 0.10, therefore it was not necessary to review their answers.

To enable the reader to understand the process, the following is a description of the theory as proposed by Saaty (1980). The AHP model expresses the thought of a person into an analytical framework. AHP has two phases namely weighting and synthesising of thoughts. To present the pairwise comparison a square matrix is the preferred form, where the square matrix is a matrix that has an equal number of rows and columns as shown in Figure 7. As there were six criteria, the matrix of this study is 6 by 6.

$$M = \begin{bmatrix} C_1/C_1 & C_1/C_2 & C_1/C_3 & C_1/C_4 & C_1/C_5 & C_1/C_6 \\ C_2/C_1 & C_2/C_2 & \dots & \dots & \dots & \dots \\ C_3/C_1 & \dots & C_3/C_3 & \dots & \dots & \dots \\ C_4/C_1 & \dots & \dots & C_4/C_4 & \dots & \dots \\ C_5/C_1 & \dots & \dots & \dots & C_5/C_5 & \dots \\ C_6/C_1 & \dots & \dots & \dots & \dots & C_6/C_6 \end{bmatrix}$$

**Figure 7: Example of a 6 x 6 comparison matrix**

Associated with square matrix are its eigenvectors and corresponding eigenvalues. The eigenvector provides weights of the priorities. To fill in the matrix of the pairwise comparisons, the 9 point scale presented in Table 6 was used, given that there were six criteria, generating a 6 by 6 matrix. The diagonal elements of the matrix are always 1. The upper triangular matrix was filled in with appropriate values based on the following rules:

- If the respondent preferred the criterion on the row, the actual judgment value was written.
- For instance  $C_1, C_2 = 3$  and the reciprocal value is  $C_2, C_1 = 1/3$  (see Table 7). The rest of the matrix is constructed based on the same approach.

If the respondent preferred the criterion on the column, then the reciprocal value of the criterion was written in the corresponding cell. If  $a_{ji}$  is the element of  $j$  row and  $i$  column of the matrix, then the lower part of the diagonal matrix is filled using the reciprocal values of upper part of the diagonal matrix, as follows:

$$a_{ji} = \frac{1}{a_{ij}} \quad (\text{Eq. 1})$$

Assuming that a respondent thought that criterion C1 was moderately more important than C2, thus the actual judgment 3 was written on the first row and second column of the matrix as shown in Table 7. Consequentially, the reciprocal value (1/3) is written on the first column and second row of the matrix.

**Table 7: Example of the output of a 6 x 6 AHP matrix**

	C1	C2	C3	C4	C5	C6
C1	1	3	3	3	1/7	5
C2	1/3	1	1	1/2	1/5	1/3
C3	1/3	1	1	1	1/7	1/2
C4	1/3	2	1	1	1/7	2
C5	7	5	7	7	1	2
C6	1/5	3	2	1/2	1/2	1

In order to compute the vector of priorities, the principal eigenvectors were computed and normalized first. The eigenvector is the result of multiplying the  $n$  elements in each row and finding the  $n^{\text{th}}$  root of the results, as follows:

$$RowC1 = \sqrt[6]{1 \times 3 \times 3 \times 3 \times (1/7) \times 5} = 1.6376 \quad (\text{Eq.2})$$

$$RowC2 = \sqrt[6]{(1/3) \times 1 \times 1 \times (1/2) \times (1/5) \times (1/3)} = 0.4724 \quad (\text{Eq.3})$$

$$RowC3 = \sqrt[6]{(1/3) \times 1 \times 1 \times 1 \times (1/7) \times (1/2)} = 0.5364 \quad (\text{Eq.4})$$

$$RowC4 = \sqrt[6]{(1/3) \times 2 \times 1 \times 1 \times (1/7) \times 2} = 0.7585 \quad (\text{Eq.5})$$

$$RowC5 = \sqrt[6]{7 \times 5 \times 7 \times 7 \times 1 \times 2} = 3.8834 \quad (\text{Eq.6})$$

$$RowC6 = \sqrt[6]{(1/5) \times 3 \times 2 \times (1/2) \times (1/2) \times 1} = 0.8182 \quad (\text{Eq.7})$$

$$RowC1 + RowC2 + RowC3 + RowC4 + RowC5 + RowC6 = 8.1065 \quad (\text{Eq.8})$$

To normalize the result, the elements of the resulting columns were divided by the sum of that column. The priorities weight of each attributes are calculated as follows.

$$\text{Priority Weight C1} = 1.6376/8.1065 = 0.2020 \quad (\text{Eq.9})$$

$$\text{Priority Weight C2} = 0.4724/8.1065 = 0.0583 \quad (\text{Eq.10})$$

$$\text{Priority Weight C3} = 0.5364/8.1065 = 0.0662 \quad (\text{Eq.11})$$

$$\text{Priority Weight C4} = 0.7585/8.1065 = 0.0936 \quad (\text{Eq.12})$$

$$\text{Priority Weight C5} = 3.8834/8.1065 = 0.4791 \quad (\text{Eq.13})$$

$$\text{Priority Weight C6} = 0.8182/8.1065 = 0.1009 \quad (\text{Eq.14})$$

The next step of the method is to rank the weights of the alternatives to each criterion (C1, C2, C3, C4, C5, and C6). The alternatives in this study are a system “with AACTS” or “without AACTS”. The comparison matrices are made for each alternative, with respect to each criterion as illustrated below. The comparison matrix of the criterion C1 related with the alternatives is illustrated below. At this example a respondent thinks that the sprayer with AACTS is strongly more important than without AACTS, thus the actual judgment 5 is written on the first row and second column of the matrix.

**Table 8: C1 Matrix**

	<b>With AACTS</b>	<b>Without AACTS</b>
<b>With AACTS</b>	1	5
<b>Without AACTS</b>	1/5	1

As explained earlier, the principal eigenvector should be computed and then normalized as follows:

$$\text{Row “with AACTS”} = \frac{1}{\sqrt[2]{1 \times 5}} = 2.2361 \quad (\text{Eq.15})$$

$$\text{Row “without AACTS”} = \frac{1}{\sqrt[2]{(1/5) \times 1}} = 0.4472 \quad (\text{Eq.16})$$

$$\text{Row “with AACTS”} + \text{Row “without AACTS”} = 2.6833 \quad (\text{Eq.17})$$

$$\text{Priority Weight “with AACTS”} = 2.2361/2.6833 = 0.8333 \quad (\text{Eq.18})$$

$$\text{Priority Weight “without AACTS”} = 0.4472/2.6833 = 0.1667 \quad (\text{Eq.19})$$

Based on the calculated results above, the respondent believed that the performance of the criterion C1 is better on sprayer with AACTS (0.8333) than on sprayer without AACTS (0.1667). All other priority vectors of each alternative (with AACTS and without AACTS) related to each criterion (C1, C2, C3, C4, C5, C6) are calculated the same.

In total there are six priority vectors. The overall weight is the normalization of linear combination of multiplication between weight and priority vector of each criterion. The equations below illustrate the computation of the overall composite weight of the alternatives.

$$\text{With ACRS} = (0.2020) \times (0.8333) + (0.0583) \times (0.5) + (0.0662) \times (0.75) + (0.0936) \times (0.8333) + (0.4791) \times (0.8333) + (0.1009) \times (0.8333) = \mathbf{0.8084}$$

(Eq.20)

$$\text{Without ACRS} = (0.2020) \times (0.1667) + (0.0583) \times (0.5) + (0.0662) \times (0.25) + (0.0936) \times (0.1667) + (0.4791) \times (0.1667) + (0.1009) \times (0.1667) = \mathbf{0.1916}$$

(Eq.21)

Based on the calculated results above, the respondent believed that the sprayer performs better with AACTS (0.8084) than on sprayer without AACTS (0.1916) in terms of minimise the investment cost (C1), minimise time taken to fill the sprayer (C2), ease of retrieval of agrochemicals input data (C3), accuracy of the data gathered (C4), avoid use of unregistered agrochemicals (C5) and operator safety (C6).

## 5.6 Results of the Analytic Hierarchy Process (AHP)

The data of each questionnaire were entered into the AHP software package (Logical Decisions<sup>®</sup>). This provides the protocols for accessing the attributes weights as described earlier; Appendix F provides the matrixes of each respondent and respective results. The results of the analysis of each questionnaire are presented in Table 9 to Table 18.

According Table 9, the priority ranking of the sprayer machine to Operator A is as follows: avoid unregistered agrochemicals > minimise time taken to fill the sprayer > easy of retrieval of agrochemical data > accuracy of data gathered > operators safety > minimise the investment cost. Hence Operator A clearly values to avoid use of unregistered agrochemicals, which was ranked highly in weight over the other five criteria. He had ranked the performance of this criterion better on sprayer with AACTS (0.8333). According to the discussion with Operator A, the automatic identification system is the major benefit of the AACTS. He believes that it could assist him to prove good practice and the records to crop assurance scheme and agronomist. Currently, his recording keeping system is paper-based and he does not perceive any benefit from the

use of a computer to keep the records. Among the improvements he suggests that the system should be as robust as possible to provide high reliability and it must not slow down the sprayer operator. Thus, minimising the time taken to fill the sprayer was also found to be important (0.2675). The overall utility for farmer A is higher for sprayer with AACTS (0.6809) than without AACTS (0.3191).

**Table 9 Priority ranking and weights for each criterion – Farmer A (CR = 0.092)**

Priority Rank	Criteria	Weight	With AACTS	Without AACTS
1	Avoid unregistered agrochemicals	0.3872	0.8333	0.1667
2	Minimise time taken to fill the sprayer	0.2675	0.5000	0.5000
3	Ease of retrieval of agrochemical data	0.1085	0.2500	0.7500
4	Accuracy of the data gathered	0.1034	0.8333	0.1667
5	Operator Safety	0.0742	0.8333	0.1667
6	Minimise the investment cost	0.0592	0.8333	0.1667
<b>Overall Weight</b>			<b>0.6809</b>	<b>0.3191</b>

According to the discussion with Operator B it was clear that he does not perceive the benefits of electronic data for small farms. Operator B values the easy of retrieval of agrochemical and accuracy of data which were ranked the same weight (0.2303). He believes that the sprayer without AACTS performs better (0.75) in terms of easy of retrieval of agrochemical data. Based on the discussion he prefers paper based system than electronic data, thus it is easy for him to retrieve the data using his current manual system. However, accuracy of the data, which was also ranked highly, performs better with sprayer with AACTS (0.75). The overall utility for farmer B is higher for sprayer with AACTS than without AACTS.

**Table 10 Priority ranking and weights for each criterion – Farmer B (CR=0.019)**

Priority Rank	Criteria	Weight	With AACTS	Without AACTS
1	Ease of retrieval of agrochemical data	0.2303	0.2500	0.7500
1	Accuracy of the data gathered	0.2303	0.7500	0.2500
2	Minimise time taken to fill the sprayer	0.2057	0.7500	0.2500
3	Minimise the investment cost	0.1502	0.8000	0.2000
4	Operator Safety	0.1090	0.8750	0.1250
5	Avoid unregistered agrochemicals	0.0745	0.7500	0.2500
<b>Overall Weight</b>			<b>0.6560</b>	<b>0.3440</b>

Operator C clearly values to avoid use of unregistered agrochemicals, which was ranked highly in weight over the other five criteria and performs better on sprayer with AACTS (0.8750). On the discussion, the farmer highlighted the importance in meeting the crop assurance schemes requirements, he pointed out that the system could be used to show good practice by the approved and prescribed agrochemical. The overall utility for Operator C is higher for sprayer with AACTS than without AACTS, as shown in Table 11.

**Table 11 Priority ranking and weights for each criterion – Farmer C (CR=0.038)**

Priority Rank	Criteria	Weight	With AACTS	Without AACTS
1	Avoid unregistered agrochemicals	0.5310	0.8750	0.1250
2	Minimise the investment cost	0.1491	0.2500	0.7500
3	Operator Safety	0.1274	0.7500	0.2500
4	Accuracy of the data gathered	0.0709	0.8750	0.1250
5	Ease of retrieval of agrochemical data	0.0612	0.1250	0.8750
6	Minimise time taken to fill the sprayer	0.0604	0.8571	0.1429
<b>Overall Weight</b>			<b>0.7189</b>	<b>0.2811</b>

Operator D uses “excel” to keep the records and manage the data. The data is manually entered into the computer. Hence he believes that the AACTS will facilitate the data input into the computer. According to the discussion the major benefit of the system is the accuracy of the data and stock control. Thus, accuracy of the data was ranked highly in weight over the other five criteria as shown in Table 12 and performs better on sprayer with AACTS (0.8571). He also pointed out the system could help on the stock control and check how much have been used and how much should be left on the store. However, he would not hesitate to use the conventional hopper to load agrochemicals which are not permitted but it is on farm’s stock. The major disadvantage pointed out was the speed of loading. Hence it is a big farm; he is concern over the short time he has to spray the 485 hectares. Thus time taken to fill the sprayer ranked second most important (0.2388) and has a higher utility on sprayer without AACTS (0.75). However, the result of the experiment shows that there is no significant difference in speed of operation between the AACTS (211.8s) and manual method including loading and record creation time (201.3s) at 5% probability level (Peets, 2009).

**Table 12 Priority ranking and weights for each criterion – Farmer D (CR=0.057)**

Priority Rank	Criteria	Weight	With AACTS	Without AACTS
1	Accuracy of the data gathered	0.2458	0.8571	0.1429
2	Minimise time taken to fill the sprayer	0.2388	0.2500	0.7500
3	Ease of retrieval of agrochemical data	0.1732	0.8571	0.1429
4	Operator Safety	0.1192	0.8889	0.1111
5	Avoid unregistered agrochemicals	0.1129	0.8571	0.1429
6	Minimise the investment cost	0.1101	0.2000	0.8000
<b>Overall Weight</b>			<b>0.6436</b>	<b>0.3564</b>

As with Operator C, Operator E also highlighted the importance in meeting the crop assurance scheme requirements. Hence avoiding use of unregistered agrochemical was ranked highly over the other five criteria as shown in Table 13. According to the discussion one of the major benefits is of the AACTS is to improve operator safety, hence it was ranked second. Currently, the spray records are manually typed into the computer, he believes that the automatic generation of records will facilitate and improve his recording system. The overall utility for farmer E is higher for sprayer with AACTS than without AACTS, as shown in Table 13.

**Table 13 Priority ranking and weights for each criterion – Farmer E (CR=0.093)**

Priority Rank	Criteria	Weight	With AACTS	Without AACTS
1	Avoid unregistered agrochemicals	0.3021	0.8000	0.2000
2	Operator Safety	0.2386	0.8889	0.1111
3	Accuracy of the data gathered	0.1690	0.8333	0.1667
4	Minimise the investment cost	0.1176	0.7500	0.2500
5	Minimise time taken to fill the sprayer	0.1167	0.2500	0.7500
6	Ease of retrieval of agrochemical data	0.0560	0.8333	0.1667
<b>Overall Weight</b>			<b>0.7682</b>	<b>0.2318</b>

According to the discussion, Operator F clearly values the accuracy of measuring the agrochemicals, hence he ranked it the most important attribute as shown in Table 14. Operator safety was ranked the second most important attribute. His only concern regarding the AACTS is that it would not allow the use of agrochemicals that are not permitted any more. He argues that it is common to have agrochemical on stock from previous year but that are not allow to use on the current season, but contain the same active ingredients of the permitted one. Hence, avoidance of unregistered agrochemical



was ranked the least important attribute. The overall utility for Operator F is higher for sprayer with AACTS than without AACTS.

**Table 14: Priority ranking and weights for each criterion – Farmer F (CR=0.088)**

Priority Rank	Criteria	Weight	With AACTS	Without AACTS
1	Accuracy of the data gathered	0.3861	0.9000	0.1000
2	Operator Safety	0.2551	0.8750	0.1250
3	Ease of retrieval of agrochemical data	0.1930	0.1000	0.9000
4	Minimise time taken to fill the sprayer	0.0699	0.3333	0.6667
5	Minimise the investment cost	0.0490	0.8000	0.2000
6	Avoid unregistered agrochemicals	0.0468	0.5000	0.5000
<b>Overall Weight</b>			<b>0.6759</b>	<b>0.3240</b>

According to the interview, Operator G values the operator safety which was ranked the first most important attributes of the AACTS. However, he believes that this attribute performs equally on sprayer with and without AACTS. The second most important attribute is minimising the time taken to fill the sprayer. It is worth noting that he was slower filling the spray using the AACTS, thus he attributes a higher rank for the sprayer without the AACTS. Ease of retrieval of agrochemical data ranked the fifth most important and minimising the investment cost ranked the least important. He uses paper based system to keep the spray application data and he believes that the farmer who uses a computer system would perceive more advantages when using it. The overall utility for Operator G is slightly higher for sprayer without AACTS than with AACTS, as shown in Table 15

**Table 15: Priority ranking and weights for each criterion – Farmer G (CR=0.080)**

Priority Rank	Criteria	Weight	With AACTS	Without AACTS
1	Operator Safety	0.3564	0.5000	0.5000
2	Minimise time taken to fill the sprayer	0.2754	0.2000	0.8000
3	Avoid unregistered agrochemicals	0.1516	0.8333	0.1667
4	Accuracy of the data gathered	0.0939	0.6667	0.3333
5	Ease of retrieval of agrochemical data	0.0746	0.2500	0.7500
6	Minimise the investment cost	0.0481	0.2000	0.8000
<b>Overall Weight</b>			<b>0.4505</b>	<b>0.5495</b>

Based on the discussion with Operator H he pointed out that he would buy the AACTS mainly because of the decrease of agrochemical spillage and accuracy of the data. Hence he ranked operator safety the most important attribute of the AACTS and accuracy of the data

gathered the second most important. His records are kept on a paper system, and he believes that the farmers who use computer system will perceive others advantages of the AACTS. The overall utility for Operator H is higher for sprayer with AACTS (0.7409) than without AACTS (0.2591).

**Table 16: Priority ranking and weights for each criterion – Farmer H (CR=0.085)**

Priority Rank	Criteria	Weight	With AACTS	Without AACTS
1	Operator Safety	0.5293	0.7500	0.2500
2	Accuracy of the data gathered	0.2099	0.8750	0.1250
3	Minimise the investment cost	0.1000	0.7500	0.2500
4	Minimise time taken to fill the sprayer	0.0751	0.7500	0.2500
5	Ease of retrieval of agrochemical data	0.0602	0.1000	0.9000
6	Avoid unregistered agrochemicals	0.0255	0.9000	0.1000
<b>Overall Weight</b>			<b>0.7409</b>	<b>0.2591</b>

Operator I clearly values to minimise the investment cost, which was ranked highly in weight over the other five criteria. However, he believes that the investment cost of the AACTS will bring benefits, thus the higher weight credited to the sprayer with AACTS (0.8) according to Table 17. Operator safety was ranked the second most important attribute. The least important attribute is the avoidance of unregistered agrochemicals. He believes that the sprayer without the AACTS performs better in terms of avoidance of unregistered agrochemical (0.9) because the operator can always use the conventional hopper in order to use an unregistered agrochemical.

**Table 17: Priority ranking and weights for each criterion – Farmer I (CR=0.092)**

Priority Rank	Criteria	Weight	With AACTS	Without AACTS
1	Minimise the investment cost	0.4615	0.8000	0.2000
2	Operator Safety	0.2725	0.8889	0.1111
3	Minimise time taken to fill the sprayer	0.1240	0.8000	0.2000
4	Accuracy of the data gathered	0.0734	0.8750	0.1250
5	Ease of retrieval of agrochemical data	0.0460	0.1250	0.8750
6	Avoid unregistered agrochemicals	0.0227	0.1000	0.9000
<b>Overall Weight</b>			<b>0.7829</b>	<b>0.2172</b>

Operator J values the time to fill the sprayer, hence the higher score over the other five criteria. He believes that the sprayer with AACTS performs better (0.6667) than without AACTS (0.3333). However, he suggested that the modified hopper should be bigger,

approximately six or seven litres. This would facilitate when pouring a 20 litres container. Accuracy of the data gathered was ranked as the second most important criteria. This operator uses a diary to record the spray application and argues that it is very easy to forget what has been applied. He pointed out that the AACTS would help him in the recording system. Minimising the investment cost was ranked the least important criteria, he believes that the sprayer with AACTS performs better (0.8) than without AACTS (0.2). Operator J revealed that he lost 13 hectares of wheat due to the wrong chemical application. He pointed out that the AACTS would have flagged up that he was using the wrong chemical and the financial lost regarding the wheat crop would have been paid.

**Table 18: Priority ranking and weights for each criterion – Farmer J (CR=0.061)**

Priority Rank	Criteria	Weight	With AACTS	Without AACTS
1	Minimise time taken to fill the sprayer	0.2582	0.6667	0.3333
2	Accuracy of the data gathered	0.2565	0.8333	0.1667
3	Operator Safety	0.2147	0.5000	0.5000
4	Ease of retrieval of agrochemical data	0.1122	0.6667	0.3333
5	Avoid unregistered agrochemicals	0.1087	0.8000	0.2000
6	Minimise the investment cost	0.0496	0.8000	0.2000
<b>Overall Weight</b>			<b>0.6947</b>	<b>0.3052</b>

### 5.6.1 Summary of the findings

Table 19 and Figure 8 show the summary of the weighted criteria of the farmers. The conclusions are shown below:

- The highest weights are concentrated on operator safety. However, only two farmers (G and H) ranked it as the first most important attribute and three (E, F and I) ranked it as the second most important.
- The second highest weights values are concern with accuracy of data gathered. Farmers D, B and F ranked it the first most important attribute and farmers H and J ranked it as the second most important attribute.
- The third highest weighted values are concentrated on the avoidance of the use of unregistered agrochemicals. Farmers A, C and E ranked this criterion as the

first most important. However, four farmers (B, F, H and I) ranked it as the least important criterion.

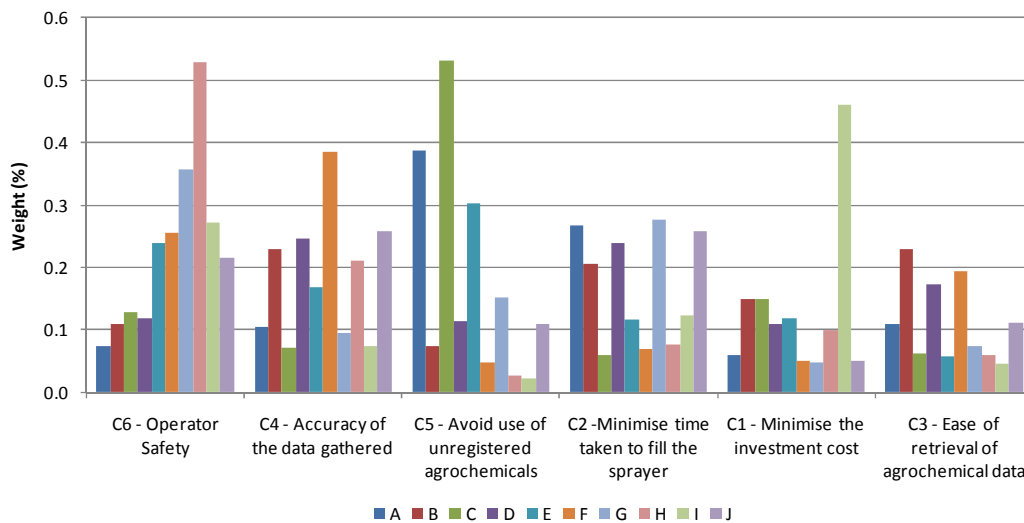
- The fourth highest weighted values concern to minimising the time taken to fill the sprayer. Three farmers (A, D and G) ranked it as the second most important attribute and other two farmers (F and H) ranked it as the fourth most important attribute.
- The fifth highest weighted values concentrate on minimising the investment cost. Farmer I ranked this criterion as the first most important. However, four farmers (A, D, G and J) ranked it the least important criterion.
- The sixth and lowest weighted values concentrate on ease of retrieval of agrochemical inputs. Farmer B ranked this attribute as the first most important. Four farmers (C, G, H and I) ranked it as the fifth most important attribute and farmer E ranked it the least important attribute.

The table below presents the summary of criteria weights from the farmers.

**Table 19: Summary of criteria weight for 10 farmers - numeric data**

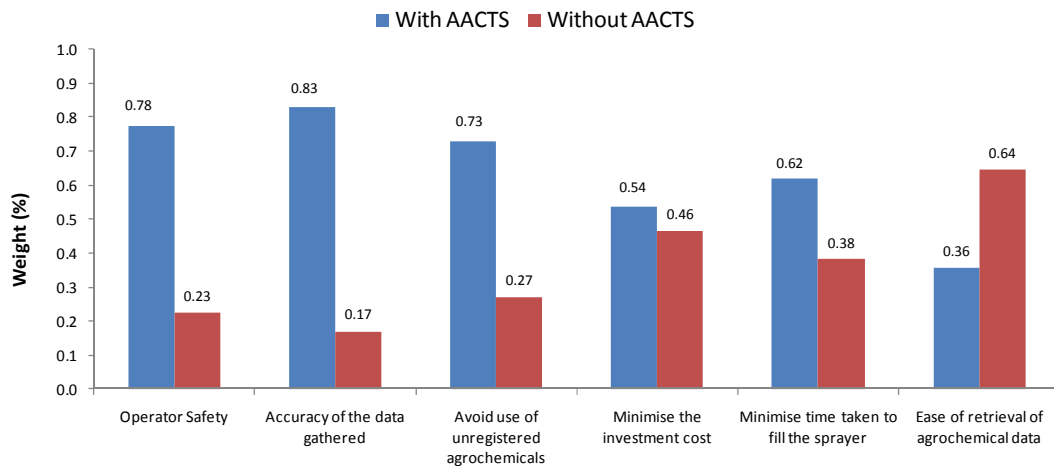
Farmer	Operator Safety	Accuracy of the data gathered	Avoid use of unregistered agrochemical	Minimise the time taken to fill the sprayer	Minimise the investment cost	Ease of retrieval of agrochemical data
<b>A</b>	0.0742	0.1034	0.3872	0.2675	0.0592	0.1085
<b>B</b>	0.1090	0.2303	0.0745	0.2057	0.1505	0.2303
<b>C</b>	0.1274	0.0709	0.5310	0.0604	0.1491	0.0612
<b>D</b>	0.1192	0.2458	0.1129	0.2388	0.1101	0.1732
<b>E</b>	0.2386	0.1690	0.3021	0.1167	0.1176	0.0560
<b>F</b>	0.2551	0.3861	0.0468	0.0699	0.0490	0.1930
<b>G</b>	0.3564	0.0939	0.1516	0.2754	0.0481	0.0746
<b>H</b>	0.5293	0.2099	0.0255	0.0751	0.1000	0.0602
<b>I</b>	0.2725	0.0734	0.0227	0.1240	0.4615	0.0460
<b>J</b>	0.2147	0.2565	0.1087	0.2582	0.0496	0.1122
<b>Total</b>	2.2964	1.8392	1.7630	1.6917	1.2944	1.1152

The graphical presentation of the data is show in Figure 8.



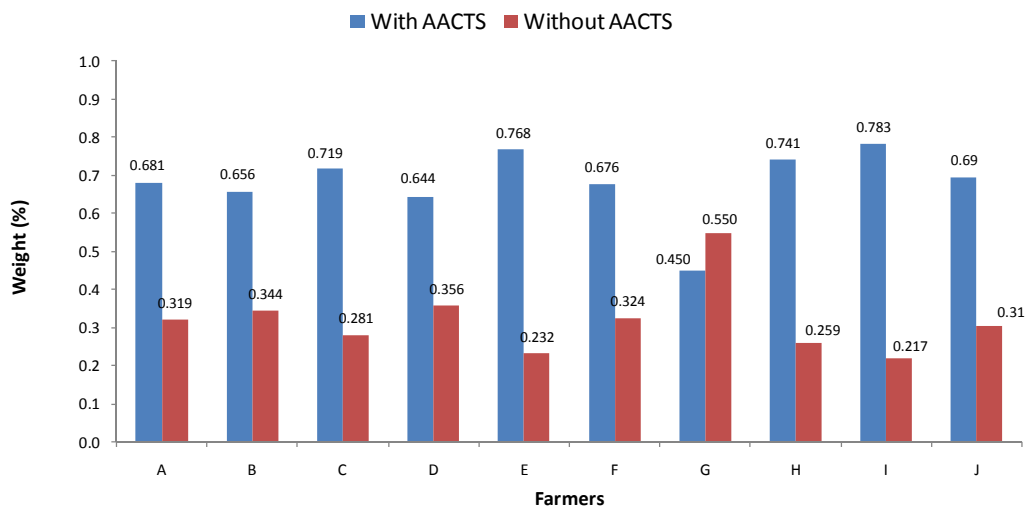
**Figure 8: Summary of the criteria weight from 10 farmers**

Figure 9 shows the weighted mean scores of the farmers of each attribute in comparison with the sprayer with and without AACTS. The sprayer with AACTS has a higher weight mean on all attributes apart from the attribute “ease of retrieval of agrochemical data”. Only three farmers (D, E and J) believe that this attribute performs better on sprayer with AACTS. It is worth noting that these three farmers use computer systems for keeping records and all the others which rank it higher on sprayer without AACTS use paper-based system. It was found that the weighting difference between the ‘minimising the investment cost’ and ‘time taken to fill the sprayer’ attributes is very small. Although the investment cost of the sprayer with AACTS is higher than without AACTS, the results of the mean weight indicate that six farmers (A, B, F, H, I and J) believed that the attribute minimising the investment cost performs better on sprayer with AACTS. Six farmers (B, C, E, H, I and J) believe that the attribute “minimising the time taken to fill the sprayer” performs better on sprayer with AACTS. Although all of them were marginally but not significantly faster using the conventional induction hopper they had the impression that the loading process without the AACTS was slower than the sprayer with AACTS.



**Figure 9: Weighted mean scores of each attribute**

Figure 10 summarises the response of the farmers. Nine out of ten farmers interviewed appear to perceive the advantages of the system. The weighted ranking of the sprayer with AACTS was greater than the sprayer without the AACTS. Farmer G was the only one which the result of the ranking was more favourable for the sprayer without the AACTS based on the total sample size of 10.



**Figure 10: Summary of response of 10 farmers**

## 5.7 Verification of the sample size power

The sample size is an important factor in experimental analysis. In this research sample size of five was initial thought not to be a right number of respondents (farmers). Hence,

it was decided to increase to ten. The sample size was verified by conducting statistical analysis using the statistical power law.

The power depends on the significant level ( $\alpha=0.05$ ), difference between the means, standards deviations between the two means and the sample size. Initially the power calculation on the sample size of 10 was conducted. In addition, two more power calculations were conducted on the first five farmers (A,B,C,D,E) and the last five (F,G,H,I,J). The equation of the power analysis and the power analysis results using STATISTICA 8 are shown in Appendix F.

For the sample size of 10, the mean weight  $\mu$ , and standard deviation  $\sigma$  of experimental results for the sprayer with AACTS were  $\mu = 0.6812$  and  $\sigma = 0.0933$  respectively. However weights from the results for the sprayer without AACTS were much lower with mean weight  $\mu = 0.3187$ , and standard deviation  $\sigma = 0.0933$ . Results show that there is a statistically significant difference between the two means ( $p=0.00017$ ) of the system with AACTS and without AACTS. According to the data analysis shown in Figure 10, this study has a power of 1 to yield a statistically significant result. In other words, assuming this sample is representative of the whole population, the sample size of 10 is large enough for this study to show a significant difference with 95% confidence. Due to the large difference in the means and the small standard deviation between the means, the power will always be 1 for sample size greater than six, considering the same means and standard deviations. Furthermore, considering the same means and standard deviations, a sample size of five has a power of 0.9963.

For the first five farmers (A,B,C,D,E) the mean weight for the sprayer with and without AACTS is 0.6935 ( $\sigma = 0.0507$ ) and 0.3065 ( $\sigma = 0.0507$ ) respectively. Results show that there is a significant statistic difference between the two means ( $p=0.0010$ ) taken from the system with and without AACTS. This sample size has a power of 1 to yield a statistically significant result as shown in Appendix F. This large power is due to large difference between the means and small standard deviations as above.

For the last five farmers (F,G,H,I,J) the mean weight for the sprayer with and without AACTS is 0.6690 ( $\sigma = 0.1290$ ) and 0.3310 ( $\sigma = 0.1290$ ) respectively. Results show that there is a significant statistical difference between the two means ( $p=0.0428$ ) taken from the

system with and without AACTS. This sample size has the power of 0.8964 to yield a statistically significant result as shown in Appendix F.

The power analyses indicate that a sample size of five farmers is satisfactory for this experiment. The first and the second group of five have a power of 1 and the 0.8964 respectively. Furthermore, a sample size of five with the same means and standard deviation of the total sample size of 10, as presented earlier, have, a power of 0.9963.

### **5.8 Multiple choice questionnaire**

A second questionnaire was conducted to determine the farmers' views of the system. This questionnaire was answered by the same group of farmers who evaluate the prototype and answered the AHP questionnaire. The responses to the questionnaire are shown below.

1. 60% thought that it decreases the risk of contamination to the operator. 40% of the farmers thought that it neither decrease nor increase.
2. 70% of the farmers thought that it decreases the risk of spillage. 30% of the farmers thought that it neither decrease nor increase.
3. 40% of the farmers agree that the identification system is straightforward, 60% strongly agree.
4. 70% of the farmers agree that the measuring system is straightforward, 30% strongly agree.
5. 80% of the farmers thought that the rinsing system is efficient, 20% thought it is very efficient.

### **5.9 Conclusion**

The result of the analysis indicates that nine out of ten farmers interviewed perceive the advantages of having the sprayer with AACTS. The weighted ranking of the sprayer with AACTS (0.6812) is greater than the sprayer without AACTS (0.3187). Although the attributes weights and ranking differs within this group, some conclusions can be made according to the AHP results and the interviews with the farmers.



When comparing the attributes without making reference if with or without AACTS, the overall prioritisation (Figure 8) shows that the highest weights are concentrated on operator safety and the lowest on ease of retrieval of agrochemical inputs. The second highest weights are concern with accuracy of data gathered. However, the attribute accuracy of the data gathered becomes first when comparing the performance of the sprayer with and without AACTS. According to Figure 9, the farmers interviewed believed that the sprayer with AACTS performs better in terms of accuracy of the data (0.83) in comparison with the sprayer without AACTS (0.17). This is a clear selling point perceived by the farmers.

Farmers which keep agrochemical stock at the farm perceive that the ability to avoid the use of unregistered agrochemical is a disadvantage of the AACTS. These farmers argue that they use the chemical available on stock from the previous season which contains the same active ingredient of the permitted one. However, three farmers believe that this attribute can help them to prove good practice to crop assurance schemes.

Three farmers which use computerised system believe that the AACTS could minimise the time spent in the office to update the spray records. The largest farms gave lower priority to “minimising the investment cost”. This is can explained because the cost can be spread across over a large area. However, two of them gave high priority to “minimising time taken to fill the sprayer” as they argue to have a large area to spray and the loading process shouldn’t taken any longer than the conventional system. The result of the experiment shows that there is no significant difference in speed of operation between the AACTS (211.8 s) and manual method including loading and record creation time (201.3s) at 5% probability level (Peets, 2009). The farmer which has two sprayers and grows a large area pointed out that the loading time is not an issue as two sprayers are enough to cover the area.

The need of computer system can be a barrier of adoption by those who do not use computer to keep the spray records. Because of that, it is suggested that the agronomist play a key role on the adoption of the AACTS. The agronomist could provide the job plan electronically and the farmer could download this information into the AACTS.

The power analyses show that a sample size of 10 farmers has the power of 1 to yield a statistically significant result. However, the power analysis shows that even the first group

of 5 farmers has the power of 1. Hence it is recommended that a power analysis should be carried out in the early stages of similar studies in order to estimate the power of the sample size.

From the multiple choice questionnaire results, it has been shown that 60% of the farmers perceive the improved performance of the AACTS in terms of minimising the risk of contamination and 40% believe that it neither decreases nor increase. 70% of the farmers perceived the improvement in terms of minimising the risk of spillage and 30% believe that it neither decreases nor increases. This in terms of chemical identification, weighing system and rinsing system, all the farmers interviewed had a positive view, none of the respondents answered in a negative or inconclusive manner.

## **6 Perceived Market Value**

### **6.1 Introduction**

The amount of money that would be paid for the AACTS is unknown as such system is not available on the market. The objective of this chapter is to estimate the market's willingness to pay (WTP) for the AACTS using the contingent valuation method. Furthermore, the break-even analysis was conducted in order to identify the most profitable retail price and the sales volume required to cover the cost in the North America and European markets.

### **6.2 Economic Valuation Techniques**

In this section the "stated preference techniques" (SP) is reviewed. The "stated preference" is a technique used to conduct an economic valuation. This term is used to refer to any questionnaire-based technique which seeks to obtain individual monetary valuations of cost and benefits (Bateman et al. 2002). Stated preference questionnaire-based techniques rely on asking people hypothetical questions, in a similar manner to a market research interview.

One of the alternatives to derive WTP indicators is to conduct the interviews using a SP called choice modelling (CM). CM is a technique that can be used to estimate non-market environmental benefits and costs. It involves a sample of people, who can choose between alternative options that contain a number of attributes with different levels. One of the alternatives - the status quo - is held constant and is included in all questionnaires.

Each respondent is offered a number of such choice sets and is asked to identify which options he/she prefers. The data analysis is based on Random Utility Theory (RUT). RUT is based on the premise that respondents act rationally, selecting the alternative that gives the highest utility. Therefore, the probability of selecting a given alternative will be higher if the utility provided by such alternative is the highest among the different choices (Loureiro et al., 2007).

Choice modelling requires the collection of primary data using a survey. The smallest sample size would normally be around 1000 valid responses for it to provide sufficient statistical power. However, smaller samples are possible where respondents may be expected to answer a greater number of choice sets in each questionnaire (Bennett, 2005)

Choice modelling was not selected to be used in this research because it requires separating the attributes into different levels and gives values indicators for that. The attributes of the automated agrochemical recording and weighing system do not have different levels and values. Hence the Contingent Valuation (CV) was chosen to estimate the farmers' willingness to pay for the AACTS. The method is explained in the following section.

### **6.3 Contingent Valuation (CV)**

Contingent valuation (CV) is a commonly method used to find the economic value of the non-market environmental commodities or new goods. Mitchell and Carson (1989) defines CV as a method that used hypothetical survey questions to elicit people's preference for public good by determining what they are willing to pay for specified improvement of them. The values generated are treated as estimates of the value of the non-market good or service, depending on the particular hypothetical market.

Although CV is more common used to find the economic value of the non-market environmental commodities, Cameron and James (1987) implemented CV to supplement pre-test-market. The authors suggested that CV is a adequate method for assessing the market potential of products that have not yet been developed. Following the results of that study, Yoo (2002) also used CV to evaluate the use of a service which was not yet available in the market, in this case a cable television service. He pointed out that the analysis of the CV provided the preliminary indication of the consumers' value of the cable television service. Following both studies it has been shown that CV can be used to assist researchers to assess the potential market of a product under development. Therefore, this research will use CV to estimate the farmer's willingness to pay for the automated agrochemical traceability system.

Applying the CV methods requires a careful development of a number of stages (Bateman et al. 2002)

1. The product to be valued should be defined. This requires the definition of the hypothetical market in which a change in the product is proposed.
2. To select the elicitation method which defines the format of the question that will be used to obtain the respondent's preferences.
3. To define the population and sample.
4. To design the questionnaire according to the elicitation method.
5. To test the questionnaire using a focus group or pilot surveys and conduct the final survey.
6. To analyse the information to estimate the WTP mean and media and WTP determinants.

### **6.3.1 The elicitation method**

The question format which will be used to obtain information about the respondent's preferences should be defined. There are many ways to ask the consumers' willingness to pay for the contingent valuation method, such as, (a) payment cards, (b) open-ended questionnaires and (c) single-bounded and (d) double-bounded dichotomous (Oxford dictionary definition: a separation or contrast between two things).

With the open ended (OE) format, the respondent is asked a question of the form: 'What are you willing to pay?'. This is an easy method to implement but this format had been criticised as unlikely to provide the most reliable data, since respondents are not familiar with placing a currency value on a particular good (Federal Register 1993 cited by Reaves et al. 1999).

With the payment card (PC) format, the respondent is presented with a range of willingness to pay values, and have to choose one which represents his/her willingness to pay for the goods. Reaves et al (1999) pointed out that PC reduces some of difficulty of trying to place a currency value with no guidance. However, PC is associated with problems involving range bias (Mitchell and Carson. 1989; Whyne et al. 2003). The range bias occurs when respondents having very low WTP valuations might take a long scale as indicative that they have to value the good more highly. On the other hand,

when those respondents having very high WTP, beyond the scale length, would consider revising their estimates downwards.

The dichotomous choice has becoming very popular and is approved by the NOAA panel because of its advantages (Arrow et al. 1993). Respondents have to answer “yes” or “no” to a specific value amount. It is not considered to be prone to strategic bias as open-ended questions (Choi et al., 2001). There are two ways of strategic bias, free-riding and over-pledging. With the Free-riding, respondents underbid because they either think that they will have to pay the amount they indicate or the good will be provided no matter what amount they indicate. Over-pledging is when respondents overbid because they think that either they will not have to pay the amount they indicate or provision of the good depends on their indicated WTP. On the single dichotomous choice (DC) format, the respondent is asked ‘Are you willing to pay £X?’ with the amount X being varied across the sample.

For this research the double-bounded dichotomous choice (DBDC) type of questions was selected. In this method, the initial DC question is followed by a second DC question. If response to the initial question was positive then the bid amount of the second question is higher. If response to the initial question was negative then the bid amount of the second question is lower. Hanemann et al. (1991) illustrate the improvement of the statistical efficiency by using DBDC. Compared to other elicitation methods, the DBDC is less sensitive to starting point and strategic biases, and reduces the demand for a large sample size (McLeod and Bergland, 1999; Hanemann and Kanninen, 1996). Starting point bias suggests that the initial starting point in a bidding game can influence the final bid.

Some of the disadvantages of the CV method are related to the number of biases that can emerge from its application. One of the biases is called yea-saying in which there is a tendency of some respondent answer “yes” trying to please the interviewer. The anchoring bias can also occur. It happens when WTP is influenced on the initial stated value. A plausible scenario should be described in order to avoid a hypothetical bias. In order to avoid strategic behaviour, the respondent should be reminded that the proposed bid levels are hypothetical. This will eliminate the problem of “strategic bias” in which

the respondent intentionally overstates or understates the true bid in order to influence the result.

### **6.3.2 Survey Method**

The face-to-face interview is the method recommended by the NOAA (Arrow et al. 1993) panel to conduct a CV survey. It is argued that a face-to-face survey allows the interviewer to provide more visual information and better explanations. A higher response rate has been shown in comparison with mail surveys (Mannestro and Loomis, 1991). Marta-Predoso et al. (2007) reported that the web based survey had a lower response rate (5.1%) than the in-person interviewing (84%). However, Tsuge and Washida (2003) reported that the response rate on an online CV survey increased when a prize draw was offered.

Common arguments against the use of the face-to-face interviews are that surveys are too expensive (Marta-Predoso et al. 2007). In addition, in-person interview are more likely to transcript wrong information when analysing the data due to paper-based. Marta-Pedroso et al. (2007) references Kaplowitz et al. (2004) stating that internet survey present lower cost and can be administrated quickly.

The web-based questionnaire was selected in this research. This was due to the low cost and time constraint. Furthermore, the web-based questionnaire would allow a great number of farmers to access the questionnaire, rather than try to find farmers available to answer the questionnaire. The questionnaire was designed using the software available at *SurveyMonkey* website which enables the creation of online surveys. The final link to the questionnaire was announced on *The Arable Group* (TAG) newsletter. TAG is the England's largest independent agronomy group. They provide agricultural research, independent agronomic information, consultancy and crop advice to progressive arable farmers. The newsletter is distributed to approximate 1,200 farmers around England. A prize (Swiss Army Penknife) was offered to encourage the respondents to go online and answer the questionnaire.

### **6.3.3 Sample population**

Since the questionnaire link was announced in a newsletter, it was difficult to target the sample population, but some assumptions can be made. For the high quality of the

service provided, TAG is known to have as a member the top arable farmers in the country. This newsletter is distributed to approximate 1,200 farmers, it was expected to have at least 8.3% response rate, due to the fact that 100 prizes was offered.

Traceability system plays a key role in environmental protection as it can be programmed to monitor the production system according to safe guidelines. The arable farmers have a high impact on the environment due to the intense use of agrochemical application. The AACTS can minimise the environmental impact by minimising the over-application of agrochemical products.

#### **6.3.4 Questionnaire design**

The questionnaire was a result of a literature review about the diverse CV studies undertaken in different places as well in collaboration with the senior technical officer who is expert on agrochemical application, a senior researcher scientist on spray application, the marketing manager of farm machinery industry, an expert on agricultural software and a farmer.

The questionnaire used a mixed of multiple choice and open questions. The structure was divided into four parts. The first seeks to identify the level of the technology of the farm and details of the spraying application. The second is the explanation of the AACTS following the DBDC questions. The third is the follow up questions. The fourth is concerned with the socio-economic information of the respondents.

The questionnaire guided the respondents to three different routes according to their business:

1. **Group A:** Farmers who hire contractors to perform the spray application (questionnaire shown in Appendix G)
2. **Group B:** Farmers who do their own spray application or have a employee (questionnaire shown in Appendix H)
3. **Group C:** Spraying Contractors (questionnaire shown in Appendix I)

All three groups are all potential users of the AACTS. They all have different characteristics which need to be identified in order to conduct a robust data analysis. Some of the questions are the same for all groups. The questionnaire structure follows the sequence:

- The first question was to identify if the respondent is a farmer or a contractor.



- If the respondent was a farmer a second question was asked to identify who does the spray application. Three variables were presented to answer this question: yourself; employee and contractor. If the answer was the latter, the respondents would belong to group A, otherwise belong to group B. The spray application question aims to identify if there is any relationship between the WTP and the type of labour at the farm.
- If the respondent belongs to group B or C he was asked how many spraying machines he owns/hires. He was also asked what was the capital cost of the most expensive sprayer and how old is it. The capital cost of the sprayer was required to determine the impact of this factor on the WTP response.
- To determine the level of technology operating on the farm, all the groups were asked if they use any Global Positioning Systems (GPS) and spatial variable application techniques.
- In order to learn the level of technology used to manage the spraying operation record data three questions were asked. If the respondent belongs to group A or B he was asked how the spray plan is received (electronic records, paper based) and how the spraying records are stored (paper based, computer data base, mixed). All the groups were asked how the chemical application records are generated. The variables presented on the multiple choice question were the same for group A and B: software based, paper based, electronic spreadsheet. Group C has an extra variable option to inform if this service was not provided.
- The second part had the purpose to explain the AACTS. All the groups were given a briefly background information aiming to outline the current manual loading system in practice as well the proposed prototype system. A 30 seconds video was shown to demonstrate the AACTS in practice (given in the CD version of the thesis).
- Following this all groups were asked the WTP question using DBDC format. The initial bid from group B and C was selected randomly from five values according to Table 20. The initial bid from group A was selected randomly from five values according to Table 21.
- After the DBDC questions the respondents were faced with “follow up” questions. An open-ended question was asked to learn the maximum WTP for

all the groups. The objective was to learn the proportion of people who were ready to pay lower or higher amount.

- The subsequent “follow up” questions searched for factors that motivated all the groups’ WTP. All the groups were asked why would they decide to use AACTS and why would they decide not to use AACTS.
- The socio economic section designed for group A and B aimed to gather basic information about the characteristic of the farm including farm type and farm size.
- The socio economic section designed for group C gathered basic information about the average annual size in hectares of the contracting business and the farm type of the customers.

### **6.3.5 Pilot survey**

As part of the survey, the CV should be evaluated before the final questionnaire is sent out. Pre-testing a CV questionnaire is a very important step to ensure reliable results, particularly because CV questionnaire presents a new set of information and characteristic that usually people are not familiar with (Arrow et al. 1993). In this study, the pilot study was used to observe unpredicted answers, testing the credibility of the scenario, observe the respondent’s behaviour regarding the WTP question’s format, readapting the questionnaire’s phrasing and defining new categories of multiple-choice questions. One pilot study was undertaken. A number of farmers and contractors received the online questionnaire and after completing feedback was obtained by phone calls, e-mail message or face-to-face interviews. Twelve respondents answered the survey at the pilot stage, of which four were contractors, seven were farmers who do the spray application themselves and a farmer who hired contractors to conduct his spray application. From the feedback received the questionnaire structure and content could be judged as satisfactory. The respondents thought that the hypothetical scenario was clear and easy to understand, they all considered that the video made the description of the system very easy to follow. Since there was no negative feedback it was decided to proceed with the final questionnaire and announce it online. The final questionnaire did not differ from the pilot version and hence the answers from the pilot version could be included on the final analysis of the data.

### 6.3.6 Bids amounts

As explained on section 6.3.1, the double-bounded dichotomous choice (DBDC) question presents a sequence of two bids and ask for “yes” or “no” answer. The second bid is conditioned on the respondent’s response to the first bid; lower if the first response is “no” and higher if response is “yes”.

Five different sets of bids offers were distributed randomly. The bids used for the AACTS system are displayed on Table 20,  $B_i$  is the initially bid presented,  $B_{Li}$  is the second bid if the response to the first bid is “no”,  $B_{Hi}$  is the second bid if the response to the first bid is “yes”. Group B (farmers who do their own spray application or have an employee) and Group C (spraying contractors) were presented with the bids from Table 20.

**Table 20: Alternative bids (£) for the AACTS (Groups B and C)**

$B_i$	$B_{Li}$	$B_{Hi}$
<b>2,000</b>	1,700	2,300
<b>2,250</b>	1,950	2,550
<b>2,500</b>	2,200	2,800
<b>2,750</b>	2,450	3,050
<b>3,000</b>	2,700	3,300

The calculation of the bids was based on the preliminary estimate of the prototype cost, which was approximately £1,000. This was considered the production cost. From the production cost the company sets the retail price which is approximately 200% higher than the production cost. Based on this information the bids prices were selected to base price (£2,000) up to 50% profit (£3,000). Five separate sets of bids distributed randomly across the farmers were offered as suggested by Hanemann et al. (1991). The starting value of the lowest initial bid ( $B_i$ ) is the minimum retail price that AACTS can be sold, £2,000. The highest initial bid is £3,000, which would provide 50% profit for the company as explained earlier. The initial bids inside these two intervals (£2,000 and £3,000) are equally distributed (£2,000; £2,250; £2,500; £2,750; £3,000). The higher ( $B_{Hi}$ ) and lower bids ( $B_{Li}$ ) within each set of bids were plus and minus £300. This is chosen because it is 10% of the highest  $B_i$  (£3,000) and 15% of the lowest  $B_i$  (£2,000); hence it is not a too large increment. However, for the purpose of the analysis, to overcome probability of overlapping, it is recommended that future researches use plus and minus £250. That would have been a preferred alternative which would be 10% of

the mid range ( $B_i = \text{£}2,500$ ).

The farmers who contract spraying application (group A) would not pay for the AACTS itself, but for the service. Therefore the bids presented on Table 21 are the respectively operation cost of the AACTS presented on Table 20 plus the contractor's profit. The bid is the extra charge the spray service would cost per hectare in order to hire a contractor which uses a sprayer fitted with the AACTS. Consequently the extra service cost presented on Table 21 can be converted into the cost that the contractor would be able to pay for the AACTS.

**Table 21: Alternative bids (£/ha) for the AACTS (Groups A)**

$B_i$	$B_{Li}$	$B_{Hi}$
<b>0.24</b>	0.21	0.28
<b>0.28</b>	0.24	0.31
<b>0.31</b>	0.27	0.34
<b>0.34</b>	0.30	0.37
<b>0.37</b>	0.33	0.40

The operation cost was calculated based on the following assumptions:

- The sprayer is fitted with GPS and data recording system (on board computer).
- The contractor has a computer and the software to analyse precision farming data.
- The depreciation of the AACTS was calculated using the same rate of the sprayer, from value given by Nix (2007). Where the average depreciation per annum is 15% for 5 years.
- The maintenance cost of the AACTS was calculated using the same rate maintenance cost as given by Nix (2007) of the sprayer machine, 17.5% for use of 400 hours per year.
- The capital cost has been calculated at an annual interest rate of 8.25%, bank base rate of 5.75% (Bank of England, 2007) plus 2.5% (Nix, 2007). This reflects the cost of the initial investment in the AACTS.
- The annual cost per hectare has been calculated for an arable area of 5,000 ha (average area covered in one year with a self propelled 24m wide spraying machine in England market).

- A profit of 50% for contractor rates over the operation cost.

Appendix J shows the calculation of the Table 21.

### 6.3.7 Definition of the mean and median WTP

One of the basic objectives of the CV studies was to determinate the WTP of the respondents. In this study a non-parametric approach was used to identify the mean and the median WTP of farmers for AACTS. Some authors argue that parametric approach is restrictive and highly dependent on the distributional assumption (Hanemann, 1984 and An, 2000). In addition, McMahan et al. (2000) pointed out that parametric approach may be unreliable where the sample size is small or the inconsistency of responses is unusually high. On the other hand, the non-parametric approach tries to estimate the mean and the median WTP values without making any distributional assumptions. This study applies the non-parametric *Turnbull's self-consistency algorithm* (TSCA) and the Kaplan-Meier. TSCA and Kaplan-Meier have been used in many CV studies (see, for examples, McMahan et al. (2000) and Hutchinson et al. (2001)).

In the double-bounded format, the two answers given by a respondent indicate one of the possible intervals into which their willingness to pay could fall:

1. "yes" to  $B_i$  followed by "yes" to  $B_{Hi}$  - interval  $B_{Hi}$  to  $\infty$
2. "yes" to  $B_i$  followed by "no" to  $B_{Hi}$  - interval  $B_i$  to  $B_{Hi}$
3. "no" to  $B_i$  followed by "yes" to  $B_{Li}$  - interval  $B_{Li}$  to  $B_i$
4. "no" to  $B_i$  followed by "no" to  $B_{Li}$  - interval 0 to  $B_{Li}$

The WTP ranges in this study overlap. Responses to a double-bounded choice survey can be classified according to the interval. The design illustrated in Table 20 defines 20 different WTP intervals. Notice that with this design there are 17 distinct boundary values for the various intervals: 0, 1700, 1950, 2000, 2200, 2250, 2300, 2450, 2500, 2550, 2700, 2750, 2800, 3000, 3050, 3300 and  $\infty$ . These boundaries  $B_j$  values will permit to write the 16 *basic intervals* which do not overlap. The following theory is reported by Bateman et al. (2002). The TSCA seeks to evaluate the survivor function at each of the boundary values. The survivor function at 0,  $S(B_0)$ , is always 1 and the survivor function at  $\infty$ ,  $S(B_{j+1})$  is always zero. The first step of the TSCA is to calculate the:

$$h_j = \frac{\sum_{i=0}^{j-1} \sum_{k=0}^{j+1} h_{ik} \frac{S(B_{j-1}) - S(B_j)}{S(B_i) - S(B_k)}}{\sum_{i=0}^{j-1} \sum_{k=0}^{j+1} h_{ik}} \quad (\text{Eq.22})$$

For  $j=1,2,\dots,j+1$ , where  $h_{ik}$  is the number of respondents in the sample in the observed interval  $B_i$  to  $B_k$ , and  $h_j$  is the estimate of the number of individuals in the basic interval  $B_{j-1}$  to  $B_j$ . The results will consist of a series of estimates of numbers of respondents lying in each basic, non-overlapping interval. Hence the number of respondents with WTP greater than the boundary value  $B_j$  can be calculated:

$$n_j = \sum_{k=j+1}^j h_k \quad (\text{Eq.23})$$

The Kaplan-Meier estimator is used to obtain a new set of estimates for the survivor function at these boundary values according to:

$$S(B_j) = \frac{n_j}{N} \quad j = 1, 2, \dots, j. \quad (\text{Eq.24})$$

The procedure is repeated by using the new estimates of the survivor function. The procedure is repeated until the point estimates of survivor function at each of the  $B_j$  converge.

The median WTP can be calculated from this the survivor function as the value which the survivor function evaluates to 0.5. Also, mean WTP can be calculated as the area under the step according to the following equation

$$C = \sum_{j=1}^J S(B_j) [B_j - B_{j-1}] \quad (\text{Eq. 25})$$

The variance of WTP in the population need to be estimated in order to calculate the confidence intervals for the mean. For interval data, the population variance  $\text{var}(C)$  is given by:

$$\text{var}(C) = (B_j - C)^2 (S(B_j) - S(B_{j+1})) \quad (\text{Eq.26})$$

Where  $B_j$  are the  $j=1$  to  $J$  bid levels and  $B_0=0$ ,  $C$  is the mean WTP,  $S(B_j)$  are the  $J$  estimates of points on the survivor function curve and we assume that  $S(B_0) = 1$  and  $S(B_{j+1})=0$ . The variance of the mean can be calculated using the following equation, where  $N$  is the sample size:

$$\text{var}(\bar{C}) = \frac{\text{var}(C)}{N} \quad (\text{Eq.27})$$

The standard error of the mean is the square root of the equation above. The 95% confidence interval will be defined by:

$$\bar{C} - (1.96)\sqrt{\text{var}(\bar{C})} \text{ and } \bar{C} + (1.96)\sqrt{\text{var}(\bar{C})} \quad (\text{Eq.28})$$

#### 6.4 Results

This section presents the results of the contingent valuation (CV) survey regarding the farmer's willingness to pay for the AACTS. As explained on section 6.3.4 the survey was focused on three potential users of the AACTS, farmers who contract spray application (Group A), farmers who does their own spray application or have employee (Group B), and spraying contractors (Group C)

The response rate was 8.92%, 107 out of the potential 1,200 respondents. The analysis will include the respondents of the pilot survey, which are 12 respondents. Out of the total of 119 respondents, seven were contractors, three farmers who contract spray application and 109 farmers who do the spray application themselves or have employees. The analysis of the data did not separate the different groups due to the lack of data belonging to groups A and C.

The summary statistics of the demographic variables and attitude variables for the survey (not including the group C) are presented in Table 22 and Table 23 respectively.

**Table 22: Summary statistics for demographic variables**

<b>Variables</b>	<b>Description</b>	<b>Distribution of survey responses (%)</b>
Farm Type	Primarily Arable	71.4
	General Cropping	11.6
	Mainly Dairy / Livestock	0.9
	Horticulture	0.9
	Mixed	15.2
Farm arable size	Size in hectares	Mean 530.12 ha Std. Dev. 545.92 ha

**Table 23: Summary of statistics for attitude variables**

<b>Variables</b>	<b>Description</b>	<b>Distribution of survey responses (%)</b>
Spray Application	Yourself	64.3
	Employee	33
	Contractors	2.7
Number of sprayers	0	2.7
	1	67.9
	2	26.8
	3 over	2.7
Cost of the sprayer	Less than £15,000	27.5
	£15,000 – £30,000	24.8
	£30,000 – £45,000	11.9
	£45,000 – £60,000	12.8
	£60,000 over	22.9
How the spray plan is received	Paper based	68.8
	Electronic records	31.3
How the spray plan is generated	Paper based	47.3
	Electronic spreadsheet	3.6
	Software based	49.1
How the spray plan is stored	Paper based	26.8
	Computer database	49.1
	Mixed	24.1
Need for the system	Yes	42.0
	No	58.0
GPS system	Yes	21.4
	No	78.6

Since the survey was announced at the “The Arable Group” newsletter, it was expected to target a high sample of arable farmers. The majority (71.4%) of the 112 respondents were primarily arable farmers. The mean arable farm size is 530.12 ha, ranging from 38



to 2200 ha. Sixty-four percent of the farmers do the spray application and thirty-three percent hire an employee to do the spray application. The majority (67.9%) of the farmers own only one sprayer. Twenty seven percent of the farmers interviewed own a sprayer which worth less than £15,000.

Forty-nine percent of the spray plan is generated using software; this is expected to be due to the high number of agronomists who use “Muddy Boots” software to generate the spray plan recommendation in the UK. The majority of the farmers (68.8%) receive the spray plan as a paper based system. Forty-nine percent of the farmers store the spray application records into a computer database. This result can be supported by the Farm Business Survey conducted by Defra (2002), which indicates that 55% of the farms in England make active use of computers in the running of the farm business. On the other hand, the result of our survey indicates that 26.8% of the farmers store in paper-based and 24.1% mixed.

Between 5% and 10% of the farms in England use GPS and spatial variable application system (Moore, personal communication, 2008). This indicates the result of this survey represents a relatively high sample of farms which use these technologies (21.4%).

The result of the follow up questions indicates that most of the farmers (58%) do not perceive a need for the AACTS.

#### **6.4.1 Perception of need**

The mean and the median WTP for the AACTS were calculated by considering only those respondents who perceive a need for the system, which represents 50 respondents (42% of 119 respondents). Out of the total of 50 respondents, three were contractors (Group C), two farmers who contract spray application (Group A) and 45 farmers who do the spray application themselves or have employees (Group B). As a result of the small size of Groups A and C their responses were pooled with those of Group B for the following analysis. Subsequently a sensitivity analysis was conducted to see if their inclusion caused any bias in the results.

#### **6.4.2 Turnbull’s self-consistency algorithm and Kaplan-Meier**

The mean and the median WTP of the results were analysed using a non-parametric

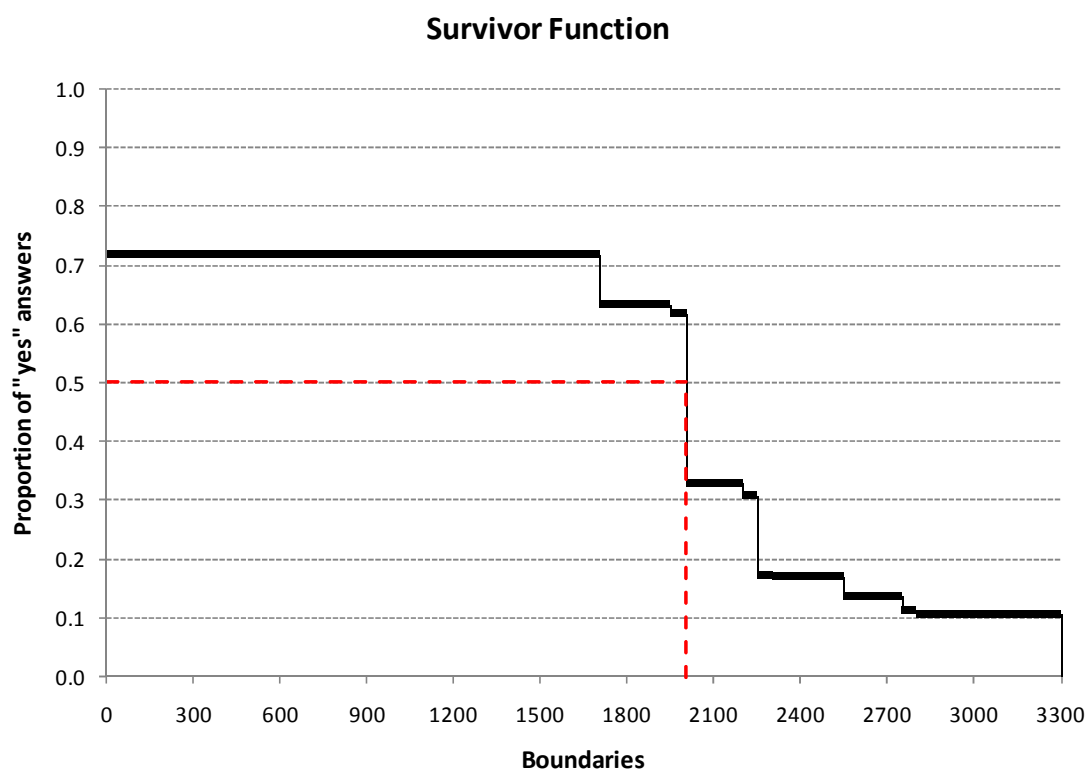
approach. The non-parametric approach aims to estimate a survival curve based on the proportion of ‘yes’ answers given to different bid levels. For DBDC format, first the TSCA and then the Kaplan–Meier estimators are used to generate data for the survival function (Bateman, 2002). The results of the Kaplan-Meier estimators (Eq. 24) are presented in Table 24.

**Table 24: Estimators according to Kaplan-Meier**

<b>Boundaries (£)</b>	<b>Proportion of “yes” respondents (S(B<sub>j</sub>) values)</b>
0	1
1700	0.719
1950	0.635
2000	0.618
2200	0.330
2250	0.310
2300	0.175
2450	0.172
2500	0.172
2550	0.171
2700	0.137
2750	0.137
2800	0.114
3000	0.109
3050	0.108
3300	0.108

Results show that 71.9% of the respondents are prepared to pay up to £1,700 for the AACTS, 63.5% are prepared to pay between £1,700 and £1,950, 61.8% are prepared to pay between £1,950 and £2,000 and so on, and 10.8% of respondents are prepared to pay a maximum cost of £3,300.

Appendix K shows the excel spreadsheet model and the formulas used to calculate the TSCA and to estimate the Kaplan-Meier. The spreadsheets were designed by the author particularly for the analysis of this research. Results of the survivor function of this study according to TSCA and Table 24 are presented in Figure 11.



**Figure 11: Kaplan-Meier analysis of mean and median WTP for AACTS**

The mean WTP is bounded by the area under the survivor function and the median WTP is determinate by inspecting where the survivor function evaluates to 0.5 (Bateman, 2002). According to Figure 11, the mean WTP is £1,632 and the median WTP is £2,000. As presented earlier, the mean WTP is calculated by Equation 26. The standard error of the mean is £155.95 (square root of Equation 27). The marginal error is £611.32. In other words there is a 95% chance that the mean being between £1,327 and £1,938.

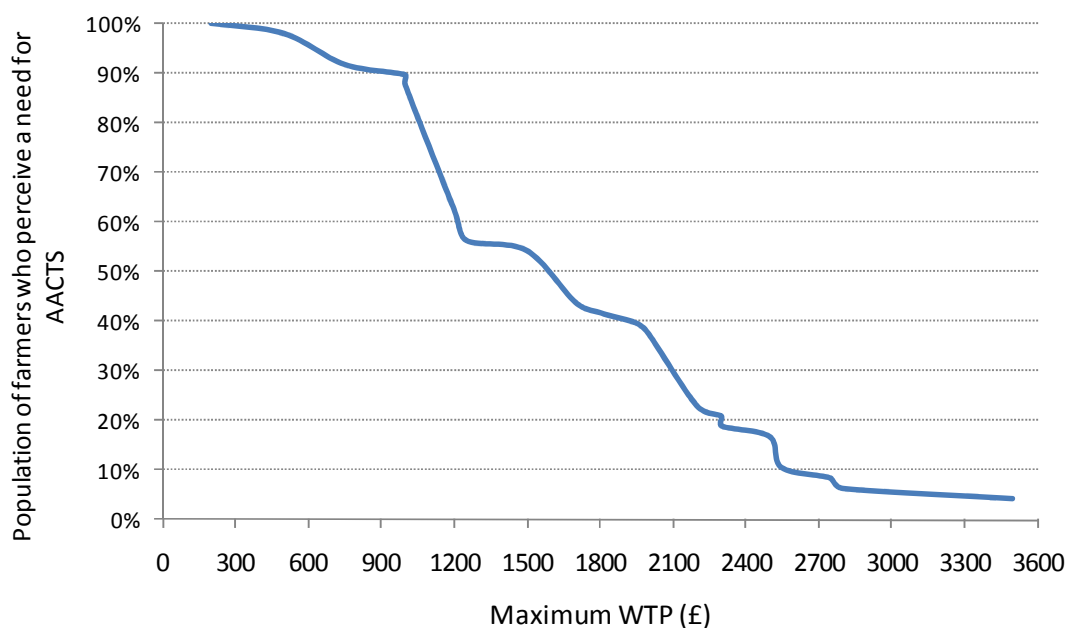
### 6.4.3 Maximum Willingness to Pay

At the “follow up” section the respondents were asked how much it would be the maximum amount they would pay for the AACTS. The mean maximum cost indicated by the 48 farmers out of 50 farmers who perceive a need for the system is £1,597. The standard deviation of the sample is £766.32 and the standard error of the mean is £110.61. The lower and upper 95% limits are £1,380 and £1,814 respectively. Table 25 and Figure 12 indicate the proportion of the respondents and their maximum willingness

to pay for the AACTS. The maximum willingness to pay ranges from £200 to £3,550. Four percent of the population is willing to pay up to £3,550 for the system and 54% are willing to pay up to £1,500.

**Table 25: Maximum Willingness to Pay (£) – follow-up question - numeric data**

Maximum WTP (£)	Population
3500	4%
2800	6%
2750	8%
2550	10%
2500	17%
2305	19%
2300	21%
2200	23%
2000	38%
1950	40%
1800	42%
1700	44%
1500	54%
1250	56%
1200	63%
1000	88%
999	90%
750	92%
500	98%
200	100%

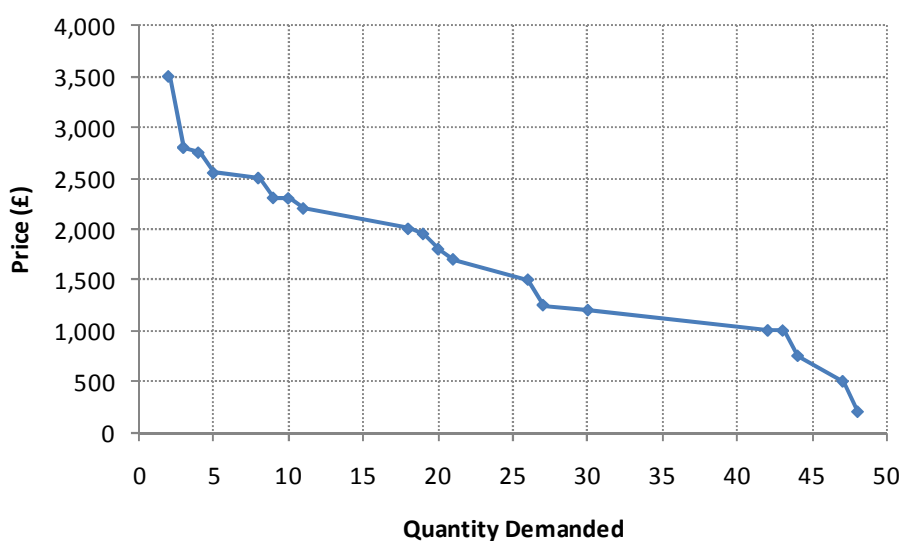


**Figure 12: Maximum Willingness to Pay (£) – follow-up question**

A *t*-test was conducted in order to compare the means of the two groups, WTP calculated using the TSCA Kaplan-Meier and the maximum WTP derived from the “follow-up” question. The result of the two tailed P value is 0.205. This difference is considered to be not statistically significant, in other words there is no statistic difference between the two groups. However, the result of the follow up question is preferred to that of the DBDC in terms of statistical efficiency as measured by the standard error and the amplitude of the confidence intervals (95%).

According to Pearce et al. (2006) the median WTP is the better predictor of what the majority of people would be actually willing to pay. He pointed out that the mean WTP is influenced by a relatively few very large bids and does not reflect the major public acceptability. It was estimated that farmers WTP mean is £1,597 and the median is £1,500 according to the “follow up” question.

The demand curve of this study was constructed based on the answers of the “follow up” question which identifies the maximum price the respondents who perceived a need for the AACTS would pay for it. Demand refers to how much (quantity) of a product is desired by buyers. The quantity demanded is the amount of a product people are willing to buy at a certain price. The demand curve is shown in figure below.



**Figure 13: Demand Curve of AACTS within a sample of 48 respondents who perceived a need for AACTS**

If the supply cost of the AACTS is £1,500 the potential quantity demanded of AACTS is 26 units per year. If the supply cost increases to £3,500, the potential quantity demanded decreases to 2 units per year.

As mentioned in section 6.4.1 the effect of Group A (farmers who contract spray application) and Group C (spraying contractors) on the overall result of the willingness to pay need to be evaluated. In order to do this their data were removed from the total data set and the statistics calculated as shown on Table 26. Three analysis were conducted, first it was removed Groups A and C, then only Group C was removed and finally only Group A was removed. As shown in section 6.4.3, the mean maximum willingness to pay indicated by the 48 farmers (Groups A+B+C) is £1,597. The standard deviation of the sample is £766 and the standard error of the mean is £111. The statistic analysis shown on Table 26 indicates that Groups A and C does not significantly affect the overall result of the willingness to pay analysis. The p values shown are the results of the comparison of the individual Groups (B, B+A, B+C) with the overall result (Group A+B+C), the results indicate that the differences are considered to be not statistically significant.

**Table 26: Statistic analysis of maximum WTP within the different groups**

	<b>Sample size</b>	<b>Mean (£)</b>	<b>Standard deviation (£)</b>	<b>Standard error of the mean (£)</b>	<b>P value</b>
Group B	43	1,608	795	117	0.9457
Groups B+A	45	1,603	784	113	0.9699
Groups B+C	46	1,601	776	112	0.9798

Group A: farmers who contract spray application; Group B: farmers who does their own spray application or have employee, and Group C: spraying contractors

#### **6.4.4 Bivariate probit model**

A software package called NLOGIT 4.0 was used to calculate the bivariate probit model of the DBDC. The bivariate probit model was used to analyse the data as we have two binary response variables that vary together, the first and the second bid. This model will relate the positive responses to the first and second bid amounts to the variables of the survey.

The independent variables tested in our bivariate probit model were the type of labour used in the spray application, the number of sprayers, the cost of the sprayer, how the spray plan is generated, received, and stored. Additionally, the bivariate probit model tested the variables regarding the use of GPS systems, if the respondents perceive a need for the AACTS and socio-economic characteristics, such as farm type and farm size. For the regression analysis all the variables had to be either interval or dichotomous, as were defined as in Table 27. For the cost of the sprayer the middle point of each category was used as an average of the cost of the sprayer of respondents in that category. Knowledge of how the spray plan is generated, received and stored, number of sprayers, GPS use, perception of need and farm type were transformed into dummy variables.

**Table 27: Description of the variables tested in the probit model**

Variable Name	Definition and code
<b>Dependent Variable (WTP)</b>	
Y1	1 if YES initially, 0 if NO initially
Y2	1 if YES in the follow-up, 0 if NO in the follow-up
<b>Bid amount</b>	
BID1	£2,000 - £2,250 - £2,500 - £2,750 - £3,000
BID2	£1,700 - £1,950 - £2,200 - £2,450, £2,700 - £2,300 - £2,550 - £2,800 - £3,050 - £3,300
<b>Independent Variables</b>	
<b>Who does the spray application at the farm</b>	
EMPLOYEE	1 if Employee; 0 otherwise
YOURS	1 if Yourself ; 0 otherwise
CONTRACT	1 if Contractors; 0 otherwise
<b>Number of sprayers</b>	
NONE	1 if none sprayers, 0 otherwise
X1	1 if one sprayer, 0 otherwise
X2	1 if two sprayers, 0 otherwise
X3OVER	1 if three or over sprayers, 0 otherwise
<b>Cost of the sprayer</b>	
COSSPRA	£7,500 - £22,500 - £37,500 - £52,500 - £60,000
<b>Sprayer Age</b>	
SPRAAGE	1 - ∞
<b>How the spray plan is received</b>	
ELERECEIV	1 if electronic records; 0 otherwise
PAPRECEIV	1 if paper based; 0 otherwise
<b>How the spray plan is generated</b>	
SOFTEBASED	1 if software based; 0 otherwise
PAPGENER	1 if paper based; 0 otherwise
ELEGENER	1 if electronic spreadsheet; 0 otherwise
<b>How the spray records are stored</b>	
PAPSTORE	1 if paper based; 0 otherwise
COMPUTER	1 if computer database; 0 otherwise
RECMIXED	1 if mixed; 0 otherwise
<b>Precision Farming System</b>	
GPS	1 if yes; 0 otherwise
<b>Perceive a need for the AACTS</b>	
NEED	1 if yes; 0 otherwise
<b>Farm Type</b>	
ARABLE	1 if arable; 0 otherwise
CROPPING	1 if cropping; 0 otherwise
HORTICULTURE	1 if horticulture; 0 otherwise
LIVESTOCK	1 if mainly livestock; 0 otherwise
MIXED	1 if mixed; 0 otherwise
<b>Farm size</b>	
SIZE	0 - ∞
ARSIZE	0 - ∞



Several models were tested including several combinations of these variables. However, the analysis of the independent variables all together does not indicate any evidence of association within them. As a result, it was decided to run separate analysis of each independent variable related with the dependent variables to find some evidence of association. Consequently, evidence of association was found with COSSPRA (cost of sprayer), NEED (need for AACTS) and ARSIZE (arable area) as given on Table 27.

Table 28 to Table 30 shows the results of bivariate probit model for each independent variable which are associated with the dependent variables. The model included 112 respondents. The analysis of these three independent variables separately indicates evidence of association with the decision to say “yes” to the bids offered.

According to Table 28 the cost of sprayer has a positive relationship with the “yes” answer for the second bid offered. This is show by the p-value of 0.0097, this indicates that there is a significant relationship between this two groups. The higher the cost of the sprayer; the higher is the probability of the respondent say “yes” to the second bid.

**Table 28: Bivariate Probit - Cost of the Sprayer**

Variable	P value
Equation for Y1 – BID 1	
<b>COSSPRA</b>	0.1679
Equation for Y2 – BID 2	
<b>COSSPRA</b>	<b>0.0097</b>

As it was expected, those respondents who perceive a need for the AACTS were more likely to accept the bids offered as shows Table 29. The willingness to pay is strongly associated with the perception of need for the AACTS. The coefficient of the NEED is positive, which indicates that respondents which perceive a need for the AACTS would be willing to pay more for it. The p-value of 0.0096 for the first bid and 0.0049 for the second bid offered, this indicates that there is a positive relationship between those farmers who perceive a need for the AACTS and their willingness to pay for the AACTS.

**Table 29: Bivariate Probit: Need for the AACTS**

Variable	P value
Equation for Y1 – BID 1	
<b>NEED</b>	<b>0.0096</b>
Equation for Y2 – BID 2	
<b>NEED</b>	<b>0.0049</b>

Table 30 shows the bivariate probit model for the arable farm size. The willingness to pay is strongly associated with the arable farm size of the respondents. The p-value of 0.0079 for the first bid and 0.0230 for the second bid offered, this indicates that there is a positive relationship between arable farm size and their willingness to pay for the AACTS. The higher the arable farm size the higher is the probability of the respondent say “yes” to the first and then to the second bid offered.

**Table 30: Bivariate Probit: Arable Farm size**

Variable	P value
Equation for Y1 – BID 1	
<b>ARSIZE</b>	<b>0.0079</b>
Equation for Y2 – BID 2	
<b>ARSIZE</b>	<b>0.0230</b>

#### 6.4.5 The chi-squared test to determine the relationship within the independent variables

The chi-squared test has been applied to all the possible combinations within the independent variables of the survey. Curiously, no evidence was found between the variable NEED to any other independent variable of the survey. However it was found evidence of dependence between the data management of the spray records.

The p-value for the chi-squared test was calculated between all the three possible combinations regarding the data management of the spray records. The result of the p-values indicates that there is relationship between all the three combinations. Appendix L shows the chi-squared analysis (actual values, expected values and chi-squared) between the three possible combinations and Table 31 summarises it.

**Table 31: Chi-square analysis**

	Chi-square	P-value	Highest contribution of chi-square	Total degrees of freedom
Generated vs. Received	10.26	0.006	ELERECEIV x SOFTBASED (3.55)	2
Received vs. Stored	6.50	0.039	ELERECEIV x PAPSTORE (3.08)	2
Stored vs. Generated	35.17	0.000	PAPGENER x PAPSTORE (9.81)	4

The highest contribution of the chi-square regarding the “generated vs. received” is the combination of the electronic records and software based (chi-squared = 3.55); the expected value (17.19) is smaller than the actual value (25). This means that when the spray plan is generated using software, the farmers are much more likely to receive the spray plan electronically.

The highest contribution of the chi-square regarding the “received vs. stored” is the combination of the electronic records and paper based (chi-squared = 3.08), the expected value (9.38) is higher than the actual value (4). This means that the farmers who received the spray plan through electronic records are much less likely to store it on paper based.

The highest contribution of the chi-square regarding the “stored vs. generated” is the combination of the both paper based systems (chi-squared = 9.81), the expected value (14.20) is smaller than the actual value (26). This means that when the spray plan is generated using paper based system, it is much more likely to be stored on paper based.

## **6.5 Attributes of the AACTS**

For the groups who don't perceive a need for the AACTS (58% of 119 respondents), the reasons why they wouldn't buy the AACTS are mostly related to complexity of use (41%), followed by investment cost (37%) and because they prefer to deal with paper based system than electronic records (15%), a few cases is because more information is needed (5%) and reliability worry (2%). On the other hand, for the groups who perceive a need for the AACTS, the reasons why they would buy it are mostly related to accuracy of the data gathered (34%), followed by management time saving (24%), preference of electronic records to paper based (22%) and operators safety (20%).

## **6.6 Cost structure**

The AACTS will be marketed by AGCO. This company sell all their equipment through licensed dealers. From the production cost the company sets the retail price which is published as the price list. The retail price varies; very often the retail price is 200% higher than the production cost. At AGCO, the dealer's margin is usually 25%.

The variable cost (raw material) can drop according to the number of units produced. Quotations have been made in order to estimate how much the cost drops according to the number of AACTS produced, this is shown in Table 32. Four quantity intervals were quoted for this study: 10-100, 101-500, 501-1000 and 1001-2000. At this stage of the project it was not possible to precisely estimate the total fixed cost of a given quantity of AACTS per year. However it is known that in terms of electrical components, which the company normally buys from a supplier, the production cost is related to assembly of the machine. Usually 60% of cost is related to raw materials and 40% related to fixed costs (factory overheads, labour and machine tooling). The total fixed costs per year were estimated multiplying the individual fixed cost by the higher quantity of the interval quoted. For instance, the total factory setup fixed cost to produce 100 units of AACTS per year would be £815.33 times 100 units which is equal to £81,533. The raw material, which represents 60% of the total production cost, is detailed according to the individual components of an AACTS unit, see Table 32.

**Table 32: Annual production cost of AACTS (£)**

Components	10-100	101-500	501-1000	1001-2000
Load cell	86	65	54	38
Amplifiers	41	39	35	33
Weighing funnel	248	218	196	171
User Interface	356	356	356	320
RFID system	255	244	234	224
Data logger	237	208	188	163
<b>Total raw material (60%)</b>	<b>1,223</b>	<b>1,130</b>	<b>1,063</b>	<b>949</b>
<b>Fixed costs (40%)</b>	<b>815</b>	<b>753</b>	<b>709</b>	<b>633</b>
<b>Total production cost</b>	<b>2,038</b>	<b>1,883</b>	<b>1,772</b>	<b>1,582</b>
<b>Total fixed cost</b>	<b>81,500</b>	<b>376,500</b>	<b>709,000</b>	<b>1,266,000</b>

## 6.7 Break-even analysis

Knowing the potential demand and cost structure of an AACTS, some assumptions can be made in order to assist the interested investing company to make judgment about investment risks. The projected quantity demanded (Figure 13) will be compared with the break-even point. The number of units of output at break-even point is calculated as follows:

$$b = \frac{\text{Total fixed cost}}{\text{Sales revenue per unit} - \text{Variable cost per unit}} \quad (\text{Eq.29})$$

The break-even point is calculated as follows:

$$b \times \text{Sales revenue per unit} \quad (\text{Eq.30})$$

Sales revenue per unit is the amount of money the company will receive per unit. In this case it is the retail price less the dealer margin which is 25%. The break-even point is the level of activity (sales) at which there is neither profit nor loss. Any number below the break-even point the investing company will make a loss, however any number above the break-even point the investing company will make a profit (Atrill and McLaney; 2002).

Assumptions can be made if we assume the same proportion of people who perceive a need for the AACTS (42%) and the same demand curve (based on the answers of the CV questionnaire, Figure 13) for the whole market where the company sells sprayers. In order to help the company to decide the best marketing strategy, four scenarios were demonstrated as follows:

1. The AACTS is sold only with new AGCO's self-propelled sprayers, see section 6.7.1.
2. In addition to new AGCO's sprayers, the AACTS is also available as a retrofit for self-propelled sprayers produced in the past five years by AGCO, see section 6.7.2.
3. The AACTS is produced by a third party company, such as Patchwork, which can reduce the fixed costs by say 10%. In addition, the AACTS is available as a retrofit for the whole self-propelled sprayer industry in North America and Europe. These markets will be analysed separately. See section 6.7.3.
4. The AACTS is produced by a third party company which can reduce the fixed costs by say 10%. In addition, the AACTS is available as a retrofit for the whole sprayer industry (self-propelled, mounted and trailed) in Europe, see section 6.7.4.

### 6.7.1 New AGCO sprayers

At AGCO, the total annual capacity of production is 1,500 sprayers. With the assumed scenario the maximum production of the AACTS per year is based on 42% of the 1,500 sprayers, which gives a total of 630 potential sales of AACTS per year. The quantity demanded, based on the demand curve (Figure 13), was converted into percentages, where 26 and 276 were 4.2% and 43.8% of 630 respectively. The contribution per unit is the sales revenue less the variable cost (the raw material cost as shown on Table 32). Table 33 shows the number of the units of output and the value (£) at the break-even point for retail prices between £3,500 and £1,700. At the retail prices below £1,700 the variable cost per unit are in excess of the retail price. A retail price of £3,500 has the highest contribution per unit, which represents the additional profit of £1,402 per unit sold above 58 units, however, projected quantity demanded has to increase by 123% in order for the business to start to make a profit. In this case it is not possible for AGCO to make a profit at any of the retail prices as the break-even number required is higher than the projected quantity demanded.

**Table 33: Break-even analysis – New AGCO sprayers**

Retail Price (£)	1) Projected Quantity Demanded	2) Sales Revenue (£)	3) Break-even		4) Contribution per unit (£)	5) Profit (£)
			Unit	Point (£)		
3,500	26	2,625	58	152,656	1,402	-44,731
2,800	39	2,100	93	195,233	877	-47,001
2,750	53	2,063	97	200,312	840	-37,459
2,550	66	1,913	118	226,152	690	-36,285
2,500	105	1,875	506	947,987	745	-298,442
2,305	118	1,729	629	1,087,537	599	-305,940
2,300	131	1,725	633	1,092,018	595	-298,573
2,200	144	1,650	724	1,195,193	520	-301,592
2,000	236	1,500	1,018	1,527,028	370	-289,255
1,950	249	1,463	1,133	1,656,768	333	-293,750
1,800	263	1,350	1,712	2,311,366	220	-318,917
1,700	276	1,275	2,598	3,312,072	145	-336,701

1) The projected quantity demanded is dependent on the retail price and both are based on the demand curve (Figure 13). 2) The sales revenue (amount of money the company will receive per unit) is the retail price less the dealer margin which is 25%. 3) The break-even analysis is the level of activity (sales) at which there is neither profit nor loss. 4) The contribution per unit is the amount of money the company will receive per unit sold above the break-even unit number. 5) The profit is calculated from the projected quantity demanded minus the break-even unit number multiplied by the contribution per unit.

### 6.7.2 New AGCO sprayers and retrofit for up to five years old AGCO sprayers

One way of achieving significant additional sales would be for the AACTS to be sold for both, new AGCO sprayers and retrofit to AGCO sprayers manufactured in the previous five years, and the sales will occur within the next five years. The maximum production of the AACTS per year is based on 42% of the 3,000 sprayers, which gives a total of 1,260 potential AACTS to be sold per year in the next five years. The quantity demanded, based on the demand curve (Figure 13), was converted into percentages, where 53 and 683 were 4.2% and 54.2% of 1,260 respectively. Table 34 shows the number of the units of output and the value (£) at the break-even point for retail prices between £3,500 and £1,500. At the retail prices below £1,500 the variable production cost per unit (raw material) are in excess of the retail price. The retail price of 3,500 has the highest contribution, which represents the additional profit of £1,402 per unit sold above 58 units. However, the projected quantity demanded has to increase by 9.4% in order to the business starts to make profit. In this scenario it is also impossible for AGCO to make a profit unless the fixed costs are reduced.

**Table 34: Break-even analysis – New AGCO sprayers and retrofit sprayers \***

Retail Price (£)	1) Projected Quantity Demanded	2) Sales Revenue (£)	3) Break-even		4) Contribution per unit (£)	5) Profit (£)
			Unit	Point (£)		
3,500	53	2,625	58	152,656	1,402	-7,928
2,800	79	2,100	93	195,233	877	-12,469
2,750	105	2,063	404	833,111	933	-278,755
2,550	131	1,913	481	920,608	783	-273,964
2,500	210	1,875	506	947,987	745	-220,217
2,305	236	1,729	629	1,087,537	599	-235,212
2,300	263	1,725	633	1,092,018	595	-220,480
2,200	289	1,650	724	1,195,193	520	-226,517
2,000	473	1,500	1,018	1,527,028	370	-201,842
1,950	499	1,463	1,133	1,656,768	333	-210,833
1,800	525	1,350	2,469	3,333,451	287	-557,992
1,700	551	1,275	3,343	4,262,030	212	-591,802
1,500	683	1,125	11,430	12,858,877	62	-666,352

\* Refer to Table 33 for additional explanation.

### 6.7.3 AACTS manufactured by a third party and available as a retrofit to the whole self-propelled sprayer industry in NA and EU

The break-even analysis will first take into consideration only self propelled sprayers, since these machines are more “high-tech” and more likely to have the technology

necessary to incorporate the AACTS (ISO 11783). Furthermore, a third party company such as Patchwork would be responsible for manufacturing the AACTS with 10% less fixed cost. The new fixed costs are given in Table 35.

**Table 35: Production Cost (£) - third party**

Intervals Quantities	10-100	101-500	501-1000	1001-2000
Total raw material (70%)	1,223	1,130	1,063	949
Fixed costs (30%)	524	484	456	407
Total production cost	1,747	1,614	1,519	1,356
Total fixed cost	52,400	242,000	456,000	814,000

### 6.7.3.1 AACTS Potential Market in Europe

According to AGCO, the self propelled sprayers industry in Europe is approximately 2,500 units per year. Assuming that the AACTS will be available as a retrofit for all new self-propelled sprayers, the maximum production is based on 42% of the 2,500 sprayers, which gives a total of 1,050 potential AACTS to be sold per year. Based on the demand curve, the quantity demanded was converted into percentages, where 44 and 109 were 4.2% and 10.4% of 1,050 respectively. At the retail prices below £2,750 the break-even number required is higher than the projected quantity demanded, hence there are no profits at retail prices below £2,750. Table 36 shows the break-even analysis and total profit. The retail price of £3,500 has the highest contribution, which represents the additional profit of £1,402 per unit sold above 37 units. However, the retail price of £2,750 gives the higher profit, £21,056 per year.

**Table 36: Break-even analysis – Europe (self-propelled sprayers)**

Retail Price (£)	1) Projected Quantity Demanded	2) Sales Revenue (£)	3) Break-even		4) Contribution per unit (£)	5) Profit (£)
			Unit	Point (£)		
3,500	44	2,625	37	98,110	1,402	8,938
2,800	66	2,100	60	125,473	877	5,153
2,750	88	2,063	62	128,737	840	21,056
2,550	109	1,913	309	591,470	783	-156,414

\* Refer to Table 33 for additional explanation.

### 6.7.3.2 AACTS Potential Market in North America

The total units of self propelled sprayers sold in North America in 2008 was approximately 5,000. Assuming that the AACTS will be available as a retrofit for all



self-propelled sprayers available in the market, the maximum production is based on 42% of 5,000 sprayers, which gives a total of the 2,100 potential AACTS to be sold per year. Based on the demand curve, the quantity demanded was converted into percentages, where 88 and 131 were 4.2% and 6.3% of 2,100 respectively. At the retail prices below £3,500 the break-even unit required is higher than the projected quantity demanded, hence there are no profits at retail prices below £3,500.

According to the demand curve, 4.2% of the population would buy AACTS if it is sold by £3,500. The retail price of £3,500 has the highest contribution, which represents the additional profit of £1,402 per unit sold above 37 units. The retail price of £3,500 also gives a higher profit per year, £70,275.

**Table 37: Break-even analysis - North America (self-propelled sprayers)**

Retail Price (£)	1) Projected Quantity Demanded	2) Sales Revenue (£)	3) Break-even		4) Contribution per unit (£)	5) Profit (£)
			Unit	Point (£)		
3,500	88	2,625	37	98,110	1,402	70,275
2,800	131	2,100	249	523,918	970	-114,688

\* Refer to Table 33 for additional explanation.

#### **6.7.4 AACTS manufactured by a third party and available as a retrofit to the whole sprayer industry in EU**

With this scenario, the AACTS is available as a retrofit for the whole sprayer industry in Europe (self propelled, mounted and trailed). Furthermore, a third party company would be responsible for manufacturing the AACTS with 10% less fixed cost. The fixed costs are given in Table 35. The total units of self propelled, mounted and trailed sprayers sold in Europe in 2008 was approximately 23,800 (information available on request from stats@aea.uk.com). Assuming that the AACTS will be available as a retrofit for all sprayers available in the European market, the maximum production is based on 42% of the 23,800 sprayers, giving a total of 9,996 potential AACTS to be sold per year. Based on the demand curve, the quantity demanded was converted into percentages, where 417 and 5,415 were 4.2% and 54.2% of 9,996 respectively. At the retail prices below £1,500 the variable production cost per unit (raw material) are in excess of the retail price. Table 38 shows the break-even analysis and total profit. The retail price of £3,500 has the highest contribution, which represents the additional profit of £1,495 per unit sold above 162 units. However, the retail price of £2,000 gives the

highest profit, £1.25 million per year. The projected quantity demanded at retail price of £2,000 is 3,749 units; however the break-even point is at 1,477 units.

**Table 38: Break-even analysis – Europe (self-propelled, mounted and trailed sprayers)**

Retail Price (£)	1) Projected Quantity Demanded	2) Sales Revenue (£)	3) Break-even		4) Contribution per unit (£)	5) Profit (£)
			Unit	Point (£)		
3,500	417	2,625	162	424,916	1,495	380,668
2,800	625	2,100	440	923,433	1,037	191,866
2,750	833	2,063	456	940,970	1,000	376,584
2,550	1,041	1,913	845	1,615,750	964	189,244
2,500	1,666	1,875	879	1,648,218	926	728,716
2,305	1,874	1,729	1,044	1,804,684	780	647,446
2,300	2,083	1,725	1,049	1,809,472	776	802,020
2,200	2,291	1,650	1,161	1,915,977	701	791,816
2,000	3,749	1,500	1,477	2,215,971	551	1,251,424
1,950	3,957	1,463	1,585	2,318,354	514	1,217,791
1,800	4,165	1,350	2,030	2,740,399	401	856,165
1,700	4,373	1,275	2,497	3,183,589	326	611,680
1,500	5,415	1,125	4,625	5,203,125	176	138,952

\* Refer to Table 33 for additional explanation.

The analyses above were based on the assumption that the demand curve of AACTS (Figure 13) is the same curve of: new AGCO sprayers, self-propelled sprayers in Europe and North America and whole sprayer industry in Europe. It is recommended that CV questionnaires should be undertaken within these different markets in order to determine their demand curve. Furthermore, as mentioned in section 6.6, it was not possible to precisely estimate the total fixed cost of a given quantity of AACTS per year. The break-even sales volume is very sensitive to changes in fixed costs, hence it is essential to precisely estimate the fixed costs in order to judge investment risks.

## 6.8 Conclusions

This chapter presented the results regarding the farmers' WTP for the AACTS. The data was analysed using a bivariate probit model. A non-parametric approach was used to calculate the mean and the median WTP. The result of the follow up question which the farmers indicate their maximum willingness to pay for the AACTS was also analysed. Furthermore, the break-even analysis was used to demonstrate the most profitable retail price of the AACTS in North America and Europe.

The analysis indicates that there is a market opportunity for the AACTS. Fifty out of the 119 respondents perceive a need for the system, which means 42% of the respondents.

The 58% who don't perceive a need for the AACTS, 41% of them wouldn't buy the system due to the complexity of use, 5% of them need more information and 2% of them have concerns regarding the reliability of the AACTS. For these total of 48% (out of the 69 respondents) there would be an opportunity to change their minds if the system were demonstrated in real life.

The willingness to pay is positively related with the cost of the sprayer. The higher the cost of the sprayer the more likely the respondents say "yes" to the second bid offered. As it was expected the higher the arable area size, the more likely the farmers are to accept the bid offered. It can be explained through the investment cost related to the AACTS and the higher incomes related to the larger farms. The WTP is also positively related with the perception of need regarding the AACTS. There was no evidence of any relationship between this and any other variable in the survey. It can be concluded that the attitude towards technology (GPS and spatial variable application) does not influence the decision to buy the AACTS. Twenty-eight percent of the farmers which perceived a need for the AACTS use GPS technology. However, 22% of the respondents who perceive a need for the system would buy the AACTS as they prefer to deal with electronic records to paper based systems. The type of the labour on the farm, again, does not influence the decision to buy the AACTS. The farmers who do the spraying application themselves are no more likely to buy the system than those who employ others to do the job.

The chi-squared test showed no relationship between any independent variable of the survey apart from the three questions regarding the spray data management. These three questions seek to identify how the spray plan is generated, how it is received by the farmers and how it is stored after the spray application. The chi-square test proved that when the spray plan is generated using a software, the farmers are more likely to receive it electronically. Since, an electronic job plan is necessary in order for the AACTS to work, it proves that the farmers could receive the job plan electronically and download it into the AACTS. It would make the farmers life much easier than those who have to create the job plan. Additionally, when the spray plan is received electronically it is less likely that it is stored on paper based.

The demand curve of the AACTS was constructed based on the answers of the "follow

question” (Figure 13). According to this curve, 4.2% of the farmers would buy the AACTS if it cost £3,500, 54% would buy if it cost £1,500 and 100% would buy if it cost £200. The analysis of the mean and median WTP was carry out using the sample of the respondents who perceived a need for the AACTS. It was estimated that farmers WTP mean is £1,597 and the median is £1,500 according to the “follow up” question. However it is not profitable for the company to sell the AACTS for £1,500 as demonstrated the break-even analysis. The break-even analysis was undertaken using the demand curve and the production cost (Table 32 and Table 35). It has been found that it is not economically viable for AGCO to make the AACTS available only to its new sprayers. The projected quantity demanded according to the retail price is smaller than the break-even units. The same applies increasing the demand, by making the AACTS available as a retrofit to sprayers manufactured by AGCO in the previous five years. However, the AACTS could be used for market differentiation and potential increase in the market share. There is no loss if the break even unit is reached.

On the other hand, it has been found that the company can make profit if the AACTS is manufactured by a third party company with 10% less fixed cost and it is available as a retrofit to the whole self-propelled sprayer industry. The most profitable retail price at North America market is £3,500, which would give a total profit of £70,275 per year. However, in the European market the most profitable retail price is £2,750, which would give a total profit of £21,056 per year. However, the analyses at both markets indicated a projected quantity demanded of 88 units per year. It is very unlikely that a company would invest to produce only 88 units of the AACTS per year in order to make the above profits mentioned. It is worth noting that the previous analyses were based on the number of sales of self-propelled sprayers since these equipments are more likely to be fitted with ISO 11783 (ISOBUS), which is currently a requirement to incorporate the AACTS. However, there is a potential larger retrofit market if the AACTS is available to the whole sprayer industry (self-propelled, mounted and trailed). With this scenario, in Europe, the most profitable retail price would be £2,000, which would give a total profit of £1.25 million per year. The total projected quantity demand would be 3,749 units per year. Hence, this could be an argument for a non ISOBUS version to satisfy user requirement.

The previous results are based on a hypothetical scenario, where the farmers had to imagine the AACTS in real life. There is a potential opportunity to increase the demand curve if the AACTS was made available in the market as the farmers will have a chance to see it in practice and assess its benefits. However, the analyses are based on a series of assumptions and should not be taken as the absolute position for the final price and the market strategy of the sponsors.

## **7 Market Uptake**

### **7.1 Introduction**

The analysis of the consumer's needs is essential for the success of a new technology development and adoption. Seaton and Cordey-Hayes (1993) pointed out that technology transfer mechanisms failed to take into account the significance of clients' needs, focused only on the economic and technical attributes. Companies should understand the risks perceived by potential buyers associated with the acquisition and use of new technologies (Clark et al., 2000).

The concept of the Automated Agrochemical Traceability System (AACTS) is completely new in the market; hence there is no evidence if the system fulfils the farmers' requirements and most important if the farmers are able and willing to use this technology. The ability of an organisation, community or individual to be aware of, to identify and to take effective advantage of a technology is known as receptivity (Seaton and Cordey-Hayes, 1993). The receptivity model was used to identify the farmers' perceptions and attitudes towards the AACTS.

### **7.2 Receptivity**

Seaton et al. (1998) pointed out that "the concept of 'receptivity' has been developed through research into technology transfer and innovation in technology based organisations". Seaton and Cordey-Haynes (1993), described receptivity as the organization's ability to be aware of, to identify and to take effective advantage of technology. Clark et al. (2000) defined receptivity "as the extent to which there exists not only a willingness (or disposition) but also an ability (or capability) in different constituencies (individuals, communities, organizations, agencies, etc.) to absorb, accept and utilise innovation options". As a result of that, the issues which influence the new technology uptake are revealed.

The "receptivity" has been used by many individuals as a model in order to conduct research towards their PhD. Lefefer (1992) has used the 'receptivity model' to explore the limitations of the role undertaken by "technology transfer" agencies in their contribution to successful innovation in the UK industry. Holden (1991) describes how

organizational and individual perspective adds new concepts, methods and tools for the technology innovation. Furthermore, Anstey (1993) addressed the problem of facilitating technology transfer to small size and medium size enterprises. The research theme of receptivity has been widely used in the service sector and with issues concerning climate change and environmental policy; in the water and waste technology sectors (Seaton, 2008).

The concept of the AACTS is new amongst the farmers. Although the prototype has been developed to assist the farmers and the food industry to improve agrochemical traceability, it is unknown if the farmers would adopt the system. Hence, the receptivity model has been chosen to identify the farmers' perception and attitudes towards the AACTS. The concept of receptivity is based on a process framework broken down into four components: 1) Awareness, 2) Association, 3) Acquisition and 4) Application (Jeffrey and Seaton, 2004). The following paragraphs explain each of the above mentioned attribute of the receptivity model related to this study.

#### 1. Awareness

The Awareness attribute indicates if farmers perceive a need for on-farm agrochemical traceability in general and why they think it is important. At this stage in an interview the farmer is not aware of the development of the AACTS. Hence, the farmer's perceptive of the importance of more accurate agrochemical traceability and problems and issues that the lack of agrochemical traceability might cause can be identified. It can be reported as a previous incidence of some problem or issue which could be directly or indirectly related to the lack of accurate agrochemical traceability; or the knowledge of the problems that could be avoided. The farmers were also asked if they knew of any appropriate methods in order to improve the agrochemical traceability.

#### 2. Association

Association is the part where the farmer recognizes the potential benefits and value of using the AACTS. Effectively, this is the process by which the farmer associates the potential benefits of the AACTS with their real needs. Before asking the association questions the AACTS will be introduced to the farmers through images, videos and technical specifications. In this process the farmers were faced with questions to address the meaning of the AACTS for them and how it could benefit their business. Some

farmers might see advantages in being able to precisely identify how much agrochemical has been applied on the crop that the developers of the technology have not noticed.

### 3. Acquisition

Acquisition is the process of identifying where the farmers would expect to be able to buy the AACTS and if they are able or willing to learn the skills necessary to operate it. On the 'receptivity model' it is important to know where to purchase the system and where to learn how to install, how to use, and, how to maintain it (Jeffrey and Seaton; 2004).

### 4. Application

Application is the process that will identify the farmer's ability to use the AACTS in order to achieve its maximum potential. The farmer will have to foresee the use of the AACTS and be able to predict if there will be any problem or challenges in using the AACTS. The farmer needs to identify who is going to operate the AACTS and how it would change and affect their routine.

The final question addresses if the farmer would be interested in purchasing the AACTS, if he is prepared to take part to a trial free of charge. If the answer is positive, they were asked to describe what benefits they would like to achieve on the trial. Furthermore, they were also asked what they would do and how would they use the data generated by the AACTS.

## **7.3 Selection of Research Technique**

The data collection was in a form of a semi-structured interview using open ended questions which guided the respondents to the topic (the AACTS) and elicited the respondents own perception towards the AACTS. Foddy (1993) described open ended question as flexible and allow the respondents to express their own opinion about the subject, furthermore Foddy suggested that the respondents are not influenced by suggestions from the researcher.

The questionnaire given in Appendix M was used in face-to-face interviews consisting of thirteen open ended questions. The questionnaire was designed to address the four



attributes of the receptivity as described earlier on: 1) Awareness, 2) Association, 3) Acquisition and 4) Application.

#### **7.4 Sample Size**

The qualitative research proposed was conducted with twenty seven farmers in England. In the first instance farmers were contacted by telephone or email and were asked if they were willing to take part in an interview related to agrochemical traceability. If they agreed then a suitable date and time was arranged to conduct the face-to-face interviews.

The results of the online questionnaire, presented in Chapter 6, found no evidence between technology (GPS and spatial variable application) and the decision to buy the AACTS. Therefore, it was decided to choose respondents with similar attitudes towards technology in order draw out common and interconnectivity factors. The majority of the respondents chosen to participate on the receptivity questionnaire were motivated with technology. Twenty four farmers were users of GPS technology and three were planning to implement this technology in the near future. All the respondents selected for the interviews were familiar with computerised systems and use software technologies to keep the farm records. Sixteen respondents were farm owner and eleven were farm manager. The mean farm size was 1048 ha, ranging from 280 ha to 3800 ha. The farmers were selected according to the viability of the members of the Commercial Farmers Group. In addition, contacts were selected from the farmers which write for Farmers Weekly in its 'Farmer Focus pages'. Specific details of farmers are not given in Table 39 for confidentiality reasons.

**Table 39: List of Respondents**

ID	Position	County	Farm Size (ha)	Crops
1	Owner	Buckinghamshire	280	Wheat, oilseed rape, barley, beans, grass and peas
2	Owner	Lincolnshire	1200	Wheat and oilseed rape
3	Owner	Hampshire	540	Barley, wheat and oilseed rape
4	Owner	Warwickshire	600	Wheat, oilseed rape and beans
5	Owner	Lincolnshire	384	Wheat, oilseed rape and beans
6	Owner	Buckinghamshire	380	Wheat, oilseed rape and winter beans
7	Manager	Cambridgeshire	1300	Wheat, oilseed rape, sugar beet and barley
8	Manager	Cambridgeshire	3800	Wheat, oilseed rape, barley, beans, sugar beet and potatoes
9	Owner	Cambridgeshire	1200	Wheat, oilseed rape and beans
10	Manager	Yorkshire	3500	Wheat, oilseed rape, barley potatoes and peas
11	Owner	Lincolnshire	930	Wheat, oilseed rape, peas, sugar beet and potatoes
12	Manager	Kent	1300	Wheat, oilseed rape, beans and potatoes
13	Manager	Lincolnshire	550	Wheat, oilseed rape, potatoes, sugar beet, cauliflower, peas and leaks
14	Manager	Yorkshire	570	Wheat, barley, peas and beans
15	Owner	Kent	1200	Wheat and oilseed rape
16	Owner	Lincolnshire	800	Wheat, oilseed rape, potatoes, broccoli, peas and oats
17	Owner	Lincolnshire	600	Wheat, oilseed rape, barley and sugar beet
18	Manager	Lincolnshire	2000	Wheat and beans
19	Manager	Lincolnshire	550	Wheat, sugar beet, potatoes, peas, celery and chicory
20	Manager	Lincolnshire	1600	Wheat, oilseed rape, potatoes, sugar beet and peas
21	Owner	Cambridgeshire	700	Wheat, barley and oilseed rape
22	Owner	Cambridgeshire	260	Wheat, barley, oilseed rape and beans
23	Owner	Buckinghamshire	800	Wheat and barley
24	Manager	Oxfordshire	900	Wheat, oilseed rape and beans
25	Owner	Leicestershire	350	Wheat
26	Owner	Hertfordshire	1200	Wheat, barley, oats, oilseed rape and sugar beet
27	Manager	Worcestershire	800	Wheat, beans, oilseed rape

## 7.5 Pilot Questionnaire

A pilot of the revised questionnaire was undertaken with five farmers. The aim was to examine the individual questions laid down in the questionnaire, as well as the whole questionnaire structure. The survey questionnaire should test respondents understanding of the questions and if the questionnaire is interpreted similarly by all respondents (Salant and Dillman, 1994).

The pilot study was used to readapt the questionnaire's phrasing and to observe the need to include or exclude questions to better explain the AACTS and collect the necessary

information. From the feedback received the questionnaire structure and content was judged as satisfactory. The respondents thought that the questions were clear and easy to understand. The explanation of the AACTS, including images and a video, was considered adequate and easy to follow. Following the pilot study, the original questionnaire was amended by rearranging some of the questions in order to make it easier to follow.

## **7.6 Data Analysis**

All raw data from the interviews were analysed using a coding system. Miles and Huberman (1994) define codes as “tags or labels for assigning units of meaning to the descriptive or inferential information compiled during a study.” The clusters of the text with related topics, typically some representative word or phrase, are coded with the same label or tag. The codes were used to analyze the transcriptions of the interviews from which the clusters were derived. The coding system developed for this research is given in Appendix N and the interviews transcriptions are given in Appendix O.

## **7.7 Synopsis of the main outcomes**

Results from the interviews have been separated by Awareness, Association, Acquisition and Application as detailed below.

### **7.7.1 Awareness**

The awareness questions attempts to identify if the farmer perceives a need for on-farm agrochemical traceability system and why such a system is perceived to be important. At this stage the respondents were not aware of the development of the AACTS.

Two out of twenty-seven respondents pointed out that careful monitoring of agrochemicals is good for environment protection. Thirteen respondents perceived that the use of agrochemical should be carefully monitored for the sake of personal safety. One farmer noted “*we are saying we are producing food safe for human consumptions, got to be agrochemical traceability to ensure safe food product.*” Another farmer stated “*We can prove we are producing healthy food, we know where the products are and we*

*record the reason for it. At the end of the day the public has the right to know what they are eating.”*

Eighteen respondents highlighted that the main benefit of collecting and keeping the agrochemical records is to be able to prove that they are using agrochemicals in a responsible way. As a consequence of that they are able to sell the products.

One farmer noted *“If we cannot show that we apply the correct agrochemical we cannot market that product. That is the most important thing we do on the farm. If we fail on pesticide application doesn’t matter how good we are, we lose the whole production.”*

None of the farmers interviewed were aware of new technologies to improve agrochemical traceability. However, amongst the methods that can be used to improve agrochemical traceability, electronic record keeping is the most mentioned.

Three respondents said they used SUM-IT, one uses Muddy Boots, two respondents used Excel™ spreadsheet and twenty one respondents used Farmade. The Farmade software can be linked with *SentinelActive* pesticide management database. This database carries information about crop approvals for pesticide and checks the spray plans and recommendations for any potential problems.

## **7.7.2 Association**

Association is the part of analysis by which the respondents associate the potential benefits of the AACTS with user’s real needs. At this stage, it was necessary to explain the AACTS functionalities in detail in order to introduce the system to respondents. In this part results were separated by perceived benefits identified and written to draw out the common and inter-connectivity factors. In total seven benefits were identified, as explained below.

### **7.7.2.1 Prevent agrochemical misapplication**

Preventing the use of incorrect agrochemical application has been identified as one of the most important benefit of the AACTS for respondents that are not directly involved in the spray operation but rely on other operators. Twenty respondents believed that the AACTS could prevent the operators using incorrect agrochemicals. Furthermore, seven

respondents shared information of incidents where the whole production was lost due to use of wrong agrochemicals. A farmer reported: *“The operator applied Roundup thinking it was growth regulator and killed the whole 33 hectares of wheat. The whole production lost was around £36,000.”* Another farmer noted: *“the operator got the product names confused, a fungicide for wheat and a fungicide that can be used for wheat but we use for beans. The wrong chemical was applied on 80 hectares of beans, it didn’t harm the crop but around £2,500 was lost.”*

It was found from the interviews conducted that the main reason for using the incorrect product was due to the agrochemicals used having similar agrochemical names, are stored in similar size and shape containers having similar labels. It was suggested that the use of incorrect agrochemicals is more likely to happen on farms that have large diversity of crops and hence large range of different chemicals in store. However, one farmer reported an incident where the agrochemical dealer supplied the incorrect chemical. The farmer ordered a Sulfonylurea for the potatoes crop, but he was supplied with Sulfonylurea for use on cereals. He didn’t check the label and consequentially sprayed the wrong chemical. The crop was not entirely damaged, but it was not able to be marketed due to the use of non-approved chemical for that specific crop.

Five farmers interviewed had farm area ranging from 260 to 384 hectares. Two out of five employed an operator but usually the owner was responsible for the spray application. It was noted that the five farmers interviewed which are directly involved on the spray application believed that the use of incorrect agrochemical would not happen on their farms because they are responsible for the operation. However, although the farmers themselves are responsible for the operation and claimed that they are in control of the chemicals used, sometimes human error is unavoidable and mistakes can be made.

#### 7.7.2.2 Improved Stock Control

Twenty respondents suggested that the AACTS could improve the on farm stock control and management. Currently the stock control is updated according to the number of containers bought and the quantity applied. The respondents highlighted that usually what is actually on the stock doesn’t match with what is recorded on the computer. Visual checking of what is in the store is carried out regularly in order to update stock

records. Mistakes made are usually due to the operators assuming that they used the exact amount requested by agronomic recommendation and do not consider if they used more or less. However, one farm manager noted that missing cans of agrochemicals can occur due to robberies.

Ten out of twenty farmers believed that if a RFID reader was fitted in the store the stock control would be improved even more. The RFID reader would assist in identifying and recording the containers left on the stock. This data would be linked with the data generated by the AACTS. The software program would keep records of exactly how much and what has been used and, how much is in the stock and potentially how much chemical is left in the part containers.

Only one farmer out of five that were responsible for the spray application believed that the AACTS could help the business with better stock control. This farmer has 384 ha farm size and is responsible for the field operations and the field records and does not employ other staff on the farm. This farmer argued that their records are always six months out of date and the AACTS could automatically update the stock control on the farm software. However, four farmers interviewed having farm area between 260 ha and 380 ha believed that the stock control is easy to be managed in relatively small farms because they are responsible for the spray operation and the stock are small.

#### 7.7.2.3 Improved Accuracy

All farmers interviewed stated that the AACTS could potentially provide better accuracy than using measuring jugs. Furthermore the use of the AACTS would assure that the correct number of agrochemical containers is being used. One farmer stated that it is very easy and common to add one extra can when loading the sprayer. He said that: *“for example if the operator has to put in eight cans of product, but instead puts nine cans of product and next tank load he puts in seven cans instead of eight”*. The farmer stated that he would never know this had happened because the total in-house stock records will still equal out. This mistake would not be possible with the AACTS. The user interface would guide the operator during the loading process informing him how many cans should be loaded and when to stop loading the sprayer.

#### 7.7.2.4 Saving time in the office

Twenty four farmers highlighted that the AACTS can help them save time in the office in order to keep the agrochemical records.

Due to the increasing number of legislation and crop assurance schemes, farmers have to collect and keep a great amount of data related to the farm business. In the UK, each individual supermarket has its own quality assurance scheme. Five farmers interviewed stated that they have to comply with four different crop assurance schemes in order to sell the fresh produce and potatoes to different supermarkets. They argued that it is time consuming to collect and organize the required data in order to satisfy all the assurance schemes and potentially the AACTS could assist them to manage the spray application records.

Five farmers having the smallest farms of the sample (260 ha to 384 ha) highlighted that the AACTS could be a great benefit for them as they are responsible for the field operations and also for the record keeping. They were all familiar with computerised systems and believed that it can assist them to keep the records more up to date as they usually update the records when the field operations finish.

However, three respondents don't perceive 'saving time in the office' as a great benefit. One farm manager argued that he prefers to manually enter the information so it can be verified. Furthermore, a farm owner argued that this information is already handled by business secretary and it is part of their job, he wouldn't buy the AACTS if saving time was the only benefit.

#### 7.7.2.5 Contractors

Five respondents interviewed provide contract spraying services. Four of them believed that an automatic agrochemical recording system could help them with contract billing. One respondent noted that *"This would take less time to check the records, because I always have to check the records at the end of the year to bill other farms, this takes a lot of time."* Furthermore, they believed that the automatic agrochemical recording system would prove that the correct product and application rate has been used. However one farmer did not see a benefit for contractors using the AACTS because he did not believe the clients would pay more for the AACTS.

#### 7.7.2.6 Spray Application Records – Benefits for the operators

A respondent responsible for managing a large scale farm (3500 ha) stated that the main operator of the farm is always involved in the decision to buy a new machine or equipment. It is argued that the operator plays a key role in the business and they need to be comfortable with operating the system. In order for the AACTS to be properly used, the operator has to perceive its benefits. Seven farmers believed that the operators will perceive a benefit as their responsibility to write the spray application records will be taken away from them. It is argued that usually operators do not like to spent time taking notes and recording of what they have done.

#### 7.7.2.7 Spray Operator Safety

Ten respondents perceived that the AACTS could potentially decrease the risk of spillage and consequentially it is safer for the spray operator as they would not need to use measuring jugs and therefore have less contact with the chemical. The five farmers which were responsible for the spray application perceived this as an important attribute of the AACTS.

### 7.7.3 Acquisition

As described earlier, the Acquisition identifies if farmers know where to buy the AACTS and would be able to learn how to use it and maintain it.

Twenty two respondents believed that the AACTS should be supplied by sprayer manufacturers. However, three said that this technology should be supplied by companies which are more specialised on GPS technology and according to one farmer *“The GPS technology companies seem to be more technology minded than the sprayer manufacturers”* Two respondents believed that the AACTS should be supplied by agrochemical companies since the system helps the farmers to use the agrochemicals more responsibly. One farmer noted that *“the system benefits the chemical company more than the machinery company this could be a seller point for people to use the chemical more responsibly”*

Twenty two respondents have operators responsible for spray application. Two have operators but usually the owner is responsible for the spray application and three are



entirely responsible for the spray application. Twenty five respondents interviewed believed that both operators and themselves would be able and willing to learn how to use the AACTS technology since they are familiar with technology onboard the sprayer. However, one farm manager was concerned regarding the number of steps required to identify, weight and record agrochemicals. He believed that it is difficult to learn how to use and easy to forget one step and carry on loading as conventionally. However, according to the experiment conducted by Peets (2009), it is suggested that the time required to become proficient with the AACTS is 1–2 days of practice, which is equivalent to 10 tank loads. One farmer was not able to respond because his sprayer was not fitted with induction hopper.

Eleven respondents suggested that the sprayer operators are key personnel in the farm and are usually keen on new technologies since there are many “high-tech” machine in the market nowadays. One farm manager states that *“Most of my employees do not want to spray. Those who want to spray generally enjoy the extra responsibility and the fact that there is more technology involved.”*

#### **7.7.4 Application**

During the application part the respondents had to foresee the use of the AACTS and be able to predict if there will be any problems or challenges with using it. The results have been separated by perceived problems identified and written to draw out the common and inter-connectivity factors. In total seven issues/recommendations were identified, each is explained below.

##### **7.7.4.1 Rinsing space**

None of the respondents suggested a larger weighing induction hopper. However, the main concern of twenty four farmers was the space available in the AACTS system to wash out the bigger containers with capacity of 10, 15 and 20 litres. Figure 14 shows the modified induction hopper with a 20 litres container. The respondents argued that the current induction hopper was already relatively small to rinse 10, 15 and 20 litre containers. One farmer noted that *“We would not want anything smaller than what we already used because we need to be able to work the container around the nozzle”*.



**Figure 14: Modified induction hopper with a 20 litre container.**

In order to allow more rinsing space some farmers suggested the weighing component should be a separate hopper assembled next to the main hopper. Others suggested the weighing hopper should be inside the system but able to be lifted up when not in use. Furthermore one farmer noted that with the weighing hopper fixed inside the conventional hopper there is more area covered for cleaning inside the hopper. All the components would get coated with chemicals, and very difficult to wash. *“If there is some residue left in the system from washing the container, then the next time the sprayer is used, the residues would be mixed in it. This would cause contamination of certain crops which are very sensitive. This is a big issue on certain farms, which handle different crops. The AACTS should be either sealed or outside the hopper”*.

One farmer couldn't give opinion regarding the induction hopper size as he was not familiar with the system because his sprayer is loaded directly from the top. The other two respondents were not sure if that would be a problem because they are not directly involved with the spray application and consequently not familiar with the practicality of the loading process.

#### 7.7.4.2 Software Compatibility

As stated earlier, twenty one respondents used Farmade software (GateKeeper, Farmplan and Multi Crop) and one used Muddy Boots software. They all highlighted

that the AACTS needs to be integrated with the existing software. The data generated by the AACTS should be able to update the field record on the Farmade or Muddy Boots software.

#### 7.7.4.3 Time to load the sprayer

The result of the experiment with the farm sprayer operators indicates that there is no significant difference between the time to load the sprayer with the AACTS and the time to load the sprayer with the conventional hopper (Peets, 2009). Even though the results were presented to the interviewees, twelve respondents were still very concerned regarding the time to fill the sprayer. They all argued that the time to load the sprayer using the AACTS shouldn't take any longer than the conventional loading. One farmer stated that *"We already have to triple rinse the containers and we have very few days to spray. We need to speed up the loading process rather than slow it down"*. Furthermore another farmer highlighted that *"we might have five different products going in one tank fill, this can be 30 or 40 containers and 250 litres of chemical. The loading needs to be fairly quick."* It is suggested that a new experiment should be conducted in order to reflect the real scenario with five different products and 30 containers, as stated by some farmers, and then compare the time to load the sprayer with and without the AACTS. This could potentially support the data presented by Peets (2009).

One farm manager, which was responsible for 2,000 ha, mentioned that they pre-mix most of the chemicals in a 9,000 litre nurse tank. He argued that the farm runs 30 miles end to end and he *"Can not afford the operator to drive back to the yard every time he has to fill up the tank"*. He suggested that the weighing hopper should be fitted in the nurse tank. Furthermore, two farmers interviewed having a 260 ha and 384 ha argued that they can not afford to lose any extra time required to fill up the sprayer tank as they are alone in the job and the filling has to be done as quickly as possible.

#### 7.7.4.4 Sprayed area versus Actual area

Due to the variation in size and shape of farm fields the actual sprayed area can be larger than the actual registered field size shown in the farm records. Five farmers believed that this can create problems with the software system which would divide the amount of agrochemical used by the actual field size showing an overdose. One farmer

stated that *“on occasions the operator might start spraying at 1.8 litres/ha although the recommendation is for 2 litres/ha to ensure the records are within the maximum dose allowed.”*

It is suggested that the AACTS should be linked with auto boom shut-off. This would more precisely apply agrochemical in the field and consequentially reduce the over-dosed areas.

Furthermore, if the sprayer is connected to a GPS receiver, the computer onboard the sprayer would record how much product has been applied at which location in the field; the “as applied map” could then be created. The data of this map could be used in the next spray application; this would allow the system to use previous knowledge to identify the actual sprayer area of the specific field. According to Peets (2009), the data recorded by the AACTS could be linked with “as applied maps”.

#### 7.7.4.5 Accuracy

Thirteen respondents interviewed highlighted that the AACTS system should be able to measure accurately quantities less than 100 grams. Fifteen grams is perceived to be the minimum amount needed in order to satisfy the accuracy criteria. One respondent noted *“Some chemicals used in fields needed are as little as 7.5 grams per hectare. Sometimes we might have 2 hectares to spray and we only need 200 litres of water in the tank and 15 grams of a chemical”*. Currently the AACTS provides resolution of  $\pm 3.6$  grams which allows loading of 100 grams of chemical with error not larger than 3.6% (Peets, 2009). However, with the engine of the sprayer switched off the AACTS provides a resolution of  $\pm 1$  gram, which would allow loading of 15 grams of chemical with error not larger than 6.66%.

#### 7.7.4.6 Agrochemical Database

Sixteen respondents highlighted that the AACTS should be flexible to accept the use of products with the same active ingredient and not only to accept the use of the same product name. One respondent noted that *“We order the chemical from a buying group, sometimes we order the chemical by active ingredient name and not by brand name, so we do not know what brand arrives until it is in the farm”*. Furthermore he noted that they have been recommended say Glyphosate from a specific product name, but he

happen to have the same chemical from a different brand name, he would use the one available at the farm.

The software could be programmed to allow the use of generic agrochemicals, however, the farmer and/or operator would be responsible for using a different product from that recommended by the agronomist.

#### 7.7.4.7 Data disclosure

Nineteen farmers were very sensitive about disclosing the agrochemical data. They all perceived the benefits of the AACTS and would use it only for their own business benefit. However they would not provide the data to supermarkets, crop assurance schemes, or legislation bodies. One farmer stated *“I would not give the information to supermarket, because they would not understand all records. Giving too much information to people who do not understand the data can be a problem.”* They believed that the current way to prove the data regarding the chemicals was already satisfactory and the detailed data provided by the AACTS might be used against the farmer if misinterpreted.

However, eight farmers would give the data to supermarkets and quality assurance schemes as a way to prove the agrochemical inputs. These farmers are somehow direct suppliers of supermarket (e.g. fresh produce and potatoes producers). One farmer which grows 220 ha of potatoes supplies 60% of the production to Waitrose. He stated that if Waitrose requests the history of potato production, he would be required to provide it in 44 minutes and the AACTS could help him provide more accurate data.

#### 7.7.4.8 Further recommendations

Three farmers believed that this system would bring more benefit if the operator could type weather conditions into the user interface.

Two farmers suggested that the sprayer should be able to automatically measure the quantity of the water that goes into the sprayer tank and this information should be linked with the AACTS data.

Two respondents mentioned that the sediment of some chemicals could be left at the bottom of the containers and may influence the accuracy of the weighing. A reminder

note could be included in the software program to remind the operator to shake the can before loading.

Two respondents asked if there was a maintenance fee in order to update the pesticide database. One farmer even suggested that the AACTS could use the database of the SentinelActive program (provided by Central Science Laboratory) since they already pay £100 per year for weekly pesticide updates.

### **7.7.5 Further questions**

This section aims to identify if the respondents would be willing to buy the AACTS and would be willing to take part in a trial of the system. Furthermore, it also intends to identify what would the respondents do with the data generated by the AACTS and any further comments, requirements regarding the system.

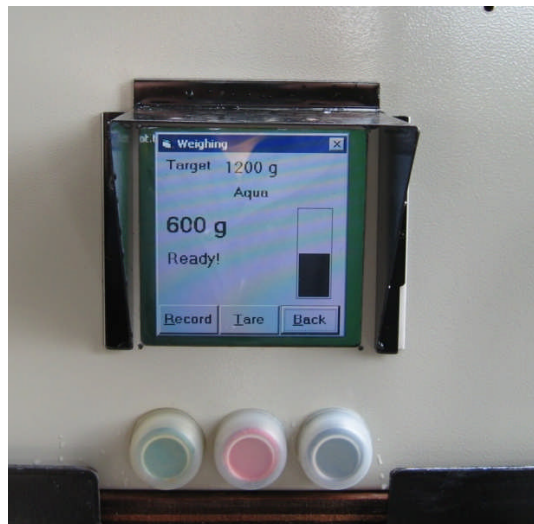
#### **7.7.5.1 Willingness to buy**

Although the farmers interviewed perceived many benefits having the AACTS they were price sensitive. Seventeen respondents stated that they would buy the system depending on the price. However, three farmers would buy the system and did not use the price as a barrier for purchase. These respondents had experienced production loss in the past due to the use of incorrect agrochemicals in the fields. Four farmers that were happy to buy the system, had farm size under 400 ha (range between 260 ha and 384 ha), the mean price they were prepared to pay was £1,375, ranging from £500 to £2,500. The mean price given by twelve farmers ranging from 500 ha and 1500 ha was £2,292, ranging from £1,500 to £3,000. The mean price given by four farmers which grow between 1600 ha and 3800 ha was £4,000, ranging from £3,000 to £5,000.

It is perceived that the decision to buy the system would depend on the cost and how much time can be saved using the system. One farm manager noted *“We need to check how much time it would save us. Nobody is going to pay us more for the crop because we have such a system. However if there are no financial savings, we would only buy the system if supermarkets request it or required by legislation”*. However seven farmers interviewed stated that the only way to financially measure the benefit of having the ACCTS system is to estimate how much loss could be avoided using the

AACTS, in terms of using the incorrect chemical and consequently loss of crop production.

Seven respondents wouldn't buy the AACTS. Three of them highlighted that they would give priority to implement auto boom shut off first. However, after acquiring this technology they would consider to acquire the AACTS. One respondent believed it was not a practical system. He found it very complex to use particularly because the operator having to press the button to confirm every time the operator scans and loads a container (Figure 15 shows the user interface). This farm manager records the spray data into a palm top as he does the loading. The data is then downloaded into the MultiCrop software. He does not perceive a huge time-saving using the AACTS in comparison with what he uses currently.



**Figure 15: User Interface**

Two respondents would not buy the system now but would be interested to get feedback from farmers when it is already available on the market. One of them noted that he had many problems in implementing the GPS technology 15 years ago. He could produce the map and the yield variation but had problems with analysing the data and identifying what was causing the yield variation. Consequently, he argued that now he tends to be one of the last to adopt new technologies. One respondent classifies himself as a non-technically minded person and would need to make sure the system is already working properly on other farms before considering buying it.

One respondent that would not buy the AACTS argue that he has a 15 years old sprayer, and it is not fitted with induction hopper but he is planning to buy a new one with an induction hopper. He noted that first he would have to get use to the new sprayer using the induction hopper and then might consider buying the AACTS.

#### 7.7.5.2 Willingness to take part in a trial

Seventeen respondents would take part in a trial of the AACTS. Two of them would take part in order to help us on the development and improvement of the system. However, fifteen of them would expect that the trial system have already incorporated the improvement on the rinsing space. Ten respondents would not take part in the trial, either because they would not buy one or because they would like to try the final version when it is already available on the market.

## 7.8 Summary of findings

The results from the interviews are summarized in the following section

---

- The Automated Agrochemical Traceability System (AACTS) is generally felt to provide management benefits and safety agrochemical application for the farm business.
  - The main benefits of having a AACTS system perceived by the farmers are:
    - More Accurate loading process
    - More Accurate and up-to-date Stock Taking.
    - Avoidance of the use of incorrect agrochemical and consequently avoidance of production loss.
    - Saving time in the office.
  - The main concerns are:
    - The induction hopper should have enough space to rinse 10, 15 and 20 litre containers.
    - Improved resolution for 15 grams load.
    - The loading process should not be slower than the current loading time.
    - Software should be able to permit the use of the generic chemicals.
  - The AACTS should be integrated with the main software providers in UK (e.g. Farmade and Muddy Boots).
  - It has been suggested that the approved pesticide database should be integrated with *SentinelActive*. (Farmade software)
  - The software should be sophisticated enough to identify the difference between sprayed area and actual area and do not interpreted as overdose (it could be either using auto boom shut off or previous “as applied map”).
  - The disclosure of the data generated by the AACTS should be a decision of the farmer.
-



## 7.9 Conclusions

A face-to-face questionnaire was conducted with twenty seven farmers in England. The mean farm size was 1048 ha. All respondents interviewed were familiar with computerized systems and users of software or Excel™ spreadsheet for farm record keeping. Twenty four out of twenty seven respondents were users of some sort of precision farming systems. The main benefits identified by the farmers were the potential improvement of the stock control, avoidance of the use of incorrect chemicals, saving of time in the office and improved accuracy. Some farmers reported incidents where the incorrect chemical was used due to human error which could have been avoided by the use of the AACTS.

This research has identified that farmer having different farm sizes have different motivation for acquiring the AACTS. It is suggested that farmers having the smallest scale farms in this sample (260 ha to 384 ha) were highly motivated in buying the AACTS for saving time in the office. This is due to the reason that the farmer is usually responsible for the field operations and for the record keeping. Those farmers that use computerised systems to keep records see benefit for receiving this data electronically. The farmers responsible for the operation also see great benefit on the weighing hopper because it does not require the use of measuring jugs.

However, farmers having the largest scale farms (500 ha to 3800 ha) and staff responsible for the spray application see it as a great benefit for monitoring the use of agrochemicals. Furthermore, more accurate and automatically up-to-date stock taking control is mentioned to be a great benefit on large scale farms which tend to keep agrochemical stock on farm.

The AACTS should be fully integrated with existing farm software (e.g. Farmade and Muddy Boots). All the respondents interviewed assume they would be able to download the data generated by the AACTS into their existing software.

Due to the difference between sprayed area and actual area, it is suggested that the AACTS should be linked with auto boom shut off. This would provide a more precise and reliable data to be collected, since the system would provide the information of how much has been loaded into the sprayer and where and how much it has been applied on the field. Furthermore, the data from previous “as applied maps” could be used in order

to permit the system to use previous knowledge to identify the actual sprayer area of the specific field.

Concerns regarding the disclosure of the data have been mentioned. Some farmers would use the AACTS only for internal management and wouldn't provide this data to crop assurance schemes or legislation bodies. They all argued that the paper based system was already acceptable for complying with the existing schemes and legislation requirements. Their main concern is giving too much information to those who are not familiar with the spray application because the data could be misinterpreted. However, some farmers do not see a problem in providing the data generated by the AACTS to supermarkets and crop assurance schemes. These farmers are somehow directly suppliers of supermarket (e.g. potatoes producers) and need to provide quick and precise retrieval data when requested.

There is general concern regarding the time to load the sprayer. The majority of farmers believed that the time to load the sprayer shouldn't take any longer than using the conventional hopper. It is argued that the time to spray is crucial and very short. Although Peets (2009) showed that there is no significant difference between the time to load the sprayer using the AACTS and the manual conventional system, the experiment with the operators should be repeated in order to test a scenario where the operator loads five different agrochemicals and at least 30 containers. This would allow a more realistic comparison between the time to load the sprayer with and without the AACTS.

The majority of the respondents were concerned regarding the available space in the system for rinsing big containers. It has been argued that the conventional hopper is already too small for rinsing 10 and 20 litres containers. Furthermore, the AACTS placed inside the induction hopper makes the cleaning of the main hopper more difficult because there are more corners to wash and consequentially it is more difficult to remove chemical residues. It is suggested that the weighing hopper should be redesigned allowing more space for rinsing area. Ninety percent of the farmers that would buy the AACTS expect that this improvement is done before acquiring the system. This information has been reported to Peets (2009) for including in his design recommendations.

It has been suggested that a positive benefit of the AACTS should allow the use of generic agrochemicals consisting of same active ingredients of the product recommended by agronomist. If the AACTS were to be more flexible, the farmer/operator would have to be responsible for the decision to use the generic product instead of the product recommended by the agronomist.

It has been suggested that the accuracy of the system should be improved in order to accurately measure load of minimum of 15 grams. Some farmers highlighted that they use minimum 15 grams per tank when need to spray a small field. The use of the AACTS with the engine switched off provides a resolution of +-1 gram. This is potentially more than what a manual loading could provide.

## **8 Case Studies**

### **8.1 Introduction**

Farms are the first step of the food chain and play a very important role by providing the raw material to food processors. For a traceable product, the farmers must be able to keep the records of the process history of the materials they sell. This primarily relates to field operations, and an identification of which location the product came from. Existing quality assurance schemes only set out the information that is required to show compliance with a given scheme and it is up to the farmer how he collects and records it. Within the farm business there are many different ways to keep the records, going from a very simple paper base to computerised software systems.

This chapter describes the existing traceability systems of three different types of farm enterprise according to different type of final product's handling: Fresh Produce, Onion Production and a Conservation Grade cereal farm. All these farm enterprises are focus on high value/quality production. Suggestions for improving the existing system are made, implications analysed and potential benefits explored.

### **8.2 Overview of potential improvement opportunities**

The increasing amount of legislation and number of farm assurance schemes raises the need for assisting the farmers in collecting traceability data in order to comply with these. Farmers have to handle with a great amount of paper in order to collect and record traceability data and there is an increased labour cost associated with collecting traceability data.

In agriculture, the relevant data is often written on paper by the field operator and given back to the farm manager. For storage, the information can be kept on the original paper, transcribed to another paper form or typed into a computer system using specific software or a spreadsheet format. In general automated traceability systems should potentially reduce the cost of collecting and managing data, as well as significantly reduce or eliminate errors in information transfer. Specifically, AACTS can be used in order to minimise time spend in the office to handle with agrochemical data and reduce or

eliminate errors in the records. Such traceability systems can potentially prevent problems before they occur by integrating the requirements set by legislation and quality assurance schemes into job planning tasks before work is undertaken.

The information regarding of where and when the product has been harvested is essential to be collected to fulfil traceability systems. Currently, fresh produce must be traceable back to the level of a whole field. However an automatic system can efficiently process more precise locations numerically using Global Positioning System (GPS) and RFID technology to tag products. The resolution of spatial data appropriate to a particular product depends on the way crops are grown and treated, for example individual lettuce versus a bulk processed material such as wheat. Generally however, it is logical to record location of harvest whenever the cost of a tag or label can be justified

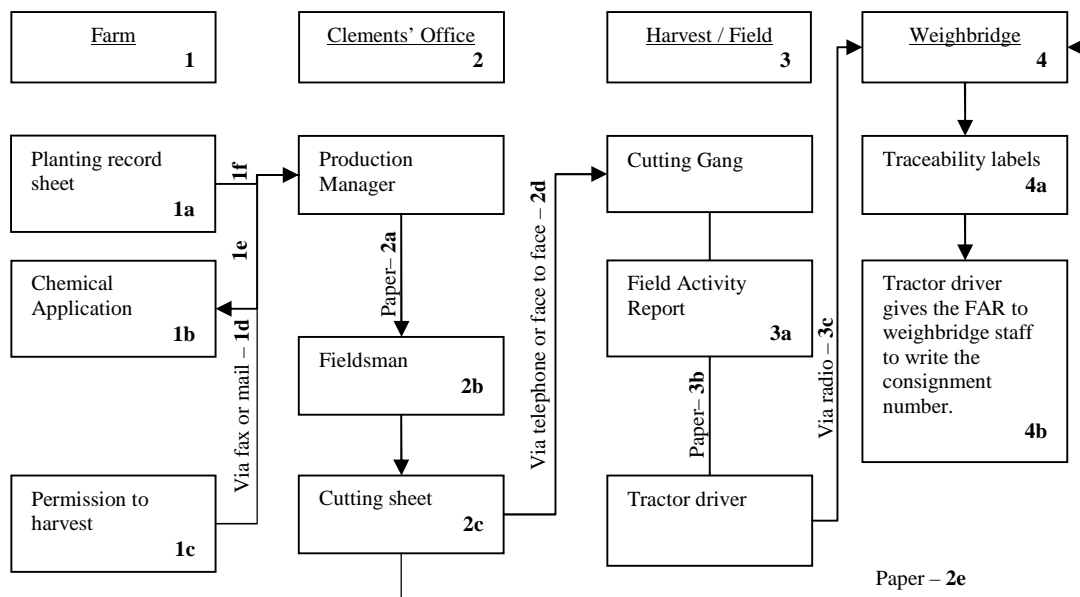
Traceability records can be used in many ways regarding food safety. The field operation records can be checked if there is a need to withdraw the produce due a contamination. These records enable to identify the source of the problem and the batches contaminated reducing the size of recall. Traceability records can also be used to check a specific production history meets a specific required standard before sending the fresh produce or grain to the supermarket in order to minimize the risk of return, or contamination during bulk mixing at later stages. However a more efficient way to prevent contamination risk and consequentially avoid financial loss is to ensure the application of the correct agrochemical at correct rate. The AACTS can help avoid the use of the incorrect agrochemical and verify that the sprayer is loaded with the recommended amount of agrochemical and rate. However, in case of an over-dose happens the application map will show the contaminated area more precisely. The farmer/grower has then the choice to leave the contaminated product in the field and harvest only the non-contaminated area or take other management action while time remains. On the other hand, if an under-dose is detected the farm manager has then the choice to monitor the affected area more closely and make further decisions as necessary, for instance, the agrochemical application could be repeated to comply with the dose recommended by the agronomist.

### 8.3 Fresh Produce - T.H. Clements & Son Ltd

This section describes the existing traceability system from field level up to the weighbridge at TH Clements & Son. Clements grow, harvest, pack and deliver brassica to supermarkets throughout the UK. The company owns 400 hectares and works with an additional fifty two others growers around the UK. Clements is responsible for the harvest of individual growers and has been using traceability systems for fifteen years.

#### 8.3.1 The existing traceability system

The traceability data regarding field inputs, field operations and field outputs is recorded in a software especially designed for Clements - the Amazon system. This software creates a consignment number of produce from the same field and plot which enables the history of produce to be traced back to the field level. The current traceability system at Clements is shown in Figure 16.



**Figure 16: Information and crop flow at Clements.**

The first step in this traceability system is to link the seed batch numbers with the field where they have been planted. The grower creates a planting record sheet with information such as grower's name, field and plot number, date of planting, variety of seed and seed batch number (1a). This sheet is filled by hand and after completion is faxed or mailed to Clements (1f). This information is manually typed into the computer by the production manager at Clements.

During the farming season, agrochemical application records such as fertilizer/chemical name, rate and date of application are registered by the growers and sent to Clements as shown on steps 1b and 1e of the Figure 16. The production manager manually types this information into the computer and it is linked with the planting record sheet of each field.

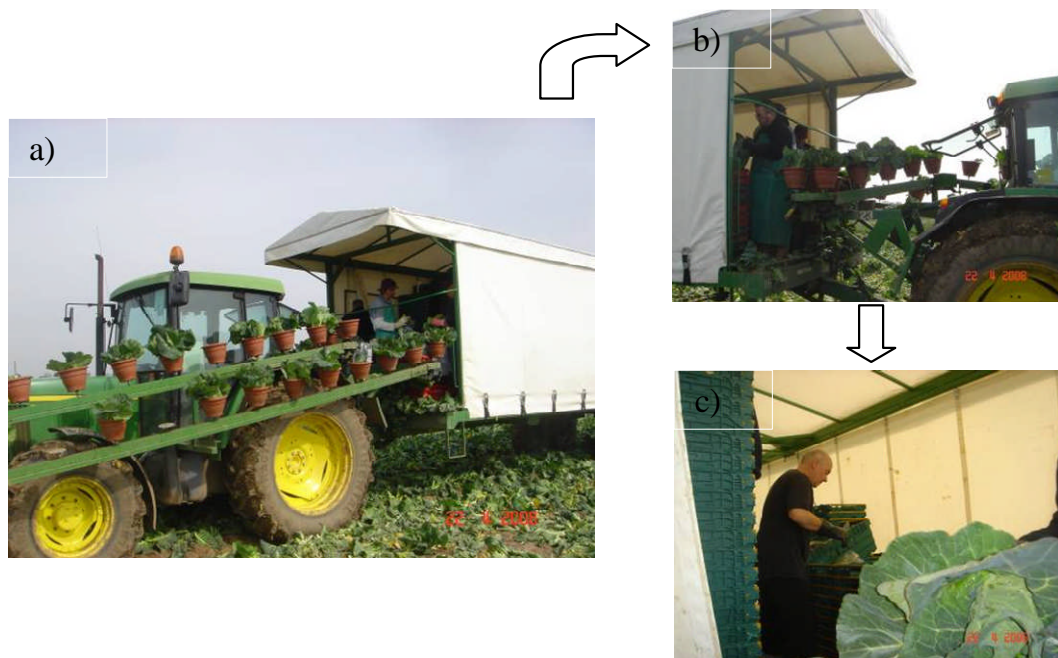
Farmers produce a “permission to harvest” document is sent to Clements by fax or mail (step 1d). The production manager approves the document, checking the maximum harvest interval for the crop and finally gives a copy to the fieldsman (2a).

The fieldsmen match the sales requirements with the crop available to be cut and release the “cutting sheets” (step 2c) in order to guide each gang to go to the correct field giving details of the quantities and the type of pack required. The data for the “cutting sheets” is generated based on the “permission to harvest” sheet, planting records and sales requirements. The communication between the “cutting gang master” and the fieldsman takes place just before harvest either in person or via telephone (step 2d). The fieldsmen do not use computers to record the field information, however, they do record the field information manually on paper. The use of paper rather than computer is mainly due to them being unfamiliar with computers. The fieldsmen work at Clements for a long period and their job is mainly to check the field operations. It has been suggested that is very unlikely that they will adopt computerised systems.

The operator in charge of the weighbridge at Clements receives a copy of the “cutting sheets” in order to prepare for receiving trailers loads of produce during the day (step 2e). The following information is typed into the Amazon system: gang name, date, product, container and pack, and provisional quantity to be received. This process of recording of information usually takes 1 minute at most. If a unique code has to be created for the product and container/pack it would take an extra minute.

At the field, the gang master fills out the “Field Activity Report” (FAR) as illustrated on step 3a. At the start he completes the necessary paperwork with the following information: the date of harvest, the names of the individuals within a gang, the grower, field name/id, plot, start time, crop, container and pack, pay rate (£/individual) and tractor rate. After finishing the harvest of each plot the gang leader completes the finish time, quantity and weight of produce. The quantity is the number of packs of produce

and the weight is the total weight of the produce harvested. The supermarket specifies how many packs go into each tray according to the type of produce and packaging used. Each tray contains 12 plastic bags of fresh greens and each pallet held 50 trays, in total 600 of plastic bags. It takes approximately 2 minutes to count the pallets and fill out the rest of the information on the FAR. Usually there are three people in the trailer, two of whom pack and weight the produce and the third places the produce into the trays. The fresh greens are moved in the “flower pots” located on the belt around the tractor (Figure 17 (a)), a gang member collects the fresh greens and puts it into a bag (Figure 17 (b)), and finally the bag is weighed and placed into the trays (Figure 17 (c)).



**Figure 17: The harvest process of fresh greens, (a) fresh greens are placed in the “flower pots”, (b) a gang member collects the fresh greens and puts it into a bag, and (c) the bag is weighed and placed into the trays**

The tractor driver communicates via radio with the weighbridge to provide the relevant information for FAR, such as grower, field and plot, product, quantity and container/pack (step 3c). The weighbridge operator checks to ensure that this information matches the information given in the “cutting sheet”, and then updates the actual quantity. The Amazon system automatically creates the consignment numbers



which are printed on the labels before the arrival of the trailers loads. This process takes approximately 20 seconds.

When a trailer arrives at the weighbridge the tractor driver gives a copy of the FAR to the weighbridge operator and the operator writes the consignment number on it and gives it back to the tractor driver together with the labels (step 4b).

Two labels are placed on the loaded pallets, these contain the information concerning the grower name, field and plot number, name of the gang, type of crop, consigned number and barcode. The tractor driver is responsible for conveying the information about the location related to the tray.

### **8.3.2 Opportunities for improvements**

Occasionally the agrochemical information recorded by the grower is illegible or unclear. In such case the production manager contacts the grower, in order to clarify the information, this usually happens once a week and takes around 5 minutes of their time. During the spraying season it takes on average 5 hours per day to type the agrochemical application records data into the main field records. There is a potential opportunity to improve the data resolution and speed of information transfer for steps 1b and 1e by using the AACTS. The chemical application records would be automatically generated by the AACTS and the farmer/grower could send the file to Clements. The production manager would upload the file into the Amazon system.

The spray plans of the fields sprayed by Clements are prepared using Muddy Boots software. The production manager see a great benefit if all the growers use Muddy Boots to prepare the spray plan and could log on to Amazon system and update the agrochemical application records themselves. The AACTS would be compatible with Muddy Boots software, this would facilitate the data recording.

The cutting gang move frequently around the field and sometimes pallets from different plots can become mixed-up in the same trailer. This may lead to incorrect labelling of produce at the weighbridge. Using as an example the plastic bags used to store the fresh greens, a misidentification from a single pallet source would result in mislabelling of 600 plastic bags. The overall outcome may result in the delivery of wrong produce to the customer. There is a potential improvement of data resolution and accuracy of data

gathered for step 3a by using GPS and RFID tagging. Alongside with the planting record sheet, the GPS boundaries of the field/plot could be downloaded into the Amazon system. The GPS technology and RFID tagging on the trays would allow recording of specific location of harvest and it could be linked with the field/plot number and consequently with the grower name and crop. Furthermore, a scale with computer interface on board the trailer could record the weight of the fresh produce as they are being loaded into the tray. Additionally the gang master could wear a wrist band fitted with RFID identification; this would enable automatic identification of the cutting gang responsible for the harvest.

The RFID tag on the tray would contain only the unique identification number. The antenna fitted in the trailer would read this number and write it into the controller database. This number would be linked with the harvest date/time, GPS location and final tray weight. The GPS system would be placed in the trailer alongside with the RFID antenna/interrogator, controller and scale. As the trays are being filled one of the gang members would be responsible for confirming the database generation. The agrochemical application map generated by the AACTS could be downloaded into the controller beforehand, if an over-dosed area is identified the controller would give an alert to the gang member. The system would operate in the following way:

1. The gang member places the empty tray on the scale.
2. The tare weight is recorded.
3. The RFID reader identifies the tray ID and records it along side with the initial GPS location and time.
4. Using the controller's commands, the gang member confirms to start the operation.
5. Each fresh produce is placed separately inside the tray.
6. The scale records the individual fresh produce weight and at the end sums the total weight of the tray.
7. If the fresh produce is lighter than it should be, the controller alerts the gang member.

8. The gang member has a choice to accept or to reject the product, pressing the button on the controller to confirm the operation.
9. As the tray reaches a specific volume and weight (number of fresh produce unit per tray required by the supermarket) a sign appears at the controller to alert the gang member.
10. Using the controller's commands, the gang member confirms to finish the operation.
11. The controller records the final GPS location, time and total weight.
12. The gang member gives the tray to the other member which places the fresh products inside the plastic bags.

By the end of the day the database would hold the records of each tray unique identification number linked with the harvest date/time, GPS location on the field and total tray weight. This would allow the identification of the approximately location on the field where produce came from.

Furthermore, the database would hold the information regarding the number of fresh produce rejected and its location on the field. This information could be further used to have a better view of the uniformity of the produces in the field. A further agronomic analysis could help to minimize the variation in produce size and meet the requirements of the supermarket. In the UK, an onion producer has already reaped the benefits for being able to identify and change the significant variation in onion size in a number of fields (Maguire et al, 2003). The onion sizes were related to each soil texture and water holding capacity of the soil. Further analysis has identified the optimal seed rates for each soil type. As a result of this study, approximately 30% extra of the total onion production is being sold into the premium target market (Godwin, 2007).

In order to implement this system, every trailer would need to have the system in place and one of the gang members would have to take part in the process. The following components, together with estimates of base cost, would be needed in order to implement the system.

- GPS system - £150
- Controller - £500

- Interrogator - £250
- Antenna - £50
- Scale with computer interface - £160
- RFID wrist band - £5
- **Total cost of components per harvesting tractor with trailer- £1,115**

This would be the only fixed components cost to implement the system. Clements has 30 harvesting tractors with trailers that harvest produce and also take in the last load of produce to the weighbridge. However if more than one trailer is packed with the same tractor, 10 tractors are used to purely run full trailers to weighbridge. It would cost approximately £33,450 to install the system at 30 harvesting tractors with trailers.

Occasionally, the tractor driver gives incorrect information to the operator in charge of the weighbridge. The step 3c could be improved in order to ensure the correct information is being received by the weighbridge operator. As the trailer arrives at the weighbridge, the information could be either transfer via wireless or using a memory card. The tractor driver would give the memory card containing the database to the weighbridge operator. The database would be downloaded into the computer and the data linked with the pre-planting recorded profile and any other information required to be passed to the supermarket.

At the moment supermarkets do not require RFID system at Clements. However, Tesco has begun work to roll out an RFID network that tracks shipments from its central distribution centre to all 98 Tesco Extra Superstores (Collins; 2004). This is the first stage of a plan to implement RFID across more than 2000 stores and distribution centres in the UK. Furthermore, Tesco is already exploring a large scale investment in RFID throughout their supply chain (RFID News, 2008). When Tesco fully implements the RFID system, all the trays will be labelled and consequentially have a unique identification number. This would allow very precise identification of every single tray. The suppliers should be prepared to handle trays with RFID label and be able to collect and record information regarding the product being loaded into the trays. Ninety-five percent of the Clements production is supplied to Tesco. The trays used at the harvest belong to Tesco and are used for a range of products marketed by them. These trays may be used by a different supplier supplying different produce; hence the trays used by Clements might not necessary end-up back to Clements. Currently, there is no control

over where the trays have been to and where they go as they are used by all Tesco's suppliers in the UK and around the World.

The RFID system could be developed and implemented to suite a specific field application. The complexity of the system would depend on the amount of investment available and required level of information details collected.

### **8.3.3 Potential benefits of the proposed system**

#### 8.3.3.1 Saving time in the office

In order to consider the benefits of the AACTS regarding on saving time some estimates can be made on the economics of management of agrochemical application records. As described earlier the production manager has to manually type into the computer the information such as agrochemical product name, rate and date of application. The manager is involved with this task 25 hours per week during six months per year. Assuming a total of 11 months of work per year, by the end of the year the manager has spent 34.09% of this time typing the agrochemical application records. The cost to hire and employ the production manager is £25,000 (excluding any overhead) per year, the cost to update the agrochemical application records would be £8,523. It should be taken into consideration that the time spent on typing the information into the computer could be used by this same employee on another task in the company. The automated agrochemical traceability system generates this information electronically. The sprayer operator only has to take the memory card from the sprayer machine and download the information into the farm computer. The time to download the information depends on the computer capability, but it can be considerably faster than manually type the same information into the computer. The investment cost of the AACTS is £3,620 as shown on section 8.4.2.1.

#### 8.3.3.2 Reduction of product withdraw

The AACTS can avoid the use of the incorrect agrochemical and potentially ensure that the sprayer is loaded with the recommended amount of agrochemical and rate. However, in case of an over-dose happens the application map will show the contaminated area. Before harvest, the application map is downloaded into the controller onboard the trailer,

if an over-dosed area is identified the controller would given an alert to the gang member. The harvest would be suspended until trailer reaches a non contaminated area. This operation would avoid the harvest of contaminated produce and consequentially avoid unnecessary work.

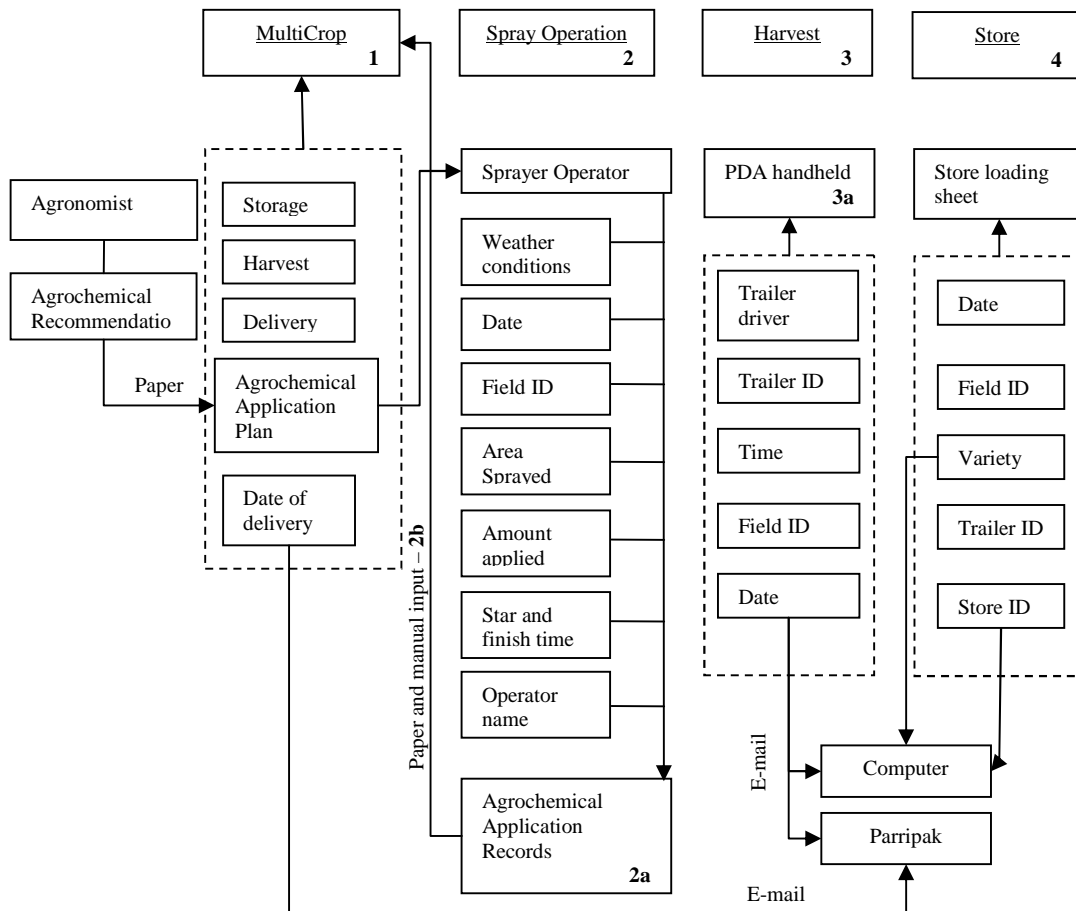
The RFID and GPS system will potentially identify the location in the field where the box of produce came from. At the moment, the box of produce is traced back to the field and plot number, however, with the proposed system the producer will be able to identify where in the plot the box of produce came from. If a batch of produce fails in the supermarket residue test, Clements would be able to identify the location in the field where the produce came from. Being able to identify the source of the problem and the location of the contaminated produce potentially reduces the number of the boxes of produces to be withdrawn. If the producer is not able to identify the precise location and source of the problem, a large number of boxes have to be removed from the market.

#### **8.4 Onion Production - F.B. Parrish and Son**

This section describes the existing traceability system from field level up to the storage at F.B Parrish. Parrish grows and harvests brown and red onions, super sweet onions, potatoes and shallots. The total area of the farm is 730 hectares; each field is approximately 8-12 hectares. The vegetables go to Parripak Food which is responsible for processing and packaging. Parripak have their record keeping system in place, therefore they know where the product comes from and where they have been supplied to, but they have no detailed farm records about the product.

##### **8.4.1 The existing traceability system**

Field and cropping records are held on MultiCrop software provided by FARMADE. The software holds the information regarding the pre-planting, harvest, storage and delivery from the farm. All the data are manually typed into the computer. The current traceability system at Parrish is shown in Figure 18.



**Figure 18: Information flow at Parrish**

The agronomist sends the spray recommendation to the farm manager, which then creates a work plan using the software. The agronomist recommendation is paper-based and is manually typed into the software. The farm manager gives the work plan to the sprayer operator, who manually records the following information during and after spraying (step 2a):

- Weather conditions
- Date
- Field ID
- Area sprayed
- Application rate
- Start time
- Finish time
- Operator name

After spraying, the records are given back to the farm manager who manually types the records into the MultiCrop software (step 2b).

In the morning prior the harvest, the operators are informed which field should be harvest. The knowledge of the field to be harvested is important because usually only one field is harvested per day. Bulk crops are harvested and placed into 12t trailers (Figure 19). Every trailer load is recorded by the harvester operator using a handheld PDA (model Palm Z22); the data recorded are the following: trailer driver name, trailer number, time, field ID and date (3a).



**Figure 19: Harvest at Parrish**

The crop is brought in bulk and separated and stored according to the variety, harvest date and field. At the collection area there is no clear separation of crop coming from different fields. Bulk crops are brought into the unloading area where they are tipped onto a conveyor where stones and other specimen are removed manually. The crops are then carried by elevator into the bulk store as shown on Figure 20.

At the store, the information from the PDA is not received together with the trailer. One person responsible for removing the stones is also responsible for writing the information on the “store loading” sheet such as date, field, variety, trailer and store number and time of each trailer unloaded. One trailer per hectare is needed.





**Figure 20: Unloading area**

Some varieties of onions (super sweet) are very soft and are not suitable for keeping in the big store. These varieties are stored into 1 t boxes. The boxes are labelled with the crop name, variety, field, size (diameter in mm), harvest date and a unique number (Figure 21). According to the farm manager, the traceability of the produce stored in boxes is 100%.



**Figure 21: 1t boxes of onion**

At the end of the harvest day, the data from the PDAs is downloaded into the computer and linked with previous field records. The data from the PDA is compared with the data from the “store loading” sheet. The following data is typed into the MultiCrop software:

- Crop Code

- Variety
- Harvest date
- Store location/number

At Parrish the traceability data is kept at the MultiCrop software. The date of harvest and pack is the information which links the batch with the field records. This means that if there is a specific problem with a batch, the date of harvest and delivery is used to retrieve the field records. The excel spreadsheet is sent via email to the buyer, before sending the products. This helps the buyer or processor to comply with traceability and quality assurance schemes.

Parripak Food is responsible for identifying the source of the product within two hours (farm and country of origin) and twelve hours to retrieve the specific field records. In 2007, three incidents happened and Parripak had to retrieve the field records from the farm in order to identify the problem. In order to retrieve the field records from Parrish; Parripak has to inform the date of harvest and pack which are specified on the delivery notes. With this information, Parrish was able to retrieve the specific field records in 5 minutes using the MultiCrop software.

#### **8.4.2 Economic Analysis**

Being a specialized farm and very close to the food processor (packer), allows Parrish to design a very simple and effective traceability system in terms of product identification and data collection. However, the collection and recording regarding the agrochemical records could be improved by using the AACTS.

The results of the Chapter 6 indicated that the AACTS should be compatible with existing farm software such as Farmade and Muddy Boots. As described earlier, at Parrish the farm manager types the agrochemical records into the Farmade software, hence there is a potential opportunity to minimise the time to deal with these records. After the spray application, the sprayer operator would give the memory card to the farm manager and the agrochemical records would be directly downloaded into the software.

Although the farm manager argued that he prefers to manually enter the agrochemical information so it can be verified and that he never identified an application that was

incorrect, sometimes human error is unavoidable and mistakes can be made. In addition, the farm manager has to rely on the sprayer operator to inform the correct application rate. The AACTS could avoid agrochemical misapplication and consequentially avoid financial and production loss.

#### 8.4.2.1 Operation cost of the AACTS

The operational cost of using AACTS in order to demonstrate agrochemical inputs will now be considered. The cost of individual components and the total fixed capital cost required at the establishment of the traceability system are calculated based on the assumption that the farmer has a computer in order to; a) produce the agrochemical job plan, b) to run the software and c) to process raw data. Only capital cost is considered on this study. The capital and associated additional cost components are summarized in Table 40 and the calculation of the annual cost is demonstrated in Appendix P.

**Table 40: Summary of the cost of precision farming equipment**

	<b>Data Recording System</b>	<b>AACTS</b>	<b>GPS</b>	<b>Total Cost</b>
<b>Investment Cost</b>	£ 1,500	£2.000	£120	<b>£3,620</b>
<b>Cost of Capital</b>	7.5%			
<b>Depreciation</b>	15% for 5 years replacement			
<b>Maintenance Cost</b>				
<b>Sprayer</b>	9.5% for use of 200 hours per year			

- The *data recording system* is the onboard computer in the sprayer which is required to download the agrochemical job plan and to transfer/receive information from the automatic agrochemical recording system attached to the sprayer.
- The *AACTS* is the system that identifies, measures and records the agrochemical inputs, and produces the “as applied map”. The cost presented is the retail price in Europe as estimated in Chapter 5.
- The *depreciation* of the precision farming equipments were calculated using the same rate of the host machine (sprayer), from values given by Nix (2008). Where the average depreciation per annum is 15% for 5 years.
- The *maintenance* cost was calculated using the same rate maintenance cost as given by Nix (2008) of the sprayer.

- The *capital cost* has been calculated at an annual interest rate of 7.5%, bank base rate before the period of recession, 5% (Bank of England, 2008), plus 2.5% (Nix, 2008). This reflects the cost of the initial investment in the AACTS.

The annual cost per hectare has been calculated for the cultivated area of the farm, 730 hectares. For land area of 730 hectares, the total annual cost per hectare is £1.59. According to Nix (2008) the gross margin of dry bulb onions is £1,435/ha. The annual cost of the AACTS represents 0.11% of the gross margin per hectare of onions. For a system which can avoid production loss, this is a small cost in comparison with the gross margin.

There is potential for mixing of product when changing from field to field as there is no clear boundary marked within the store. The store capacity is 800 t (Figure 22). The total amount of products that could be mixed in the store might be as high as 30t. This is due to the store having no clear physical boundaries in order to separate the produce coming from different fields. If there is a problem with the agrochemical application and it is not identified at the verification point, crops from different fields will be end up mixed in the store. The AACTS can potentially prevent problems before it occurs and allows onions from different fields being mixed as the whole production would comply with the requirements of the quality assurance schemes. However, if a problem happens, the information provided by the AACTS along side with the “as applied map” would give the farm manager the choice to redirect the crop if necessary and do not mix with crops from different fields or parts of fields.



**Figure 22: Onions' store at Parrish**

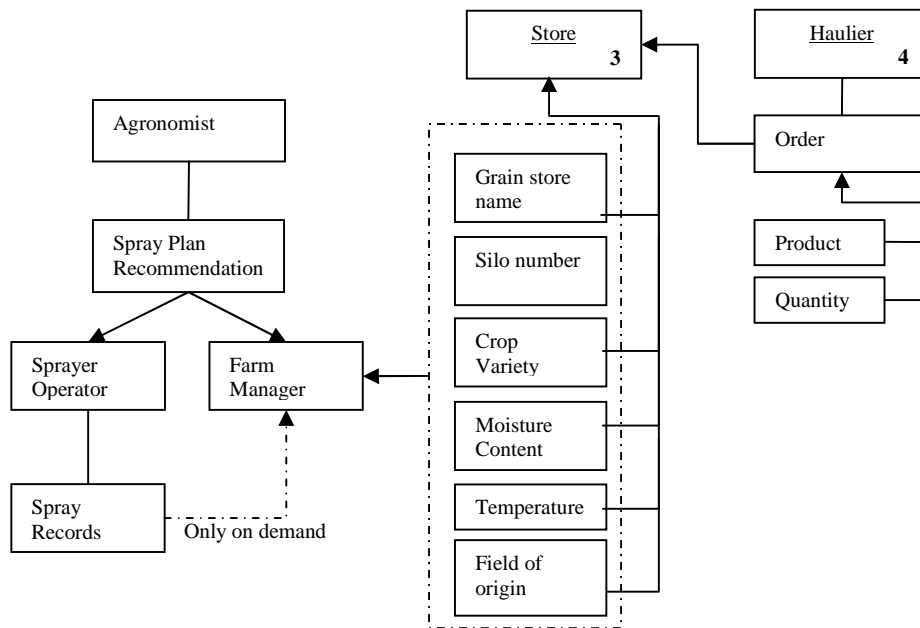
## **8.5 Conservation Grade - Arable Farm**

This section describes the existing traceability system at a 1200 hectares arable farm in Hertfordshire, UK. The farm grows 400 ha of wheat, 100 ha of barley, 200 ha of oats, 100 ha of oilseed rape, 100 ha of sugar beet and 120 ha are reserved to wildlife protection. The rest of the land is grassland for sheep grazing for lamb production. The farm has five full time employees, three are responsible for the machinery operations and silos and two are responsible for the livestock production. Over the harvest two extra people are hired.

The 6,100t of cereals produced each year is harvested by two combines and a significant proportion is grown on multi-year contracts to supply Jordans Cereals. In order to supply Jordans Cereals, the farm has to be a member of the Conservation Grade scheme. This quality scheme was created to protect the environment and wildlife and the farmer is required to dedicate 10% of the farmed land to wildlife. This farm is currently the main supplier of Jordans Cereals.

### **8.5.1 The existing traceability system**

In order to facilitate the separation and identification all the grains are grown and stored as Conservation Grade. Even though not all the grains are supplied to Jordans Cereals, the farm manager argued that it is more convenient to treat all grain in the same manner. The main difference is that Conservation Grade does not permit any post-harvest treatment. In total, five varieties of wheat are grown and only one variety of wheat is grown per field. As well only one variety of barley, oats, oilseed rape and sugar beet are grown and these are planted in separate fields. Having only one variety per field facilitates the separation and identification of the crops varieties. Each field has in average 15 hectares. The current traceability system is shown in Figure 23.



**Figure 23: Information flow - Arable farm**

The spray application is always conducted by the same operator using a sprayer with a capacity of 4,000 litres and 24m wide boom. The spray plan recommendation is given by a full time agronomist working on the farm. One copy of the recommendation is given to the farm manager and another copy is given to the sprayer operator. After the spray application the operator keeps the application records in paper file and it is only given to the farm manager if he requires it. The farm manager usually assumes that the spray application was done according to the recommendation and only requires it to be supplied before the annual farm inspection conducted by Cmi plc.

Neither the combine operator nor the tractor driver collects any information regarding the cereals being harvested and transported from field to silo. All they know is the field they are to harvest on that day and the silo into which the grains should be unloaded.

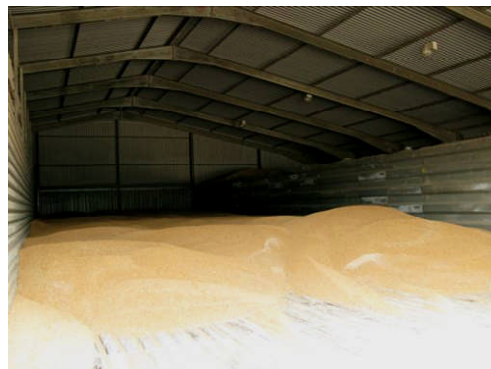
The combine harvesters have a seven to eight tonne grain tank and can harvest up to 35t per hour. The capacity of the grain trailers (see Figure 24) used to transport the grains from field to silos is 14t.





**Figure 24: Trailer unloading the grains**

In total, the farm has 24 silos that have the capacity to store a total of 6,100t. One of the grain storage units contains 16 internal silos. Each individual silo has the capacity of 75t. This grain storage enables a clear separation by field. Moreover, there are bigger grain storages with capacity of 300t, 400t and 700t. These silos have the capacity to store grains from up to seven different fields. At these silos there are no clear boundaries between the grains from different fields. The loading order is done according to the fields. Although the operator knows which order the fields have been unloaded, the grains from different fields can be easily mixed.



**Figure 25: Left image: 400t silo. Right image: 700t silo.**

The information recorded from each silo is: grain storage name, silo number, crop variety, tonnage, moisture content, temperature and field of origin. The data regarding the moisture and temperature are collected monthly. This information is handwritten by

the staff responsible by the silos and then the farm manager types it into the computer using an excel program.

The lorries used to transport the grains from the farm to the grain mill has the capacity of 29t. Usually it requires two lorries to transport grains from one single field. The haulier carries with him the order, specifying the product required by the mill and the quantity. The farm manager keeps a copy of the order and attaches it to the records regarding the silo which the grains had been supplied to the mill.

At this farm the traceability is the form of paper trail back system. The invoice number is the information which links the grain lorry with the store and field records. This means that if there is a specific problem with a batch, the invoice number is used to retrieve the store and field records. All the field records are kept and only informed to the buyer if it is requested.

### **8.5.2 Analysis of potential financial savings**

According to Jordan Cereals, less than once a year, a grain load is rejected. The whole load is rejected in case of over-dose, and if a banned agrochemical or other noxious contaminant is found. If the rejection is for a banned agrochemical input, then the rejection is terminal, which means that the farmer is removed from the scheme. At the farm in this study it was reported only one case which Jordans Cereals rejects a batch due to glass contamination. The manager was able to identify the field of origin and then find out what happened. This field is located on the corner of a road close to a village. It was identified that the glass fragments was from Vodka bottle. Walking on the field the manager was able to identify fragments of a bottle probably left by people passing by.

A number of workshops conducted in UK by HGCA in 2003 tried to identify the number of grain rejections (wheat and barley). In total 203 workshops were run and 2230 farmers attended. When asked what the percentage of the loads were rejected in 2001/2002, 17.3% and 9.5% of all farmers responded for wheat and barley respectively. From those that responded and had a load rejected, 3.9% and 6.4% reported rejections for wheat and barley respectively. However, according to the author of the report (Hook, 2004), these results might not reflect the real scenario because it was not



possible to confirm that those who left the answer blank had no incident of grain rejection.

As described earlier, the farm manager has no control of the spray application. The spray application records are kept with the sprayer operator and the farm manager always assumed it has been applied according to the agronomist recommendation. The farm manager argues that he never had to retrieve the agrochemical application records due to a problem. If an overdose is detected or any other problem regarding the agrochemical application, the farm manager would have to contact the sprayer operator and collect the spray application records to check what happened. The use of the AACTS could avoid misapplication; however, if a problem happens the farm manager could identify it right after the application. As the tractor and sprayer always goes back to the farm yard the operator could give the memory card with the information to be downloaded into the farm computer.

The analysis of the potential improvements are focused on the proportion of the annual operation cost of the AACTS in relation with the extra profit for being able to sell the crops to Conservation Grade.

#### 8.5.2.1 Food recall scenario at Jordans Cereals

In order to estimate the economic impact of a recall at Jordans Cereal, information regarding its production has been collected. Per year, cereals products are produced from 22,000 tonnes of grains using oats, barley and wheat. The company contracts a restricted number of suppliers to produce the grains to comply with a Conservation Grade assurance scheme.

Following a hypothetical confirmation of a high agrochemical residue level in products in the market a recall would be required, which would have the following impacts:

- At the production stage the batch size of 1,000 tonnes of cereals produces approximately 2,000 tonnes of finished product. As a pack of the cereal weighs 500 grams, 4 million packs of cereals products are produced. Assuming the average price of each pack is £2.00, the lost revenue would cost £8 million. Since the processor produces 22,000 tonnes of grains per year, this lost would represent 4.5% of the annual production. As a typical farmer supplies the company with 500 tonnes of oats,

we can conclude that a single farm has potential to impact one whole batch. The damage could be increased if it contaminated material was included in several different batches.

The AACTS would provide an extra assurance for the food processor and it would avoid high residue levels before sending the batch to the production line. This illustrates that the real value of traceability for grains is for brand protection for the processor.

#### 8.5.2.2 Operation cost of the AACTS

The annual cost per hectare has been calculated for the cultivated area of the farm, 900 hectares based on the information on section 8.4.2.1 . For land area of 900 hectares, the total annual cost per hectare is £1.29. However, if the farmer wants to invest in a yield mapping system, the extra cost is £ 3,890 for the yield meter and yield mapping kit for a combine. In this case, the GPS is already included in the yield mapping kit. The total investment cost would be £7,390. The operation cost for an area of 900 hectares is £2.37 per hectare. The calculation of the operation cost is demonstrated in Appendix O.

#### 8.5.2.3 Gross Margin

Having the AACTS in place and the GPS technology will allow the farmers to map the area and identify how much and what agrochemical has been applied to the field and furthermore to avoid misapplication. According to the interviews of Chapter 6, there are evidences of financial and production loss due to the incorrect agrochemical application at cereal farms.

Being a member of Conservation Grade gives this farmer an extra 10% payment for the outcomes. If for some reason the grains are rejected by Conservation Grade, the farmer has to sell it to the conventional market without any premium price. Hence, being able to prevent spray misapplication provides an extra assurance to comply with Conservation Grade quality scheme.

The price paid by the conventional market and the price paid by CG will be compared. As stated earlier, CG pay up to 10% premium for assured crops. It has been assumed that the value of the crop at Farmers Weekly (2009) is the value of conventional crop. Therefore in this estimative the gross margin of the CG will be gross margin stated at

Farmers Weekly (2009) plus 10%. According to Table 41, the value per ton of the conventional winter oats crop is £90.4 (Farmers Weekly, 2009), hence the value per tonne of CG would be £99.4. Assuming the same average yield (ton/ha) for both crops, the output of the conventional winter oats is £587.6/ha and the CG is £646.4/ha.

**Table 41: Gross Margin – £ per hectare**

	<b>Winter Oats</b>	<b>Wheat</b>
Average yield ton/ha (Nix, 2008)	6.5	7.55
Value per ton	90.4	109
Output	587.6	708.5
Variable Cost	197	329
Value per ton Conservation Grade (more 10%)	99.4	119.9
Output Conservation Grade	646.4	779.4

According to the table above, the extra output for being able to sell to CG is £58.8 and £70.9 per hectare of winter oats and wheat respectively. However, if the load is rejected by CG due to over stated dose or a presence of a banned agrochemical, the extra payments would represent the loss per hectare. The annual cost per hectare of the AACTS with and without the yield mapping system represents 4.0% and 2.2% respectively of the total potential loss per hectare of winter oats. Per hectare of wheat, the annual cost per hectare of the AACTS with and without the yield mapping system represents 3.3% and 1.8% respectively. These are relative small costs in comparison with the total loss that could be avoided.

In 2008, this farm received a total of £208,138 regarding the single farm payment. As described on section 2.5, the Cross Compliance check that only approved pesticides were used and that they are used in compliance with their conditions of use, good agricultural practice and where possible as part of an integrated approach to controlling pests and diseases. Failure to comply with these requirements may lead to reductions in a farmer's single farm payment. The use of the AACTS can prove records regarding the agrochemical usage.

The segregation of bulk products is more difficult than in fresh produce. Fresh produce are harvested and usually individually packed, hence it is relatively simple to identify the pack and link with the field records of the field where it came from. However, cereals coming from different fields are usually mixed in the same silo and the farmer is taking a risk if a contamination is detected as the premium price could be lost. Hence

there is a need for ensuring good product quality before mixing the cereals in one silo. The AACTS can ensure that the correct agrochemical and prescribed amount has been loaded into the sprayer. In addition with precision farming systems, the “as applied map” could be created which would link the total amount of agrochemical and demonstrate the area sprayed. By ensuring the correct agrochemical application the grains from different fields could be mixed as the whole batch complies with the requirements of the quality assurance schemes. However if a problem happens, the farmer would be able to identify in advance the specific area in the field which is contaminated due to over-dose, he would have the choice to harvest only the non-contaminated area and do not mix quality grains with contaminated grains.

## **8.6 Conclusions**

The three farms analysed in this study are producers of high quality crops as demonstrated. Clements and Parrish are specialised on high value crops. Furthermore the cereal farm receives a premium for supplying to Conservation Grade, known to be a high quality standard. The following conclusions can be drawn from the analyses of the three different farm enterprises:

1. The AACTS can avoid the use of the incorrect agrochemical. Furthermore, it can ensure the use of the correct amount of agrochemical as prescribed by the agronomist. In addition, the AACTS alongside with application map can potentially identify areas of over-doses and under-doses. The analyses demonstrated that the AACTS could avoid market and financial loss for relatively small costs. The operation cost for an area of 900 hectares are £1.29/ha and £2.37/ha with and without yield mapping system respectively.
2. At the moment the agrochemical application records are manually written and typed into the computer. At Clements, the production manager spends around 600 hours per year typing the agrochemical application records into the computer. There is a potential time and financial saving if this information is received electronically. However, the savings will depend on the capability of the computer and its reliability.

3. The use of the RFID system together with GPS can potentially record the location in the field where the fresh produce has been harvested. This information alongside with the agrochemical application records and other field operation records can identify the source of a problem if a contamination is detected in the fresh produce. This can potentially reduce the amount of produces withdrawn. Currently the fresh produce are trace back to field and plot location, however with the proposed system at high value crops, the fresh produce will be trace back to the area in the plot where it came from.
4. At onion and cereal production there is a need for ensuring good product quality before mixing the products in the same store/silo. By ensuring the correct agrochemical application, the products could be mixed into the same store/silo as the whole batch would comply with the requirements of the quality assurance schemes. It would potentially avoid the expense of having to separate the crop from different fields or parts of fields.

## **9 Discussion**

This chapter discusses the findings of the previous research and it is divided in nine sections. The first one discusses the concept of the research and the second discusses the stakeholders' perception towards traceability systems. The third section discusses the evaluation of AACTS conducted by farmers with practical experience in spray application. The fourth part discusses the results of the face-to-face interviews with farmers and their attitudes towards AACTS. The fifth section discusses the results of the willingness to pay (WTP) questionnaire. The sixth part discusses the business risks of the different market strategies that the company could face and the most profitable retail price and sales volume for the European market. The seventh part discusses the practical benefits of AACTS in three types of farm enterprises. The eighth section discusses the range of social science methods used in this research to address the aim and objectives. Finally, the last section discusses the role of the agrochemical companies for the success of the AACTS.

### **9.1 Concept**

The increasing legislation concerning traceability and the number of farm assurance schemes raises the need to assist farmers in collecting agrochemical traceability data in order to comply with these. In the UK, 80% of the crop production is covered by farm assurance schemes (Defra; 2006), this means that the farmers have to collect and record a large amount of data regarding farm business. Within the farm business the relevant traceability data is often written on paper by the field operator and given back to the farm manager. For storage, the information can be kept on the original paper, transcribed to another paper form or typed into a computer system using specific software or a spreadsheet format. In order to automate the data collection regarding the agrochemicals usage at production stage, an automated agrochemical traceability system (AACTS) was designed and built at Cranfield University at Silsoe by my colleague Peets (2009). This system automatically identifies and records the quantity and the name of agrochemicals being loaded into a sprayer, decreasing the scope for human error. Additionally, the information regarding the application will be stored electronically so it can be downloaded directly into a computerised system. The AACTS will ensure that the sprayer

has the correct product and rate as prescribed by the agronomist. Peets (2009) proved that the AACTS has a resolution within  $\pm 1$  gram with the engine switched off and  $\pm 3.6$  grams when it is not. Furthermore, there is no significance difference in speed of operation between the AACTS and the manual method including loading and record creation time at the 5% probability level. According to Zaske (2003) an automated traceability system would automatically collect data and generate the required documents to comply with farm assurance schemes and legislation. Furthermore, Auernhammer (2002) argued that there is a need to make agriculture machines more intelligent and able to collect real time information from every stage of the food production.

## **9.2 Stakeholders' perceptions towards traceability systems**

In order to understand the requirements for traceability and potential for the AACTS, 17 stakeholders were interviewed to identify their perceptions towards traceability systems. The results of these face to face semi-structured interviews with open ended questions allowed the respondents to express their own opinion about traceability without being influenced by suggestions from the researcher (Foddy, 1993). The stakeholders interviewed represented the agri-food industry, quality assurance providers, manufacture of agriculture equipment, agrochemical industry, farm software providers, an agronomist and the UK government Food Standards Agency. The stakeholders were faced with questions according to their role in the food chain and their experience with traceability systems. This group of stakeholders perceived that the concept of the automated agrochemical recording system is good for those farmers who want to improve the business, to identify errors, and to ensure better use of agrochemicals. It is a practical management tool for farmers however it will not work as a "strict" policing tool because there are ways to falsify information, the operator could bypass the system by not using the user interface to record the information. Furthermore, the stakeholders believe that the AACTS should be time efficient and offer both competitive advantage and differentiation in the market place. In order for the system to gain acceptance in the field, there must be demand from retailers who are engaged and have been interested in it as they see the potential benefits. The results gathered from this research suggest that

there is a market opportunity to implement automated traceability systems as shown by stakeholders interviewed and their support in development.

### **9.3 Practical evaluation of the AACTS**

In conjunction with Peets (2009) ten farmers were invited in order to evaluate the performance of the AACTS. The farm sprayer operators were asked to load the sprayer using both the AACTS and the conventional manual system. After the loading process the farmers answered a questionnaire designed to identify their impressions of the AACTS in comparison with the conventional loading system. The sprayer with and without the AACTS was compared in terms of: 1) Minimise the investment cost; 2) Minimise time taken to fill the sprayer 3) Ease of retrieval of agrochemicals input data; 4) Accuracy of the data gathered; 5) Avoid use of unregistered agrochemicals and 6) Operator safety. The results indicated that the farmers who frequently use computer in their business see more advantages in using the system than those who do not use computer to keep their records. Hence, this could be a barrier to the adoption of the AACTS by those who do not use computerised databases. All the farmers interviewed reported that the spray plan is generated by the agronomist using commercial computer software. The group of farmers who personally do not use computers will have to rely on the agronomist in order to create the electronic job plan.

### **9.4 Farmers' attitudes towards AACTS**

In order to reach a higher number of technology minded farmers and to identify their attitudes towards the AACTS face to face interviews were conducted to identify if the farmers were willing and able to absorb, accept and utilise the AACTS. The majority of the 27 farmers interviewed were familiar with technologies onboard current agriculture equipment and all were users of computerised systems and use of software to manage the farm business. The concept of the AACTS was perceived as a management tool for the majority of the farmers rather than a system to improve traceability system and to prove agrochemical records per se. The main benefits identified by the respondents were: potential improvement of stock control, avoidance of the use of incorrect agrochemicals, saving time in the office and improved accuracy. However, it was



strongly recommended that the AACTS should be redesigned in order to allow greater rinsing space to wash out 10 and 20 litre containers. Farmers argued that the current induction hoppers are already too small and the insertion of the weighing hopper further reduces the available space in the induction hopper. Ninety percent of the farmers that would buy the AACTS expect that this improvement is done before acquiring the system. Furthermore, the AACTS should allow the use of generic agrochemicals consisting of same active ingredients of the product recommended by agronomist and a generic agrochemical database produced and promulgated through the industry. The software and appropriate database should be programmed to enable the identification of the corresponding generic product. However, there should be a warning on the screen informing the farmer/operator that he/she will be responsible for the decision to use the generic product instead of the “branded” product recommended by the agronomist. This would ensure that the farmer/operator deliberately wants to use a generic product.

Due to sensitivity of data disclosure, it is suggested that the marketing campaign should be focused on the listed perceived benefits of the AACTS and not as a tool to help the farmers to prove the records in order to comply with legislation and quality assurance schemes. Some farmers would use the AACTS only for internal management and would not provide this data to crop assurance schemes or legislation. They all argued that the paper based system is already acceptable and complies with the existing schemes and legislation requirements. Their main concern was giving too much information to people who are not familiar with the spray application who could therefore misinterpret the data. However, a number of farmers do not see a problem in providing the data generated by the AACTS to supermarkets and crop assurance schemes. These farmers were more familiar with the practice as they were directly suppliers to supermarkets (e.g. potatoes producers) and understand the need to provide quick and precise retrieval of data when requested.

### **9.5 Willingness to Pay for AACTS**

In order to identify the farmers willingness to pay for the AACTS an online questionnaire was designed. The initial bid values (Table 20 and Table 21) presented to the farmers were based on insufficient evidence given for a realistic selling price for the

AACTS and this low values might have influenced the price range anticipated by the farmers. Ideally this should not be an issue, however, it was not feasible to repeat the questionnaire to evaluate this hypothesis. Fortunately, the farmers were also faced with an open ended “follow up” question in order to identify their maximum WTP for the AACTS. The result of the “follow up” question had more statistical strength than the result of the first questions; hence these results of the “follow up” question were used to estimate the demand curve. What the author could not say with confidence is that the maximum WTP was not influenced by the prices listed in the previous questions. Furthermore, the online questionnaire was answered by an open market which 78.6% of the respondents weren't users of GPS technology and 71.4% were primarily arable farmers. The online questionnaire was available to a group of 1,200 farmers in the UK with 8.92% response rate. This was the best option to reach a higher number of farmers to answer the questionnaire due to time and money constraints. Although the result of the online questionnaire indicated that the mean WTP for the AACTS is £1,597, the face-to-face interviews with more specialised farmers demonstrated that there is evidence that some farmers would pay £4,000 and £5,000 for the AACTS. It is worth noting that these farmers were given personal detailed explanation regarding the AACTS and could ask questions regarding the system. Furthermore, they were all familiar with computerised systems; technology minded and had a larger mean farm size (1,048 ha) than the farmers which answered the online CV questionnaire (530 ha).

## **9.6 Analysis of the most profitable retail for AACTS**

The calculation of the most profitable retail price was based on the demand curve (Figure 13) and the production costs as shown on Table 32 and Table 35. The profit is very sensitive to the fixed cost; hence the company will have to precisely estimate the fixed cost to produce the AACTS in order to access its most profitable retail price. The break-even analysis was based on primary assumptions regarding the fixed cost as given by AGCO. Furthermore, the total potential demand per year will depend on the marketing strategy set by AGCO. Initially it was thought that the AACTS would be only available to AGCO sprayers, however the results of the break-even analysis demonstrated that this strategy is not profitable unless the company wishes to use it as a market differentiation and consequentially potentially help to increase the company's

market share. The projected quantities demanded are smaller than the break-even units (Table 33 and Table 34).

On the other hand, there are small profits if the AACTS is available as a retrofit to the whole self-propelled sprayer market in the North America and Europe and in addition it is produced by a third party company, such as Patchwork, which could reduce the fixed cost by say 10%. However, the annual projected quantity demanded would be only 88 units of the AACTS per market and the annual profit would be £70,275 and £21,056 in North America and Europe respectively. It would be difficult to convince a company such as Patchwork to invest in such a system to produce only 88 units due to the low level of profit margin as mentioned above. Conversely, considering the whole sprayer industry in Europe (trailed, mounted and self-propelled sprayers), there is opportunity for Patchwork to make a large profit if the AACTS is sold for £2,000. This would give a total profit of £1.25 million per year if 3,749 units are sold. It is worth noting that in order to receive the AACTS the sprayer has to be fitted with ISOBUS systems. According to William (2007), the major agriculture manufactures provide tractors and implements with ISOBUS system on board. However, as there is a large retrofit market there could be an argument for a non ISOBUS version to satisfy user requirement. The results of the break-even analysis are based on a hypothetical scenario, where the farmers had to imagine the AACTS in real life. There is a potential opportunity to increase the demand curve if the AACTS was made available in the market as the farmers will have a chance to see it in practice and assess its benefits.

### **9.7 The application of AACTS at different type of farms**

The three case studies were conducted at different farm enterprises: Clements (fresh produce), Parrish (onion production) and a cereal farm which supplies Jordan's Cereals with Conservation Grade produce for breakfast cereals. These farms are related by providing high quality products to the food industry however the farms differ from the type of product handling. At Clements the fresh produce are harvested and directly stored into boxes. At Parrish the onions are stored according to the variety, e.g. it can be in 1t boxes or in a store with capacity of 800t. The cereal farms harvest in bulk and the grains are stored in silos with capacity of 75t, 300t, 400t or 700t. The grains from

different fields are mixed, however the silos separate the grains by variety. There are issues concerning on how to segregate grains coming from different fields, the industry needs to see the benefits for doing so and justify the investment cost. However, if traceability systems could prevent problems before they happen, there would be no need to separate grains from different fields as the whole batch would comply with quality assurance schemes. As stated by the farmers interviewed, the AACTS can help to avoid the use of the incorrect agrochemical and ensure that the sprayer is loaded with the recommended amount of agrochemical and rate. However, in case of overdose the application map will show the contamination area and the farmer would have the choice to leave the contaminated products in fields and only harvest the non- contaminated area.

This research has demonstrated that the operation cost of the AACTS is relative small in comparison with the potential premium price loss given by Conservation Grade. Furthermore, the AACTS can minimise the 600 hours that the production manager at Clements spends in typing the agrochemical application records per year. The cost to update the agrochemical application records at Clements is approximately £8,523 per year; however, the investment cost of the AACTS is £3,620. GPS and RFID system can improve the product identification and identify the precise location in the field of where the fresh produce stored in small trays came from. This could potentially minimise the size of the recall in case a contamination is detected.

## **9.8 Critique of methods used**

This research showed that a combination of social science methods can be used to estimate the market uptake of new technologies under development. It was specifically used for a PhD study conducted in parallel with the development of the technology by Peets (2009). The methods used in this research were the following: face-to-face semi-structured interviews with members of food chain and farmers, the latter based on the Receptivity model, the Analytical Hierarchy Process (AHP) to evaluate the prototype system of AACTS, and a Contingent Valuation (CV) questionnaire to estimate the farmers' willingness to pay for the AACTS as illustrated on Table 42.

**Table 42: Summary of the methods used, some key advantages and disadvantages and recommendations**

Method	Advantages	Disadvantages	Recommendations
Face to face semi-structured interviews	Allows identification of the interviewees' own opinion regarding the subject.	Can be time consuming. Can be expensive to collect the data.	Where there are severe budget constraints, the face-to-face interview could be replaced with telephone interviews.
Analytical Hierarchy Process	It can measure both qualitative and quantitative attributes at the same time. It can provide a prioritized list of the alternatives and criteria.	The length of the questionnaire increases with the number of criteria. The questionnaire development can be difficult and time consuming.	Keep the number of criteria lower than six. Initial semi-structured interviews are needed to determine the appropriate criteria.
Online Contingent Valuation questionnaire (Willingness to pay)	Able to value goods not currently available.	People are unfamiliar with the situation so possibility of misunderstanding. Possible protest bias	Link the data collection with face to face or telephone interviews. Use an open ended question to compare the result of the double-bounded dichotomous choice (DBDC) questions.

Face-to-face semi-structured interviews were used to identify both the stakeholders' perceptions towards traceability systems and the farmers' attitudes towards the AACTS. The use of face-to-face semi-structured interviews was extremely useful to gather people's opinions regarding a broad subject. However, face-to-face interviews can be time consuming, both to arrange a suitable date for the interview and to travel to meet the interviewee; hence their use can be limited by budget constraints. As an alternative, telephone interviews could be used to collect the data. In order to ensure the interviewee is presented with visual information, the images could be made available on the web and the discussion could be conducted while the respondent is accessing the information. However, face-to-face interviews are preferred to minimise any potential barrier in communication.

The results of the Receptivity model questionnaire showed that this technique is very valuable to help researchers identify and understand the drivers and barriers in the adoption of an innovation. The interviews allowed the identification of the key concerns

which need to be addressed in order to fulfil the farmers' requirements and the perceived benefits of AACTS associated with their real needs. As stated earlier, the data collection should be in the format of semi-structured interview as the interviewees can express their own opinion towards the innovation without being influenced by the interviewer.

This research demonstrated that the Analytical Hierarchy Process (AHP) can be used at the evaluation process to understand how the potential adopters judge the innovation in comparison with the conventional system/method. For this research the AHP was particularly valuable to combine the quantitative and qualitative criteria of AACTS. The AHP model allowed measurement of the farmers' preference towards the sprayer with and without AACTS in terms of the criteria presented. The use of the AHP is only valuable when the criteria of the innovation are correctly established. The selection of the appropriate criteria is crucial for the reliability of the results. Therefore, there might have a limitation of using the AHP in the early stages of the product development while the criteria might not be very clear for the researchers. This can be overcome by conducting a number of semi-structured interviews with potential adopters to determine if the perceived criteria are appropriate and to identify others relevant criteria. Hence, the questionnaire development can be difficult and time consuming. One of the disadvantages of the AHP is the length of the questionnaire, it increases as a power function with the number of pairwise comparisons, the more criteria to be measured the larger is the questionnaire. For this research, six criteria were chosen, and it is suggested that this should be the maximum number of criteria to be used as the interview can be long and demanding of the interviewer and interviewee.

The high response rate of the online Contingent Valuation questionnaire (8.9%) showed that there is an opportunity to consult farmers via web provided a small reward is offered. Furthermore, this research showed that instead of gathering an appropriate database of potential respondents, the link to the questionnaire can be announced in a relevant newsletter in order to reach the required number of respondents. However, the use of online CV questionnaire can be limited as the respondents are unfamiliar with the new technology and might not be able to understand the hypothetical scenario. This might increase the probability of bias as the respondents are not sure about the benefits of the technology and particularly if the technology requires high investment cost. It is

recommended that when possible the data collection should be combined with face-to-face or telephone interviews in order to ensure that the farmers understand the new technology which is being assessed.

The format of the willingness to pay question is very important to collect reliable data. For this research the double-bounded dichotomous choice (DBDC) type of question was selected. In this method, the question presents a sequence of two values and ask for “yes” or “no” answer. The second value is conditioned on the respondent’s response to the first value; lower if the first response is “no” and higher if response is “yes”. For this research, an open ended question was asked after the DBDC questions to identify the farmers’ maximum willingness to pay for the AACTS. The use of the open ended question was found to be particularly appropriate as greater precision was obtained in comparison with the results of the DBDC.

### **9.9 The role of the Agrochemical Companies**

In order to be possible to use the AACTS, it is crucial to identify the agrochemicals containers with a robust and reliable identifier. It was proved that RFID labels are efficient identifiers for agriculture environment (Watts, 2004 and Peets, 2009). Peets (2009) has proved that the AACTS would assist the farm sprayer operator to load the sprayer, in addition, this work identified that the farmers perceived the benefits provided by the automatic data collection. In order to encourage the agrochemical companies to implement RFID to its products, they should be informed of this development and its benefits. Furthermore, the RFID labels could avoid product counterfeit. According to European Crop Protection Association Report (2008), 5-7% of annual pesticide turnover in Europe (worth €360-510 million) is affected by illegal pesticide, particularly in eastern Europe, as much as 25% of the market could be counterfeit, while illegal products account for about 2% of the UK market.

## 10 Conclusions and recommendations

### 10.1 Conclusions

From the programme of work to explore the acceptance of on farm automated traceability systems the following conclusions can be drawn.

1. The agri-food industry supports the need for an automated agrochemical traceability system and will accept the new technology if it can reduce the cost, time, business risk and/or increase value of certified produce.
2. Nine out of ten farm sprayer operators interviewed after using the AACTS perceive the advantages of having the sprayer with AACTS. The weighted ranking of the sprayer with AACTS was greater than the sprayer without the AACTS at 0.68 opposed to 0.32 respectively. The sprayer with AACTS has a higher weight mean on all the listed attributes with the exception of the 'easy of retrieval of agrochemical data'. This later point raises the issues concerning computerised systems which are perceived as a barrier to adoption by those who do not use a computer to maintain the spray records.
3. Potential users identified the benefits of the AACTS as:
  - a. Improvement to stock control in the chemical store from the use of RFID labels on the agrochemical containers.
  - b. Avoidance of the use of incorrect agrochemicals by prompting an alert on the user interface screen. The use of the AACTS could potentially avoid both the loss of production and damage the environment from using the non specified agrochemical.
  - c. Saving time for record keeping by providing the spray application records electronically.
  - d. Improved accuracy over the currently in use measuring jugs by ensuring that the operator is using the correct number of full cans of agrochemical recommended. The results of Peets (2009) showed that the AACTS has a resolution within  $\pm 3.6$  grams when the engine is operating and  $\pm 1$  gram with the engine switched off. .



4. Whilst the concept of the AACTS was accepted by the farmers and the agri-food industry, two improvements were recommended:
  - a. The AACTS should be redesigned in order to allow greater rinsing space to wash out 10 and 20 litre containers.
  - b. The AACTS should allow the use of generic agrochemicals consisting of same active ingredients of the product recommended by agronomist.
5. Due to sensitivity of data disclosure, the marketing campaign should be focused on the listed perceived benefits of the AACTS and not as a tool which helps the farmers to prove the records in order to comply with legislation and quality assurance schemes.
6. The price that a farmer would be willing to pay for the AACTS is positively related to the size of arable holding land, the cost of sprayer and the perception of the need towards the AACTS. Out of the total of 119 online respondents, 42% perceive a need for the AACTS. The demand curve of the AACTS is shown in Figure 13, according to this curve 4.2% of the farmers would buy the AACTS if it costs £3,500, 54% would buy it if it costs 1,500 and 100% would buy it if it costs £200.
7. According to the break-even analysis, which is rather imperfect due to the assumptions that have had to be made, it is not economically viable to sell the AACTS only with new AGCO's sprayers and by retrofitting for AGCO's sprayers manufactured in the previous five years. These two market strategies would be suitable if AGCO uses the AACTS as a market differentiation tool which could consequentially increase the company's market share of self-propelled sprayers. The most profitable scenario would be to make the AACTS available as a retrofit for the whole sprayer market with a third party company manufacturing the AACTS with say 10% lower fixed cost. With this scenario, the most profitable retail price in Europe is £2,000, which would give a total annual profit of £1.25 million if 3,749 units are sold per year.

These analyses are based on a series of assumptions and should not be taken as the absolute position for the final price and market strategy.

8. The analysis of the three farm enterprises (fresh produce, onion production and a cereal farm) demonstrated that the AACTS could avoid market and financial loss for relatively small costs. The investment cost of the AACTS with and without yield mapping system is £7,390 and £3,620. The annual operation cost for an area of 900 hectares are £1.29/ha and £2.37/ha with and without yield mapping system respectively. The annual cost per hectare of the AACTS with the yield mapping system represents 4% of the total potential loss per hectare of winter oats. Furthermore, the time spent typing the agrochemical application records could be minimised by receiving this information electronically. However, the savings will depend on the capability of the computer and its reliability.
9. The consultant agronomist who advises the farmer on agrochemical application plays a key role in the adoption of the AACTS. The job plan could be generated by the agronomist and the farmer would automatically download this information into the AACTS. Thus, after the spray application is conducted, the farm sprayer operator would provide the spray data in the electronic format to the agronomist and this would print a copy for the farmer. This would give the agronomist the responsibility of handling all the electronic data.
10. The results have demonstrated that through the selection of the methods chosen a detailed knowledge of the attributes of the food industry, the farm perceptions of new technology and their “willingness to pay” have been identified. These methods, whilst frequently used by social scientists/marketers and relatively infrequently used in the agricultural machinery industry, and information gathered from their collective use provide a valuable suite of methods for product development.

Whilst the collected data was based on surveys and investigations conducted in the United Kingdom, many of the issues have wider international significance. However, parallel studies should be conducted in others markets using the protocols developed for a full understanding.

## **10.2 Recommendations for future work**

1. The AACTS should be redesigned in order to allow greater rinsing space to wash out 10 and 20 litre containers. This information has also been reported to Peets

(2009) for including in his design recommendations.

2. Seventeen out of 27 farmers are willing to buy the AACTS considering that the recommended improvements are incorporated. However, further research should be conducted focusing if the farmers that would consider buying the AACTS would also consider buying a different sprayer brand in order to get the AACTS.
3. The analysis of the Contingent Valuation (CV) to pre-test-market provided a preliminary indication of the farmers' value for the AACTS. However, it would be worth conducting face-to-face interviews with farmers using the CV methodology presented in this study to identify a difference or change in the demand curve and willingness to pay. Furthermore, the interviews should be conducted with farmers in other countries and continents that have high shares in the agribusiness market, such as South and North America, Europe and Australia.
4. It is suggested that the AACTS should be linked with auto boom shut-off. This would more precisely apply agrochemical in the field and consequentially reduce the over-dosed areas.
5. The data from previous "as applied maps" should be used in conjunction with the following spray applications. This combination would allow the system to use previous knowledge to identify the actual sprayer area of the specific field and do not treat it as an over-dosed.
6. The AACTS should allow the use of generic agrochemicals consisting of same active ingredients of the product recommended by agronomist. A generic agrochemical database should be produced and promulgated through the industry. The software and appropriate database should be programmed to enable the identification of the corresponding generic product. However, there should be a warning on the screen information the operator that he will be responsible for the decision to use the generic product instead of the product recommended by the agronomist. This would ensure that the operator deliberately wants to use a generic product.
7. The data collected by the AACTS should be compatible with existing farm software. In the UK, the most commons software used by farmers is Farmade and Muddy Boots.

8. It is worth considering a non ISOBUS version of the AACTS for the retrofit market.

## References

- Adrian, A. M., Norwood, S. H., Mask, P. L. (2005), "Producer's perceptions and attitude towards precision agriculture technologies", *Computers and Electronics in Agriculture*, vol. 48, pp. 256-271.
- ALCUE-FOOD. (2005), *Project Summary*. [Online] (Updated 2005) Available at: [www.alcuefood.org/online/site](http://www.alcuefood.org/online/site) [Accessed 7 July 2009]
- An, Y. (2000), "A semi parametric distribution for willingness to pay and statistical inference with dichotomous choice contingent valuation data", *American Journal of Agricultural Economics*, vol. 82, pp. 487-500.
- Anon. (2005), *GM Contamination Report 2005*, GeneWatch UK & Greenpeace International, UK.
- Anon. (2004), *Food Traceability and Assurance in the Global Food System - Farm Foundation's Traceability and Assurance Panel Report*, Farm Foundation, Oak Brook, U.S.
- Anstey, M. (1993), *A study of receptivity and technology transfer in small engineering companies* (PhD thesis), Cranfield University, Cranfield.
- Arrow, K., Solow, R., Leamer, E., Portney, P., Radner, R. and Schuman, H. (1993), "Report of the NOAA Panel on Contingent Valuation", *US Government Federal Register*, vol. 58, no. 10, pp. 4601-4614.
- Atrill, P. and McLaney, E. (2002), "Cost-volume-profit analysis", in *Management Accounting for Non-specialists*, Third Edition ed, Pearson Education Limited, Essex, UK, pp. 37-46.
- Auernhammer, H. (2002), "The Role of Mechatronics in Crop Product Traceability", *Agricultural Engineering International: the CIGR Journal of Scientific Research and Development*, vol. IV
- Bank of England. (2007) "News Release Bank of England Maintains Bank Rate at 5.75%" [Online] (Updated 2 August 2007) available at: <http://www.bankofengland.co.uk/publications/news/2007/081.htm> [accessed 10 August 2007]
- Bank of England. (2008), "New Releases Bank of England Maintains Bank Rate at 5%" [Online] (Updated 4 September 2008) available at: <http://www.bankofengland.co.uk/publications/news/2008/045.htm> [accessed 30 April 2009]
- Bateman I., Carson, R. T., Brett D., Hanemann, M., Hanley N., Tannis H., Jones-Lee M., Loomes G., Mourato S., Ozdermiroglu E., Sugden R. and Swanson J. (2002), *Economic Valuation with Stated Preference Techniques: A Manual*, Edward Elgar, Cheltenham, UK.

- 
- Bennett, J. (2005), *Choice modelling: A step-by-step guide by Jeff Bennett*, [Online] (Updated April 2005) Available at: [https://www.epa.qld.gov.au/publications/p01585aa.pdf/Choice\\_modelling\\_A\\_stepb\\_ystep\\_guide\\_by\\_Jeff\\_Bennett.pdf](https://www.epa.qld.gov.au/publications/p01585aa.pdf/Choice_modelling_A_stepb_ystep_guide_by_Jeff_Bennett.pdf) [accessed 8 January 2008].
- Blackburn, D. W. K., Peets, S., Gasparin, C. P. and Godwin, R. J. (2008), "Application for radio frequency Identification for agricultural traceability systems", In: *Proceedings of 9th International Conference on Precision Agriculture*, 20-23 July 2008, Denver, USA, edited by R. Kholsa. USA: Colorado State University
- Bodria, L. (2003), "System Integration and Certification. The Market Demand for Clarity and Transparency - Part 2", *Agricultural Engineering International: the CIGR Journal of Scientific Research and Development*, vol. V.
- Bolloju, N. (2001), "Aggregation of analytic hierarchy process models based on similarities in decision makers preferences", *European Journal of Operation Research*, vol. 128, no. 3, pp. 499-508.
- Bredahl, M., Northen, J., Boecker, A. and Ormile, M. (2001), *Consumers Demand Sparks the Growth of Quality Assurance Scheme in the European Food Sector*, WRS-01-1, ERS/USDA, U.S.
- British Standards Institution, 2007 BS ISO 11783-1:2007. *Tractors and machinery for agriculture and forestry – Serial control and communications data network – Part 1: General standard for mobile data communication*. London: BSI
- Cameron, T. A. and James, M. D. (1987), "Estimating Willingness to Pay from Survey Data: An Alternative Pre-Test-Market Evaluation Procedure", *Journal of Marketing Research*, vol. XXIV, pp. 389-395-389-395.
- Choi, K. S., Lee, K. J. and Lee, B. W. (2001), "Determining the value of reductions in radiation risk using contingent valuation method", *Annals of Nuclear Energy*, vol. 28, pp. 1431-1445.
- Clark, T., Jeffrey, P. and Stephenson, T. (2000), "Complex agendas for new technology adoption in the UK water industry", *Technovation*, vol. 20, no. 5, pp. 247-256.
- Codex Alimentarius. (2006), *Understanding Codex Alimentarius*. [Online] (Updated 2006) Available at: [ftp://ftp.fao.org/codex/Publications/understanding/Understanding\\_EN.pdf](ftp://ftp.fao.org/codex/Publications/understanding/Understanding_EN.pdf) [Accessed 6 July 2009]
- Co-Extra. (2006), *Project Summary*. [Online] (Updated May 2009) Available at: [http://www.coextra.eu/project\\_description/](http://www.coextra.eu/project_description/) [Accessed 6 July 2009]
- Collins, J. (2004), "Tesco Begins RFID Rollout", *RFID Journal*, [Online] (Updated 28 September 2004) Available at: <http://www.rfidjournal.com/article/articleprint/1139/-1/1/>. [accessed 23 March 2009]
-

- 
- Collins, J. (2005), "SYSCO Gets Fresh with RFID", *RFID Journal*, [Online] (Updated 13 June 2005) Available at: <http://www.rfidjournal.com/article/articleprint/1652/-1/4/>. [accessed 23 March 2007]
- Daberkow, S.G., McBride, W.D. (2003). "Farm and operator characteristics affecting the awareness and adoption of precision agriculture technologies in the US" *Precision Agriculture*, vol. 4, pp. 163–177
- DEFRA (2002), *Farm business use of Information Technology in England*. [Online] Available at: <https://statistics.defra.gov.uk/esg/publications/fiuk/2002/a2.pdf> [accessed 16 April 2009]
- DEFRA (2006), *Code of practice for using plant protection products*, PB 1109, DEFRA, London, UK
- DEFRA (2008), *Sustainable Farming and Food Strategy*. [Online] (Updated 4 November 2008) Available at: [https://statistics.defra.gov.uk/esg/indicators/d107\\_data.htm](https://statistics.defra.gov.uk/esg/indicators/d107_data.htm) [accessed 8 May 2009].
- Diederer, P., Van Meijl, H. and Wolters, A. (2003), "Modernisation in agriculture: What makes a farmer adopt an innovation?", *International Journal of Agricultural Resources, Governance and Ecology*, vol. 2, no. 3-4, pp. 328-342.
- DNA-TRACK. (2003), *Scientific and Technological Objectives*. [Online] (Updated 2003) Available at: <http://www.dsa.unipr.it/foodhealth/dna-track/home.htm> [Accessed 6 July 2009]
- Douthwaite, B., Keatinge, J. D. H. and Park, J. R. (2001), "Why promising technologies fail: the neglected role of user innovation during adoption", *Research Policy*, vol. 30, no. 5, pp. 819-836.
- Douthwaite, M. B. (2002), *Enabling innovation: a practical guide to understanding and fostering technological change*, Zed Books in association with Cambia, Canberra; Distributed in the USA exclusively by Palgrave, London : New York; New York.
- EAN.UCC (2003), *EAN.UCC Traceability Implementation*. [Online] (Updated February 2003) Available at: [http://www.gs1uk.org/uploaded/doc\\_library/Traceability%20guidelines340.pdf](http://www.gs1uk.org/uploaded/doc_library/Traceability%20guidelines340.pdf) [accessed 20 October 2006]
- Environment Agency (2006), *Good Farming, Better Environment*, Environment Agency, Bristol.
- European Crop Protection Association (2008), *Counterfeit Pesticide Across Europe - 2008*, PP/08/RB/17853, Brussels, Belgium.
- Farmers Weekly. (2009) "HGCA Grain" [Online] (Updated 23 April 2009) available at: <http://www.fwi.co.uk/gr/fwihgcagrains.pdf> [accessed 30 April 2009]
-

- 
- Fearne, A. and Walters, R., 2004. The Cost and Benefits of Farm Assurance to Livestock Producers in England, Centre for Food Chain Research, Imperial College London.
- Feder, G. and Umali, D. L. (1993), "The adoption of agricultural innovations: A review", *Technological Forecasting and Social Change*, vol. 43, no. 3-4, pp. 215-239.
- Feigenbaum, A. V. (1991), *Total quality control*. 3rd ed. McGraw-Hill, Singapore
- Fernandez-Cornejo, J. (2007), *Off-Farm Income, Technology Adoption, and Farm Economic Performance*, [Online] (Updated February 2007) Available at: <http://www.ers.usda.gov/publications/err36/err36.pdf> [accessed 1 July 2009]
- Foddy, W. (1993), "The open vs. closed questions debate", in *Constructing questions for interviews and questionnaires: theory and practice in social research*, Cambridge University Press, Cambridge, pp. 126-152.
- Food Standard Agency (2002), *Traceability in the Food Chain; A preliminary Study*, [Online] (Updated March 2002) Available at: <http://www.food.gov.uk/multimedia/pdfs/traceabilityinthefoodchain.pdf> [accessed 17 September 2006].
- Food Standard Agency (2004), *Update on Traceability in the Food Chain*, INT 04/10/07, Food Standards Agency.
- Food Standard Agency (2006), *Consumer attitudes to food Standard 2005*, [Online] (Updated February 2006) available at: <http://www.food.gov.uk/multimedia/pdfs/casengreg05.pdf> [accessed 20 October 2006].
- FoodTrace (2004), *FOODTRACE Generic Framework*. [Online] (Updated 12 May 2004) Available at: <http://www.eufoodtrace.org/framework/FOODTRACE%20Generic%20Framework-Final%20Approval.pdf> [Accessed 6 July 2009]
- Ghadim, A. K. and Pannell, D. J. (1999), "A conceptual framework of adoption of an agricultural innovation", *Agricultural Economics*, vol. 21, no. 2, pp. 145-154.
- Godwin, R. J. (2007), "Advances in Labour and Machinery Management for a Profitable Agriculture and Forestry", *Agricultural Engineering International: the CIGR EJournal*, vol. IX.
- Golan, E., Krissoff, B., Kuchler, F., Calvin, L., Nelson, K. and Price, G. (2004), *Traceability in the U.S. Food Supply: Economic Theory and Industry Studies*, 830, USDA/Economic Research Service, Washington, DC, U.S.
- Grandzol, J. R. (2005), "Improving the Faculty Selection Process in Higher Education: A Case for the Analytic Hierarchy Process", *IR Applications*, vol. 6.



- 
- Gray, A., Boehlje, M., Amanor-Boadu, V. and Fulton, J. (2004), "Agricultural innovation and new ventures: Assessing the commercial potential", *American Journal of Agricultural Economics*, vol. 86, no. 5, pp. 1322-1329.
- Greengard, S (2007), "Wells' Dairy Milks RFID for Benefits", *RFID Journal*, [Online] (Updated 15 January 2007) Available at: <http://www.rfidjournal.com/article/articleprint/2907/-1/4/>. [accessed 23 March 2007]
- Hanemann, M. (1984), "Welfare evaluations in contingent valuation experiments with discrete responses." *American Journal of Agricultural Economics*, vol. 663, pp. 32-41.
- Hanemann, W. M. and Kanninen, B. J. (1996), "The statistical analysis of discrete-response CV data," *CUDARE Working Paper Series 798*, University of California at Berkeley, Department of Agricultural and Resource Economics and Policy.
- Hanemann, M., Loomis, J. and Kanninen, B. (1991), "Statistical efficiency of double-doubled dichotomous choice contingent valuation", *American Journal of Agricultural Economics*, vol. 73, pp. 1255-1263.
- Holden, P. D. (1991), *A multiple perspective approach towards the assessment and development of expert systems in manufacturing* (PhD thesis), Cranfield University.
- Hook, S. C. W. (2004), *A national grain sampling and analysis system for improved food marketing and safety*, Project 270, Home-Grown Cereals Authority (HGCA).
- Hutchinson, G., Scarpa, R., Chilton, S. and McCallion, T. (2001), "Parametric and non parametric estimates of willingness to pay for forest recreation in Northern Ireland: a discrete choice contingent valuation study with follow-ups", *Journal of Agricultural Economics*, vol. 1, pp. 104-122.
- International Standards Office, 2005. ISO 22000:2005. *Food safety management systems - Requirements for any organization in the food chain*, UK.
- International Standards Office, 1995. EN ISO 8402:1995. *Quality management and quality assurance - Vocabulary*, UK.
- International Standards Office, 2007. ISO 22005:2007. *Traceability in the feed and food chain - General principles and basic requirements for system design and implementation*, UK
- Jeffrey, P. and Seaton, R. A. F. (2004), "A Conceptual Model of "Receptivity" Applied to the Design and Deployment of Water Policy Mechanism", *Environmental Sciences*, vol. 1, no. 3, pp. 277-300.
- GeoTraceAgri. (2005), *Geotraceability: an innovative concept for the qualification of crop production*. [Online] (Updated March 2005) Available at: [http://www.geotraceagri.net/doc/GeoTraceAgri\\_Finalreport\\_EN.pdf](http://www.geotraceagri.net/doc/GeoTraceAgri_Finalreport_EN.pdf) [Accessed 6 July 2009]
-

- 
- GLOBALGAP. (2009), *About Us*. [Online] (Updated 2009) Available at: [http://www.globalgap.org/cms/front\\_content.php?idcat=2](http://www.globalgap.org/cms/front_content.php?idcat=2) [Accessed 6 July 2009]
- Jochinke, D. C., Noonon, B. J., Wachsmann, N. G. and Norton, R. M. (2007), "The adoption of precision agriculture in an Australian broadacre cropping system- Challenges and opportunities", *Field Crops Research*, vol. 104, no. 1-3, pp. 68-76.
- Jorgenson, B., Pape, W., Boyle, R. and Pauwels, J. (2003). Who pays for traceability?, *Food Traceability Report* [Online] (Updated September 2003) available at: [http://www.deere.com/en\\_US/foodorigins/articleSep03.htm](http://www.deere.com/en_US/foodorigins/articleSep03.htm) [accessed 5 November 2007]
- Khan, F. (2004) "Chip Maker Tries "Snack and Trace"", *RFID Journal*, [Online] (Updated 31 May 2004) available at: <http://www.rfidjournal.com/article/articleprint/964/-1/4/>. [accessed 27 March 2007]
- KPMG (2000), *Customer Loyalty & Private Labels Products*, London, UK.
- Kunisch, M., Frisch, J., Martini, D. and Bottinger, S. (2007), *agroXML - a standardized language for data exchange in agriculture*, IT Food Trace.
- Lefever, D. B. (1992), *Technology transfer and the role of intermediaries* (PhD thesis), Cranfield University, Cranfield, UK
- Linkov, I., Satterstrom, F. K., Kiker, G., Batchelor, C., Bridges, T. and Ferguson, E. (2006), "From comparative risk assessment to multi-criteria decision analysis and adaptive management: Recent developments and applications", *Environment International*, vol. 32, no. 8, pp. 1072-1093.
- Llewellyn, R. S. (2007), "Information quality and effectiveness for more rapid adoption decisions by farmers", *Field Crops Research*, vol. 104, no. 1-3, pp. 148-156.
- Loureiro, M. L. and Umberger, W. J. (2007), "A choice experiment model for beef: What US consumer responses tell us about relative preferences for food safety, country-of-origin labelling and traceability", *Food Policy*, vol. 32, no. 4, pp. 496-514.
- Lupien, J. R. (2005), "Food quality and safety: traceability and labelling", *Critical Reviews in Food Science and Nutrition*, vol. 45, no. 2, pp. 119-123.
- Maguire, S., Earl R., Smith, D. F., Cripsey P and Godwin R. J (2003), "Technology for variable rate precision drilling of onions", in J V Stafford and A Werner (eds.), Berlin, Germany, Wageningen Academic Publishers, The Netherlands, .
- Mannestro, G. and Loomis, J. B. (1991), "Evaluation of mail and in-person contingent value surveys: Results of a study of recreational boaters", *Journal of Environmental Management*, vol. 32, no. 2, pp. 177-190.
-

- 
- Marta-Pedroso, C., Freitas, H. and Domingos, T. (2007), "Testing for the survey mode effect on contingent valuation data quality: A case study of web based versus in-person interviews", *Ecological Economics*, vol. 62, no. 3-4, pp. 388-398.
- McBratney, A., Whelan, B., Ancev, T. and Bouma, J. (2005), "Future directions of precision agriculture", *Precision Agriculture*, vol. 6, no. 1, pp. 7-23.
- McLeod, D. and Bergland, O. (1999), "Willingness-to-Pay Estimates Using the Double Bounded Dichotomous Choice Contingent Valuation Format: A Test for Validity and Precision in a Bayesian Framework.", *Land Economics*, vol. 75, no. 1, pp. 115-25.
- McMahon, P., Moran, D., Sutherland, P. and Simmonds, C. (2000), "Contingent valuation of first-time sewerage provision in South-East England", *Journal of the Chartered Institution of Water and Environmental Management*, vol. 14, no. 4, pp. 277-283.
- Miles, M. B. and Huberman, A. M. (1994), *Qualitative Data Analysis*, Second Edition, SAGE Publications, London.
- Mitchell, R.C. and Carson, R.T., (1989), *Using Surveys to Value Public Goods: The Contingent Valuation Method*, Washington, D.C.
- Moore, M. (2008), *Precision Farming in England*. AGCO (Personal communication, 20 June 2008).
- Naas, I. A., Campos, S. G. C. and Silva K.O. (2005), "Comparison of Manual and Electronic Traceability in Swine Production", *Agricultural Engineering International: the CIGR EJournal*, vol. VII, Manuscript IT 05 001.
- Neuman, W. L. (2003), *Social Research Methods: qualitative and quantitative approaches*, Fifth Edition, Logman, United States of America.
- Nilsson, H., Tunçer, B. and Thindell, A. (2004), "The use of eco-labelling like initiatives on food products to promote quality assurance - is there enough credibility?", *Journal of Cleaner Production*, vol. 15, no. 2, pp. 517-526.
- Nix, J. (2007), *Farm Management Pocketbook*, 37th ed, Imperial College London Wye Campus, London.
- Nix, J. (2008), *Farm Management Pocketbook*, 38th ed, Imperial College London Wye Campus, London.
- Office of Public Sector Information (2004), *The General Food Law Regulation 2004 178/2002*. [Online] (Updated 14 December 2004) Available at: <http://www.opsi.gov.uk/si/si2004/20043279.htm> [accessed 15 June 2006]
- Oger, R. (2005), *The GTIS-CAP Project, geographical origin of food crops and corresponding quality indicators*. [Online] (Updated January 2005) Available at:
-

- 
- <http://www.gtis-cap.net/publications/GTIS-project-Brussels2005.pdf> [Accessed 6 July 2009]
- OLIV-TRACK. (2004), *Scientific and Technological Objectives*. [Online] (Updated 2004) Available at: <http://www.dsa.unipr.it/foodhealth/oliv-track/objectives.html> [Accessed 6 July 2009]
- Payne, D., (2006), *Discussion on quality assurance schemes*. Syngenta (Personal Communication, 8 August 2006)
- Pearce, D.; Atkinson, G. and Mourata, S. (2006), *Cost Benefit Analysis and the Environment: Recent Developments*, OECD Publishing, Paris.
- Peets, S., Gasparin, C. P. and Blackburn, D. W. K. a. G.,R.J. (2007), "RFID tags for identifying and verifying agrochemicals in traceability systems", In: *Proceeding of the 6<sup>th</sup> European Conference on Precision Agriculture*, 3-6 June 2007, Skiathos, Greece, edited by J.V. Stafford. Netherlands: Wageningen Academic Publishers, p.801-808
- Peets, S., Blackburn, D. W. K., Gasparin, C. P. and Godwin, R. J. (2008), "Development of an Automatic Agrochemical Recording System for Crop Sprayers", In: *Proceedings of the 9<sup>th</sup> International Conference on Precision Agriculture* 20-23 July 2008, Denver, USA, edited by R. Kholsa. USA: Colorado State University
- Peets, S., (2009), *Specification, design and evaluation of an automated agrochemical traceability system*. (PhD thesis), Cranfield University, Cranfield, UK.
- Pesticide Safety Directorate (2008), *Better Regulation, Compliance & Enforcement Strategy*, [Online] (Updated 25 February 2008) Available at: [http://www.pesticides.gov.uk/uploadedfiles/Web\\_Assets/PSD/PSD\\_Better\\_Regulation\\_Compliance\\_Enforce\\_ent\\_Strategy\\_\(25-02-08\).pdf](http://www.pesticides.gov.uk/uploadedfiles/Web_Assets/PSD/PSD_Better_Regulation_Compliance_Enforce_ent_Strategy_(25-02-08).pdf) [accessed 03 March 2009]
- Peter Project. (2006), *Promoting European Traceability Excellence & Research*. [Online] (Updated April 2008) Available at: <http://www.eu-peter.org/PETERbrochure.pdf> [Accessed 6 July 2009]
- Pierce, F. J. and Cavalieri, R. P. (2002), "Globalization and Traceability of Agricultural Production: the Role of Mechanization", *Agricultural Engineering International: the CIGR Journal of Scientific Research and Development*, vol. IV.
- Price, R. (2007), *Farm Software Providers: Data Format*. Patchwork. (Personal communication, 9 July 2007)
- Public Health Security and Bioterrorism Preparedness and Response Act of 2002 (The Bioterrorism Act)* (2002), 107th Congress ed., Public Law 107-188.
- Reaves, D. W., Kramer, R. A. and Holmes, T. P. (1999), "Does Question Format Matter? Valuing an Endangered Species", *Environmental and Resource Economics*, vol. 14, pp. 365-383-365-383.

- 
- RFID News. (2008), *Report: Europe's RFID market share 40% by 2016*, [Online] (Updated 7 July 2008). Available at: <http://www.rfidnews.org/2008/07/07/report-europes-rfid-market-share-40-by-2016> [accessed 27 March 2009].
- Roberti, M. (2005), *Wal-Mart To Expand RFID Tagging Requirement*, *RFID Journal*. [Online] (Updated 14 October 2005). Available at: <http://www.rfidjournal.com/article/view/1930/1/1> [accessed 9 May 2008]
- Robson, C. (2002), *Real world research: a resource for social scientists and practitioner-researchers*, 2nd ed, Blackwell Publishers, Malden, Mass.; Oxford.
- Rogers, E. M. (2003), *Diffusion of innovations*, 5th ed, Free Press, New York.
- Saaty, T. L. (1980). *The Analytic Hierarchy Process*, Mc Graw-Hill, USA.
- Salant, P. and Dillman, D. A. (1994), *How to Conduct Your Own Survey*, New York: John Wiley & Sons, Inc.
- Sarig, Y. (2003), "Traceability of Food Products", *Agricultural Engineering International: the CIGR Journal of Scientific Research and Development*, vol. Invited Overview Paper. Vol. V.
- SEAFOODplus. (2003), *Project Objectives*. [Online] (Updated 2009) Available at: [http://www.seafoodplus.org/RTD\\_objectives.22.0.html](http://www.seafoodplus.org/RTD_objectives.22.0.html) [Accessed 6 July 2009]
- Seaton, R. A. F. (2008), *A working note on receptivity and decision making for ISBP WP3*. Cranfield University, Cranfield, UK.
- Seaton, R. A. F. and Cordey-Hayes, M. (1993), "The development and application of interactive models of industrial technology transfer", *Technovation*, vol. 13, no. 1, pp. 45-53.
- Seaton, R. A. F., Jeffrey, P., Stephenson, T. and Parsons, S. (1998), "From Marketing to Receptivity: Structuring Community Involvement in Integrated Water Management", *WATERTECH 98 Conference on Water Management*, 27-28 April 1998, Brisbane, Australia.
- Syngenta. (2008), *Syngenta Annual Review 2007*, Basel, Switzerland: Syngenta.
- The European Parliament and the Council of the European Union, (2003), *EC Regulation No. 1830/2003 on the traceability and labelling of genetically modified organisms and the traceability of food and feed products produced from genetically modified organisms and amending Directive 2001/18/EC*, Brussels.
- The European Parliament and the Council of the European Union, (2003), *No.1829/2003 on genetically modified food and feed*, Brussels.
- Toyryla, I. (1999), *Realising the potential of traceability* (unpublished Doctor of Technology thesis), University of Technology, Espoo, Finland.
-

- 
- Trace. (2005), *From fork back to farm*. [Online] (Updated January 2005) Available at: [http://www.trace.eu.org/tin/doc/TRACE\\_EC\\_brochure.pdf](http://www.trace.eu.org/tin/doc/TRACE_EC_brochure.pdf) [Accessed 6 July 2009]
- Tsuge, T. and Washida, T. (2003), "Economic valuation of the Seto Inland Sea by using an Internet CV survey", *Marine Pollution Bulletin*, vol. 47, no. 1-6, pp. 230-236.
- U.S. Food and Drug Administration (2006), *Nationwide E.Coli O157:H7 Outbreak: Questions and Answers*. [Online] (Updated 20 October 2006) Available at: <http://www.cfsan.fda.gov/~dms/spinacqa.html#howmany> [accessed 24 July 2007].
- U.S. Food and Drug Administration (2008), *Salmonella Saintpaul Outbreak*, [Online] (Updated 28 August 2008) Available at: <http://www.fda.gov/oc/opacom/hottopics/tomatoes.html> [accessed 6 April 2009].
- Van der Grijp, N., Marsden, T. K. and Cavalcanti, S. (2005), "European Retailers as Agents of Change Towards Sustainability: The Case of Fruit Production in Brazil", *Environmental Sciences*, vol. Volume 2, no. Number 1, pp. 31-46.
- Vorman, J. (2000), *Star Link Recall Climb 300 Different Items*. [Online] (Updated 01 November 2000) Available at: <http://www.organicconsumers.org/ge/starlink300.cfm> [accessed 22 March 2009].
- Wang, N., Zhang, N. and Wang, M. (2006), "Wireless sensors in agriculture and food industry - Recent development and future perspective", *Computers and Electronics in Agriculture*, vol. 50, no. 1, pp. 1-14.
- Watts, A. J. (2004), *The monitoring and control of chemical inputs to arable farming systems*. (EngD thesis), Cranfield University at Silsoe, Silsoe, UK.
- Whynes. D.K., Wolstenholme. J.L. and Frew. E. (2003), "Evidence of range bias in contingent valuation payment scales", *Health Economics*, vol. 13, no. 2, pp. 183-190.
- William, R. (2007), *ISOBUS 101: understanding the implement and aftermarket electronics Controller Area Network (CAN) will help dealers explain ISOBUS equipment to customers*. [Online] (Updated 01 March 2007) Available at: <http://www.thefreelibrary.com/ISOBUS+101%3a+understanding+the+implement+and+aftermarket+electronics...-a016326434> [accessed 03 May 2009]
- Willgoss, P. (2005) *Traceability Systems*. Marks & Spencer (Personal communication, 2005)
- Yin, R. K. (1994), *Case study research: design and methods*, second edition ed, SAGE Publication, London.
- Yoo, S. (2002), "Extending dichotomous choice contingent valuation methods to pre-test-market evaluation: the case of a cable television service", *Applied Economics Letters*, vol. 9, pp. 315-318.
-

Zahedi, F. (1986), "The analytic hierarchy process - a survey of the method and its application", *Interfaces*, vol. 16, no. 4, pp. 96-108.

Zaske, J. (2003), "Mechanization and Traceability of Agricultural Production: a Challenge for the Future. System Integration and Certification. The Market Demand for Clarity and Transparency—Part 1", *Agricultural Engineering International: the CIGR Journal of Scientific Research and Development*, vol. V.

## **Appendix A. Interviews Transcripts, stakeholders**

### **Interview with Respondent A**

#### **I: Have you had previous experience with traceability systems?**

R: The traceability here starts with the Field Planting Records. The grower records their planting information on the planting record sheet. The sheet contains the grower name, field name and field number and then lists the plots within the field, detailing the number of rows, variety, plant date, plot size, plant density information (plant per hectare and/or total plant tray count) and the plant, seed batch number, which links the plants back to the original batch information. The planting record sheet is then forwarded, via fax e.mail or post onto THC. The planting record is manually entered in the system.

Along with the planting record the growers send the chemical/fertilizer applications information. Clements's staff input the information such as grower name, field, plot, agrochemical used and days of application. The rates are visually checked to ensure they are safe recommended rates. I see a great benefit to have an automatic traceability system to provide this information electronically.

We use the Muddy System to make a plan to put the pesticides at the crop. We would like that the grower could log on to their system and put the information themselves. Crops are monitored as they mature by the fieldsmen. The farmer sends in a permission to harvest sheet that lets they know that they are then allowed to go in and cut their crop. The fieldsmen provides the cutting sheet to the weighbridge staff as information prior to harvesting, so at they are prepared for the days produce to be received. After harvesting, a field activity report is filled out detailing the grower name, field, plot, starting and finishing time, gang, quantities cut and packaging used. When the produce is weigh at weighbridge it receives a unique identification number in a bard code label. This constitutes what is known as a consignment - Produce from the same field and plot cut in one session on one rig and delivered back to the yard. The bar code holds the consignment number and the farm name and plot.

The harvest dates is monitored according to the Field Activity Report and the days of application. If the rig arrive at weighbridge with a crop from a field plot that were not allowed to be cut because of the minimum interval of application they don't accept it. The crops are monitored as they approach maturity by the fieldsmen.

Information required by Clements: Field plot – Crop – Chemical (check if it is approval) – Rates – Grower - Harvest interval - Dates of application

#### **I: What problems or benefits do you see from viewpoint of the rest of the industry if a system were available to automatically record inputs onboard a spraying vehicle.**

R: The cost of the GPS, hardware/software necessary to have automatic traceability can not exceed the cost of employ people to do it. Our system doesn't rely on technology but on what people write on piece of paper. Currently the cost is to employ people to work to input all the data manually. The system can't impact on the cost they have to



employ people to do it manually. The automation would be great providing it could be done in the right price.

We are not concern with maximum or minimum application, but I believe that the grower want to have this information. If the grower could guarantee the amount of agrochemical applied in the field it would be a great benefit. The grower must keep the records of the amount of chemical received and the amount the chemical used. So if they behave irresponsible he should have a gap somewhere. Clement does residue test all the time. Tesco assurance requires that the farmers have agronomist's recommendation. Clements rely on the farmers are following the agronomist's recommendation but they don't know that something goes wrong unless the audit show.

From 52 growers in the UK, around 15 are automated, the rest are still working with pen and paper. The system has to be simple and cheap. System that can be multiple input, a system that can be use by everyone. The farmers can't hire somebody almost to do nothing else, just to use the system. The system need to have automatic failsafe, to prevent to over application. We would like to have a reporting system to inform if something happened.

We got 30 tractor harvesting and one spraying tractor. Colleting information at the application stage would be relative cost effective. Application is around 10 times per crop. The application end could be very useful. So we could use the as applied map to prove the application in the field.

**I: Commercial benefit or an infringement of personal/commercial liberty?**

R: We gain a lot of business with the initial traceability system. We gained Tesco's confidence, because we are able to protect them and we are able to prove what we do. If our residue test has failed and Tesco detected the over application they keep this information between Tesco and us. If we detect the over applications at the residue test here then we can check the farmer record and figure out what happened. Tesco needs to identify where their business present a risk. We need to show the list of the chemicals we want to apply at the crop, so they access the risk.

**I: Would a Clearing House useful to collect and certify the information?**

R: I am not sure what we would do with it. Tesco don't even collect the consignment details we send. Tesco is only interested in delivery details, such as product code, quantity, order number and date of delivery. Tesco assume that Clements has an efficient traceability system, but they don't require the information with all delivery, they just assume that Clements can retrieve information whenever they really need it using the consignment number.

**I: What are the trends for the future?**

R: We are concentrated in the field side. We need improve the logistics in the field. A protocol that helps us moving into different plot, because there are different trays in the rig and it is easily mixed. When the produce arrives at Clements the produce are encoded at the weighbridge and they need to rely on the tractor operator to encode the right tray.

**Interview with respondent B**

**I: Have you had previous experience with traceability systems?**

R: Muddy Boots Software is a provider of food traceability and quality assurance solutions for the agricultural and food industry. CropWalker records all aspect of the crop production cycle. The concept is to manage the growing activity and provide traceability. Since it is a hand-help computer, the data can be manually entered immediately right after the action. They believe that the data entered after the action is more precise than the data input later in the day at a farm computer.

The CropWalker has been developed to give advisor, agronomist, farmers the ability to carry out all crop-recording task. CropWalker contain a pesticides database called ProCkeck. They update this data base based on the PSD and agrochemical manufacture directory. The grower must to follow the chemical applications protocol of the country to which they will export the produce. If the produce will be exported, it has to follow the country of origin and country of destiny chemical protocols. The structure of the ProCheck is the same, but they maintain locally the database in the countries.

The link of the CropWalker and Produce Manager System is which makes the complete traceability cycle. The farmer sends the data record from the CropWalker to Produce Manager where the food processor can double check the information. They can rerun a pesticide audit on that field record against their own standard and protocol for that particular crop. If a processor has a number of farmers using CropWalker and a number using Farmade it is possible to link this data to the factory managements system using an identification number. Allocation labels that CropWalker or Farmade use to allocate the field record along side a consignment number. So the farmer sends the data to the food processor with that consignment number assign to it. So the processor can allocate this unique number along side with the raw material, this unique number link the field records. Quickfire is a mobile auditing system designed for food and retail technical and quality management. The retail use Quickfire to verify the correct procedures, protocol and standards. It is a check that the retailer can make sure that all the protocol has been followed by the suppliers. It can be Tesco protocol, M&S protocol or EureGap. It captures date, conformities information about the supplier to their customers. It will give the information if a particular supplier can supply a particular retail according to their protocol. It has an audit function to prevent that the agronomist makes pesticides recommendation that are illegal. The system also checks the previous application of a specific pesticide on the crop, timing, and dose rate. It goes through a number of checks if it appropriate put that pesticide on that crop. It give you a projective harvest dates according to the agrochemical application. With this system the retail can monitor their supplier and identify where the risk and weakness is. Quickfire's principle of one time data entry is based around using a mobile device to capture the audit data. Data is uploaded from the device from any location via the web and synchronized into the 'Quickfire manager' database.

**Linking CropWalker to the tractor terminal**

This has been developed in conjunction with Patchwork. The CropWalker sends the operation request to the box that is in the tractor. Then the information comes up in the screen, the tractor driver confirm and start the application. The date and time is recorded according to the job, and it can not be change. Then at the end of the job, it creates the report. The tractor driver needs to input the weather condition, wind speed, etc... this

report is send back to CropWalker. The manager receives the report and agrees or not with the report and confirms the operation. The piece missing is that they need to rely on the driver about the chemical input. They believe that there is no need to have an output format that suit the input format that the retails are using. Because if they need the information the grower can send a report with what have been done.

The project should focus on the protocol and compatibility up to the supplier chain rather than the retail chain. The retailer doesn't want to have the information unless they request it. The reason is because if they receive that data they would be responsible for any issue. The data stops at with farmer. The supplier needs to have the information collected at the farm because if the retailer asks for this, the supplier needs to have this information on hand.

**I: What is the acceptable format for the Crop Management Recommendation delivered by agronomist?**

R: The agronomist usually prints it out and gives it to the farmer or email as a PDF. But the ideal is if both have the CropWalker, so the agronomist can email the data file to the farmer and then he can read the recommendation into his own system.

**I: What technical data is needed to develop new software or to improve current software**

R: CropWalker already captures a vast amount of data, field information which probably satisfy the needs. Traceability is becoming more environmental management rather than just about the production. Decision support system when from the environmental prospective is the best time to apply certain type of nutrient to the soil based on soil type, rain fall; the impact of the activity on that crop and the environmental. Traceability information is less about production and more about how the farmer manages the environmental. If the farmer could demonstrate the decision process in relation with the safety of the food produce and the environmental it would be a great marketing tool.

**I: What problems or benefits do you see from viewpoint of the rest of the industry if a system were available to automatically record inputs onboard a spraying vehicle.**

This system need to able to edit the information after automatic recording. Some customers ask for a system that they can edit the information after recording, after confirming the information they need to be able to go back and edit it, because they might have incorrectly confirmed some wrong information. The issue in having automatic recording system is that it is not editable. But I think it is a great benefit to be able to prove records and avoid paper work.

**I: What are the trends for the future?**

R: In the future there will be much more integration between different operating systems but with the same objective. The tractor could be an essential capture mechanism, not just create the record but confirm it. The tractor driver shouldn't be responsible for the decision, because the numbers of management decisions are increasing and everybody wants to see the decision process. The market wants to know what have been considered to make the final decision to apply a certain amount of

agrochemical on that specific crop. In the future there will be more demand been made on the decision process.

### **Interview with respondent C**

**I: From the viewpoint of the later stages of the food processing industry, in order to deliver ISO 22000 etc, what traceability data should be recorded and what information do you need from the farm to certify traceability? Each one requires more information?**

R: They all require traceability information; the traceability system which exists is in livestock farm. Every cattle in the field is identified with a unique tag and every movement is recorded from his birth and death. The farmer pay high fee if he don't fill the form from each cattle properly. Cattle in this country are very policed. It is been drive by disease. Under the ACCS scheme most farmers will inform what order the field length and the variety. By the time they are loading they have a good idea what they are loading according with the variety and what field(s) it came from. There is no requirement to keep the field separately but the variety. Farmer will invest in better traceability according to the market demand. If the market demands to have the grains separated by field they will do it. They need to see the benefits.

**I: How is the information currently received? Can it be an electronic format, and what moves are already being made in the area?**

R: The Assessment Checklist is on paper. The auditor goes to farm and manually enter the information. The form comes back here we and we grade it. If there are nonconformities we send this other form to the farm and it's up to him to submit the backup evidence. Al the Assessment Checklist and the Nonconformities form are scan here. When the farmer sells their products they show their grade and certification. ACCS got a stick which goes onto every load of grain with an ACC number. We supply the data base to ACCS, so when the processor receives a grain load they can check with ACCS that ACC number. We will go to electronic format. As soon the nonconformities is identified that will be email back to the farmer straight to me I will grade it then it will go onto the system. This would replace our scanning process. The next step would to certify each individual lorry, with a unique tag number where we could check the history of that particularly lorry. So the farmer could have a management system with all the traceability information of that lorry and provide it to us so we could certify.

**I: From your experience with ACCS and beef and lamb schemes, do you think it is possible one standard and methods of information transfer can be developed across "arable", "livestock" and possibly "horticulture" industries?**

R: I don't believe that could happen; we need to maintain the identity. Because there are so many expertises require on each scheme. Genesis, our competition, tried to do that but they ended coming back to each scheme again. What I believe is that we could end up with some main ones in each are. There are many different certification schemes, but only traceability system would be satisfactory

**I: For both paper and electronic data transfer, what thought has been given to signoff / responsibility for data and maintaining integrity as the data moves through systems?**

R: The assessor signs the report and the nonconformities report is signed by assessor and the producer. The spray records have to be sign by the operator, we need to know what was sprayed, quantities and rate. It comes in very different formats, some will add another column and indicated the wind speed and direction. A management system that could prove the veracity of that information would be useful.

The supermarkets don't want to hold the information, all they want to know if it is alright.

**I: What problems or benefits do you see from viewpoint of the rest of the industry if a system were available to automatically record inputs onboard a spraying vehicle**

R: I need to see the system working, but I think that this is manufacture product that is missing on farms. At the moment we rely on the spray operator. The system could identify if the spray wasn't calibrate properly. The accuracy on what has been load would be very good.

**I: Recognizing the general direction of the requirements for information, how can we make the adoption of traceability protocols and appropriate technology attractive to farmers?**

R: The farmers need to see the benefit, especially in the market. I would say that farmers need to see a name like JORDANS (Conservation Grade) stands behind this system so they would have it.

**I: How can traceability information best be provided to obtain value for the final customer? – is there only a role for “certified levels” or should there be direct presentation of the history of a particular food item.**

R: I don't believe that the customers are interested on it, all they want to check is if the product is certified. If we provide all the information the tag would be very extensive. Desirable information on beef would be the head number and the field number where the cattle came from. Then probably with the field number we could have the pesticides and fertilize history. The industry need to see the benefit in term of consumer's confidence, because we can not charger a fee to somebody see the information it need to be free.

**I: Who could be responsible for the Database Maintenance?**

R: It must be a third party, got to be independence. We could do that because it is an extension on what we do. Conservation grade could hold the data base as well.

**Interview with respondent D**

**I: Have you had previous experience with traceability systems?**

R: I am littler involved with onions and potatoes, and there traceability is very important. In arable crops the traceability tends to start from the grain store rather than the field. Some farms do segregation. Every load grain from the combined is analysed as it goes into the store for protein and specific weight. So they can separate according to the quality. But it still means that they are vending bulk from several fields but it has been tested going into store. I still believe that the test has to be done before vending. I don't think any grain trade will buy any bulk only because it came from a field that has

been spraying with an automatic recording system. Only identification is not good enough, they still need to test.

**I: How precise are the recommendations?**

R: I can't tell you how precise are my recommendation, but I would like to think that it is 95-100%. The aim is to achieve an economic return on the inputs which the farmer will apply. My precision is based on economic decision. On fungicides I would be 95% sure. My recommendation sheet varies, some will be the brand name and others will be the active ingredients.

**I: If the system provides a more accurate measure, would the recommendation be less?**

R: If you have the same field on two separated farms you might treat the fields in different ways, depending on the farmer perceptions of what need controlling. The recommendation always depends on the farm. There are some farmers that go spray two weeks after I give the recommendation, the rates are different when I know that he will spray on the same day.

**I: What problems or benefits do you see from viewpoint of the rest of the industry if a system were available to automatically record inputs onboard a spraying vehicle**

R: Farmers are generally not very good on records keeping. With the increasing requirements for keeping records, they have to record things that they are not use to. The spray records are very imprecise. I think automation record in principle farmers would like but I think their concern would be they may record things they don't want recording. I believe that the weather condition would be one of their main concerns. I think 98% would have nothing to hide. Sometimes the farmer comes back to me and says that the recommendation didn't work. What we do is to eliminate all the possible reasons, if they followed the recommendation, rates and the weather condition. We try to eliminate all the possible causes. Automatic recording system would help the agronomist in these cases.

The operator should not apply the product don't have the MAPP/MAFF number. The only issue I see would be things like specific label approval, but then the farmer should have that approval on his desk. There is specific label approval which allows for the farmer to apply a particular product to crop that are not on the MAFF label, but they have approval to use at their own risk.

**I: What is the process for making the Crop Management Recommendation?**

R: It is increasing the number of FARMADE agronomist package. I usually email the recommendation to the client. The only concern I see on having an electronic recommendation (memory card on the sprayer terminal) is that I would have to recommend the MAFF number which will create a lot of work, it is not flexible.

**I: What are the trends for the future?**

R: The farmers will have to accept they need to keep more records; the requirements are increasing every day. I believe that keep records is the best way to improve the management of the crop. The contracts applications are increasing and they are more professional. It will be easier to start the automatic recording system with them.

**Interview with respondent E****I: Have you had previous experience with traceability systems?**

R: Farmade develop software solution to provide component of traceability.

**I: How should we make the information useful on the farmer computer?**

R: The farmer can keep all the information to prove what he has done. The food industry doesn't want the information unless there is a problem. They need access to that data but they don't want the data, they need to know that it is available.

**I: What technical data is needed to develop new software or to improve current software?**

R: Our software covers those part of traceability records which require documentation of field application, harvest operation and storage. To have all the traceability information in one system could be misleading. I believe we are very broad in the type of information we can hold, it would be wrong to assume we have everything, nobody can't hold everything. The entire traceability requires information from many components in the food chain, it is much better to have one system or book for each component, i.e. application record in one system, medical record information in another one and so on.

**I: What is the acceptable format for the Crop Management Recommendation delivered by agronomist?**

R: This should be defined by the crop management software provider. It is much easier to be defined by the software providers because we know our needs. The important is the format of the data and not how it will be transferred.

**I: How should the traceability information be transferred from field to food industry?**

R: I don't know the answer for that question. The only thing I can confirm is that the food industry doesn't want to hold the information, if they need it they will ask for it. The information need to be available. Our system produces a report related to which consignment. The grower can send an email to their customer with the report in PDF format and the data in xml format.

**I: What problems or benefits do you see from viewpoint of the rest of the industry if a system were available to automatically record inputs onboard a spraying vehicle**

R: Could be enormous benefit but should be focus to make the operator life easier and make the recording of information easier. The system needs to be easier to use than pen and paper; otherwise people will not use it. The grower needs to perceive the cost benefit analysis.

It's easy developing a software solution which will create more robust data and it is not editable, but the customers tends no to accept that, unless all the growers are using the same system. The reason is because one grower will not accept a system which is so robust and collects the data and it is unchangeable, knowing that there is another grower supplying the same customer, using a system that is editable and he can change the information if there is any problem with that. It is extremely common to have two

products with exactly the same active ingredient and formulation but only one has crop approval.

The system needs to carry on the crop approval details; because if the operator has to read the label to check if it is approved every time he loads the sprayer tank, there is no difference. The operator can not hold this responsibility. It would be a tremendous advantage if the system could identify the equivalent product recommended. If the agronomist recommends a product, and the farm has the generic, the system could identify and allow the operator to go ahead. When the information comes back to the farm system the data base will be update with the product that was actually applied.

We buy our crop approval data from Centre Science Laboratory. The PSD information is available in a format that is not manageable.

The agronomist recommendation flow is the following: The agronomist issues an instruction. Sometimes the instruction goes straight to the operator but quite often the instruction goes to the farm system and then to the operator. After spraying, the work done need to come back to the farm system, to facilitate this is likely the agronomist issue goes to the farm system for the verification. 90% of the time the route is from the agronomist to farm system to the operator. The easy and fast route is from the agronomist straight to the operator. Some people are already looking for engineering solution to take the farm system out of the loop but the problem is that this way there is no verification before the operation, who will be responsible is something goes wrong? I believe that a recording system which records what actually happened; it is a much simpler, durable and powerful system. This way you would eliminate the issues involve agrochemical crop approval. The agronomist would issue the recommendation to the operator, the operator takes the container, the system identifies, if there is a incorrect active ingredient the system declines it if there is the correct active ingredient the system agrees. Then it is up to the farmer asks to the operator call him if the product recommended is different from the product name on the container. Then the information that comes back to the farm system is what actually happened, and that would be a good help to us. How this data will come back to the farm system, the data format needs to be defined. But the interested club is so huge that is impossible to define a standard format that everybody agreed.

### **Interview with respondent F**

#### **I: Have you had previous experience with traceability systems?**

R: Farm Works is a private USA company. Products now marketed by Farm Works are a mapping and field and chemical record-keeping program; a farm cost accounting package; a herd management program, and a multi-layer, GPS based mapping program. Farm Site Mate utilizes a palm or handheld computer along with a GPS receiver for site specific mapping and scouting in the field. We are focus on the farm side, we not operate beyond farm.

#### **I: How should we make the information useful on the farmer computer**

**R: Internal use:** In order to get the farmers record information it got to be either advantage or necessity. It provides better information for farm management information, financial and meets the market requirements.



**External use:** Provide better information to their partners. It is common practice printed reports but in the future might have some kind of automatic exchange data.

**I: What technical data is needed to develop new software or to improve current software?**

R: The more manufacture can automate the data collection; the more information will be collected and make our job easier. We don't need to provide a system that can provide all the traceability information from the field to the final customer, there are so many requirements, it is almost impossible.

**I: What is the acceptable format for the Crop Management Recommendation delivered by agronomist?**

R: We don't have software for agronomist recommendation. In our system the farmer needs to type the recommendation delivered by the agronomist. We have the facility to import xml format, but we never actually done it. In theory Patchwork can create a job in xml format and then import into our system. We never promote it because nobody asks for it, so we don't know if the data exchange works or not. Xml file would be the best, either transferred electronically, memory card or USB stick.

**I: What problems or benefits do you see from viewpoint of the rest of the industry if a system were available to automatically record inputs onboard a spraying vehicle**

R: It can't be too tight. The information will be more accurate, more valuable and more honest the easier you make for the operator to record. It needs to help the operator and not control him. It needs to be acceptable by those who audit it. The farmer needs to be able to preload the plan. The communication, connected to controller need to be ISOBUS & SERIAL. The numbers of systems that are connected from a terminal to another device probably 95% are serial based at the moment. Easy data transfer back from the tractor terminal. The system can't have any restrictions on changing, amending or filling. The system needs to be efficient; it can't make the operator stop filling the tank. The information need to return to the management system / traceability system.

**I: What are the trends for the future?**

R: We have to figure out how the management system can produce the sales invoice automatically. Then in the future when the operator goes to the tractor terminal and inform with agrochemical he wants to use then the system could go all the way back through the management system, traceability system, who ordering the agrochemicals. We will be able to upload the precision farm information into the Google earth, and downloaded the bdl files and field boundaries. Third part agricultural application ought to be a future trend as well.

**Interview with respondent G**

**I: What problems or benefits do you see from viewpoint of the rest of the industry if a system were available to automatically record inputs onboard a spraying vehicle**

R: The benefits is to identify where a particularly crop come from and then link to what have been applied to that crop. Another benefit would be for manufactures which do residue test and identify higher level of agrochemical on the produce, with an automatic

recording system they could be able to identify each supplier have been applied the high level of agrochemical. If there is a problem with high level of agrochemical the risk is to withdraw more than necessary when you don't know which crop is contaminated.

**I: *Consumer attitudes to food Standard 2005 indicate that chemicals are the key areas where people would like more information from the FSA. – What moves are already being made in that area?***

R: One of strategies from 2005 to 2010 is to set target to reduce the level of contamination. Chemical is our major issue in the food industry at the moment. At the moment we identify the contamination through the residue test, local authorities submit sample to public analyse then if contamination is identified we start to examine in more dept. Once you realise there is a problem you go for more sample and then realize the extension of the problem to our industry. In some case the European commission will determinate that certain type of produce need to be sample for certain type of contamination. It depends on the history of the region and produce.

**I: *What are the penalties for not complying?***

R: The general penalties of the food legislation for unsafe food on magistrate court is £20000 or six month in prison or both, if it was crown court then a nominated fine, two year on prison or both.

**I: *Recognising the general direction of the requirements for information, how can we make the adoption of traceability protocols and appropriate technology attractive to farmers?***

R: If it can limit the damage by having a reasonable traceability system, then the farmer will buy it. If there any problem of contamination in the field then the farmer could withdraw only the produce damaged. This system would be driven by retailers.

**I: *How can traceability information best be provided to obtain value for the final retail customer? – is there only a role for “certified levels” or should there be direct presentation of the history of a particular food item – and if so, who might pay for disseminating such information.***

R: Usually when the consumers shop their time is limited they want to have the information they want to see as visible as possible and shorter is possible. Most consumers are not interested on traceability information, maybe they are interested in information like country of origin. I don't think there is a big market for consumers on traceability information. The consumers would interest to know if the traceability system exist and the product could be withdraw if there is any problem. We got some research on assurance scheme and is clearly that the consumers don't know the difference between them. It dangerous to let the consumers know the particularly farm where the produce come from, because if it is available to consumers it is available to the whole industry and then you fall in to areas of commercial sensitivity.

I don't believe if the industry wants to release this information because other competitors can use this information for their own commercial advantage.

**I: *Who could be responsible for the Database Maintenance?***

R: The database needs to be done on a per supply chain. The information need to be available in 24 hours. Accuracy is to be able to say what is gone where. The traceability

system is only good as we can link chain, there are a lot of weak. A food industry can be pretty confidence where they buying from can we say that they supplier are also confidence with their inputs? Another issue is the internal traceability which is not required by the Food Law Regulation, the industries need to know which produce they process they where they go, otherwise there is no traceability. In case of a withdraw of a product with multiple inputs we have to consider the worst scenario if there is not reliable traceability.

### **Interview with respondent H**

#### **I: Have you had previous experience with traceability systems?**

R: Yes, any number of systems; Babble, Genesis, ACCS. These are all paper systems and they rely on honesty which unfortunately means they can be easily falsified.

#### **I: What are the common forms of agrochemicals: how many % liquids? granules? % powder?**

R: It is 80% liquids and 20% granules. It is changing because they are trying is to concentrate some these liquids into granules to reduce the size of the package.

#### **I: What is the trend for the future?**

R: The trend is towards granulations and small highly potent small amount of chemical.

#### **I: What is the common range of application rate? What is the trend?**

R: The application rate range from 5 to 6 liters per hectare down to 25 grams per hectare.

#### **I: What is the common container size range? What is the trend?**

R: The common container size is 1000 liters IBC down to 150 mole for some products or 60 grams for others.

#### **I: Possibility to identify the container with RFID tag**

R: As long it is not too large that is fine and need to be water proof and chemical proof.

#### **I: What problems or benefits do you see from viewpoint of the rest of the industry if a system were available to automatically record inputs onboard a spraying vehicle**

I don't rely 100% on ProCheck (Muddy Boots). Because sometimes I can not use certain products because it has been revoked and actually it's haven't. I use knowledge, experience and the Green Book. The data base maintenance will be a constant changing because it changes every new season. These changes will not be at the Green Book and the system will not recognize the product. The system need to have a reliable data base, because if the operator needs to type the product manually every time that the system does not recognize the product name it will not be an efficient system he will not use it. If the operator does the job even if the system didn't recognize the chemical and type it manually, how they can stand it? Once the job been done it is too late to somebody verify. The system got to be fool proof. In somewhere need to be a link where by you have applied this chemical, who then make sure that it is recognize before you get on to the reporting stage. Some products don't appear at the PSD list, we need a most comprehensive list than just the PSD.

Is common practice to over-doses an application, because even machinery equipped with GPS can not finish spraying exactly where the first headland finished. The system got to be clever enough to recognize the over-doses in the field. The GPS receiver got to be put on to the sprayer in the right place; it can not be away from the spray vent.

The system need to be perceived by the operator/farmer as a method of checking agrochemical levels in crops and not a system to police his work. Because the person that will verify will not know what happened in the field, they don't understand the logistic in the field. The operator is the only who knows what happened. Farmers growing cereal or combinable crops don't have the pressure that the supermarket suppliers have (fresh produce). The supermarket suppliers have somebody to keep the data base and general requirements of the supermarkets. Cereals supplies can't afford an employee just to making sure if the records are correct. The system has to be simple. The data verification has to be a simple procedure how to verify if a certain unknown chemical is actually approved.

**I: How precise are the recommendations?**

R: The recommendation is very precise. If he supplies a product which requires 15.9 liters, most of the farmers will put 16 liters.

**I: If the system provides a more accurate measure, would the recommendation be less?**

R: No, most of the recommendation they make are reduced doses. The application rate recommended by the manufacture is always more than necessary. As an agronomist based on knowledge and experience gain through research he knows that, i.e. the half of the manufacture recommends is perfectly effective.

**I: Can the recommendation be electronic?**

R: The recommendation goes with the product by fax or email. There are some recommendations with products from different manufacture, some products require adjuvant and some products are not for agronomic use. If you need this electronically, it can not be separate. Usually the farmer likes to be visited by the agronomist, to visually check what's going on in the field. If we considerer the recommendation on a memory card, we need to considerer that most of the machinery in the market don't have this sophistication. Most of the sprayers in the field are from 1990-1994.

**I: What are the trends for the future?**

R: The future requires worldwide traceability, not just in UK. I believe that if TESCO require an automatic recording system to verify and guarantee what the farmers are doing then they will be paid for the system. The farmers need to see a turn over. The system need to be simple, quickly and cheap.

**I: Whose is the responsibility on the spraying operation?**

R: If the operator makes a mistake and over-doses he can not get round it, it is quite clear what he have done. He has to write down what he has done. If the operator over-doses and the crop is scotched it is his responsibility because he applied more than recommended. If the crop is damaged and the agrochemical spray records comply with the recommendations then the insurance company will provide compensation for the damaged crop.

### **Interview with respondent I**

#### **I: In order to deliver LEAF Marque, what traceability data should be recorded and what information do you need from the farm to certify traceability?**

R: LEAF Marque certification standard is complementary to existing farm and food assurance schemes. The farmers need to be a member of assurance scheme to join LEAF. The members need to have traceability system in place. In the LEAF Marque Warranty/ Custody Agreement there is a term related to traceability:

- To operate an effective system of traceability that will ensure that the Logo is used only on eligible products. In particular, effectively to segregate eligible raw materials and products from any other material in the facility, to keep necessary records to be able to demonstrate traceability and to regularly challenge the traceability system to test its effectiveness.

#### **I: How the is information currently received? Can it be an electronic format, and what moves are already being made in the area?**

R: At the moment is all paper based. We have a plan to use the internet to receive the information from the farmer. We want to include all the packers and buyers in that process. The farmer could complete the information on our web site and everybody else in the process could check this information. We want to use traceability to help farmers market their products. It is actually using data, because the data is already there we only need to make this available to the buyers. I want to be able to check from the buyers and processor directory where they are buying their produced from.

The CMi provides the database to us and then we make this available on web site - LEAF Track.

#### **I: For both paper and electronic data transfer, what thought has been given to signoff / responsibility for data and maintaining integrity as the data moves through systems?**

R: The farm is responsible for the information. At the moment we haven't go any check in place we get the information at the farm audit.

#### **I: How do you verify if the information is correct?**

R: The farmers need to declare which products they want to sell with Leaf Marque logo. To verify we can take a product carrying Leaf logo from Waitrose and check the grower code and the packer code. We certify as a farm then they can use LEAF Marque in the products that they declared.

#### **I: What problems or benefits do you see from viewpoint of the rest of the industry if a system were available to automatically record inputs onboard a spraying vehicle**

R: I believe that it would be advantage to the industry, but not to LEAF. We are not interested on this information. We are concern on what goes into the crop but we don't need that information. The retail would do, although they don't want to hold the information, but it need to be available in the farm. Any automated recording system is an advantage, as soon it collects data from a number of different people.

**I: Recognising the general direction of the requirements for information, how can we make the adoption of traceability protocols and appropriate technology attractive to farmers?**

R: The farmers need to see and use it as a market tool. Any system that makes their live easier and keeps them in the market is attractive.

**I: How can traceability information best be provided to obtain value for the final retail customer? – is there only a role for “certified levels” or should there be direct presentation of the history of a particular food item – and if so, who might pay for disseminating such information.**

R: I believe that the consumers don't want to know all the information from a particularly product. The data information should be held about the product, in the farm level, should be a system where the information can be retrieve quickly.

**I: How widely / frequently is LEAF Tracks being used? Do you think it would be an interest to have more detailed information available on LEAF Tracks?**

R: We can't check how widely LEAF Tracks being used. We want to keep the traceability information at grower level.

I believe that the consumers trust on the retailers and each quality assurance scheme logo, they are not interested on that much detailed information. The sort of traceability we want to is down to the grower level, we believe that is the maximum where the customers would like to know. If the consumers and retailers want to have this information we would help our members to provide it automatically, but we have no plan to provide this levels of information.

**I: What are the trends for the future?**

R: I believe that the retailers will take the farmers into the stores to promote their produces and get the farmers close to the consumers. Then the grower will be serving the customers.

#### **Interview with respondent J**

**I: Do you think it is possible one standard and methods of information transfer can be developed across “arable”, “livestock” and possibly “horticulture” industries?**

R: There are different sectors schemes for farm assurance. If you are a dairy farmer before you had to have beef and dairy assurance, now there is harmonization they only need one scheme. There are some opportunities of standardization but we still have to look differently because the sectors are different. We have standardized technology and data transfer as far it is possible to go. There are some opportunities for standardization on data transfer for different schemes.

**I: How can we make the adoption of traceability protocols and appropriate technology attractive?**

R: You can make it attractive by looking what farmer have to do now, it terms of farm assurance. At the moment they see a cost on it and paper work. You need to make it cheaper and more efficient in terms of time. If there is finance incentive somewhere from the end of the supply chain passes back down to the farmer. If you make this

technology only available in this country then they will have a tool to be more competitive. They are looking for differentiation on market place.

You have to have the retail engaged, because there is no point for the farmer has this technology if his customer is not interested on it. At the moment the retailers feel they have strong traceability system. In fact the traceability systems are quite long, paper based but the retail rely on it. If your technology makes that system more efficient, quickly, more cost effective, I believe they would be interested.

**I: What problems or benefits do you see from viewpoint of the rest of the industry if a system were available to automatically record inputs onboard a spraying vehicle**

R: The ability to demonstrate and provide assurance and prove they are doing what they say they are doing is a competitive advantage.

The consumers don't understand the different scheme, they just assume that the supermarket make sure that the food is safe. As a general rule people go to supermarket and they assume all the products are safe. I don't know if the final consumers would check the traceability information if it is available. It would be interested to know if many consumers check the LEAF information.

**I: What information needs to be sent through the food chain?**

R: The retailers will come out every so often and check the processor. The processor (the marketing agency between the grower and supermarket) need to hold the traceability information. Usually the retail is only interested in the product name, quantity, order number and date of delivery. Each retail and grower has different method of data transfer, it is usually manually entered and pen and paper. A standard method of data transfer would be very useful. I like the idea where a product goes along with a chip and the retail could check the information.

**I: Would a Clearing House useful to collect and certify the information?**

R: That's basically what the processor does now. The retailers trust on the processor to verify and keep the information. A small fresh produce grower is also assured by independent audited, then the processor check the records and that processor has an independent audited, so a Clearing house is not necessary in this sector. When there are a multiple suppliers coming into one place (combinable crop and meat) a clearing house to keep the information would be interesting.

**I: Commercial benefit or an infringement of personal/commercial liberty**

R: Farmer would say a bit of both. Be able to demonstrate the traceability information gives them an advantage, but at the same time there is cost on doing that. At the moment NFU are pushing all members to be farm assurance. The farmers see traceability as a competitive advantaged with some imported products. Some food services also started looking for traceability information from their suppliers. Brakes use Red Tractor on some meat products. Brakes owns *Slug and Lettuce* chain, consequently, all 56 pubs will use the Red Tractor logo chicken on its menus

**I: What is the trend for the future?**

R: The traceability requirements will keep on increasing. I don't think the consumers will drive this, unless there is a food scare. To have the ability to demonstrate the environmental compliance is becoming more important.

### **Interview with respondent K**

#### **I: Have you had previous experience with traceability systems?**

R: OF&G is the second largest in terms of number of operators organic certification in UK, the number of farmers and growers registered are 1100.

From organic point of view the traceability starts from where the seed comes from. What we need from traceability in organic system is to verify from "farm to fork" if what has been sell it is organic. We are less interested in the inputs, we need to be able to identify if the produce came from an organic farm, follow an organic process, from farm, retail to the final consumer. That is the kind of verification we are looking for, if the system can supports that then we would be very interested on it. The system that can prove the input might be useful but not essential for us. You can't test if something is organic, you can only test if something organic contain something than shouldn't. You can only test for specific agrochemical, you need an idea what you are looking for, it is not possible test for everything. For an organic food production the inputs to same extent are less important. But I believe that it is important a traceability system to feed the inputs, because you would want to know to certify the product is organic, if the farmer used organic seeds and what sort of rotation they have. The kind of information that would be useful are the following: who packed; who audited; who processed; who produced; who produce the seeds; the rotation used. The farmer could feed this information into a traceability system and this could verify by the certification body.

#### **I: What traceability data should be recorded and what information do you need from the farm to certify traceability?**

R: An arable farm would be expected to keep a field record which details the inputs and outputs to the system. Details of the origin, nature and quantities of all materials brought in and the use of such materials. They need to keep the records the seed they used. When we do the inspection, we can verify what the farmer bought and the inventory.

The livestock farmers we basically require the records they already keep, they need to keep the vet treatments records which are already required by UK law. They need to keep the record of the medicine in stock and feed they use.

We do the inspection at least once a year. After visiting the farm, the inspector create his own reports and send it to OF&G. Then we analyse the report and send the list of the correction actions the farmer got to deal it. We believe that the verification should be doing in a different way; it takes a lot of time to get the set of records. A reliable automatic system it would be a great use for us.

#### **I: How the information is received? Data format.**

R: We hope to move to electronic system, but at the moment the reports are paper based. Defra is holding a system called whole Farm Approach which has a central data base where the farmers inputs their details, which is then use by others systems. It reduces the hours they spend filling in forms and having farm inspections.



**I: What problems or benefits do you see from viewpoint of the rest of the industry if a system were available to automatically record inputs onboard a spraying vehicle**

R: We are looking really “farm to fork” type of traceability more than inputs into the systems although it would be very interesting. If you have this system in place, and it is not much cost that’s sounds fine. You don’t fail as an organic farmer by the level of the pesticides concentration. We are not concern in many respects with residue levels because we don’t have residue levels. For us, the most important aspect of traceability is to be able to identify if the produce came from one of our certified organic farm, and identify this produce all the way through the food chain. Our business also affects animal feeds, for organic meat. We would be interested in a system that could collect the feed and the vet treatments inputs.

A valuable research would be a system that could create automatic data along side with best management practice. A system that holds what happened with each field, and then creates a data base with the harvest information and previous information inputted. Then the farmer could analyse the yield information and match the best rotation, rates and so on. A system that could manage the livestock would also be a great benefit.

**I: How can we make the adoption of traceability protocols and appropriate technology attractive?**

R: There are so many schemes that the farmers has to comply that make their job very hard and it take a long time filling reports for each one. The only way to make this attractive is to make in a system in complying with the requirements (government and supermarket), so they don’t have to spend time filling report. The attractive technology is the one that allows the farmers save time.

**I: The information need to be available to the final customer? How it can be available?**

R: Some traceability information needs to be available, they need to verify if the product is organic or not. From the marketing point of view the most interesting thing is to be able to link the consumer with the producer, accessing a web site and checking the farm information.

The thing that would help us most would be a centre organic data base. Then the consumer could check the data base to certify if the retail has an organic certification.

There is a private initiative that creates a data base that could hold the information of organic farms. Then the retailer could go to the web site and check if the farmer is assured. The results of the publications will release in 6 months.

**I: What are the trends for the future?**

The need to traceability is increasing every day. The trend is much great usage in electronic recording systems, data base, and internet access for consumer, retails and body certification.

**Interview with respondent L**

**I: How can we make the adoption of traceability protocols and appropriate technology attractive?**

R: Money and reduce regulation. We need to be able to demonstrate our records very clearly. It needs to provide a competitive advantage. Traceability records are seen as a market tool as a competitive advantage over those in the market that don't have traceability records. Then we can prove that we have traceability and ask to the supermarket show that the other farmers and doing the same.

**I: What problems or benefits do you see from viewpoint of the rest of the industry if a system were available to automatically record inputs onboard a spraying vehicle**

R: It's a benefit having a memory card that could download the information into the tractor/sprayer terminal and come back to the farm computer. This information could be also tied with my stock control data. We need to find a way to demonstrate that people use the agrochemical in a responsible way.

**I: What costs do see?**

R: This technology is cheap and has to be standard in the equipment. We are use to buy expensive agricultural equipment and we would expect this to come with free charge.

**I: What information needs to be sent through the food chain?**

R: Spray dates, product names, drill periods. We have to keep the records; it doesn't need to go along with every single pallet.

**I: Would a Clearing House useful to collect and certify the information?**

R: If the system is sophisticated enough we don't need to have farm inspection. If my case I suspect because of the storage I will always have to have some inspection. If having this automatic recording system will give me a gold start performance (ACCS), if that means my charge will get less the system worthwhile.

**I: Commercial benefit or an infringement of personal/commercial liberty?**

R: When the government don't put any new regulations because the farmers are already demonstrating best practice that is big commercial win.

If Tesco, Waitrose and M&S see more value in demonstrate best practice that is a commercial benefit. The more we can prove traceability the more we add value to our products. We need to find ways on demonstrate our best behaviors in environmental protection and agrochemical application.

**I: What are the trends for the future?**

R: We got find a way that livestock farm could demonstrate best practice. In arable farm we have enough professional farmers to drive it forward, and in the livestock there many farmers doing it as a hobby and they don't want to change.

We have now in arable sector and it's increasing in the dairy sector, professional relationship between the agronomist and farmer. My agronomist emails me the recommendation sheet that came in a useful format. He takes my records so he knows what I have done, once we start with that professional relationship to demonstrate good practice become much easier.

Product Identification: This is an area that we need more help. If I could have a system where I could keep the records of all the sprays in stock, the balance and application,

this would be a very useful tool. At the moment there is no tie between the chemical I buy, delivered and how we handle the waste, what happened to the waste and cost.

**Interview with respondent O**

**I: In order to deliver Conservation Grade, what traceability data from the farm should be recorded?**

R: The farmer needs to be able to show what materials he has used, what areas he has used them, why the he has used, who recommended the application.

The farm can treat the grain before harvest, but it cannot be treated once it is in the store.

**I: How the information is currently received? Can it be an electronic format, and what moves are already being made in the area?**

R: It is a paper system and it is post event. The ideal world all the information should and could be capture in real time, and should and could be fed all the way back into the conservation grade system. The consumers would be able to check the source from their pack of cereals on the web site. We would like to develop that level of traceability, but the problem is how get the farmers to be that open and transparent on what they are doing.

It is a pass/fail criterion. The Cmi are putting the audit system in the laptop so the auditor can email to us. It is just an electronic version of the existing paper version then this information will be send to us.

**I: What costs at farm level are related with traceability records?**

R: The cost related with traceability records are mainly management time. There is no extra cost to do that, the farmer need to have for any other standard.

**I: Is there a future to separate grains by origin/field/quality and keep the integrity all the way from “farm to fork”? Or traceability for grains is only achieved by a two-stage traceability system: Farm to processor / Processor to retailer**

R: There are possibilities for segregation on quality. Some farmers are quite good on measure and quantity each stream the grain goes into according with its quality standard. Some farmers are quite good at measure and assess their product against specification, some farmers don't know how to do it. Because we adopt as whole farm approach I don't see any segregation on traceability inputs based on input control. All the field in that farm will be treat the same.

A typical farmer supplies us with 500 tones of Oats. It ranges from 150 to 1200. We don't buy the whole grains from the farm, usually we buy 20%. Typically we use about only 20% of the grain on total grown as a conservation grade in the farm. The approach historically is to have a proportion on a wide of large number than all from a few.

**I: What problems or benefits do you see from viewpoint of the rest of the industry if a system were available to automatically record inputs onboard a spraying vehicle**

R: Yes, most of the farmers are forward thinking, they are the early adopters of whatever in new on the market. The problems are going to be around the practically.

What else the farmers will have to buy in order to have the system running. But if the system will be available as a retrofit it would be good.

**I: How can we make the adoption of traceability protocols and appropriate technology attractive to farmers?**

R: We will make it mandatory requirement. That is the only way to do it.

If the farmer is going to be conservation grade, he will need to separate some land for the habitat, then he will lose some production. I will provide you some numbers of a typical farm to establish conservation grade. They get a premium for conservation grade, about 10%. £65 membership fee – first year

Following years: £95 for each audit; £20 for the habitat assessment.

Some habitat last for 10 years, then is just management time

**I: How can traceability information best be provided to obtain value for the final retail customer?**

R: There is an opportunity to present the traceability information to some consumers. To provide the information will give them consumers more confidence.

**I: Is there a problem that can be shared in order to undertake a cost/value analysis:**

- a. To minimize major disasters.
- b. To ensure customer confidence in maintaining Conservation Grade.

R: We haven't had any recall yet. Let's take an example if they find residue in a box of cereals already in the market. A batch is 1000 tones of cereals as an input. It could be 2000 to 3000 tons of finished product. Average pack weighs 500 grams. It would be 4 millions pack of cereals contaminated. Considering an average price of 1.50 each pack, it would be 6 million pounds of recall. It hasn't happened and we are not prepared if it does happen.

The real value is down in the supply chain. To sell the retailer need to be engaged.

### **Interview with respondent Q**

**I: What traceability data you require?**

R: The data required depend on the issue we have. We don't require all the traceability data, we only need to know that the data is there in case we need it. There are many traceability data that can not be analyzed and don't add any value to the market. Access to source is essential for us. Our relationship with farmers is expressed through the data that is available.

**I: What costs at farm level are related with traceability records?**

R: I could say something about the benefits that could be achieved by traceability records. Data management is an example, if you got LEAF scheme which claim to minimize pesticide, there is a benefit in providing traceability records.

There is no premium price for traceability records, the benefits is the market share.

**I: What problems or benefits do you see from viewpoint of the rest of the industry if a system were available to automatically record inputs onboard a spraying vehicle**

R: Yes it is a interesting system, but we wouldn't impose that, it would be a tool that could provide us more confidence. The acquisition would be their decision to prove best practice. Our farmers like comparison and continuous improvement.

The problem would be the understanding and access of the high technology. Waitrose has 15,000 growers. Roughly 75% of the volume comes by growers that don't have access to email or electronic data. 80% of the number are non English speaking (huge number are Turkish) and don't have access to computers. We are very keen on small growers, that why the high proportion.

**I: How can traceability information best be provided to obtain value for the final retail customer?**

R: Consumers are desperately engaged with farmers and not necessarily engage with records. We found that when we have put the farmer's records the number of visits on the web site that gets back is not that high. The numbers of engagements locally with consumers and farmers is very high. Consumers want to know where the food come from they want to engage, they want to hear not just the hard records side, but the soft side. It is relationship rather than database.

**I: Do you see any issue at on farm level regarding traceability records?**

R: Some issues, when the operator system in on holiday the information can not be retrieved. Sometimes the traceability system is there but we don't have the passport to get into this.

**I: Is there a problem that can be shared in order to undertake a cost/value analysis**

R: Nothing is more important than our brand reputation. Anything that could damage this is going to be treated seriously. If we lost our confidence in some of our growers it would be a loss of business for them. We had a few problems because we can not see the problems; it is hard to detect the residue level if you don't know what you are looking for.

**I: What are the trends for the future?**

R: There will be issue with age of products and environmental storage. The traceability data of a product regarding on the energy and cost required to produce that product is going to be probably the biggest question, and how traceability could be related with that is going to be an interesting challenge.

---

## Appendix B. Coding System – Stakeholders' interviews

<b>Req</b>	<b>Requirements</b>	<b>Pro</b>	<b>Process</b>
Req-dat	Data Management System	Pro-agr	Agronomist Recommendation
Req-aut	Automatic Exchange Data	Pro-far	Farm Inspection
Req-pro	Product Identification	Pro-cer	Certification
Req-dec	Decision Process	Pro-int	Internal Traceability
Req-dba	Data base	Pro-res	Farm responsibility
		Pro-fis	Farm issues

<b>Dri</b>	<b>Drivers</b>	<b>Mot</b>	<b>Motivation</b>
Dri-con	Consumers	Mot-reg	Regulation
Dri-ret	Retailers	Mot-ret	Retailers
Dri-reg	Regulation	Mot-tra	Traceability

<b>Dat</b>	<b>Data Required</b>	<b>Aut</b>	<b>Automated Recording System</b>
Dat-fre	Fresh produce	Aut-iss	Issues
Dat-ara	Arable	Aut-ben	Benefit
Dat-org	Organic Production	Aut-req	Requirements
Dat-res	Responsibility		

---

## **Appendix C. Multiple choice questionnaire**

- 1. Does the prototype hopper decrease or increase the risk of contamination to the operator?**
  - Decrease
  - Increase
  - Neither Decrease nor Increase
- 2. Does the prototype hopper decrease or increase the risk of spillage?**
  - Decrease
  - Increase
  - Neither Decrease nor Increase
- 3. The way the system identifies the chemical is straightforward**
  - Strongly Agree
  - Agree
  - Neither Agree nor Disagree
  - Disagree
  - Strongly Disagree
- 4. The way the system measure quantity is straightforward**
  - Strongly Agree
  - Agree
  - Neither Agree nor Disagree
  - Disagree
  - Strongly Disagree
- 5. How efficient is the rinsing system used on the prototype hopper?**
  - Very Efficient
  - Efficient
  - Neither Efficient nor Inefficient
  - Inefficient
  - Very Inefficient

## Appendix D. AHP questionnaire

Name.....Date.....

### Guide to the Questionnaire

#### Scenario

Think of spray application: consider how effective a sprayer machine with or without the Automatic Agrochemical Traceability System (AACTS) is in completing this task. This questionnaire aims to identify how you judge the “**sprayer machine with AACTS**” and “**sprayer machine without AACTS**” compare against the key criteria, identified later, in the context of **spray application**.

#### Method

This questionnaire consists of two parts. You will first be asked to compare one criterion against a set of other criteria and then asked to score how well each of the above alternatives performs against each criterion.

Criteria to be compared:

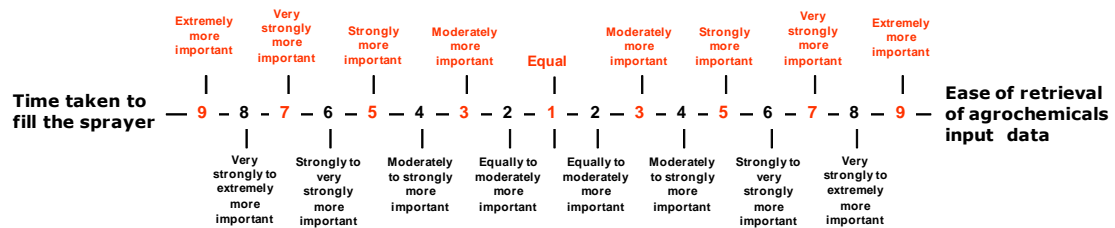
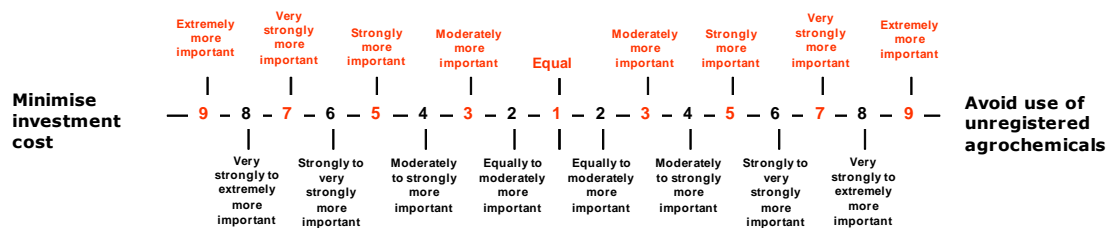
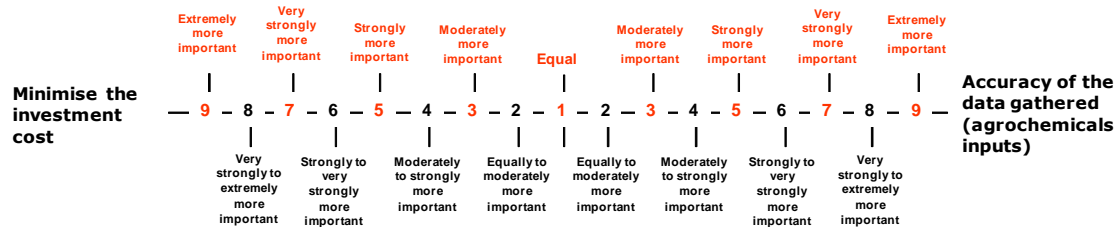
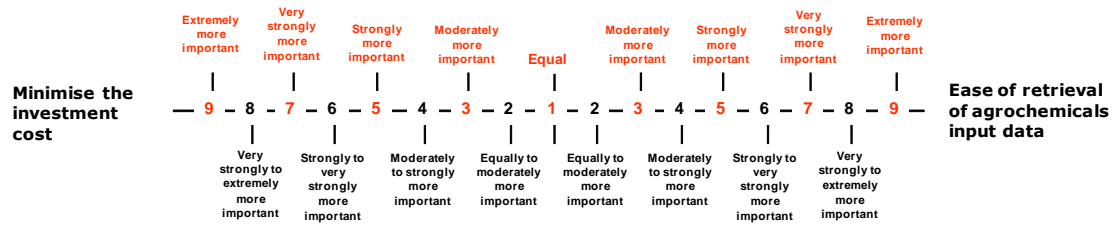
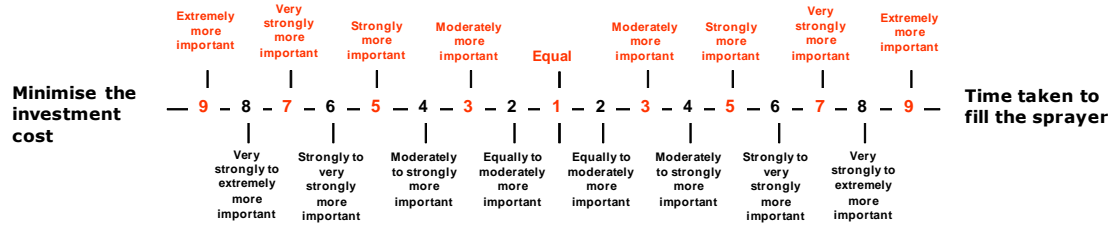
- **Minimise the investment cost:** The objective of minimising the investment cost.
- **Minimise the time taken to fill the sprayer:** This refers to the time spent filling the sprayer machine with the agrochemicals inputs.
- **Ease of retrieval of agrochemicals input data:** This refers to how easily the data can be retrieved; the data can be held on paper or electronically.
- **Accuracy of the data gathered (agrochemicals inputs):** This refers to the accuracy of the data that have been collected on agrochemical use on the farm.
- **Avoid use of unregistered agrochemicals:** This refers to the use of registered agrochemicals, according to the Pesticides Safety Directorate (PSD).
- **Operator Safety:** This refers to the risk of spillage when filling up the induction hopper.

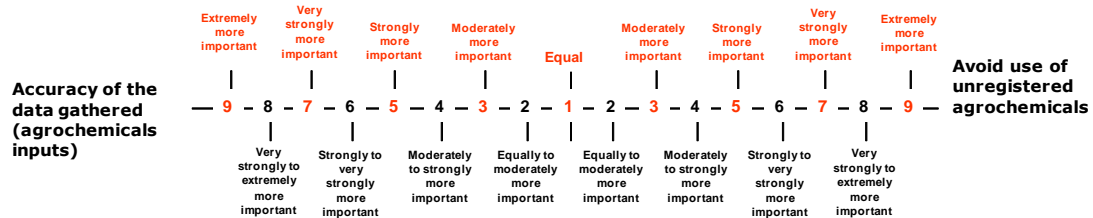
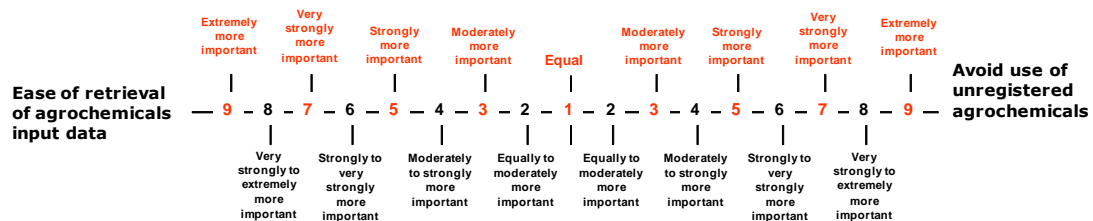
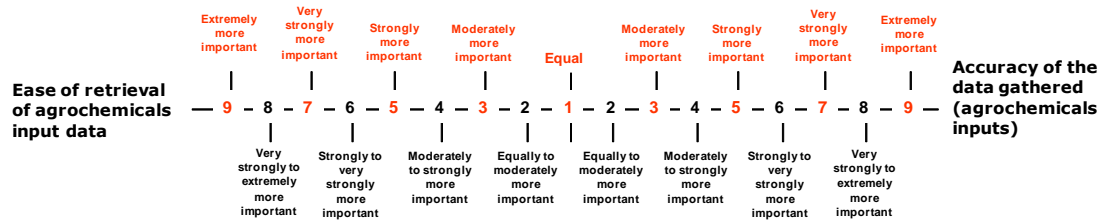
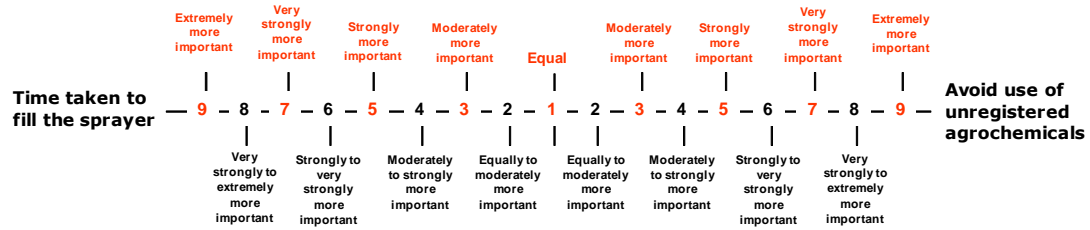
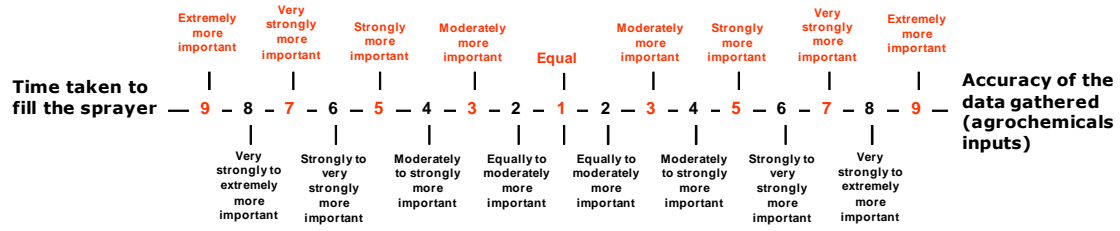


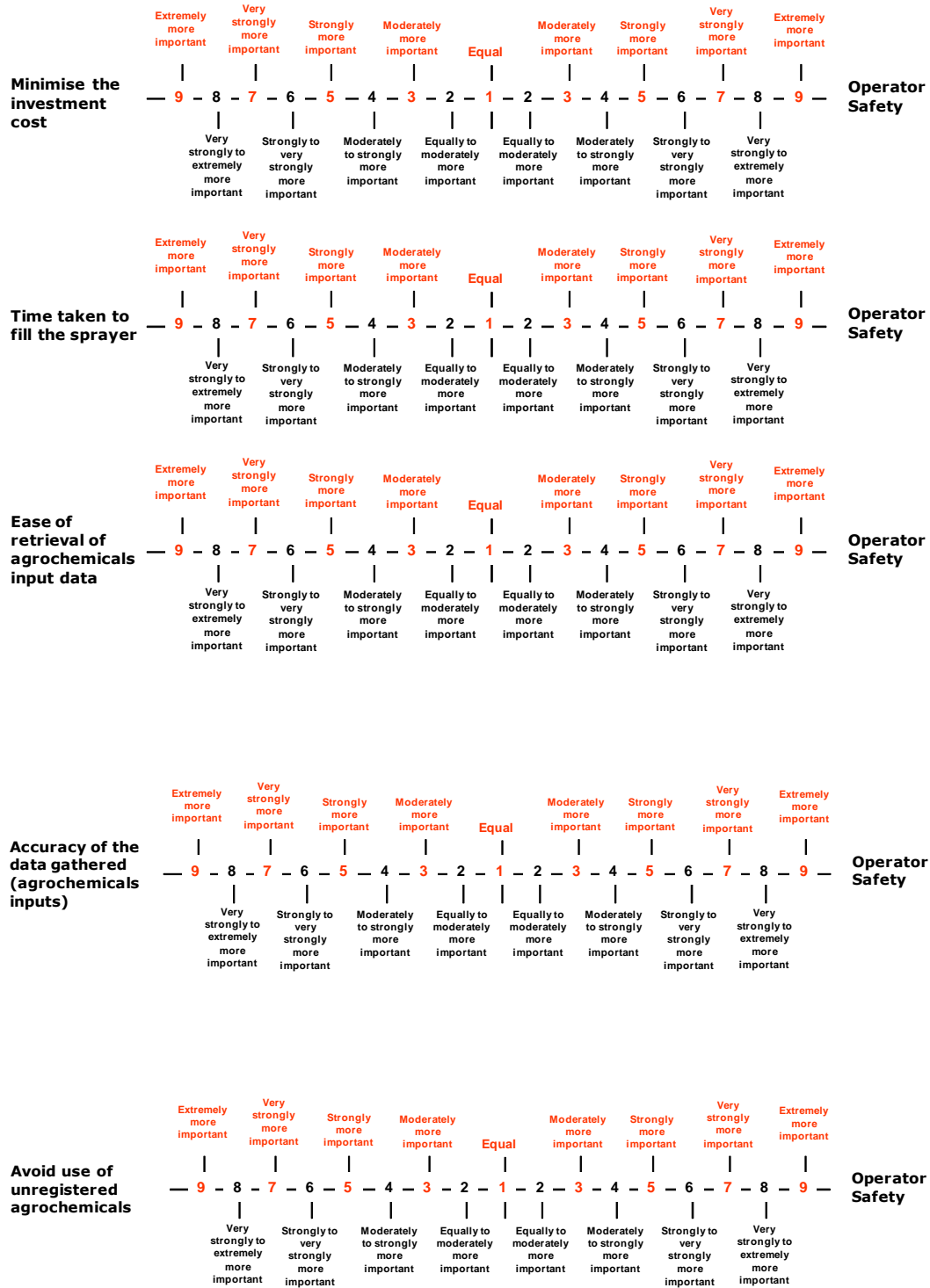
A description of how the alternative data recording methods may perform against these criteria is given in the Table below

<b>Criteria</b>	<b>Sprayer <i>with</i> AACTS</b>	<b>Sprayer <i>without</i> AACTS</b>
<b>Minimise the investment cost</b>	<p>The investment cost is the cost of the sprayer machine and the AACTS.</p> <p>An example of the total investment cost would be: <b>£66,380</b></p> <p>Details of the total investment:</p> <ul style="list-style-type: none"> <li>• Sprayer (Spra-Coupe 4455): <b>£62,760</b></li> <li>• AACTS: <b>£2,000</b></li> <li>• Data Recording System onboard the sprayer: <b>£1,500</b></li> <li>• GPS: <b>£120</b></li> <li>• <b>Total: £66,380</b></li> </ul>	<p>The investment cost is only the cost of the sprayer machine.</p> <p>An example of the total investment cost would be: <b>£62,760</b> (using as an example the Spra-Coupe 4455).</p>
<b>Minimise the time taken to fill the sprayer</b>	Data from previous AACTS trials indicate that the operator takes approximately <b>220</b> seconds to fill the sprayer.	Using the conventional induction hopper, the operator takes approximately <b>150</b> seconds to fill the sprayer.
<b>Ease of retrieval of agrochemicals input data</b>	The AACTS automatically records the history of agrochemicals inputs to the field. This data can be downloaded to the farm computer and is available electronically for retrieval. There is a potential saving on labour associated in retrieving the data.	Without electronic records the data retrieval is done manually (paper-based). In order to have electronic data retrieval the agrochemical inputs have to be manually typed into the farm computer.
<b>Accuracy of the data gathered (agrochemicals inputs)</b>	The agrochemicals inputs recorded by the AACTS will reflect the actual amount that has been applied to a specific field.	The "Pesticide Application Record" is filled in by the sprayer operator and is subject to human error.
<b>Avoid use of unregistered agrochemicals</b>	The AACTS holds the pesticide data base and only allow the use of agrochemicals registered at Pesticides Safety Directorate (PSD).	The records are manually recorded and there is no way to ensure if the operator has used registered agrochemicals.
<b>Operator Safety</b>	With the AACTS the operator will load the agrochemical straight into the sprayer.	A graduated measuring jug is normally used to measure the amount of product to be loaded into the sprayer. The operator has to wash the measuring jug

Please, answer the set of questions below in the context of spray application.  
 How important is each criterion relative to the other criteria when you are thinking of spray application?

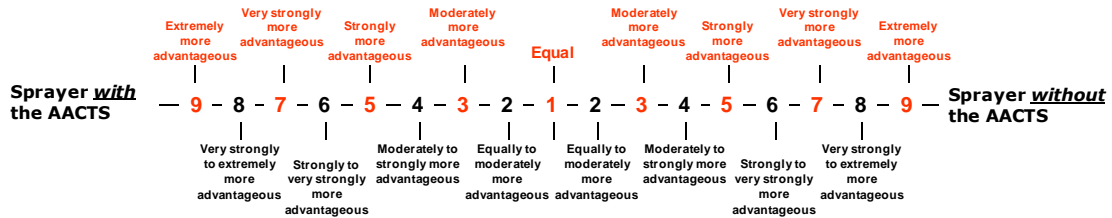




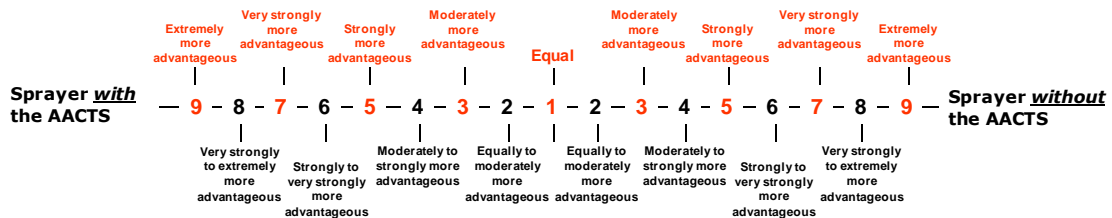


**Now please complete the last part of the questionnaire**

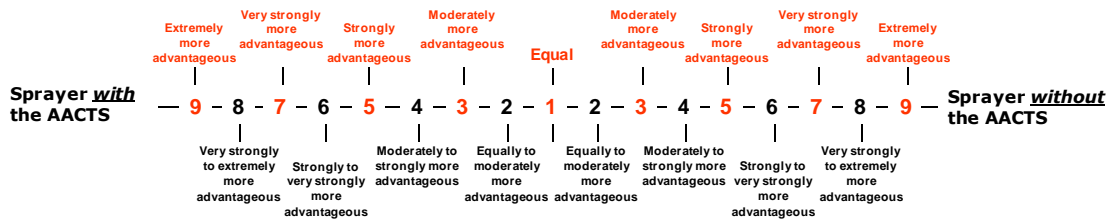
**1. How does the two alternatives compare relative to each other against the "minimise investment cost"?**



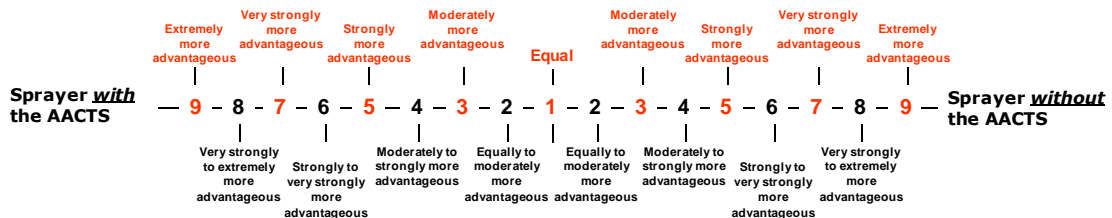
**2. How does the two alternatives compare relative to each other against the "minimise time taken to fill the sprayer "?**



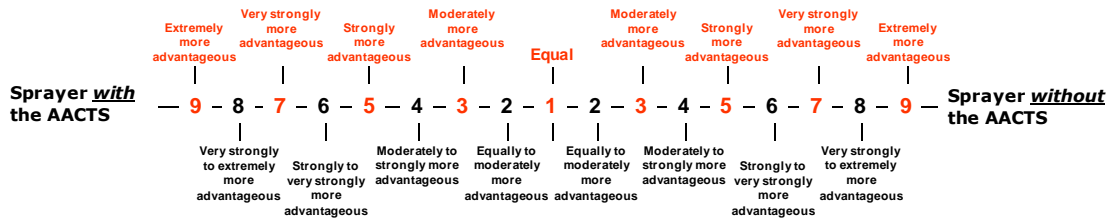
**3. How does the two alternatives compare relative to each other against the "ease of retrieval of agrochemicals input data"?**



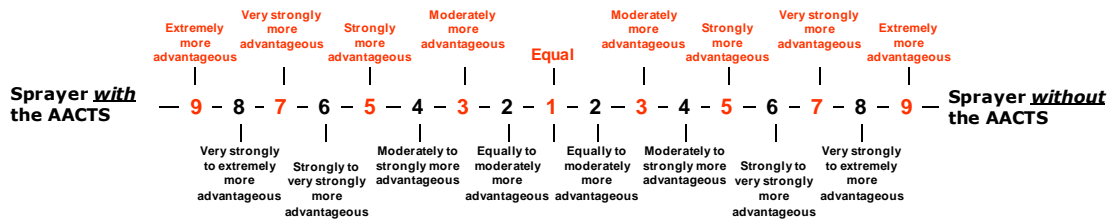
**4. How does the two alternatives compare relative to each other against the "accuracy of the data gathered (agrochemicals input)"?**



5. How does the two alternatives compare relative to each other against the "avoid use of unregistered agrochemicals"?



6. How does the two alternatives compare relative to each other against the "operator safety"?



**Thank you for participating.**

## Appendix E. Logic Decisions, results of the AHP questionnaire

This appendix is the results of the AHP questionnaire generated by the software, Logical Decisions (version 5.129)

### Assessment summary for Preference Set Farmer A

#### Common Units

1. Minimise the investment cost: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	5
2. Sprayer with AACTS	0.2	1
Consistency Ratio = 0		

2. Minimise time taken to fill the sprayer: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	1
2. Sprayer with AACTS	1	1
Consistency Ratio = 0		

3. Ease of retrieval of agrochemicals input data: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	0.333333
2. Sprayer with AACTS	3	1
Consistency Ratio = 0		

4. Accuracy of the data gathered: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	5
2. Sprayer with AACTS	0.2	1
Consistency Ratio = 0		

5. Avoid use of unregistered agrochemical: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	5
2. Sprayer with AACTS	0.2	1
Consistency Ratio = 0		

6. Operator Safety: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	5
2. Sprayer with AACTS	0.2	1
Consistency Ratio = 0		

#### Weights

OVERALL: a Utility function assessed using AHP:

	Minimise the investment cost	Minimise time taken to fill the sprayer	Ease of retrieval of agrochemicals input data	Accuracy of the data gathered	Avoid use of unregistered agrochemical	Operator Safety
Minimise the investment cost	1	5	5	1	5	1
Minimise time taken to fill the sprayer	0.2	1	0.2	0.333333	2	0.5
Ease of retrieval of agrochemicals input data	0.2	5	1	1	5	1
Accuracy of the data gathered	1	3	1	1	4	0.333333
Avoid use of unregistered agrochemical	0.2	0.5	0.2	0.25	1	0.2
Operator Safety	1	2	1	3	5	1

Consistency Ratio = 0.0917549

**Assessment summary for Preference Set Farmer B**

## Common Units

1. Minimise the investment cost: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	4
2. Sprayer with AACTS	0.25	1
Consistency Ratio = 0		

2. Minimise time taken to fill the sprayer: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	3
2. Sprayer with AACTS	0.333333	1
Consistency Ratio = 0		

3. Ease of retrieval of agrochemicals input data: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	0.333333
2. Sprayer with AACTS	3	1
Consistency Ratio = 0		

4. Accuracy of the data gathered: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	3
2. Sprayer with AACTS	0.333333	1
Consistency Ratio = 0		

5. Avoid use of unregistered agrochemical: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	3
2. Sprayer with AACTS	0.333333	1
Consistency Ratio = 0		

6. Operator Safety: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	7
2. Sprayer with AACTS	0.142857	1
Consistency Ratio = 0		

## Weights

OVERALL: a Utility function assessed using AHP:

	Minimise the investment cost	Minimise time taken to fill the sprayer	Ease of retrieval of agrochemicals input data	Accuracy of the data gathered	Avoid use of unregistered agrochemical	Operator Safety
Minimise the investment cost	1	1	2	2	0.333333	1
Minimise time taken to fill the sprayer	1	1	1	1	0.333333	0.5
Ease of retrieval of agrochemicals input data	0.5	1	1	1	0.333333	0.5
Accuracy of the data gathered	0.5	1	1	1	0.333333	0.5
Avoid use of unregistered agrochemical	3	3	3	3	1	1
Operator Safety	1	2	2	2	1	1

Consistency Ratio = 0.0185549



**Assessment summary for Preference Set Farmer C****Common Units**

1. Minimise the investment cost: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	0.333333
2. Sprayer with AACTS	3	1

Consistency Ratio = 0

2. Minimise time taken to fill the sprayer: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	6
2. Sprayer with AACTS	0.166667	1

Consistency Ratio = 0

3. Ease of retrieval of agrochemicals input data: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	0.142857
2. Sprayer with AACTS	7	1

Consistency Ratio = 0

4. Accuracy of the data gathered: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	7
2. Sprayer with AACTS	0.142857	1

Consistency Ratio = 0

5. Avoid use of unregistered agrochemical: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	7
2. Sprayer with AACTS	0.142857	1

Consistency Ratio = 0

6. Operator Safety: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	3
2. Sprayer with AACTS	0.333333	1

Consistency Ratio = 0

**Weights****OVERALL: a Utility function assessed using AHP:**

	Minimise the investment cost	Minimise time taken to fill the sprayer	Ease of retrieval of agrochemicals input data	Accuracy of the data gathered	Avoid use of unregistered agrochemical	Operator Safety
Minimise the investment cost	1	0.333333	0.333333	0.333333	7	1
Minimise time taken to fill the sprayer	3	1	1	2	5	2
Ease of retrieval of agrochemicals input data	3	1	1	1	7	2
Accuracy of the data gathered	3	0.5	1	1	7	2
Avoid use of unregistered agrochemical	0.142857	0.2	0.142857	0.142857	1	0.25
Operator Safety	1	0.5	0.5	0.5	4	1

Consistency Ratio = 0.0377682

**Assessment summary for Preference Set Farmer D****Common Units**

1. Minimise the investment cost: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	0.25
2. Sprayer with AACTS	4	1

Consistency Ratio = 0

2. Minimise time taken to fill the sprayer: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	0.333333
2. Sprayer with AACTS	3	1

Consistency Ratio = 0

3. Ease of retrieval of agrochemicals input data: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	6
2. Sprayer with AACTS	0.166667	1

Consistency Ratio = 0

4. Accuracy of the data gathered: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	6
2. Sprayer with AACTS	0.166667	1

Consistency Ratio = 0

5. Avoid use of unregistered agrochemical: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	6
2. Sprayer with AACTS	0.166667	1

Consistency Ratio = 0

6. Operator Safety: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	8
2. Sprayer with AACTS	0.125	1

Consistency Ratio = 0

**Weights**

**OVERALL: a Utility function assessed using AHP:**

	Minimise the investment cost	Minimise time taken to fill the sprayer	Ease of retrieval of agrochemicals input data	Accuracy of the data gathered	Avoid use of unregistered agrochemical	Operator Safety
Minimise the investment cost	1	1	3	4	1	1
Minimise time taken to fill the sprayer	1	1	0.5	1	0.333333	0.5
Ease of retrieval of agrochemicals input data	0.333333	2	1	1	1	1
Accuracy of the data gathered	0.25	1	1	1	0.5	0.5
Avoid use of unregistered agrochemical	1	3	1	2	1	1
Operator Safety	1	2	1	2	1	1

Consistency Ratio = 0.0571902

**Assessment summary for Preference Set Farmer E**

## Common Units

1. Minimise the investment cost: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	0.333333
2. Sprayer with AACTS	3	1

Consistency Ratio = 0

2. Minimise time taken to fill the sprayer: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	3
2. Sprayer with AACTS	0.333333	1

Consistency Ratio = 0

3. Ease of retrieval of agrochemicals input data: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	5
2. Sprayer with AACTS	0.2	1

Consistency Ratio = 0

4. Accuracy of the data gathered: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	5
2. Sprayer with AACTS	0.2	1

Consistency Ratio = 0

5. Avoid use of unregistered agrochemical: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	5
2. Sprayer with AACTS	0.2	1

Consistency Ratio = 0

6. Operator Safety: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	8
2. Sprayer with AACTS	0.125	1

Consistency Ratio = 0

## Weights

OVERALL: a Utility function assessed using AHP:

	Minimise the investment cost	Minimise time taken to fill the sprayer	Ease of retrieval of agrochemicals input data	Accuracy of the data gathered	Avoid use of unregistered agrochemical	Operator Safety
Minimise the investment cost	1	1	1	1	4	1
Minimise time taken to fill the sprayer	1	1	0.25	1	5	3
Ease of retrieval of agrochemicals input data	1	4	1	3	4	7
Accuracy of the data gathered	1	1	0.333333	1	1	1
Avoid use of unregistered agrochemical	0.25	0.2	0.25	1	1	1
Operator Safety	1	0.333333	0.142857	1	1	1

Consistency Ratio = 0.0925935

**Assessment summary for Preference Set Farmer F**

## Common Units

1. Minimise the investment cost: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	4
2. Sprayer with AACTS	0.25	1
Consistency Ratio = 0		

2. Minimise time taken to fill the sprayer: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	0.5
2. Sprayer with AACTS	2	1
Consistency Ratio = 0		

3. Ease of retrieval of agrochemicals input data: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	0.111111
2. Sprayer with AACTS	9	1
Consistency Ratio = 0		

4. Accuracy of the data gathered: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	9
2. Sprayer with AACTS	0.111111	1
Consistency Ratio = 0		

5. Avoid use of unregistered agrochemical: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	1
2. Sprayer with AACTS	1	1
Consistency Ratio = 0		

6. Operator Safety: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	7
2. Sprayer with AACTS	0.142857	1
Consistency Ratio = 0		

## Weights

OVERALL: a Utility function assessed using AHP:

	Minimise the investment cost	Minimise time taken to fill the sprayer	Ease of retrieval of agrochemicals input data	Accuracy of the data gathered	Avoid use of unregistered agrochemical	Operator Safety
Minimise the investment cost	1	3	3	8	0.5	6
Minimise time taken to fill the sprayer	0.333333	1	6	5	1	3
Ease of retrieval of agrochemicals input data	0.333333	0.166667	1	4	0.166667	2
Accuracy of the data gathered	0.125	0.2	0.25	1	0.125	1
Avoid use of unregistered agrochemical	2	1	6	8	1	3
Operator Safety	0.166667	0.333333	0.25	1	0.333333	1

Consistency Ratio = 0.0882822

**Assessment summary for Preference Set Farmer G**

## Common Units

1. Minimise the investment cost: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	0.25
2. Sprayer with AACTS	4	1

Consistency Ratio = 0

2. Minimise time taken to fill the sprayer: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	0.25
2. Sprayer with AACTS	4	1

Consistency Ratio = 0

3. Ease of retrieval of agrochemicals input data: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	0.333333
2. Sprayer with AACTS	3	1

Consistency Ratio = 0

4. Accuracy of the data gathered: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	2
2. Sprayer with AACTS	0.5	1

Consistency Ratio = 0

5. Avoid use of unregistered agrochemical: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	5
2. Sprayer with AACTS	0.2	1

Consistency Ratio = 0

6. Operator Safety: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	1
2. Sprayer with AACTS	1	1

Consistency Ratio = 0

## Weights

OVERALL: a Utility function assessed using AHP:

	Minimise the investment cost	Minimise time taken to fill the sprayer	Ease of retrieval of agrochemicals input data	Accuracy of the data gathered	Avoid use of unregistered agrochemical	Operator Safety
Minimise the investment cost	1	4	2	3	4	4
Minimise time taken to fill the sprayer	0.25	1	0.2	0.25	0.333333	3
Ease of retrieval of agrochemicals input data	0.5	5	1	1	2	4
Accuracy of the data gathered	0.333333	4	1	1	3	2
Avoid use of unregistered agrochemical	0.25	3	5	0.333333	1	3
Operator Safety	0.25	0.333333	0.25	0.5	0.333333	1

Consistency Ratio = 0.0798445

**Assessment summary for Preference Set Farmer H**

## Common Units

1. Minimise the investment cost: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	3
2. Sprayer with AACTS	0.333333	1
Consistency Ratio = 0		

2. Minimise time taken to fill the sprayer: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	3
2. Sprayer with AACTS	0.333333	1
Consistency Ratio = 0		

3. Ease of retrieval of agrochemicals input data: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	0.111111
2. Sprayer with AACTS	9	1
Consistency Ratio = 0		

4. Accuracy of the data gathered: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	7
2. Sprayer with AACTS	0.142857	1
Consistency Ratio = 0		

5. Avoid use of unregistered agrochemical: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	9
2. Sprayer with AACTS	0.111111	1
Consistency Ratio = 0		

6. Operator Safety: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	3
2. Sprayer with AACTS	0.333333	1
Consistency Ratio = 0		

## Weights

OVERALL: a Utility function assessed using AHP:

	Minimise the investment cost	Minimise time taken to fill the sprayer	Ease of retrieval of agrochemicals input data	Accuracy of the data gathered	Avoid use of unregistered agrochemical	Operator Safety
Minimise the investment cost	1	0.5	0.5	2	0.25	7
Minimise time taken to fill the sprayer	2	1	0.5	5	0.2	7
Ease of retrieval of agrochemicals input data	2	2	1	5	0.2	7
Accuracy of the data gathered	0.5	0.2	0.2	1	0.142857	5
Avoid use of unregistered agrochemical	4	5	5	7	1	9
Operator Safety	0.142857	0.142857	0.142857	0.2	0.111111	1

Consistency Ratio = 0.0845774

**Assessment summary for Preference Set Farmer I**

## Common Units

1. Minimise the investment cost: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	4
2. Sprayer with AACTS	0.25	1
Consistency Ratio = 0		

2. Minimise time taken to fill the sprayer: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	4
2. Sprayer with AACTS	0.25	1
Consistency Ratio = 0		

3. Ease of retrieval of agrochemicals input data: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	0.142857
2. Sprayer with AACTS	7	1
Consistency Ratio = 0		

4. Accuracy of the data gathered: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	7
2. Sprayer with AACTS	0.142857	1
Consistency Ratio = 0		

5. Avoid use of unregistered agrochemical: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	0.111111
2. Sprayer with AACTS	9	1
Consistency Ratio = 0		

6. Operator Safety: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	8
2. Sprayer with AACTS	0.125	1
Consistency Ratio = 0		

## Weights

OVERALL: a Utility function assessed using AHP:

	Minimise the investment cost	Minimise time taken to fill the sprayer	Ease of retrieval of agrochemicals input data	Accuracy of the data gathered	Avoid use of unregistered agrochemical	Operator Safety
Minimise the investment cost	1	0.142857	0.125	0.125	0.111111	0.5
Minimise time taken to fill the sprayer	7	1	0.333333	0.5	0.111111	2
Ease of retrieval of agrochemicals input data	8	3	1	1	0.5	7
Accuracy of the data gathered	8	2	1	1	0.111111	7
Avoid use of unregistered agrochemical	9	9	2	9	1	9
Operator Safety	2	0.5	0.142857	0.142857	0.111111	1

Consistency Ratio = 0.0918936

**Assessment summary for Preference Set Farmer J**

## Common Units

1. Minimise the investment cost: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	4
2. Sprayer with AACTS	0.25	1

Consistency Ratio = 0

2. Minimise time taken to fill the sprayer: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	2
2. Sprayer with AACTS	0.5	1

Consistency Ratio = 0

3. Ease of retrieval of agrochemicals input data: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	2
2. Sprayer with AACTS	0.5	1

Consistency Ratio = 0

4. Accuracy of the data gathered: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	5
2. Sprayer with AACTS	0.2	1

Consistency Ratio = 0

5. Avoid use of unregistered agrochemical: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	4
2. Sprayer with AACTS	0.25	1

Consistency Ratio = 0

6. Operator Safety: a Utility function assessed using AHP:

	1. Sprayer without AACTS	2. Sprayer with AACTS
1. Sprayer without AACTS	1	1
2. Sprayer with AACTS	1	1

Consistency Ratio = 0

## Weights

OVERALL: a Utility function assessed using AHP:

	Minimise the investment cost	Minimise time taken to fill the sprayer	Ease of retrieval of agrochemicals input data	Accuracy of the data gathered	Avoid use of unregistered agrochemical	Operator Safety
Minimise the investment cost	1	5	2	5	2	4
Minimise time taken to fill the sprayer	0.2	1	0.2	1	1	1
Ease of retrieval of agrochemicals input data	0.5	5	1	2	0.5	2
Accuracy of the data gathered	0.2	1	0.5	1	0.25	1
Avoid use of unregistered agrochemical	0.5	1	2	4	1	2
Operator Safety	0.25	1	0.5	1	0.5	1

Consistency Ratio = 0.0609678



## Appendix F. Power Analysis

The power law equation:

$$1 - \beta = \phi\left(-z_{\alpha/2} + \frac{|\Delta|\sqrt{n}}{\sigma}\right)$$

Where:

$1 - \beta$  is the power

$|\Delta|$  is the standardized effect in this case is calculated as  $\frac{Mu_1 - Mu_2}{\sigma}$

$N$  is the sample size

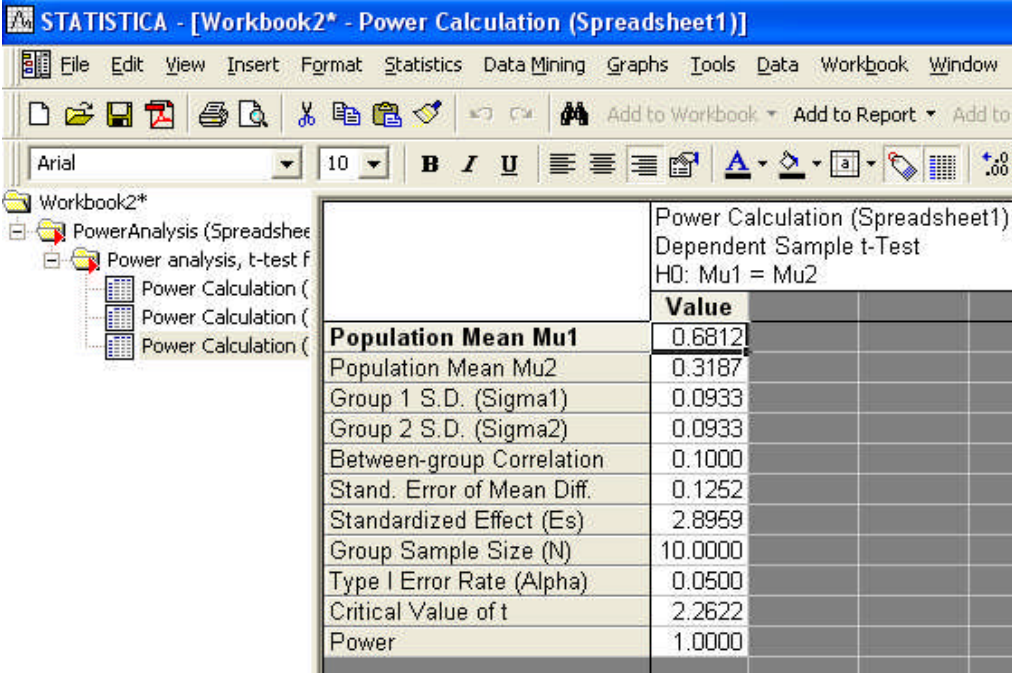
$\sigma$  is the standard error of mean difference.

$\phi(z)$  is the probability under a standard normal curve of being less than  $z$ .

$\alpha$  is the significance level.  $z_{\alpha/2}$  is the  $z$  value so that  $\phi(z) = \alpha/2$  (if  $\alpha = 0.05$  then  $z_{\alpha/2} = 1.96$ )

Result of the STATISTICA 8 Software:

Power analysis of sample size of 10:



Power Calculation (Spreadsheet1)	
Dependent Sample t-Test	
H0: Mu1 = Mu2	
	Value
Population Mean Mu1	0.6812
Population Mean Mu2	0.3187
Group 1 S.D. (Sigma1)	0.0933
Group 2 S.D. (Sigma2)	0.0933
Between-group Correlation	0.1000
Stand. Error of Mean Diff.	0.1252
Standardized Effect (Es)	2.8959
Group Sample Size (N)	10.0000
Type I Error Rate (Alpha)	0.0500
Critical Value of t	2.2622
Power	1.0000

T-test for Dependent Samples (Spreadsheet1)  
Marked differences are significant at  $p < .05000$

Variable	Mean	Std.Dv.	N	Diff.	Std.Dv. Diff.	t	df	p
Var1	0.681240	0.093332						
Var2	0.318750	0.093321	10	0.362491	0.186652	6.141350	9	0.000170

Power analysis of the sample size of 5 considering the means and standard deviation from sample size of 10:

Power Calculation (Spreadsheet1)  
Dependent Sample t-Test  
 $H_0: \mu_1 = \mu_2$

Variable	Value
Population Mean $\mu_1$	0.6812
Population Mean $\mu_2$	0.3187
Group 1 S.D. (Sigma1)	0.0933
Group 2 S.D. (Sigma2)	0.0933
Between-group Correlation	0.1000
Stand. Error of Mean Diff.	0.1252
Standardized Effect (Es)	2.8959
Group Sample Size (N)	5.0000
Type I Error Rate (Alpha)	0.0500
Critical Value of t	2.7764
Power	0.9963

Power analysis of the first group of five (A,B,C,D,E):

STATISTICA - [Workbook4\* - Power Calculation (Spreadsheet1)]

File Edit View Insert Format Statistics Data Mining Graphs Tools Data Workbook Wi

Power Calculation (Spreadsheet1)  
Dependent Sample t-Test  
H0:  $\mu_1 = \mu_2$

	Value
Population Mean $\mu_1$	0.6935
Population Mean $\mu_2$	0.3065
Group 1 S.D. (Sigma1)	0.0507
Group 2 S.D. (Sigma2)	0.0507
Between-group Correlation	0.1000
Stand. Error of Mean Diff.	0.0680
Standardized Effect ( $E_s$ )	5.6898
Group Sample Size (N)	5.0000
Type I Error Rate (Alpha)	0.0500
Critical Value of t	2.7764
Power	1.0000

STATISTICA - [Workbook7\* - T-test for Dependent Samples (Spreadsheet16)]

File Edit View Insert Format Statistics Data Mining Graphs Tools Data Workbook Window Help

T-test for Dependent Samples (Spreadsheet16)  
Marked differences are significant at  $p < .05000$

Variable	Mean	Std.Dv.	N	Diff.	Std.Dv. Diff.	t	df	p
Var1	0.693513	0.050728						
Var2	0.306487	0.050728	5	0.387025	0.101456	8.529937	4	0.001037

Power analysis of the second group of five (F,G,H,I,J):

	Value
<b>Population Mean Mu1</b>	0.6690
Population Mean Mu2	0.3310
Group 1 S.D. (Sigma1)	0.1290
Group 2 S.D. (Sigma2)	0.1290
Between-group Correlation	0.1000
Stand. Error of Mean Diff.	0.1731
Standardized Effect (Es)	1.9527
Group Sample Size (N)	5.0000
Type I Error Rate (Alpha)	0.0500
Critical Value of t	2.7764
Power	0.8964

T-test for Dependent Samples (Spreadsheet19)  
Marked differences are significant at p < .05000

Variable	Mean	Std.Dv.	N	Diff.	Std.Dv. Diff.	t	df	p
Var1	0.668968	0.129033						
Var2	0.331012	0.129017	5	0.337956	0.258050	2.928480	4	0.042879

## **Appendix G. Contingent Valuation Questions, Group A: Farmers who hire contractor to perform the spray application**

### **Thank you for accessing this questionnaire.**

We would like to emphasise to you that you will not receive any direct further contact from this research. It is our plan to publish a brief summary of the results in TAG newsletter in few months. The information collected here will not be used for any purposes other than this research. The questionnaire is split in three parts and will take approximately **10 minutes** to be completed. Contact details in event of problems or concern:

Carla P. Gasparin - Cranfield University Email Me

### **Please answer the following questions:**

#### **1. Please tick a box which best describe your business**

- I am a Farmer
- I am a Contractor

#### **2. Who usually does the spray application at your farm?**

- Contractors
- Employee
- Yourself

#### **3. How do you receive the spray plan?**

- Electronic records
- Paper based
- Other (please specify)

#### **4. How do you generate or obtain the spray application records?**

- Software based
- Paper based
- Electronic spreadsheet
- Other (please specify)

#### **5. How do you store the spraying records?**

- Paper based
- Computer Database
- Mixed
- Other (please specify)

#### **6. Do you use equipments which incorporate any Global Positioning System (GPS) and spatial variable application to assess, understand and compensate any in-field variation in soil type and crop performance?**

- Yes
- No

Please read the following information and watch the video before answering the questions.

### **Data collection at farm**

In order to comply with increasing amount of regulation and quality assurance schemes, farmers have to collect and keep the records of the crop production. There is a potential opportunity to assist the farmers/growers in collecting the data by using automatic recording systems. Such systems will support current traceability systems used at farm level and potentially reduce the cost of collecting and managing data.

### **The current scenario**

A graduated measuring jug is normally used to measure the amount of product to be loaded into the sprayer. The operator has to wash the measuring jug after each use. The accuracy of the amount dispensed depends on how carefully the sprayer operator measures the prescribed amount. After loading, the pesticide application record sheet is filled in by the sprayer operator and could be subject to human error. Often, the operators spray record reflects the agronomist recommendation and not the actual amount dispensed in to the sprayer. The data management can be either electronic or paper-based. In order to have electronic data the agrochemical inputs have to be manually entered into the desktop/laptop/handheld computer.

### **Proposed Prototype System**

The video shows an *automatic agrochemical recording and weighing system (AACTS)* which will identify and record the quantity and the name of agrochemicals being loaded into a sprayer and decrease the possibility of human error. The operator will save time in filling out the pesticide application record sheet. Additionally, the information regarding the application will be stored electronically so it can be downloaded directly onto a computer. This will minimise the time required to input spray data in order to satisfy environmental and traceability scheme regulations. There is a potential opportunity to save time on data retrieval using electronic data instead of manual paper based data.

Please click [here](#) to see a 30 seconds video.

The **potential benefits** of the AACTS are:

### **Prevention of agrochemical misapplication**

The automatic identification of the agrochemical name and amount used will ensure that the sprayer has the correct product and rate as prescribed by the agronomist.

### **Labour saving regarding the data management.**

The following data will be automatically recorded by the *AACTS*:

1. Date of application
2. Start and Finish time of application
3. Product Name
4. Product Rate
5. MAPP number (Ministerially Approved Pesticide Product)
6. Field treated



7. As applied map
8. The unique identification of each container

**Accuracy of the data gathered**

The operator together with *AACTS* will identify, weigh and record the precise amount of the agrochemicals loaded into the sprayer. The agrochemicals inputs recorded by the system will reflect the actual amount that has been applied to a specific field.

**Operator Safety**

The *AACTS* will minimise the chance of contamination associated with pouring the agrochemical into the measuring jug and washing it out. The operator will load the agrochemical straight into the sprayer.

**7. Would you hire a contractor if his sprayer was fitted with the AACTS if it cost you EXTRA £0.25 per hectare? Please don't agree to pay an amount if you think you can't afford it or if you are not sure about being prepared to pay or not.**

- . Yes
- . No

**8. Would you hire a contractor if his sprayer was fitted with the AACTS if it cost you EXTRA £0.28 per hectare?**

- . Yes
- . No

**9. Would you hire a contractor if his sprayer was fitted with the AACTS if it cost you EXTRA £0.21 per hectare?**

- . Yes
- . No

**10. What would be the maximum you would pay?**

....

**11. Do you perceive a need for AACTS system?**

- . Yes
- . No

**12. Why would you decide to use the AACTS?**

- . Accuracy of agrochemical records
- . Management time saving
- . Operator Safety
- . Preference of electronic records to paper based
- . Other (please specify)

**13. Why would you decide NOT to use AACTS?**

- . Investment Cost
- . Complexity of use
- . Preference of paper based system to electronic records
- . Other (please specify)

**14. Farm area size**

Total area size (ha)....  
of which arable (ha)....

**15. Farm Type**

- . Primarily Arable (e.g. cereals, oil seed rape, peas, beans)
- . General Cropping (e.g. vegetables, potatoes, cereals)
- . Horticulture (e.g. vegetables, fruits, glasshouse flowers)
- . Mainly Dairy / Livestock
- . Mixed

**16. The firsts 100 respondents will win a Camper Swiss Army Knife. Please write your contact information.**

**Name:**

**Address 1:**

**Address 2:**

**City/Town:**

**State/Province:**

**Postal Code:**

**Phone Number:**



## **Appendix H. Contingent Valuation Questions, Group B: Farmers who do their own spray application or have a employee**

**Thank you for accessing this questionnaire.**

We would like to emphasise to you that you will not receive any direct further contact from this research. It is our plan to publish a brief summary of the results in TAG newsletter in few months. The information collected here will not be used for any purposes other than this research. The questionnaire is split in three parts and will take approximately **10 minutes** to be completed. Contact details in event of problems or concern:

Carla P. Gasparin - Cranfield University Email Me

**Please answer the following questions:**

**1. Please tick a box which best describe your business**

- I am a Farmer
- I am a Contractor

**2. Who usually does the spray application at your farm?**

- Contractors
- Employee
- Yourself

**3. How many sprayers do you have?**

- 1
- 2
- 3 over

**4. What was the capital cost of your only or most expensive sprayer?**

- Less than £15,000
- £15,000 - £30,000
- £30,000 - £45,000
- £45,000 - £60,000
- £60,000 over

**5. How old (in years) is your only or most expensive sprayer?**

**6. How do you receive the spray plan?**

- Electronic records
- Paper based
- Other (please specify)

**7. How do you generate or obtain the spray application records?**

- Software based
- Paper based

- Electronic spreadsheet
- Other (please specify)

**8. How do you store the spraying records?**

- . Paper based
- . Computer Database
- . Mixed
- . Other (please specify)

**9. Does your equipment incorporate any Global Positioning Systems (GPS) and spatial variable application to assess, understand and compensate any in-field variations in soil type and crop performance?**

- Yes
- No

Please read the following information and watch the video before answering the questions.

**Data collection at farm**

In order to comply with increasing amount of regulation and quality assurance schemes, farmers have to collect and keep the records of the crop production. There is a potential opportunity to assist the farmers/growers in collecting the data by using automatic recording systems. Such systems will support current traceability systems used at farm level and potentially reduce the cost of collecting and managing data.

**The current scenario**

A graduated measuring jug is normally used to measure the amount of product to be loaded into the sprayer. The operator has to wash the measuring jug after each use. The accuracy of the amount dispensed depends on how carefully the sprayer operator measures the prescribed amount. After loading, the pesticide application record sheet is filled in by the sprayer operator and could be subject to human error. Often, the operators spray record reflects the agronomist recommendation and not the actual amount dispensed in to the sprayer. The data management can be either electronic or paper-based. In order to have electronic data the agrochemical inputs have to be manually entered into the desktop/laptop/handheld computer.

**Proposed Prototype System**

The video shows an *automatic agrochemical recording and weighing system (AACTS)* which will identify and record the quantity and the name of agrochemicals being loaded into a sprayer and decrease the possibility of human error. The operator will save time in filling out the pesticide application record sheet. Additionally, the information regarding the application will be stored electronically so it can be downloaded directly onto a computer. This will minimise the time required to input spray data in order to satisfy environmental and traceability scheme regulations. There is a potential opportunity to save time on data retrieval using electronic data instead of manual paper based data.

Please click [here](#) to see a 30 seconds video.

The **potential benefits** of the AACTS are:

**Prevention of agrochemical misapplication**

The automatic identification of the agrochemical name and amount used will ensure that the sprayer has the correct product and rate as prescribed by the agronomist.

**Labour saving regarding the data management.**

The following data will be automatically recorded by the *AACTS*:

9. Date of application
10. Start and Finish time of application
11. Product Name
12. Product Rate
13. MAPP number (Ministerially Approved Pesticide Product)
14. Field treated
15. As applied map
16. The unique identification of each container

**Accuracy of the data gathered**

The operator together with *AACTS* will identify, weigh and record the precise amount of the agrochemicals loaded into the sprayer. The agrochemicals inputs recorded by the system will reflect the actual amount that has been applied to a specific field.

**Operator Safety**

The *AACTS* will minimise the chance of contamination associated with pouring the agrochemical into the measuring jug and washing it out. The operator will load the agrochemical straight into the sprayer.

**10. Would you buy the AACTS if it cost you £2,000? Please don't agree to pay an amount if you think you can't afford it or if you are not sure about being prepared to pay or not.**

- Yes
- No

**11. Would you buy the AACTS if it cost you £2,300?**

- Yes
- No

**12. Would you buy the AACTS if it cost you £1,700?**

- Yes
- No

**13. What would be the maximum you would pay?**

.....

**14. Do you perceive a need for AACTS system?**

- Yes
- No

**15. Why would you decide to use the AACTS?**

- . Accuracy of agrochemical records
- . Management time saving
- . Operator Safety
- . Preference of electronic records to paper based
- . Other (please specify)

**16. Why would you decide NOT to use AACTS?**

- . Investment Cost
- . Complexity of use
- . Preference of paper based system to electronic records
- . Other (please specify)

**17. Farm area size**

Total area size (ha)....  
of which arable (ha)....

**18. Farm Type**

- . Primarily Arable (e.g. cereals, oil seed rape, peas, beans)
- . General Cropping (e.g. vegetables, potatoes, cereals)
- . Horticulture (e.g. vegetables, fruits, glasshouse flowers)
- . Mainly Dairy / Livestock
- . Mixed

**19. The firsts 100 respondents will win a Camper Swiss Army Knife. Please write your contact information.**

**Name:**

**Address 1:**

**Address 2:**

**City/Town:**

**State/Province:**

**Postal Code:**

**Phone Number:**

## **Appendix I. Contingent Valuation Questions, Group C: Spraying Contractors**

**Thank you for accessing this questionnaire.**

We would like to emphasise to you that you will not receive any direct further contact from this research. It is our plan to publish a brief summary of the results in TAG newsletter in few months. The information collected here will not be used for any purposes other than this research. The questionnaire is split in three parts and will take approximately **10 minutes** to be completed. Contact details in event of problems or concern:

Carla P. Gasparin - Cranfield University Email Me

**Please answer the following questions:**

**1. Please tick a box which best describe your business**

- I am a Farmer
- I am a Contractor

**2. How many sprayers do you have?**

- 1
- 2
- 3 over

**3. What was the capital cost of your only or most expensive sprayer?**

- Less than £15,000
- £15,000 - £30,000
- £30,000 - £45,000
- £45,000 - £60,000
- £60,000 over

**4. How old (in years) is your only or most expensive sprayer?**

**5. How do you generate or obtain the spray application records?**

- Software based
- Paper based
- Electronic spreadsheet
- Other (please specify)
- I don't offer this service

**6. Does your equipment incorporate any Global Positioning Systems (GPS) and spatial variable application to assess, understand and compensate any in-field variations in soil type and crop performance?**

- Yes
- No

Please read the following information and watch the video before answering the questions.

### **Data collection at farm**

In order to comply with increasing amount of regulation and quality assurance schemes, farmers have to collect and keep the records of the crop production. There is a potential opportunity to assist the farmers/growers in collecting the data by using automatic recording systems. Such systems will support current traceability systems used at farm level and potentially reduce the cost of collecting and managing data.

### **The current scenario**

A graduated measuring jug is normally used to measure the amount of product to be loaded into the sprayer. The operator has to wash the measuring jug after each use. The accuracy of the amount dispensed depends on how carefully the sprayer operator measures the prescribed amount. After loading, the pesticide application record sheet is filled in by the sprayer operator and could be subject to human error. Often, the operators spray record reflects the agronomist recommendation and not the actual amount dispensed in to the sprayer. The data management can be either electronic or paper-based. In order to have electronic data the agrochemical inputs have to be manually entered into the desktop/laptop/handheld computer.

### **Proposed Prototype System**

The video shows an *automatic agrochemical recording and weighing system (AACTS)* which will identify and record the quantity and the name of agrochemicals being loaded into a sprayer and decrease the possibility of human error. The operator will save time in filling out the pesticide application record sheet. Additionally, the information regarding the application will be stored electronically so it can be downloaded directly onto a computer. This will minimise the time required to input spray data in order to satisfy environmental and traceability scheme regulations. There is a potential opportunity to save time on data retrieval using electronic data instead of manual paper based data.

Please click [here](#) to see a 30 seconds video.

The **potential benefits** of the AACTS are:

### **Prevention of agrochemical misapplication**

The automatic identification of the agrochemical name and amount used will ensure that the sprayer has the correct product and rate as prescribed by the agronomist.

### **Labour saving regarding the data management.**

The following data will be automatically recorded by the *AACTS*:

1. Date of application
2. Start and Finish time of application
3. Product Name
4. Product Rate
5. MAPP number (Ministerially Approved Pesticide Product)

6. Field treated
7. As applied map
8. The unique identification of each container

**Accuracy of the data gathered**

The operator together with *AACTS* will identify, weigh and record the precise amount of the agrochemicals loaded into the sprayer. The agrochemicals inputs recorded by the system will reflect the actual amount that has been applied to a specific field.

**Operator Safety**

The *AACTS* will minimise the chance of contamination associated with pouring the agrochemical into the measuring jug and washing it out. The operator will load the agrochemical straight into the sprayer.

**7. Would you buy the AACTS if it cost you £2,000? Please don't agree to pay an amount if you think you can't afford it or if you are not sure about being prepared to pay or not.**

- Yes
- No

**8. Would you buy the AACTS if it cost you £2,300?**

- Yes
- No

**9. Would you buy the AACTS if it cost you £1,700?**

- Yes
- No

**10. What would be the maximum you would pay?**

....

**11. Do you perceive a need for AACTS system?**

- Yes
- No

**12. Why would you decide to use the AACTS?**

- . Accuracy of agrochemical records
- . Management time saving
- . Operator Safety
- . Preference of electronic records to paper based
- . Other (please specify)

**13. Why would you decide NOT to use AACTS?**

- . Investment Cost
- . Complexity of use
- . Preference of paper based system to electronic records
- . Other (please specify)

**14. What is the average yearly size (ha) of your contracting business?**

....

**15. What best describes the farm type of your customers that involves spraying application? (Please choose all that apply approximately in percentage)**

- Primarily Arable (e.g. cereals, oil seed rape, peas, beans)
- General Cropping (e.g.vegetables, potatoes, cereals)
- Horticulture (e.g.vegetables, fruits, glasshouse flowers)

**16. The firsts 100 respondents will win a Camper Swiss Army Knife. Please write your contact information.**

**Name:**

**Address 1:**

**Address 2:**

**City/Town:**

**State/Province:**

**Postal Code:**

**Phone Number:**



## Appendix J. Calculation of the alternatives bids for the AACTS, Group A

Operation Cost = (Initial Bid\*(Depreciation/100))/land area (ha)

Maintenance Cost = (Initial Bid\*(Maintenance Cost/100))/land area (ha)

Cost of Capital at 8.25% = (0.0825\*Initial Bid)/land area (ha)

Total Cost = Operation Cost + Maintenance Cost + Cost of Capital at 8.25%

Depreciation % 15  
 Maintenance % of cost new, sprayer 17.5  
 Land Area (ha) 5,000

Initial Bid £	Operational Cost	Maintenance Cost	Cost of Capital @ 8.25 %	Total Cost	Profit	Initial Bid £/ha
2,000	0.06	0.07	0.03	0.16	50%	0.24
2,250	0.07	0.08	0.04	0.18	50%	0.28
2,500	0.08	0.09	0.04	0.20	50%	0.31
2,750	0.08	0.10	0.05	0.22	50%	0.34
3,000	0.09	0.11	0.05	0.24	50%	0.37

Lowest Bid £	Operational Cost	Maintenance Cost	Cost of Capital @ 8.25 %	Total Cost	Profit	Lowest Bid £/ha
1,700	0.05	0.06	0.03	0.14	50%	0.21
1,950	0.06	0.07	0.03	0.16	50%	0.24
2,200	0.07	0.08	0.04	0.18	50%	0.27
2,450	0.07	0.09	0.04	0.20	50%	0.30
2,700	0.08	0.09	0.04	0.22	50%	0.33

Highest Bid £	Operational Cost	Maintenance Cost	Cost of Capital @ 8.25 %	Total Cost	Profit	Highest Bid £/ha
2,300	0.07	0.08	0.04	0.19	50%	0.28
2,550	0.08	0.09	0.04	0.21	50%	0.31
2,800	0.08	0.10	0.05	0.23	50%	0.34
3,050	0.09	0.11	0.05	0.25	50%	0.37
3,300	0.10	0.12	0.05	0.27	50%	0.40

## Appendix K. Excel spreadsheet model used to calculate the TSCA and to estimate the Kaplan-Meier.

The survivor function at 0,  $S(B_0)$ , must be equal to 1 (all respondents are at least indifferent to the AACTS) and the survivor function at  $\infty$ ,  $S(B_{16})$  must be equal to zero (no respondent has an infinite WTP for the AACTS). The starting values for the  $S(B_j)$ 's inside these two intervals are fractions of the total interval and are calculated as follows: e.g.,  $S(B_1)$  value is  $15/16=0.938$  and  $S(B_{15})$  value is  $1/16=0.063$ . The other  $S(B_j)$ 's are calculated based on the same approach, as shown in.

Table below: a) WTP intervals and number of observations. b) Distinct boundaries values and  $S(B_j)$  values

a)

	WTP Intervals (Bi-Bk)		n° of obs ( $h_{ik}$ )
1	<b>NN2000</b>	<b>0 – 1700</b>	<b>6</b>
2	<b>NY2000</b>	<b>1700 – 2000</b>	<b>1</b>
3	<b>YN2000</b>	<b>2000 – 2300</b>	<b>5</b>
4	<b>YY2000</b>	<b>2300 - <math>\infty</math></b>	<b>3</b>
5	NN2250	0 – 1950	6
6	NY2250	1950 – 2250	2
7	YN2250	2250 – 2550	0
8	YY2250	2550 - $\infty$	1
9	<b>NN2500</b>	<b>0 -2200</b>	<b>8</b>
10	<b>NY2500</b>	<b>2200 – 2500</b>	<b>1</b>
11	<b>YN2500</b>	<b>2500 – 2800</b>	<b>1</b>
12	<b>YY2500</b>	<b>2800 - <math>\infty</math></b>	<b>1</b>
13	NN2750	0 – 2450	4
14	NY2750	2450 – 2750	0
15	YN2750	2750 – 3050	1
16	YY2750	3050 - $\infty$	0
17	<b>NN3000</b>	<b>0 – 2700</b>	<b>8</b>
18	<b>NY3000</b>	<b>2700 – 3000</b>	<b>0</b>
19	<b>YN3000</b>	<b>3000 – 3300</b>	<b>0</b>
20	<b>YY3000</b>	<b>3300 - <math>\infty</math></b>	<b>2</b>
			N=50

b)

Number of intervals		
Distinct boundary values	$S(B_j)$	$S(B_j)$ values
0	$S(B_0)$	1.000
1700	$S(B_1)$	0.938
1950	$S(B_2)$	0.875
2000	$S(B_3)$	0.813
2200	$S(B_4)$	0.750
2250	$S(B_5)$	0.688
2300	$S(B_6)$	0.625
2450	$S(B_7)$	0.563
2500	$S(B_8)$	0.500
2550	$S(B_9)$	0.438
2700	$S(B_{10})$	0.375
2750	$S(B_{11})$	0.313
2800	$S(B_{12})$	0.250
3000	$S(B_{13})$	0.188
3050	$S(B_{14})$	0.125
3300	$S(B_{15})$	0.063
$\infty$	$S(B_{16})$	0.000

## Non-overlapping intervals

Basic intervals		WTP Intervals (Bi- Bk)	h <sub>j</sub> (Eq. 22)	n <sub>j</sub> (Eq. 23)	Basic intervals		WTP Intervals (Bi- Bk)	h <sub>j</sub> (Eq. 22)	n <sub>j</sub> (Eq. 23)
1	0 - 1700	<b>0 - 1700</b>	6.00	12.371	8	2450 - 2500	2250 - 2550	0.00	1.050
		0 - 1950	3.00				<b>2200 - 2500</b>	0.25	
		<b>0 - 2200</b>	2.00				2450 - 2750	0.00	
		0 - 2450	0.57				<b>0 - 2700</b>	0.80	
		<b>0 - 2700</b>	0.80						
2	1700 - 1950	<b>1700 - 2000</b>	0.50	6.871	9	2500 - 2550	2250 - 2550	0.00	1.050
		0 - 1950	3.00				<b>2500 - 2800</b>	0.25	
		<b>0 - 2200</b>	2.00				2450 - 2750	0.00	
		0 - 2450	0.57				<b>0 - 2700</b>	0.80	
		<b>0 - 2700</b>	0.80						
3	1950 - 2000	<b>1700 - 2000</b>	0.50	4.538	10	2550 - 2700	<b>2300 - ∞</b>	0.30	1.493
		1950 - 2250	0.67				2550 - ∞	0.14	
		<b>0 - 2200</b>	2.00				<b>2500 - 2800</b>	0.25	
		0 - 2450	0.57				2450 - 2750	0.00	
		<b>0 - 2700</b>	0.80				<b>0 - 2700</b>	0.80	
4	2000 - 2200	<b>1700 - 2000</b>	0.50	6.205	11	2700 - 2750	<b>2500 - 2800</b>	0.25	0.250
		<b>2000 - 2300</b>	1.67				2450 - 2750	0.00	
		1950 - 2250	0.67				<b>2700 - 3000</b>	0.00	
		<b>0 - 2200</b>	2.00				<b>2500 - 2800</b>	0.25	
		0 - 2450	0.57				2750 - 3050	0.33	
5	2200 - 2250	<b>0 - 2700</b>	0.80	3.955	12	2750 - 2800	<b>2700 - 3000</b>	0.00	0.583
		<b>2000 - 2300</b>	1.67				<b>2500 - 2800</b>	0.25	
		1950 - 2250	0.67				2750 - 3050	0.33	
		<b>2200 - 2500</b>	0.25				<b>2700 - 3000</b>	0.00	
		0 - 2450	0.57				<b>2800 - ∞</b>	0.25	
6	2250 - 2300	<b>0 - 2700</b>	0.80	4.121	13	2800 - 3000	2750 - 3050	0.33	0.583
		<b>2000 - 2300</b>	2.50				<b>2700 - 3000</b>	0.00	
		2250 - 2550	0.00				2750 - 3050	0.33	
		<b>2200 - 2500</b>	0.25				<b>3000 - 3300</b>	0.00	
		0 - 2450	0.57				3050 - ∞	0.00	
7	2300 - 2450	<b>0 - 2700</b>	0.80	1.921	14	3000 - 3050	<b>3000 - 3300</b>	0.00	0.333
		<b>2300 - ∞</b>	0.30				<b>3050 - ∞</b>	0.00	
		2250 - 2550	0.00				<b>3000 - 3300</b>	0.00	
		<b>2200 - 2500</b>	0.25				<b>2300 - ∞</b>	0.30	
		0 - 2450	0.57				2550 - ∞	0.13	
8	2300 - 2450	<b>0 - 2700</b>	0.80	1.921	15	3050 - 3300	<b>2800 - ∞</b>	0.25	2.675
		<b>2300 - ∞</b>	0.30				3050 - ∞	0.00	
		2250 - 2550	0.00				<b>3300 - ∞</b>	2.00	
		<b>2200 - 2500</b>	0.25						
		0 - 2450	0.57						

**New S(B<sub>j</sub>) values**

Number of intervals		
Distinct boundary values	S(B <sub>j</sub> )	S(B <sub>j</sub> ) values (Eq. 24)
0	S(B <sub>0</sub> )	1.000
1700	S(B <sub>1</sub> )	0.713
1950	S(B <sub>2</sub> )	0.575
2000	S(B <sub>3</sub> )	0.484
2200	S(B <sub>4</sub> )	0.360
2250	S(B <sub>5</sub> )	0.281
2300	S(B <sub>6</sub> )	0.199
2450	S(B <sub>7</sub> )	0.160
2500	S(B <sub>8</sub> )	0.139
2550	S(B <sub>9</sub> )	0.118
2700	S(B <sub>10</sub> )	0.089
2750	S(B <sub>11</sub> )	0.084
2800	S(B <sub>12</sub> )	0.072
3000	S(B <sub>13</sub> )	0.060
3050	S(B <sub>14</sub> )	0.054
3300	S(B <sub>15</sub> )	0.054
∞	S(B <sub>16</sub> )	0.000

Eq. 22, Eq. 23 and Eq. 24 were repeated nine times until the points estimates of survivor function at each of the B<sub>j</sub> diverge. After nine repetitions, the following new S(B<sub>j</sub>) values were found.

**Final S(B<sub>j</sub>) values**

Boundaries	New S(B <sub>j</sub> ) (Eq. 24)	Mean WTP (C) (Eq. 25)	Variance (C) (Eq. 26)
0	1		748,741
1700	0.719	1222.369	384
1950	0.635	158.737	1,671
2000	0.618	30.919	38,937
2200	0.330	66.025	6,387
2250	0.310	15.515	51,652
2300	0.175	8.743	1,414
2450	0.172	25.752	1
2500	0.172	8.584	137
2550	0.171	8.575	29,149
2700	0.137	20.531	2
2750	0.137	6.843	28,402
2800	0.114	5.706	7,515
3000	0.109	21.723	873
3050	0.108	5.407	-
3300	0.108	27.037	300,724
∞	0	0	-
		<b>1,632</b>	<b>1,215,989</b>

$$\text{Eq. 27} = 24,320$$

Standard error (square root of Eq. 27) = 155.95

$$\text{Eq. 28} = 1,327 \text{ and } 1,938$$

$$\text{Marginal Error} = 1,938 - 1,327 = 611.32$$

### MEAN WTP – Follow up question

ID	Maximum WTP
1	200
2	500
3	500
4	500
5	750
6	999
7	1000
8	1000
9	1000
10	1000
11	1000
12	1000
13	1000
14	1000
15	1000
16	1000
17	1000
18	1000
19	1200
20	1200
21	1200
22	1250
23	1500
24	1500
25	1500
26	1500
27	1500
28	1700
29	1800
30	1950
31	2000
32	2000
33	2000
34	2000
35	2000
36	2000
37	2000
38	2200
39	2300
40	2305
41	2500
42	2500
43	2500
44	2550
45	2750
46	2800
47	3500
48	3500

Standard error of the mean is calculated as follows:

$$SEM = \frac{Stdv}{\sqrt{N}}$$

Where:

Stdv = Standard deviation, which is 766.32

N= sample size which is 48

SEM is equal = 110.61

Limits at 95%:

$$SEM \times 1.96 = 217$$

$$1,597 \text{ (Mean)} \pm 217 = 1,380 \text{ and } 1,814$$

*t-distribution* is calculated as follows:

$$t = \frac{M_1 - M_2}{\sqrt{\left[ \frac{(N_1 - 1)S_1^2 + (N_2 - 1)S_2^2}{N_1 + N_2 - 2} \right] \left( \frac{N_1 + N_2}{N_1 \times N_2} \right)}}$$

Where:

$M_1$  is the mean of the sample 1, which is 1632

$M_2$  is the mean of the sample 2, which is 1597

$N_1$  is the sample size of sample 1, which is 50

$N_2$  is the sample size of sample 2, which is 48

$S_1$  is the standard error of the mean of sample 1, which is 155.95

$S_2$  is the standard error of the mean of sample 2, which is 110.61

*t-distribution* is equal to 1.28

Degree of freedoms:  $N_1 + N_2 - 2 = 96$

P value calculated (TDIST excel) = 0.205

## Appendix L. The Chi squared test

expected counts = (sum actual col\*sum actual row)/total actual sum

Chi-squared = ((actual - expected)<sup>2</sup>)/expected

d.f. = (number of cols - 1)\*(number of rows - 1)

Generated vs. Received					
Actual Counts		Generated			Total
		SOFTEBASED	PAPGENER	ELEGENER	
Received	ELERECEIV	25	9	1	35
	PAPRECEIV	30	44	3	77
total		55	53	4	112
Expected Counts		Generated			Total
		SOFTEBASED	PAPGENER	ELEGENER	
Received	ELERECEIV	17.19	16.56	1.25	35
	PAPRECEIV	37.81	36.44	2.75	77
Total		55	53	4	112
Chi-squared		Generated			
		SOFTEBASED	PAPGENER	ELEGENER	
Received	ELERECEIV	3.55	3.45	0.05	7.05
	PAPRECEIV	1.61	1.57	0.02	3.21
total		5.17	5.02	0.07	<b>10.26</b> = Chi-Stat
2 = cols d.f. 1 = rows d.f. 2 = total d.f. <b>0.006 = p-value</b>					

Received vs. Stored					
Actual Counts		Stored			Total
		PAPSTORE	COMPUTER	RECMIXED	
Received	ELERECEIV	4	22	9	35
	PAPRECEIV	26	33	18	77
total		30	55	27	112
Expected Counts		Stored			Total
		PAPSTORE	COMPUTER	RECMIXED	
Received	ELERECEIV	9.38	17.19	8.44	35
	PAPRECEIV	20.63	37.81	18.56	77
Total		9.375	55	27	112
Chi-squared		Stored			
		PAPSTORE	COMPUTER	RECMIXED	
Received	ELERECEIV	3.08	1.35	0.04	4.47
	PAPRECEIV	1.40	0.61	0.02	2.03
		4.48	1.96	0.05	<b>6.50</b> = Chi-Stat
2 = cols d.f. 1 = rows d.f. 2 = total d.f. <b>0.039 = p-value</b>					

Stored vs. Generated					
Actual Counts		Stored			Total
		PAPSTORE	COMPUTER	RECMIXED	
Generated	SOFTEBASED	4	39	12	55
	PAPGENER	26	12	15	53
	ELEGENER	0	4	0	4
		30	55	27	112
Expected Counts		Stored			Total
		PAPSTORE	COMPUTER	RECMIXED	
Generated	SOFTEBASED	14.73	27.01	13.26	55
	PAPGENER	14.20	26.03	12.78	53
	ELEGENER	1.07	1.96	0.96	4
		30	55	27	112
Chi-squared		Stored			
		PAPSTORE	COMPUTER	RECMIXED	
Generated	SOFTEBASED	7.82	5.32	0.12	13.26
	PAPGENER	9.81	7.56	0.39	17.76
	ELEGENER	1.07	2.11	0.96	4.15
		18.70	14.99	1.47	<b>35.17</b> = Chi-Stat
2 = cols d.f. 2 = rows d.f. 4 = total d.f. <b>0.000 = p-value</b>					

## **Appendix M. Receptivity Questionnaire**

1. Should the use of agrochemicals be carefully monitored (& why / why not)
2. Does agrochemical traceability benefit individual farmers (& why / how)?
3. What problems might a lack of agrochemical traceability cause?
4. What methods do you know of that can be used to improve agrochemical traceability?
5. Do you already use a tracing system (if yes, what one)
6. How might the AACTS benefit you or your business?
7. Where would you expect to be able to acquire an AACTS from?
8. Who would be responsible for using the AACTS if you did acquire one?
9. Would you be able/willing to learn the necessary skills to operate the AACTS?
10. Can you foresee any particular challenges or problems in using the AACTS (explore in detail if any are mentioned)?
11. Based on what you have learned today, would you be interested in acquiring an AACTS?
12. Would you be prepared to take part in a trial of the system free of charge? If yes, what benefits do you like to achieve?
13. What would you do with the data generated by the AACTS?



## Appendix N. Coding System – Farmers’ Interviews

<b>AWA</b>	<b>Awareness</b>	<b>PEF</b>	<b>Precision Farming</b>
AWA – IMPA	Awareness of methods to improve agrochemical traceability	PEF – ABSO	Auto boom shut off
AWA – UIMPA	Unawareness of methods to improve agrochemical traceability	PEF – YM	Yield map
AWA – FIN	Awareness of financial benefits	PEF - LIG	Light bar
AWA – FSY	Awareness of food safety	PEF - AUT	Auto steer
<b>ASB</b>	<b>Business Benefits</b>	<b>CON</b>	<b>Concerns</b>
BSB – MASC	More Accurate Stock Control	CON - LTI	Concerns regarding the loading time
BSB – MASC - REAS	More Accurate Stock Control, link with reader on the shed	CON – RIN	Small rinsing area
BSB – AWC	Avoid use of incorrect chemical	CON-SAB	Sprayed area bigger than actual area
BSB – ACD	More accurate data	CON – REA	Reliability
BSB – STO	Save time in the office	CON – ANR	Annual Fee registration
BSB – ASC	Be able to sell the crops	CON - COM	Compatibility with generic agrochemicals
BSB – LCT	Less contamination		
BSB – CON	Contractors		
BSB – ENV	Environment protection		
BSB – PRO	Prove records to legislation and crop assurance schemes		
<b>REQ</b>	<b>Requirements</b>	<b>IDE</b>	<b>Ideas</b>
REQ - RIH	Rearrange the induction hopper	IDE - WEA	Integrate with weather conditions
REQ – SOF	Software compatibility	IDE – WAT	Measures the water going into the tank
<b>RES</b>	<b>Responsibility</b>	<b>WLG</b>	<b>Willingness</b>
RES – LPA	Less paper work for the operator	WLG – BUY	Willingness to buy
		WLG – BUY - ENF	Willingness to buy if there is an enforcement
		WLG – UBUY	Unwillingness to buy
		WLG – TRY	Willingness to try
		WLG - UTRY	Unwillingness to try
		WLG – LEARN	Willingness to learn
<b>DAT</b>	<b>Data disclosure</b>		
DAT – SEN	Sensitivity about it		
DAT – SUP	Give to supermarket		

## **Appendix O. Interviews Transcripts, farmers**

### **Interview with respondent ID 1**

#### **I: Should the use of agrochemicals be carefully monitored (& why / why not)**

R: Yes, for consumers confidence. As well for quality assurance, monitor is the only way to make sure we are using agrochemical responsible.

#### **I: What problems might a lack of agrochemical traceability cause?**

R: There would be no way to check if the farmers used excessive levels of agrochemicals. On the other hand we don't want to use more than necessary because agrochemical is very expensive. Lack of agrochemical could cause contamination and not being able to identify the area which has been overdose.

Check if the harvest happened on the right time, respecting the harvest interval for certain agrochemical.

#### **I: What methods do you know that can be used to improve agrochemical traceability?**

R: Stock Control. I use SUM-IT software to keep the farm records. We need to know how much has been bought and how much has been used (and where). We use GPS – light bar.

#### **I: Does agrochemical traceability benefit individual farmers (& why / how)?**

R: Yes, because this all part of the stock control system. We need to know where we have used the chemical we bought.

#### **I: Do you already use a tracing system (if yes ... what one)**

R: Yes, we use the SUM-IT to keep the records.

#### **I: How might the AACTS benefit you or your business?**

R: Yes, because will not have to take notes when we are filling the sprayer and the spray application records will be automatically downloaded into the computer. Save time in the office.

#### **I: Where would you expect to be able to acquire an AACTS from?**

R: I think it should be sell by machinery manufacture, such as Hardi and Bateman.

#### **I: Can you foresee any particular challenges or problems in using the AACTS (explore in detail if any are mentioned)?**

R: I think the design and the idea is quite good. But the space available to wash the containers is small, it should be bigger, we need space to wash 20 litres containers.

#### **I: Who would be responsible for using the AACTS if you did acquire one?**

R: Myself and the sprayer operator

#### **I: Would you be able/willing to learn the necessary skills to operate the AACTS?**

R: Yes, that is not a problem.

**I: Based on what you have learned today, would you be interested in acquiring an AACTS?**

R: Depend on the cost: I would be prepared to spend around £1,500, assuming it going to last between 5 and 10 years with minimum maintenance cost. I use under 200 hours per year on my sprayer.

**I: Would you be prepared to take part in a trial of the system free of charge? If yes, what benefits do you like to achieve?**

R: Yes. I would like to check if the recording information is more accurate we do at the moment.

I would like to see some potential time savings in the office.

Check how easy it is going to be to prepare the job plan and download into the sprayer and finally update my records.

**I: What would you do with the data generated by the AACTS?**

R: I would put into my software – SUM-IT and agronomist. He could check against the recommendation. I would give it to FABBL and supermarket only if they requested it, I think detailed information might make them confused and maybe they could misinterpret the information.

**Interview with respondent ID 3**

**I: Should the use of agrochemicals be carefully monitored (& why / why not)**

R: Yes, because it avoids abuse. It helps to guide the farm industry.

The most important is to consider the interest of our consumers, they need to be confident and know that the use of agrochemicals is monitored.

**I: What problems might a lack of agrochemical traceability cause?**

R: Misuse of agrochemical; use the agrochemical in the wrong place, in the wrong quantity and wrong concentration. Consequentially, this can cause a production loss and decrease the yield.

It might cause loss of consumers' confidence.

**I: What methods do you know that can be used to improve agrochemical traceability?**

R: Software can help the farmers to record the agrochemical data, so this helps to improve the agrochemical traceability. We have software to record the data, FARMADE.

Satellite navigation, it should improve the accuracy of the spray application. We use satellite navigator to auto steer the tractor, so the system puts the sprayer in the right field and place which should receive the spray application then the driver doesn't have to worry about driving the tractor. We have a trailed sprayer, 24m boom.

We manually record the deliveries and what we have in stock. The sprayer operator records what he used and how much he used.

**I: Does agrochemical traceability benefit individual farmers (& why / how)?**

R: Yes, it reduces the chances of wrong application and helps the farmers to manage the business.

**I: Do you already use a tracing system (if yes ... what one)**

R: We have manual recording system, but we use the software to put the information together and satellite navigation.

**I: How might the AACTS benefit you or your business?**

R: If we assume it is going to be more accurate, we should be able to economise on the amount of chemical concentration, we should be able to use less quantity.

We should be able to use a less skill operator.

It is good publicity; we could prove our records. By being able to prove the spray application, we give more confidence to consumers.

**I: Where would you expect to be able to acquire an AACTS from?**

R: I would go to the chemicals' manufacture, such as Syngenta. I think that the major agrochemical companies are more interested on us using this system.

**I: Can you foresee any particular challenges or problems in using the AACTS (explore in detail if any are mentioned)?**

R: What happened if the system doesn't work properly? We don't have staff trained to fix computer or electronic systems in case the system goes wrong. We will have to trained people on the farm to repair computerised systems.

Furthermore, maybe the operator doesn't know how to load the sprayer manually.

We have onboard computers on the combiners, when we have a problem no one here can fix it. But with combine we can continue work without any problem. Maybe if you offer this system, the authorities will say "if it doesn't work you may not use the sprayer". We will need to be sure about the reliability of the system.

The system should not slow down the operator.

**I: Who would be responsible for using the AACTS if you did acquire one?**

R: We have three qualified operators, they would operate the system.

**I: Would you be able/willing to learn the necessary skills to operate the AACTS?**

R: I would be willing to the staff to be trained. We would have to trained the three operators to use the system. The electronic job plan would be responsibility of the farm manager, but it would not be a problem because he is familiar with computer.

**I: Based on what you have learned today, would you be interested in acquiring an AACTS?**

R: Depends on how much it will cost. Our sprayer costs £25,000 (new machine). It shouldn't be more than 10% of the cost of the sprayer.

**I: Would you be prepared to take part in a trial of the system free of charge? If yes, what benefits do you like to achieve?**

R: Yes. I would be more interested on the difficulties. I would like to see if it is as quick as the manual loading system. As well how easy the operators will learn how to use and

make sure they will be able to use in real situation without any supervision. As well make sure the operator will be confident he can use, because there is no point to give it to the operator to use if he doesn't know how to use and if he doesn't feel confident on using it. He needs to be confident and know how to use without any help.

**I: What would you do with the data generated by the AACTS?**

R: We would put it into the FARMADÉ software to link with all the field records.

We kept all our records; we wouldn't provide it to supermarket unless they required it.

**Interview with respondent ID 4**

**I: Should the use of agrochemicals be carefully monitored (& why / why not)**

R: Yes, for safety reason. The product goes to the food chain and need to be safe. However I don't agree on the pesticide banned. We already use chemical in a safe way, we don't use more than we need to, and we only chemical we are allow to use it.

**I: What problems might a lack of agrochemical traceability cause?**

R: Market loss.

**I: What methods do you know that can be used to improve agrochemical traceability?**

R: I don't know.

**I: Does agrochemical traceability benefit individual farmers (& why / how)?**

R: Help us to manage the business, control de cost of the chemical we used and at the end of the year check the profit.

**I: Do you already use a tracing system (if yes ... what one)**

R: We use GateKeeper software to keep the records. We use Precision Farming (SOYL) system to check yield map.

**I: How might the AACTS benefit you or your business?**

R: This tide up the operation, avoid piece of papers. This is the next step for the business. This would also help on the stock control, maybe the manager will not have to manual check it.

Sometimes we use 5 different chemical per tank load, it could guide to the operator to load the sprayer. Telling him he is using the right chemical and amount, maybe he could use the wrong rate and will never find out unless a problem is detected down in the food chain.

We also spray another 600 ha under contract, this system could help us on the billing. It would be a very impressive system for contractors.

**I: Where would you expect to be able to acquire an AACTS from?**

R: The sprayer machinery, such as Househam. Maybe the agrochemical manufacture.

**I: Can you foresee any particular challenges or problems in using the AACTS (explore in detail if any are mentioned)?**

R: Maybe the old operators will have difficulty to use the computer.

I don't see any problem. This is the future.

**I: Who would be responsible for using the AACTS if you did acquire one?**

R: The spray operator and the manager to keep the records.

**I: Would you be able/willing to learn the necessary skills to operate the AACTS?**

R: We are training an operator to use computer, will not be difficult to learn.

**I: Based on what you have learned today, would you be interested in acquiring an AACTS?**

R: We need to get the GPS first, then we need to get this system. There are more important thing first such as GPS.

**I: Would you be prepared to take part in a trial of the system free of charge? If yes, what benefits do you like to achieve?**

R: Yes, I would like to check how quick and easy it would be to use it.

**I: What would you do with the data generated by the AACTS?**

R: We would download into the GateKeeper.

**Interview with respondent ID 5**

**I: Should the use of agrochemicals be carefully monitored (& why / why not)**

R: Yes, principally because of the farm's image.

Many people use wrong conditions and the wrong time (grown stage), it should be monitored to avoid contaminated food goes to the chain.

**I: What problems might a lack of agrochemical traceability cause?**

R: Financial lost, for not being able to market the crop as well for the use not approved chemical.

**I: What methods do you know that can be used to improve agrochemical traceability?**

R: No.

**I: Does agrochemical traceability benefit individual farmers (& why / how)?**

R: Yes, we need to monitor because if we spray in the wrong weather conditions, maybe only half of the chemical goes to the plan the rest if wasted. We need to monitor the use as well, and I think it is traceability.

**I: Do you already use a tracing system (if yes ... what one)**

R: I use GateKeeper software to keep the field records.

**I: How might the AACTS benefit you or your business?**

R: I run the business and also work on the field so this would help me to save my time in the office. Because, I spend all day on the field and have less time to spend in the office. I only have one student working for me for 6 weeks. Saving time in the office, would be huge benefit. My data on computer are 6 months out of date because we just finish harvesting, planting and spraying again. Now I will start updating it.

This could cut down the paper work and save my time on the office.

This should be part of the whole package with GPS system and tied with the GateKeeper.

Quite often we get number for rate such as 0.5l, this would save a lot of time setting the calculator working out the total amount per chemical and then try to remember how much you are suppose to use. Something we use 5 different chemicals, this would give us the total amount per tank.

Stock Control: My stock control never matches with my application records. The sprayed area is always slightly bigger than actual area. I might use the correct amount on the field and sprayed a slightly large area. So this means I used more chemical than I put on my records. But I don't this to be treated as an overdose.

I usually have to check in the store how much chemical I have left, because it is usually not right on my computer software.

**I: Where would you expect to be able to acquire an AACTS from?**

R: I can't associate with the machinery. I expect to be able to buy at Chemical Company. Benefit more the chemical company than the machinery, this could be a seller point for people to use the chemical more responsibly. It's more accurate and environmentally friendly.

**I: Can you foresee any particular challenges or problems in using the AACTS (explore in detail if any are mentioned)?**

R: On the practical level, usually farmers don't like electronic system. Because it is fully automated, when it works it would be fantastic, when it doesn't work then it may become a problem like any other electronic equipment, we are back on pen and paper.

Do we have to pay an annual registration to use it? For Sentinel we pay 150 per year.

The weighing system is taking space of the normal hopper, it is very small to wash big containers, it should be bigger.

**I: Who would be responsible for using the AACTS if you did acquire one?**

R: Myself.

**I: Would you be able/willing to learn the necessary skills to operate the AACTS?**

R: Yes.

**I: Based on what you have learned today, would you be interested in acquiring an AACTS?**

R: I would buy one depend on the cost. The only way for me have an idea how much I would pay for that it co calculate how much time I spend to transfer my data into computer and how much I would save on the filling process. For year, it would be around £500.

**I: Would you be prepared to take part in a trial of the system free of charge? If yes, what benefits do you like to achieve?**

R: Yes, I would like. I could justified my cost and make sure it worth using it in terms of cost saving for my farm scale.

I would like to see this working with my software, GateKeeper.

I would like feedback from this project.

**I: What would you do with the data generated by the AACTS?**

R: Put into my software, GateKeeper and give it to FABBL if they ask, they don't ask. They only check one spray record per year and one fertilizer per year.

**Interview with respondent ID 6**

**I: Should the use of agrochemicals be carefully monitored (& why / why not)**

R: Yes, to protect the environment. Special at this time at public awareness, we need to be more carefully how we used. For safety issue and Accountability.

**I: What problems might a lack of agrochemical traceability cause?**

R: This section is more related with fresh produce sector, at arable sector this is not a problem.

Some buyers don't want certain products to be used certain dates, so the lack of agrochemical traceability might cause a problem with some buyers.

**I: What methods do you know that can be used to improve agrochemical traceability?**

R: Only through record keeping and goods agronomic advice. We use Farmplan software to keep the records.

**I: Does agrochemical traceability benefit individual farmers (& why / how)?**

R: Yes, to prove records and be able to sell the products.

**I: Do you already use a tracing system (if yes ... what one)**

R: No, we only paper based system. I received the recommendation in a piece of paper. I adjust to use full containers rather than part container, but don't exceed the maximum rate. We always go down.

I am agronomist but also have an agronomist to discuss the recommendation. He is worry of what is right to the crop and the cost, and I more interested of what is better for environment and right for the crop. Then we can discuss to decide for the better recommendation.

There is a lot of footpath and people walking on the farm around here, we have to be very carefully with what we are spraying and when.

**I: How might the AACTS benefit you or your business?**

R: It could help: Cost, Environment, doing a better job, speed the job up.

Yes, as long the cost cover it. If it costs say £2,000 that a lot of mistakes or poor measure to get that money back. I try not to make that much mistakes anyway. Maybe I would pay £1,000.

Usually 15% of the chemical I buy per year are 1 litre container. It is usually the most expensive product and we need small quantities, this system could help on a more accuracy measurement. We maybe need to measure 0.7 of a litre.



The main benefit I see is better accuracy and better for environment. As well potential product saving.

I think it will be very difficult to get all the agrochemical companies to use the same RFID label. I wouldn't worry on high volume produce such a herbicide, not to have the label. But on fungicide and small quantities products which are very expensive, they all need to have it. Because that is where the potential savings are.

Currently we use pen and paper and long after the application is done we update our records using FarmPlan. It would be a big plus to have the application records on a memory stick and download it on a computer, so I don't have to deal with paper work.

This should be integrated with other software provides, such as Farmade and Muddy Boots.

I spray for other people, but I don't think they would pay any extra for that. I use their chemical anyway, I don't charge for the chemical. So they know what much I used anyway.

I try not to keep stock on farm, but we always do. It is very small, easy to check.

**I: Where would you expect to be able to acquire an AACTS from?**

R: Better to buy someone who understands the spray and spraying. We need good support to use it, we need more specialist people to deal with that. People would still buy it doesn't come from the manufacture of the sprayer. Even if Landquip don't support it I would buy anyway, considering I have a support for that. Actually sometimes the dealer just want to sell the equipment and are not interested to help with the accessories and maybe not even know how this works.

We use N sensor (Yara) on the fertilizer spreader. The only reason I am using that is because a a farmers at Oxford looks after this area. He is a farmer and he also looks after 10 N sensors in this area, so he can troubleshoot and he has experience. If he has big problem, if can get back to the Precision Decision company who then will help. Having something like that adds values, having the network of people who use the system. Having using the system makes you more capable to sort problems out.

**I: Can you foresee any particular challenges or problems in using the AACTS (explore in detail if any are mentioned)?**

R: The area to wash a 20 litres can is too small. It is already difficult to wash on a standard induction hopper already, and that looks nearly impossible. We need to move to wash the corners. This hopper should flit out, maybe would it help.

With 4000 litres I sprayed 40 hectares. Especially at this time of the year I have to put 150 or 200 litres of chemical. We try to use full containers and leave the part container at the end, maybe one or two chemicals. The weighing induction hopper should be enough for the small amount I use as part container. Some product has to be very accurate, 0.1 or 0.3 of a litre per tank, this system would help.

Until you don't know how quickly or slow it makes your tank filling. If it takes twice to fill up the tank, we will not use, because it cost a lot of time. If we can fill the tank on the same time or less, than it is paying back. It would pay back in time efficiency as

well accuracy. But if it takes longer and is more accurate; I better keep my conventional method and save time.

Spraying season is crucial, I am responsible for spraying all the farm and I also spray under contract as well. I have another full time man, which don't use the spray, because I want to be responsible for making the decision when I am on the field and the weather changes, if I should stop or carry on. I don't put pressure on my labour. I am very fussy about my soil, I look after it, so I want to make the decision when to go on the field.

We input our data into Farmplan software once a year to do the gross margin. A long time after the work being done. I am not good with computers, I am very slow so my wife helps me when we are doing the gross margin.

So, I don't use Farmplan to input my application plan before I go and spray. I use pen and paper. This time I have to spent in the office to create the job plan would be difficult for me. As I said, I am responsible for spraying.

Let say we need 1,75 litre per hectare, and we have a 5or 10 litre tank. We need to put quite a lot through this little hopper, it is a problem to decide the size.

**I: Who would be responsible for using the AACTS if you did acquire one?**

R: Myself.

**I: Would you be able/willing to learn the necessary skills to operate the AACTS?**

R: Yes, I would be willing to learn how to create the job plan using a software. Of course, it should be easy to use but because I am very slow with computers.

**I: Based on what you have learned today, would you be interested in acquiring an AACTS?**

R: Yes, depends on the cost. As I said I would pay £1,000.

I would be happy to take how it is now, but have to be a very good price, because maybe in two years it is developed and cost 5,000 but does everything much better. However, I like for being able to take part of the development process, makes thinks better and show others how it works.

**I: Would you be prepared to take part in a trial of the system free of charge? If yes, what benefits do you like to achieve?**

R: Yes. Then I can see how quick it is to use on the field.

**I: What would you do with the data generated by the AACTS?**

R: Into Farmplan and give it to my farm consultant, but he don't use computers. I would give it to my quality assurance scheme. Maybe agronomist who uses muddy boots would like it.

I wouldn't give it to supermarket, because they don't understands all this records. Giving too much information for people who don't understand can be a problem.

**Interview with respondent ID 7**

**I: Should the use of agrochemicals be carefully monitored (& why / why not)**

R: Yes, because it goes to the food chain. It is a safety issue.

**I: What problems might a lack of agrochemical traceability cause?**

R: If the use of agrochemicals was not monitored and the residue test were not conducted, a overdose would never be detected before it goes to the food chain and someone could get contaminated.

We need to keep the records to check the harvest interval and know when we are able to harvest. (28 days after spraying).

**I: What methods do you know that can be used to improve agrochemical traceability?**

R: A sprayer with GPS system, which can map the spray application, can improve the agrochemical traceability.

**I: Does agrochemical traceability benefit individual farmers (& why / how)?**

R: Yes, especially on the stock taking control. Being able to identify how much has been used (and where) and how much is left is a huge benefit.

**I: Do you already use a tracing system (if yes ... what one)**

R: We use manual tracing system. We check how much is in stock and how much has been used. But we rely on human brain, this is very unreliable. A computerized system would be more reliable. Maybe a barcode system would help me on the records, as the products goes out of the store, my computer would know that. What I would like to have is a reliable link of the chemical store and the operators. We use Farmplan (Farmade software) to keep the records.

**I: How might the AACTS benefit you or your business?**

R: I think the principle behind of the idea is excellent.

Main benefit is stock taking. We spend over a £150,000 per year on chemical. The AACTS would tell me exactly where the chemical is being applied.

More accurate data. The actual sprayed area is bigger than the field size (depend on the field shape). So, we use more chemical than recommended by the agronomist. This doesn't mean we overdose. At the end of the day I need to know how much chemical has been used. I usually have to double check on the stock and check how much has been used. We can take some of the recording emphasis away from the operators.

I think that the vegetable producers (fresh produce) will be the first to use it. Because they sell directly to supermarket and they have their own quality assurance schemes. We, the arable farmers, would follow this people.

It would save time in the office. We have 60 fields on the farm, every time we spray I have to update my records. Receiving the spray application records electronically would save a great amount of time. I would only have to type in the weather conditions.

**I: Where would you expect to be able to acquire an AACTS from?**

R: I think it would be available through agricultural manufacture – John Deere or AGCO.

**I: Can you foresee any particular challenges or problems in using the AACTS (explore in detail if any are mentioned)?**

R: Maybe older generation will be afraid of electronic systems.

I like electronic system and new technologies and I don't see any problem on this system. But on the practical side the hopper should be bigger, we need space to wash up to 20 litre cans.

**I: Who would be responsible for using the AACTS if you did acquire one?**

R: Myself and one sprayer operator.

**I: Would you be able/willing to learn the necessary skills to operate the AACTS?**

R: Yes. We use GPS (auto steer system) and onboard computer on the combine (yield map). It takes few hours for the operator to learn how to use it. It wouldn't be difficult for them to learn how to use the AACTS.

**I: Based on what you have learned today, would you be interested in acquiring an AACTS?**

R: Yes, but depends how much it cost. It need to justified the money and identified the potential savers, which I think it would be the time saving on the office (labour). £3,000 is a reasonable price, we would buy it.

**I: Would you be prepared to take part in a trial of the system free of charge? If yes, what benefits do you like to achieve?**

R: Yes, I would be very interested to take part of a trial system. I would like see how it works on the field, how easy to use and reliable the system is. Also to ensure the data transfer to the office is easy and possible.

**I: What would you do with the data generated by the AACTS?**

R: I would like to have this system linked with the Farmplan, and then I could download the information into my computer.

I would give it to the supermarket only if they requested.

### **Interview with respondent ID 8**

**I: Should the use of agrochemicals be carefully monitored (& why / why not)**

R: Yes, because we can prove we are producing health food, we know where the products are, we records the reason for it. We can prove we are producing a clean product. At the end of the day the public has the right to know what they are eating.

**I: What problems might a lack of agrochemical traceability cause?**

R: If we can't prove the records, we are not able to market the product. If something is detected on a final food product, and we are requested to show the field records, if we don't have it we are in trouble.

**I: What methods do you know that can be used to improve agrochemical traceability?**

R: We use Farmade Multi Crop, which relies on quite a lot of manual inputs. But it is very difficult to match the stock, it never balances. We have Sentinel to make sure we are using approved chemicals.

**I: Does agrochemical traceability benefit individual farmers (& why / how)?**

R: We can use it as a marketing to get the maximum benefit from our crop.

**I: How might the AACTS benefit you or your business?**

R: I like the idea, give a card to the operator, then receive it back and we know exactly how much has been taken from the stock – Stock Control. It saves time. It is going to improve traceability, it is going to be more accurate.

We have had problems in the past where the operator picked the wrong chemical, we haven't lost too much, but it does happen. Avoid human error.

It is going save us some money. We have auto steer (Green Star), and auto shut off, this could be linked with our system. We use the GPS to map the area.

We could have a reader on the stock, and read the cans on stock.

If I do a 100 hectares spray plan for the sprayer operator, it will probably take 30 minutes, and another 30 minutes to update the records. It could save me 30 minutes.

**I: Where would you expect to be able to acquire an AACTS from?**

R: I would go to one of the sprayers manufacture. Or maybe at the hopper manufacture.

**I: Can you foresee any particular challenges or problems in using the AACTS (explore in detail if any are mentioned)?**

R: It has to be bigger, we need more space to triple rinse the can. The weigh hopper could fit on the side of the sprayer, so we just drop in when we need to weigh part cans. Or you could have a small weighing hopper next to the conventional one just to measure part cans.

**I: Who would be responsible for using the AACTS if you did acquire one?**

R: We have dedicated sprayer operator. And myself to use the record keeping.

**I: Would you be able/willing to learn the necessary skills to operate the AACTS?**

R: They use GPS, computer on cab, an extra button wouldn't make any difference. I think they would appreciate, because in theory it's going to tell them how much they need to take out of the store, and they don't need to write on the paper what they have done and how much they used.

**I: Based on what you have learned today, would you be interested in acquiring an AACTS?**

R: Yes, depend on how much it is. I would be paying around £5,000. I can see a benefit and I could easily justify something like that.

**I: Would you be prepared to take part in a trial of the system free of charge? If yes, what benefits do you like to achieve?**

R: Yes, I would be very interested.

**I: What would you do with the data generated by the AACTS?**

R: I would put back into my software, Farmade Multi Crop.

### **Interview with respondent ID 9**

**I: Should the use of agrochemicals be carefully monitored (& why / why not)**

R: I believe society is very worry about the use of agrochemical, I agree with that. But I don't want this data is used against us, the farmers.

**I: What problems might a lack of agrochemical traceability cause?**

R: No I don't see any problem.

**I: What methods do you know that can be used to improve agrochemical traceability?**

R: Machinery with satellite which records what has been sprayed on the field and where.

**I: Does agrochemical traceability benefit individual farmers (& why / how)?**

R: If we don't do it we get even less money for the crop. The industry has the choice to buy crops from countries which have no traceability systems in place and cheaper. That is the only benefit, keep the market. I am very cynical about traceability. I am not more

profitable for being able to check my stock or check what has been applied and where. The only reason I keep the records is to comply with quality assurance scheme.

**I: Do you already use a tracing system (if yes ... what one)**

R: No - We use GPS to drive on straight lines, four tractors with GPS. The spraying is fitted with a simple track device.

**I: How might the AACTS benefit you or your business?**

R: It could help me to do the records quickly, save time in the office. Currently I use excel program to keep the agrochemical records.

**I: Where would you expect to be able to acquire an AACTS from?**

R: The big sprayers manufactures, such as John Deere, because they already have GPS fitted on most of their tractors.

**I: Can you foresee any particular challenges or problems in using the AACTS (explore in detail if any are mentioned)?**

R: The weighing hopper should be the size of the normal hopper, 1,5l it is too small.

I don't know how easy it is going to use it, and how my staff will find it easy or not. A lot of farmers are older, and the discipline to learn that might be a barrier.

I concern about the label, what happens if the label is not there. Maybe the label should be melted into the plastic.

It might slow down the loading system. I don't do the records on field, do it later on. Don't see it as a problem.

I tried not to use half containers, because then we have to handle these chemicals on store. The only time we use half container is the last corner, when we need to spray 15 acres, only need quarter of a tank.

I can see that there is a potential for this to become compulsory for farmers. The way the government is conducting the legislation today, I think there will be market for that, because they are planning to ban 85% of the chemicals.

**I: Who would be responsible for using the AACTS if you did acquire one?**

R: Myself and other two operators. Six people works on the farm, half of the staff would have to understand it, to make it works.

**I: Would you be able/willing to learn the necessary skills to operate the AACTS?**

R: I think we all would be able to learn. The willingness will have to start with me, I need to be sure I understand how to use it before giving it to them.

If I can empty 3 litres from my bottle, but I have to put 2.6 litres, I will do it, and my records will show 2.6 litres. But if this system tells I did 3 litres, I am going hate it. I want to be able to sensible cheat. I want to tidy up my shelf, I and don't have in stock what I am not allow next year.

**I: Based on what you have learned today, would you be interested in acquiring an AACTS?**

R: Not today. I wouldn't buy it until I was forced to have it. Or until I improve my computer software technology such as yield map. It would be another step. I think when it is in place, we will be able to use quite quick and quite well.

**I: Would you be prepared to take part in a trial of the system free of charge? If yes, what benefits do you like to achieve?**

R: I wouldn't try the system with 1.5 litres hopper. This should be definitely bigger, the size of the normal hopper. Then I would take part of the trial.

I would like to check if it is simple to use it on the field and the speed.

**I: What would you do with the data generated by the AACTS?**

R: To Genesis and supermarket if they request it. They don't understand this data and might use it against me.

**Interview with respondent ID 10**

**I: Should the use of agrochemicals be carefully monitored (& why / why not)**

R: Definitely for safety reason.

**I: What problems might a lack of agrochemical traceability cause?**

R: Product contamination and consequentially loss of market.

**I: What methods do you know that can be used to improve agrochemical traceability?**

R: We use Farmade to keep the records.

**I: Does agrochemical traceability benefit individual farmers (& why / how)?**

R: We need to be able to demonstrate we are complying with legislation, we are applying only the approved chemical and no exceeding the maximum rates. Otherwise, our customers will not buy the products from us.

**I: Do you already use a tracing system (if yes ... what one)**

We collect at the records and it is update using the Farmade. We use GPS on sprayer, every time the sprayer goes on the field it is scanning the crop. We use yield mapping.

**I: How might the AACTS benefit you or your business?**

R: I think it a very sensible system, it is a evolution of what we are recording manually.

I think it could stop the operator loading the wrong material into the tank.

At the end of the day it should be compatible with Farmade or Muddy Boots.

This could update your stock day by day instead of someone going to the store once a month to check the chemicals left.

Everything today is based on computer system, I liked the idea to avoid paper based system, the manager would give a memory card to the operator and he will follow the instructions. The sprayer operator is one of the most technical minded person on the farm. There is a potential saving time for the operator and farm manager.

The thought of this doesn't scare me at all. I am a technical person.

**I: Where would you expect to be able to acquire an AACTS from?**

R: I would talk with sprayer manufacture.

**I: Can you foresee any particular challenges or problems in using the AACTS (explore in detail if any are mentioned)?**

R: But I don't see any major problem, because if this system doesn't work we can always use pen and paper.

We always have a worry with electronic on tractor. Because when it stop, it can take forever to find someone who understand the system to sort the problem out. When it is working is fine, when it stop working is a problem, we can't afford to have any machine stopped half a day.

One practical comment: doesn't seem to have enough space to rinse the container, on the commercial version the weighing hopper could be lifted out the hopper to give more space (1,5 litres is big enough). The rinsing systems are not good at the moment anyway, even with the other induction hopper. We try to buy bigger containers such as 10 litres, so we have less containers to rinse.

**I: Who would be responsible for using the AACTS if you did acquire one?**

R: The sprayer operator and the farm manager.

**I: Would you be able/willing to learn the necessary skills to operate the AACTS?**

R: We always involved the farm manager and more important the spray operator when we are planning to buy a new machine. He needs to be comfortable with that, because he will have to use it. He needs to see a benefit from his side. If he doesn't like he will use it wrongly. Recently we went to Demark to choose a new machine and the operator went to give this opinion.

**I: Based on what you have learned today, would you be interested in acquiring an AACTS?**

R: The concept is great. We are low cost commodities producers, we are competing on a global market. If we are going invest on this we have to justified financially. We are already complying with traceability requirements anyway, this wouldn't be a priority. I can see some savings such as recording time, reduce the labour by using it. We need to check how much it would save us. Nobody is going to pay us anymore because we have such a system.

We need to demonstrate that there is saving in labour, we got accurate records, the record is back much quicker, it is saving the sprayer man consequentially he can spray more hectares per day. Maybe 30 hour a day to filling up the records. I think we wouldn't pay more than £3,000 for such a system.

The other drive would to have to do something to comply with legislation, sometime we have to accept cost to keep on the market. But that is not the case.

At the end of the day if there is no savings, we would only buy that if supermarket request it or legislation requirement. Apart from that have to be a very good advantage.

**I: Would you be prepared to take part in a trial of the system free of charge? If yes, what benefits do you like to achieve?**



R: I would take part of the trial to check the saving times.

**I: What would you do with the data generated by the AACTS?**

R: We would save it into our Farmade software. We would give it to quality assurance schemes if they request it.

**Interview with respondent ID 11**

**I: Should the use of agrochemicals be carefully monitored (& why / why not)**

R: Yes, because the consumers want to have confidence on the food they eat. It is a safety reason.

**I: What problems might a lack of agrochemical traceability cause?**

R: Market loss.

**I: What methods do you know that can be used to improve agrochemical traceability?**

R: No.

**I: Does agrochemical traceability benefit individual farmers (& why / how)?**

R: Keeping the agrochemical records is the only way to sell our production.

**I: Do you already use a tracing system (if yes ... what one)**

R: We have a mapping system on the farm (A-MAP). We use Farmplan (Farmade), plugged on Sentinel System, which only allow to issue an approved plan. We have a weather station, we are able to demonstrate the temperature and wind speed at the time of the application.

**I: How might the AACTS benefit you or your business?**

R: The biggest benefit is to help us to comply with traceability schemes and to prove the records. This could be used as evidence that we are following the law and not using more chemical than necessary.

I don't think there will be a reduction on agrochemical use by improving accuracy.

I can see supermarket will want this include within their protocols to make sure the operator didn't made a mistake. This is a concern, because these ideas can become compulsory.

One sprayer does more work than anything else on the farm, the sprayer (£80,000) is the most critical equipment on the farm, has around £250,000 of chemical per year going through it. Last year we did 10,000 hectares per year. The cost wouldn't be an issue for us, because of the farm size. Anything which can help the operators to do their job is beneficial.

We have around 200 fields; it is very time consuming to update the records manually. This could save my time in the office. We are member of APS (Sainsbury), Tesco, LEAF (Waitrose), Field to Fork (M&S) and ACCS. We pay £500 for someone to produce all evidence of each of the schemes, in the same order as the auditor wants to see, plus the membership fee and our time. LEAF wants to know the carbon footprint. M&S is the most difficult, they want to know such as how much water we have put on

for every tones of potatoes and how many grams of active ingredient of pesticides do you use per ton of potatoes?

We will normally only order the chemical when we need it. We are not carrying big stock of chemical. This system can help farmers which keep stock, bigger farmers. Stock control is a very intense labour. We try to avoid part container, because we don't want the hassle to have containers around the floor, we tend to round up and use it all.

**I: Where would you expect to be able to acquire an AACTS from?**

R: It would be much easier to find it at the machinery manufactures.

**I: Can you foresee any particular challenges or problems in using the AACTS (explore in detail if any are mentioned)?**

R: I don't know how easy is to use it, it seems very easy looking the video, but in practically can be different. The hopper seen small to rinse 20 litre containers, it should be bigger.

Usually farmers are more mechanic and not familiar with computers; too much technology and electronic can scare some people. However, the sprayer operator might like it because they don't have to write the information anymore. They don't like to keep the records.

The difficulty will be if smaller farmers, such as 240ha, is forced to used it as part of the conditions to supply a supermarket, then it will be a cost problem.

**I: Who would be responsible for using the AACTS if you did acquire one?**

R: One sprayer operator.

**I: Would you be able/willing to learn the necessary skills to operate the AACTS?**

R: Yes, this wouldn't be a problem. We are familiar with computers and the sprayer operator would see the benefits on the record keeping.

**I: Based on what you have learned today, would you be interested in acquiring an AACTS?**

R: Yes, but this need to be linked with the GateKeeper software. I would pay £3,000 for the system

**I: Would you be prepared to take part in a trial of the system free of charge? If yes, what benefits do you like to achieve?**

R: Yes, probably. But the hopper should be redesigned.

**I: What would you do with the data generated by the AACTS?**

R: Give it to quality assurance schemes, supermarket and put into my software.

## **Interview with respondents ID 12**

**I: Should the use of agrochemicals be carefully monitored (& why / why not)**

R: Yes, it is important because it goes to food production and for environment protection as well.

**I: What problems might a lack of agrochemical traceability cause?**

R: Loss of market, we will not be able to market the crops.

**I: What methods do you know that can be used to improve agrochemical traceability?**

R: We use GateKeeper software to keep the records. It is linked with Sentinel list (Central Science Laboratory), which don't allow issuing the plan unless it is approved (check if the chemicals are approved).

**I: Does agrochemical traceability benefit individual farmers (& why / how)?**

R: No, it is just a responsibility and necessity.

**I: Do you already use a tracing system (if yes ... what one)**

R: Apart from the software we will start using GPS system next year, for tramlines and automatic nozzle shut-off, to avoid overlap.

**I: How might the AACTS benefit you or your business?**

R: Traceability system is not a good name, it got practice uses. Save time in the office is a great benefit.

Depend on the operator do you have, this system could be more accurate than the manual system. Help on the accuracy of application rates.

This could make the stock keeping of the chemical on store more accurate. We try to avoid keeping chemical on store but unfortunately sometimes this happens.

I have to check the chemical stock after the application just to make sure he applied the right amount. It is always slightly out, what they say they actually used it's never quite matches with the chemicals remaining on store. Sometimes he uses more and sometimes less.

We have two chemical stores, once a month we have to check the stock, to count the containers. Very often agrochemicals disappears, are stolen. We could have a RFID system at our store to check the stock automatically.

We also spray for others farmers, as a contractor it helps on a more accurate billing.

It also makes sure he got the right chemical on the hopper, it never happens here, occasionally we hear people using the wrong chemical and loss the production. All the containers look very similar, and if the farmer grows different crops there more chemicals on stock and the operator can use the wrong one. We are always in a hurry when it is times to spray.

This system should be linked with my software (Gatekeeper), then the sprayer plan can be created here and the application records can be downloaded back, without any paper work. It takes hours to process the data.

**I: Where would you expect to be able to acquire an AACTS from?**

R: Sprayer manufactures such as Househam.

**I: Can you foresee any particular challenges or problems in using the AACTS (explore in detail if any are mentioned)?**

R: The first thing it to make sure the chemical comes with the RFID label. The hopper should be bigger, it seen small to triple rinse 20 litre containers.

**I: Who would be responsible for using the AACTS if you did acquire one?**

R: Two sprayer operators to use on the field and myself to check the system afterwards on the computer.

**I: Would you be able/willing to learn the necessary skills to operate the AACTS?**

R: Yes, it is just a matter of training the operators, which I think can be very easy. The sprayer operators have to use computer on the sprayer anyway, they are very technical minded anyway.

**I: Based on what you have learned today, would you be interested in acquiring an AACTS?**

R: Yes, I would in time, once it is link with the software. Also depends on the cost, I think it could cost £2,000.

**I: Would you be prepared to take part in a trial of the system free of charge? If yes, what benefits do you like to achieve?**

R: Yes, I would. To prove the system could work and is practical.

**I: What would you do with the data generated by the AACTS?**

R: I would put into the GateKeeper. As well to the supermarket because we are member of Tesco Nature Choice and we give this information anyway. Tesco and APS are the difficult ones, in term of technical questions they asked and the record keeping required.

### **Interview with respondent ID 13**

**I: Should the use of agrochemicals be carefully monitored (& why / why not)**

R: Yes, we as farmers are monitoring the use of chemicals to comply with market requirements and make sure consumers are confident of what they are eating. However, it is still an element to trust that we are doing what we saying.

The supermarkets are the main drivers: We wouldn't be recording the amount of data we are recording at the moment if the supermarkets don't request it.

**I: What problems might a lack of agrochemical traceability cause?**

R: If we can't show that we apply the correct chemical we cannot market that product. That is the most important thing we do on the farm. If we put illegal chemical we can't sell that crop. If we fail on pesticide application doesn't matter how good you are, we loss the production. Waitrose have a higher specification of what chemical you can use, they generally pay more (potatoes).

**I: What methods do you know that can be used to improve agrochemical traceability?**

R: Companies are offering smart card technology to map field, we could put the recommendation in the smart card than this can be downloaded into the sprayer computer, but the operator still have to weigh the chemical.

We don't use GPS on combines, we used to 15 years ago, the technology just came on. We could produce the map and the yield variation but the problem was to analyse the data, what was causing that yield variation. I suspect in few years time we will have GPS guidance on our tractors, but that it.

**I: Does agrochemical traceability benefit individual farmers (& why / how)?**

R: There is a financial benefits for us, we don't apply more than we are suppose to use and we cross check with our invoices and what we did on the field, we cross check with what's on store. There is a high level of training with the operator, and a high level between the manager and the operator.

**I: Do you already use a tracing system (if yes ... what one)**

R: We use Farmade software to keep the records, all manual data entry.

**I: How might the AACTS benefit you or your business?**

R: Purely saving time.

I buy the chemical today, I might apply today, the invoice will come next month, when I update my records on my Farmade software, maybe today, maybe next week, there is always a bit of time delay, potentially we could make a mistake, and not find it until later. I can see a benefit because as soon as we apply the chemical, the information is already available. But there is always a problem with cost.

We have a store on farm; we don't carry big stock, but a little bit. We have a little bit of everything because we have many varieties of crops and different chemicals. This could help me on stock control. I can take one week to update the records on my computer, and meantime I might don't know how much I have in stock.

M&S and Waitrose would like to see this system, you would be successfully market this system thought supermarket.

**I: Where would you expect to be able to acquire an AACTS from?**

R: I would contact the manufacture of my sprayer, Bateman. If this is available as a retrofit from another company I would still contact Bateman. If they don't support it, then I wouldn't buy it. They need to be convinced that this system would enhance their machinery and not take away from them. A system fitted on a sprayer reflects on the performance of the sprayer.

**I: Can you foresee any particular challenges or problems in using the AACTS (explore in detail if any are mentioned)?**

R: My main worry, how reliable the system will be? I know people that have problem with the GPS reception on combines, sometimes have to stop 10 minutes to carry on. If I have a problem when I am loading my sprayer, I am sure I will not be able to stop and fix the problem; we are always in a hurry when spraying. Electronics, if the wire is working.

How easy is to transfer one unit from one sprayer to another, in case we change our sprayer? We change our sprayer every 8 or 9 years, it would be practical if every time we change our sprayer we have to buy one of these.

Do we have to pay a fee every year to update the chemical list? It would be a small cost, but have to be there. We don't have Sentinel on our Farmade software, this is an extra.

Using my manual system, I read the recommendation and read the spray records I got an immediately association with the number. If you automated the system, as a manager, we become more detached, because we know the data is there and maybe we will not have the hurry to check it if it is correct or not. That is my worry.

That is so many products we don't put the maximum rate anyway, because if we go over the rate, immediately we can't see the crop. We tend to make sure we do slightly under, but I don't think we are compromising the efficiency of the product.

There is so many variability and practically on the spray operation. We can go and spray the same field 3 times on 3 different days. The areas are always slightly different, could be 9.74; 9.50; 9.6. If this system allows me to put the exactly the maximum in for 9.75 hectares, then I spray 9.7, then immediately flag up, you put too much chemical, you overdose. Most of the machine we are switch on and off manually. Our sprayer measures the area and flow rate. This system should allow the operator to make some notes.

**I: Who would be responsible for using the AACTS if you did acquire one?**

R: The sprayer operators and myself. I need to be comfortable with the system.

People who drive sprayers are been always keen on new technology anyway, because they are very high tech machinery now days. I got 6 people working; most don't want to do spray. Those who want to spray generally enjoy the extra responsibility and the fact that there is more technology, they have to think what they are doing.

**I: Would you be able/willing to learn the necessary skills to operate the AACTS?**

R: Most people who use sprayer wouldn't have a problem with that, because enjoy high tech sprayer. They would have a problem if it is unreliable.

**I: Based on what you have learned today, would you be interested in acquiring an AACTS?**

R: At the moment I wouldn't. I would be interested to get feedback from a person who is already using it, when it is already available on the market.

**I: Would you be prepared to take part in a trial of the system free of charge? If yes, what benefits do you like to achieve?**

R: I wouldn't. I would consider buying if it is already in the market and if it is testify by other farmers. We are very busy and have on time to try new system, unless it is already tested by the market.

**I: What would you do with the data generated by the AACTS?**

R: Supermarket and FARMADÉ software.

**Interview with respondent ID 14**

**I: Should the use of agrochemicals be carefully monitored (& why / why not)**

R: Yes, mostly for our cost control and costing plan.

We also do some contract; we have to invoice them for the cost of the chemical, so we have to keep the records.

**I: What problems might a lack of agrochemical traceability cause?**

R: Production loss. If Birds Eye finds high residue level on the peas, then they reject the whole batch and the cost come direct back to the farm. Residue can be found for using chemical too late, or too much or not respecting the harvest interval.

It never happened, but if it happens it will cost a lot for the farm.

Traceability helps us to prove the records.

**I: What methods do you know that can be used to improve agrochemical traceability?**

R: We use GateKeeper to keep the records and it is synchronized with Sentinel that checks the recommendation (100 pounds a year). Check is you are using approved agrochemical also if you use chemical twice. We will soon start using handheld computer, so the operator can type in the information and it will reduce the amount of paper work. This could be synchronized with my computer records.

We use GPS for yield mapping and got GPS on the sprayer.

**I: Does agrochemical traceability benefit individual farmers (& why / how)?**

R: To keep the cost down.

**I: Do you already use a tracing system (if yes ... what one)**

R: We use GateKeeper and the handheld computer.

**I: How might the AACTS benefit you or your business?**

R: This should be linked with the weather conditions, because we spend a lot of time typing in the weather conditions. The operators write how much he has actually used and I update the records, typing in the rates doesn't take long at all. We have 60 fields on the farm. Saving time would be the major benefit.

It would save the operator time because they usually don't like to do that.

It could also help me on the stock control, because I always have to check on the store how much is left and check is the records are correct. Usually have to check twice a month the stock.

I could have RFID antenna on the store that could identify how much chemical we got there. This could synchronised with the spray records and also identify how much is left on the part containers. We try not to have stock but it is impossible because we have to order in advance, we need to make sure we will have the chemical available when we need it.

This could help us on the contract billing. This would take less time to check the records, because I always check the records at the end of the year to bill the other farm, this take a lot of time.

The size of our farm we can afford to have a person like me to do the paper work, so I spend most of my time updating records. But small farmers cannot afford that; this

system would be a great benefit for them. Because they have to do the field work and office work.

At the end of the tax year, we got to put our stock taking to know what value of goods we have on stock and that have to be very accurate.

**I: Where would you expect to be able to acquire an AACTS from?**

R: Probably at the Househam sprayer company. We would expect to find it at Cereals Show.

**I: Can you foresee any particular challenges or problems in using the AACTS (explore in detail if any are mentioned)?**

R: The only thing is the size of the hopper, it should be bigger. It is not enough space to wash 15 and 20 litre cans.

**I: Who would be responsible for using the AACTS if you did acquire one?**

R: The farm manager and the sprayer operator. The sprayer operator is willing to learn how to use the PDA, so it would be a problem to learn how to use it.

**I: Would you be able/willing to learn the necessary skills to operate the AACTS?**

R: The sprayer operator is willing to learn how to use the PDA, so it wouldn't be a problem to learn how to use it.

**I: Based on what you have learned today, would you be interested in acquiring an AACTS?**

R: Yes, but depend on the cost. I need to look how much time it saves me, how long it last and do we need to put into our sprayer. This should be linked with the GateKeeper.

Roughly, let's say it takes me 250 hours per year to update the spray records. £6 per hour, it would cost £1,500 per year. But we always under estimate how long it takes.

Now the agronomist sends the spray plan that can be synchronizes into the GateKeeper. He use MultiCrop, this saves me a lot of time.

**I: Would you be prepared to take part in a trial of the system free of charge? If yes, what benefits do you like to achieve?**

R: Yes, then I could estimate the time saving and accuracy.

**I: What would you do with the data generated by the AACTS?**

R: GateKeeper. I would give it to supermarket and Bird Eye if they want it.

The farm operator needs to keep the records of what spray he has done, for health safety. In case he has a problem in the future, so he can check the records. At the moment we print the records from GateKeeper.

### **Interview with respondent ID 15**

**I: Should the use of agrochemicals be carefully monitored (& why / why not)**

R: Yes, to avoid overdose.

**I: What problems might a lack of agrochemical traceability cause?**



R: We use £140,000 worth on agrochemicals per year. We need to keep the records for the accounting.

**I: What methods do you know that can be used to improve agrochemical traceability?**

R: Record keeping and proper training to the tractors operators.

**I: Does agrochemical traceability benefit individual farmers (& why / how)?**

R: Yes, we need to account the chemicals we used and where. This is a business like anything else, we need to know how much we bought, how much we applied and make sure there is no waste and we are using the right amount.

**I: Do you already use a tracing system (if yes ... what one)**

R: We use Farmade, GateKeeper to keep the farm records. We comply with traceability schemes.

**I: How might the AACTS benefit you or your business?**

R: I am not responsible for entering the data into the software. We have staff that does that, saving time in the office is not a benefit for me, because this is already part of her job. Stock control is already covered with system we have in operation. We already have the stock control system in place.

This has to be integrated with Farmade software.

This system should avoid contamination and less spillage. For my point of view, avoiding human error is the main benefit. The main benefit is to avoid the use of wrong chemical. The chemicals have similar names, labels and containers. The only way to measure the benefit is to calculate how much a farm loses if the operator puts the wrong chemical.

A very large strawberry grower lost £250,000. The operator said that he applied what he as told to apply, convenient all the empty cans were putted away, and we could check what he had applied. You should talk with NFU mutual; they insure a lot of people on the agriculture world.

There are mistakes due to the application of wrong chemical. I know a farmer lost around £140,000 worth of crop, due to improper chemical, or mistake.

Would this incorporate nutritional sprays at the fruit production? But it is different sprayers (fruit sprayer – Fantini). It would be good this technology include this product.

I think Central Science Laboratory is more reliable and quick in updating the data base than PSD, maybe you should link this system with CSL.

The need for a system like that is probably greatest for the fruit. Because what we do is directly reported to Tesco and Sainsbury. They would be interested, and would like to see a technology like that. If it costs £2,000 cost, the sprayer cost £100,000, not such a big deal. But fruit sprayer cost £12,000, and the value of chemical I put into the fruit is less than arable, (£50,000). But still the system is more important for fruit production.

This would be very helpful on contract spraying service.

This help on the accountability, confirm how much you have applied on the crops. Account where this product has putted on it, it confirm that it has been applied and take out the human error factor. It is 100% accountability.

**I: Where would you expect to be able to acquire an AACTS from?**

R: Sprayer manufactures.

**I: Can you foresee any particular challenges or problems in using the AACTS (explore in detail if any are mentioned)?**

R: Yes, the hopper size. We use 10 and 20 litre can, the space left for triple rinse it is too small. I thinks as it is stands now, it only enough to rinse 5 litre containers.

If for instance, more on the fruit side than the arable side. Sometimes we need to put 5 different chemical on the tank, it may need to put one chemical before another. This system should show on the screen do not put this chemical first that chemical, then we can plan the job and specify the order to of loading.

**I: Who would be responsible for using the AACTS if you did acquire one?**

R: The sprayer operator and the farm manager.

**I: Would you be able/willing to learn the necessary skills to operate the AACTS?**

R: Yes. They are familiar with computers.

**I: Based on what you have learned today, would you be interested in acquiring an AACTS?**

R: Depend on the cost; I would pay up to 2,000. More than that maybe takes 3 years to pay back, just accounting the saving time.

**I: Would you be prepared to take part in a trial of the system free of charge? If yes, what benefits do you like to achieve?**

R: Yes.

**I: What would you do with the data generated by the AACTS?**

R: Give it to my agronomist and crop assurance schemes.

#### **Interview with respondent ID 16**

**I: Should the use of agrochemicals be carefully monitored (& why / why not)**

R: Yes, for our stock control, to know where we are using the chemicals. As well consumers confidence, give them the prove that we are using safe rates.

**I: What problems might a lack of agrochemical traceability cause?**

R: If we exceed the residue level, we might contaminate the field and loss the production. If the supermarket finds high residue level then they condemn you whole crops.

**I: What methods do you know that can be used to improve agrochemical traceability?**

R: Carefully monitor, proper training for operators and computerized system that can trace back the application records.

**I: Does agrochemical traceability benefit individual farmers (& why / how)?**

R: This will be more benefit for the broccoli production, that where the supermarket can check the residue level with more precision than the cereals.

**I: Do you already use a tracing system (if yes ... what one)**

R: We use the GateKeeper software to keep the records. If we use GPS, light bars. We have the yield map on combine, but don't use it, we just got it, still learning.

**I: How might the AACTS benefit you or your business?**

R: Give us an idea that we are not using too much chemical and also too little chemical and do not compromise the resistant problem.

Keep the cost down if we using too much chemical.

This could avoid use of wrong chemical, because if has been known to use the wrong chemical. I know a person who lost the whole production because use the wrong chemical. The containers are so similar, and it can be very easy to mix if we are in a hurry, usually if we have so many different chemical in stock.

It could save my time, I like the idea to keep a memory stick with the information and don't have to type the information into computer. It could also save the operator a job, don't have o write the information as he goes. Maybe he could spray more hectares per day.

We try to keep stock records, but it is never accurate. I have to go to store and check what we have, usually late in winter, then try to match with my records. But it never correct. This could help my stock control.

**I: Where would you expect to be able to acquire an AACTS from?**

R: It should be available through the machinery industry. It should be easy to attach on the sprayer. If Bateman recommends this I would trust them much more than see an advert ton a magazine.

**I: Can you foresee any particular challenges or problems in using the AACTS (explore in detail if any are mentioned)?**

R: Got to be simple to use, less complicate as possible to the driver. If it is simple, reliable, I can't see any problem. If this monitor the water that goes inside, would also be interested.

Maybe the hopper should be bigger, I am not sure if I could rinse 20 litre containers in there.

The parts should be easy to replace.

**I: Who would be responsible for using the AACTS if you did acquire one?**

R: One operator on the field and myself on the office.

**I: Would you be able/willing to learn the necessary skills to operate the AACTS?**

R: I am sure, it doesn't seem very complicate to use, if he only have to scan and confirm. A training would be required he would learn easily.

**I: Based on what you have learned today, would you be interested in acquiring an AACTS?**

R: Yes, but depend on cost. I would pay between around £2,000.

**I: Would you be prepared to take part in a trial of the system free of charge? If yes, what benefits do you like to achieve?**

R: Yes, I would like. Interested to get the stock right, more accurate, make sure it would be more accurate than the manual.

**I: What would you do with the data generated by the AACTS?**

R: Give it to supermarket (Waitrose LEAF, Sainsbury (APS) and Tesco and M&S). This could help to prove the detailed records and quick data retrieval.

**Interview with respondent ID 17**

**I: Should the use of agrochemicals be carefully monitored (& why / why not)**

R: Yes, for food safety.

**I: What problems might a lack of agrochemical traceability cause?**

R: Not being able to sell the crops.

**I: What methods do you know that can be used to improve agrochemical traceability?**

R: I don't know any.

**I: Does agrochemical traceability benefit individual farmers (& why / how)?**

R: There is a financial benefit, make sure we are using the right chemicals and right rates.

**I: Do you already use a tracing system (if yes ... what one)**

R: I get the recommendation by email then I download into the Multi Crop then I print out and give it to my operator. I get the recommendation back and have to put in the computer.

**I: How might the AACTS benefit you or your business?**

R: The operator still has to write in a piece of paper the wind speed and temperature, if this system is also recording the weather conditions then it would be a benefit. Not automatic weather station but a way to input it manually in the user interface. That would make far more sense.

It would be useful to have a reader to read how much chemicals I have in the shed.

Most of the BASF cans are very similar, couples of years ago I put the wrong chemical in but I realise before I left the yard, it wasn't a problem because I went and sprayed a different field. A system like that would avoid it. It certainly make foolproof, so we have a peace of mind I suppose. But I have a very good sprayer operator.

**I: Where would you expect to be able to acquire an AACTS from?**

R: At the sprayers manufacture.

**I: Can you foresee any particular challenges or problems in using the AACTS (explore in detail if any are mentioned)?**

R: I think there is extra work to do when you are loading. I don't know if the operator will remember to push the buttons when necessary.

The weighing cell has to be an extension rather than inside. It will be very difficult to wash 20 litre cans.

**I: Who would be responsible for using the AACTS if you did acquire one?**

R: The operator and myself.

**I: Would you be able/willing to learn the necessary skills to operate the AACTS?**

R: When I started using the MultiCrop program I tried to use the palm top, but it was not very user-friendly, so I never bored the operator. My operator does quite like records on a piece of paper, because he can retrieve the data easily. But I am sure he would be able to learn.

**I: Based on what you have learned today, would you be interested in acquiring an AACTS?**

R: As it is stands I probably wouldn't buy one. I would spend this money on GPS on my sprayer. I suspect have to be legislation enforcement then I would be forced to buy one of this.

If I buy a new sprayer, then I would be more interested on this, because it could be built into the sprayer. I wouldn't buy as a retrofit.

The fresh producers would see more benefits.

**I: Would you be prepared to take part in a trial of the system free of charge? If yes, what benefits do you like to achieve?**

R: Yes I would be interested in trying it, but the hopper has to bigger. I would be interested to see how quick and easy it is to use it.

**I: What would you do with the data generated by the AACTS?**

R: I would put into the MultiCrop system.

I wouldn't give it to crop assurance scheme or legislation because the current system is already enough. If we give this sort of data, they don't understand too many details and maybe it will cause a problem for me.

**Interview with respondent ID 18**

**I: Should the use of agrochemicals be carefully monitored (& why / why not)**

R: For health and safety reason more than anything else. We a producing food products, we are saying we a producing food safe for human consumptions, got to be agrochemical traceability to ensure safety food product.

**I: What problems might a lack of agrochemical traceability cause?**

R: My biggest concern is potential loss of market.

**I: What methods do you know that can be used to improve agrochemical traceability?**

R: All of our products are put into stop at Farmade program (MultiCrop, older version of GateKeeper). I do the agronomist recommendation, we have a complete monitor program run by Sentinel, it will tell me the rates are ok and if the products are approved. We do have a mechanism in place that traces agrochemical.

**I: Does agrochemical traceability benefit individual farmers (& why / how)?**

R: I don't think we can't quantify the individual financial benefit on individual farm, but on global farm picture in Europe, yes it does benefits us. Because we have high level of crop assurance schemes and legislation more than anywhere else on the world.

**I: How might the AACTS benefit you or your business?**

R: I see benefits. We had an incident here, where the operator got the product names confused, a fungicide for wheat and a fungicide that can be use for wheat but we use for beans. So he applied the wrong chemical on 80 hectares of beans, it didn't harm the crop but it cost us around £2,500. The cost of that chemical and also the time of whole day applying the wrong product on the wrong crop. This system would warn the operator before he put into the sprayer. We had another farm in the Velcourt group that the operator applied Roundup on wheat; the operator picked the wrong chemical because the cans are very similar and they lost 50 hectares of wheat.

At the moment we are on paper system, I print out the application plan using the software, the operator fill out and bring me back and then we have to update the records. This could save us time in the office. At the moment I have to trust the operator.

We have to have a system to recognize the stock coming in. We operate the stock in, product usage and stock taking at the end of the month. We could have a reader on our shed to then read the stock. At the moment we entry the product coming in manually into the software, after the application we update the records. At the end of the month we have to go for a physical reconciliation. Some time it takes us two days to do a stock check. Because we run five farms business. We have all the chemicals under one shed. It could simplify the logistic of maintaining stock in out and record product use. It helps the accountability, because I am taking care of others farms money.

We use other means to load the sprayer, we pre mix most of the chemical in a 9,000 litre water tank on a lorry chassis, on the back there is a 2,000 litre water tank which has an induction hopper "nurse tank". This can saves time, the operator don't have to come back on the yard. This farm runs 30 miles to end to end, we can't afford them to drive back to the yard every time they have to fill up the tank. But your system could be integrated with this induction hopper.

**I: Where would you expect to be able to acquire an AACTS from?**

R: Someone like Ag Leader (Trimble) because they do all the GPS technology. They seem to be more technology minded that the sprayer manufacture. We have auto boom shut off on the sprayer, this improve accuracy of the application and reduce operator fatigue. We have no square fields, it is very difficult and required a lot of attention.

**I: Can you foresee any particular challenges or problems in using the AACTS (explore in detail if any are mentioned)?**

R: The number of cans per tank, we might have 5 different products going in one tank fill, 250 litre of chemical. It needs to be fairly quick.

We need the ability to rinse 10 and 20 litre can. The weigh cell, should be outside. We wouldn't want anything smaller than what we have today. Our pump runs 480 litres a minute, so it takes the liquid out of the induction hopper very quickly, so if we have half size, we will end up with a lot of foam in the tank because it will be sucking air rather than product. We got to it keep full. The weigh cell should be on the side, not inside. Something like, when it is not in operation is in the hopper, when it is in operation you pull it out. Then we have the big hopper and the small one for part container.

**I: Who would be responsible for using the AACTS if you did acquire one?**

R: We have four sprayer operators. Myself, the assistant farm manager, the main sprayer operator and another operator that sometime will drive to operator.

We need simple system. The operator needs to see the benefit for using it. Some days he might sprays 30 and 40 fields, he will like it because he don't need to write the information anymore. At the moment at the end of the day he figures out how much produce he used. The product usage is down to his degree of accuracy. I have to trust him. On very low rate product, I need 250g on a product, how do I know if he puts 250g or 300g, because it is 300g container. Your system will improve the accuracy to some extent.

**I: Would you be able/willing to learn the necessary skills to operate the AACTS?**

R: Yes, would be a problem, but has to be simple and quickly.

**I: Based on what you have learned today, would you be interested in acquiring an AACTS?**

R: I probably would, we would consider quite close anyway. Because I see it helps to manage the stock and manage application as well. In terms of how much time we spend to manage the stock. Put it in the software, updating the application records, checking at the store. Two days per month, 8 hours a day, times £25 per hour. We spend £4,800 per year on labour just for stock control. We are normally very good on to match the number of can in stock and the information on the computer, I believe that it is because the auto boom shut off, makes us more accurate. I would pay £4,000 for this system

Usually when there is a problem, is an operator error. If you got 8 cans to put in, then we realise you put 9 cans, the little things that happens...I would probably never know about that this happened because if the next load is 8 can again, he will put 7 cans. At the end of the day, he used all the chemicals. I guess it happens in a lot of farms. I would rather prefer he let me know and get the next load right, using 8 cans as requested.

**I: Would you be prepared to take part in a trial of the system free of charge? If yes, what benefits do you like to achieve?**

R: We probably would, we always embrace new technologies. We wouldn't be an ease farm to do it because we got a lot things going on here.

**I: What would you do with the data generated by the AACTS?**

R: I would put into the Farmade software, it has to be integrated. I wouldn't give to ACCS, because they don't request it. They are more interested on the health safety side

of application such as wind speed, buffer zone. Your system could be linked with weather conditions. This would be a great saving time.

**Interview with respondent ID 19**

**I: Should the use of agrochemicals be carefully monitored (& why / why not)**

R: Yes, must be monitored. Stock control, legislation.

We are keen to do the best job as possible on spray because we are under pressure from the retailer, protocols and from the general public. We can show the world and the auditors that we are using it responsibly.

**I: What problems might a lack of agrochemical traceability cause?**

R: If I am not able to prove my agrochemical records, I am not able to sell the crops.

**I: What methods do you know that can be used to improve agrochemical traceability?**

R: We use FARMADE for record keeping and stock control. We use Sentinel to check the recommendation.

**I: Does agrochemical traceability benefit individual farmers (& why / how)?**

R: Yes, it helps with stock control.

**I: How might the AACTS benefit you or your business?**

R: A more accurate weighing of part cans. We can check what the operator has used, rather than him telling what he used.

If this is linked with Farmade, our stock control will be more accurate in what we have left.

I can see benefit from preventing wrong chemicals going in, which does occur. Never happened here, but I know incidents. Someone put roundup thinking it was grow regulator and kill the whole 80 acres of wheat. Cans are very similar, and labels as well. The loss there would be 80 acres times £450, quite a big loss. They realise when the wheat died. They investigate their stock records, and find out that the roundup has been used and not the grow regulator. Mistaken can be made.

Mistaken can happen when the operator is counting the cans, as a manager we will never know. If he needs 9 cans, by mistake uses 10, then tomorrow he will use 8 then it will match the stock, I will never know that this happens.

**I: Where would you expect to be able to acquire an AACTS from?**

R: I would expect to find it at manufacturer sprayers. They should integrate into the machine.

**I: Can you foresee any particular challenges or problems in using the AACTS (explore in detail if any are mentioned)?**

R: The hopper seems very robust but not much room to wash 20 litres can out. This has to be outside or on the side. I guess it will be quite difficult to clean underneath. Some of the chemicals are very sticky, if get inside it is very difficult to wash. Some of the



chemicals, very small quantities, if you put on the wrong crop, you will know about it, because it will damage the crop. If you get residue, it is very seriously.

We pour granular fertilizer, like magnesium and manganese into the induction hopper. We need quite a lot of room to put it in and then the water, takes spaces. We need more space.

**I: Who would be responsible for using the AACTS if you did acquire one?**

R: The sprayer operator.

**I: Would you be able/willing to learn the necessary skills to operate the AACTS?**

R: Our operator would be keen to use. I think in generally sprayer operator seems to be a very high standard, this quite complicate computers in the sprayer.

**I: Based on what you have learned today, would you be interested in acquiring an AACTS?**

R: If next time we buy a new sprayer, if this is available I think we would do it. I would pay around £3,000.

**I: Would you be prepared to take part in a trial of the system free of charge? If yes, what benefits do you like to achieve?**

R: Yes, but the hopper has to be rearranged. Either the hopper has to be bigger or on the side.

**I: What would you do with the data generated by the AACTS?**

R: Put it into the FARMMADE software.

### **Interview with respondent ID 20**

**I: Should the use of agrochemicals be carefully monitored (& why / why not)**

R: It should be monitor for food safety, make sure we are not exceeding MRL, harvests intervals. At the end of the day it is a legal requirement.

**I: What problems might a lack of agrochemical traceability cause?**

R: The pack house always requires in advance the field records of the batches of potatoes. If we don't have it, we would be able to sell it.

**I: What methods do you know that can be used to improve agrochemical traceability?**

R: The GateKeeper system is all automated. I do the recommendation sheet, we create a work plan on GateKeer and that calculates for the operator how much material he uses. If this is what he has uses he just tick the boxes, if for some reason he uses a little more or less he writes the amount. We are using GateKeeper for field records not for recommendation, next step is to have Sentinel. It a safe guide that makes sure we are using approved recommendation.

**I: Does agrochemical traceability benefit individual farmers (& why / how)?**

R: Yes, there is a financial benefit. We are able to check the stock control and make sure we are not using the wrong chemical and wrong doses.

**I: Do you already use a tracing system (if yes ... what one)**

R: Just record keeping.

**I: How might the AACTS benefit you or your business?**

R: This system can be very helpful to make sure the operator is using the right chemical. We haven't had any problem, but our neighbour next door which had an incident. We as suppose to put Chlormequat on his wheat, which is an green 20 litre can, and the roundup is also the green 20 litre can, so he putted the wrong chemical and lost about 80 to 100 hectares of wheat kill the whole crop.

There is a product called Sulfonylurea which is mostly produced by DuPont, they have all similar packages and sizes. A farmer went to a local merchant and order Sulfonylurea for his potatoes crops. But it was supplied with Sulfonylurea for using on cereals, he dint bored to check the labels and spray on his potatoes crops the wrong product. He didn't kill all the crops, but he lost the yield, the potatoes were small, he was not able to sell anyway because he used an illegal chemical.

It is saves the operator for using measures jugs, less contamination. Don't need to wash out the jugs.

It looks very simple system in terms of operation. Accurate record keeping. Absolute 100% sure you got the right chemical.

Possibly saving time by not to have to measure chemical, limitation of operator's explosion as well. More accurate and automatic stock control.

**I: Where would you expect to be able to acquire an AACTS from?**

R: At the sprayer manufactures.

**I: Can you foresee any particular challenges or problems in using the AACTS (explore in detail if any are mentioned)?**

R: The clean nozzles is not good to rinse 20 litre can. We need to be able to work the can roundly. I am not too worry about the weighing cell, but you got to make sure the main hopper is large enough to be able to wash out 20 litre can.

The generic agrochemical manufactures should also use RFID labels. The common products we do tend to buy generics. A buying group which sells about 8 different suppliers, they should be able to labels the cans.

How about Sulfonylurea, we use 15 grams per hectare, can we weight that accurate?

If it is the same speed, that's fine. It shouldn't slow down the operation. Some time it takes longer put the chemical in to fill the sprayer with water.

If we have a recommendation for Glyphosate, for a specific product name. But in the shed we have Glyphosate but different brand name, would this work? We order the chemical from a buying group, sometimes we order the chemical buy chemical name and not by brand name, and we don't know what brand arrives until it is in the shed.

**I: Who would be responsible for using the AACTS if you did acquire one?**

R: The sprayer operator.

**I: Would you be able/willing to learn the necessary skills to operate the AACTS?**

R: Yes. Particularly if it saves the amount of paper work.

**I: Based on what you have learned today, would you be interested in acquiring an AACTS?**

R: Yes, I would pay £4,000.

**I: Would you be prepared to take part in a trial of the system free of charge? If yes, what benefits do you like to achieve?**

R: Yes, but the hopper but has to have enough space to rinse the 20 litre cans. The most important is to make sure the operator is happy with this. If it is not right, he is not happy and will not use it properly.

**I: What would you do with the data generated by the AACTS?**

R: I would put it into the FARMADE software. Give it to supermarket.

**Interview with respondent ID 21**

**I: Should the use of agrochemicals be carefully monitored (& why / why not)**

R: I think we are monitoring for a reason, we have very good system in place.

**I: What problems might a lack of agrochemical traceability cause?**

R: Not being able to market the product.

**I: What methods do you know that can be used to improve agrochemical traceability?**

R: We use GateKeeper linked with Sentinel to check approved chemicals.

**I: Does agrochemical traceability benefit individual farmers (& why / how)?**

R: No financial benefit, we need to do it to comply with traceability. It gives the public the confidence to buy our food. There is not direct benefit, but we have to do it.

**I: How might the AACTS benefit you or your business?**

I can see benefits, it makes the application safer. Tell us when to stop pouring it.

It a good idea to check the operators, they still work on acres and the recommendation is in hectares. This could stop them to use wrong chemical.

We are in a rush, mistakes can be made, this would stop us. Because when the operator is on his own I already seen him putting one extra can, because he is not paying attention. I do the recommendation, I get the chemicals required on stock, if it is part container, I weighing and sort it out before the sprayer operator comes up. So all that is there is what he needs to load into the sprayer, there is not risk to use more or less. That the way I found to check his job and I also do the record keeping, I write the paper for him, because I know what he used better than him.

Last year, we bought chemicals from a different manufacture, and the same chemical were provided on a 3 litre can, but the operator though it was 2 litres can because it was similar with the previous we used to buy and he was used to it. As a result he use the wrong quantity.

I wouldn't need the weighing because I always try to use full container, but the scanning idea is good.

**I: Where would you expect to be able to acquire an AACTS from?**

R: Sprayer manufactures.

**I: Can you foresee any particular challenges or problems in using the AACTS (explore in detail if any are mentioned)?**

R: Yesterday we used 7 different cans, it is going to take forever. I think it takes longer. We already have to triple rinse the cans. We put the can in, and we rinse it, while clean water is coming in we got clean water to rinse it, if we can load the sprayer quick enough before it is full we got no clean water to rinse it, we rinse with chemical. This is going to slow down us even more.

I don't believe I will be able to weight 20 grams using this.

We have very few days to spray, we need speed up the loading process instead of increase. If the weather changes we are not allow to spray anymore, so we lost the load.

The weigh hopper has to be outside, we use 15 and 20 litres. The hopper is already small.

**I: Who would be responsible for using the AACTS if you did acquire one?**

R: The sprayer operator and myself.

**I: Would you be able/willing to learn the necessary skills to operate the AACTS?**

R: Yes, wouldn't be a problem. But it got to improve the system before we use it.

**I: Based on what you have learned today, would you be interested in acquiring an AACTS?**

R: If GateKeeper is ready to get it, then I would consider. This has to be integrated with GateKeeper. I would pay £1,500.

**I: Would you be prepared to take part in a trial of the system free of charge? If yes, what benefits do you like to achieve?**

R: No, I would wait to see how it works on another farm before buying one of these.

**I: What would you do with the data generated by the AACTS?**

R: I would put back into my software, Farmade GateKeeper.

**Interview with respondent ID 22**

**I: Should the use of agrochemicals be carefully monitored (& why / why not)**

R: Yes, to provide safe food.

**I: What problems might a lack of agrochemical traceability cause?**

R: We might to be able to identify which chemicals we used, where and when.

**I: What methods do you know that can be used to improve agrochemical traceability?**

R: No.

**I: Does agrochemical traceability benefit individual farmers (& why / how)?**

R: It helps to manage the business, we know what we have used, where and when.

**I: Do you already use a tracing system (if yes ... what one)**

R: I use Muddy Boots to keep the field records.

**I: How might the AACTS benefit you or your business?**

R: It is an excellent idea. The main advantage is that there are no measure jugs to wash up and less spillage possible. It is safer.

It also takes cares of the stock taking at the same time, it all done for you. Saves time in the office.

We normally we put 3 products in, we do make mistake some times. This would stop us using the wrong chemical. That is where a mistake can be made, when we use measure jugs.

It could be very useful when I spray other farms, I could prove what I done.

**I: Where would you expect to be able to acquire an AACTS from?**

R: Sprayer manufacture.

**I: Can you foresee any particular challenges or problems in using the AACTS (explore in detail if any are mentioned)?**

R: This has to be compatible with Muddy Boots package.

This shouldn't slow the loading process. If it takes the same time, is OK, but not longer.

My concern are in terms of reliability and longevity, in the side of the sprayer corrosion everything against electric, this is quite exposed.

The hopper is already very small, this small hopper is taking too much space in the existing software. If we load very slowly we got a lot of air in the system, because it will suck air if we not keeping it full. The weighing hopper has to be outside.

**I: Who would be responsible for using the AACTS if you did acquire one?**

R: Myself. I do all the spray and also spray another 300 hectares farm.

**I: Would you be able/willing to learn the necessary skills to operate the AACTS?**

R: Yes, not a problem, used with computer and electronic on sprayer.

**I: Based on what you have learned today, would you be interested in acquiring an AACTS?**

R: How much it would cost? I would buy one, but no more than £2,500. I couldn't justify the cost more than that.

**I: Would you be prepared to take part in a trial of the system free of charge? If yes, what benefits do you like to achieve?**

R: No, I would consider when it is available on the market. I think it can help to resell the sprayer if I have it on.

**I: What would you do with the data generated by the AACTS?**

R: Put it on my software, Muddy Boots.

### **Interview with respondent ID 23**

#### **I: Should the use of agrochemicals be carefully monitored (& why / why not)**

R: It definitely should, for safety and public health.

#### **I: What problems might a lack of agrochemical traceability cause?**

R: If someone has a problem, we need to be able to show the records. To prove the product is legal and that we haven't used too much, and we follow the agronomic recommendation.

#### **I: What methods do you know that can be used to improve agrochemical traceability?**

R: Record keeping, I don't know any other method.

#### **I: Does agrochemical traceability benefit individual farmers (& why / how)?**

R: There is no much money involved, we need to make sure we are not spending more than we have to and unnecessary. I spend £100,000 per year on agrochemical inputs.

The records are used to prove good practice and give it to crop assurance scheme. If we could automated the record keeping; that would be a good thing.

To show the public that we are responsible users. People are very suspicious about chemical use in this country; anything we can do to reassure them that we are responsible is an extra assurance.

#### **I: Do you already use a tracing system (if yes ... what one)**

R: I have a stock sheet, which I keep on the store. I keep my data.

#### **I: How might the AACTS benefit you or your business?**

R: The biggest benefit is Stock Control! If we can take the card from the sprayer, then downloaded the data into my computer and update my stock sheet that would be more benefit than anything else. I have to go in the shed and count the cans left, this is a time consuming. The stock never matches with how much we used and how much we bought. We need to have a system that automatically check the stock on the shed. We could have a RFID reader on the store to check the stock and how much has left and when. If we have a part can, then it could be linked with the sprayer records. The whole system should be market together "automatic stock taking". It would save time in the office.

The agronomic recommendation is paper based, then I typed into my own excel spreadsheet to create the Sprayer Operator Sheet. So the operator know every tank, how much chemical and how much water to use it. I make it easy for him to follow. I think it is foolproof, he can't make a mistake. He knows exactly how much chemical and water to use, because I specify on the sheet. The Hardi sprayer allow us to specify the total water, once it reaches that it shut off and that include the chemical, measures the total volume on the tank. We also have automatic high control. It attached on John Deere tractor, with satellite received and auto steer. The computer onboard the tractor show the field you are spraying, the area you done and what you haven't done. The sprayer has auto section shut off boom, which also measure the area. Our actual sprayer area are getting smaller, less overlap, there is a saving. Our sprayer records the start time and

finish time, but it is easy to write it on a piece of paper rather than downloaded into the computer. The AACTS should be integrated with the rest of my sprayer.

Then after the sprayer operator fill out the records (date of application, time, wind speed, direction and temperature) I update into the Excel, this is what I show to ACCS. Then when it is completed I entry onto the SUMMIT software for my financial gross margin recording.

This system should be integrated with automatic weather conditions data collection.

**I: Where would you expect to be able to acquire an AACTS from?**

R: It should be available thorough sprayer machinery. There is a potential to this system become compulsory.

**I: Can you foresee any particular challenges or problems in using the AACTS (explore in detail if any are mentioned)?**

R: There should be a scale inside the hopper; that would help and the screen should be protected.

The weighing hopper shouldn't be inside the big hopper, because it limits the capacity for using whole cans. This should be out of the hopper or be able to lift it out. Should have more space for the rinsing. We need 10 and 20 litres container, we need space to rinse it.

Like any other electronic system on the farm, has to be reliable. If one day it doesn't work, then I will have problem to update my records.

This should be linked with all the software available on the market.

**I: Who would be responsible for using the AACTS if you did acquire one?**

R: Myself and the sprayer operator.

**I: Would you be able/willing to learn the necessary skills to operate the AACTS?**

R: Yes, we are already familiar with computer system.

**I: Based on what you have learned today, would you be interested in acquiring an AACTS?**

R: Yes, but depends on the cost. £2,000 is a reasonable price.

**I: Would you be prepared to take part in a trial of the system free of charge? If yes, what benefits do you like to achieve?**

R: Yes. I could try to measure the benefits. But definitely I would like to have a reader in the store as well. I can see the whole system working together, integrated. The hopper should be redesigned as well.

**I: What would you do with the data generated by the AACTS?**

R: I would put into my software SUMMIT. The program to read the card has to be integrated into my software. We want to cut down duplication as much as possible.

**Interview with respondent ID 24**

**I: Should the use of agrochemicals be carefully monitored (& why / why not)**

R: Yes, because it costs money. We don't want to use it a wrong way because can be more expensive than it already is. It avoids contamination for the environment as well.

**I: What problems might a lack of agrochemical traceability cause?**

R: If they discover a problem, maybe too much chemical, then they can trace back the field records. A lack of this data can be crucial to market the product.

**I: What methods do you know that can be used to improve agrochemical traceability?**

R: No.

**I: Does agrochemical traceability benefit individual farmers (& why / how)?**

R: Primarily is to comply with crop assurance. But also is also our interested to make sure we put in the optimum rate, financially. Not use too much or too little and having to spray again.

**I: Do you already use a tracing system (if yes ... what one)**

R: I am agronomist, I do my own recommendation. I use Gatekeeper to keep the records. I have a PDA when I go spray to record the star time and weather conditions. The PDA is with the old system, Multi Crop, which then can be downloaded into the GateKeeper. I select the field and then start time, then select finish to records the finish time and the weather conditions. It is quicker when I come back to the office, don't need to type in the data.

The sprayer operator keep on paper the date, start time, and weather conditions, later I type it into computer. I have application map on the sprayer (John Deere GPS system on it), a GPS for auto steer.

**I: How might the AACTS benefit you or your business?**

R: It tends to be more accurate, but I think we are already very accurate at the moment.

We have problem with contamination and spillage using measure jugs. This system can avoid contamination and spillage. We have to clean the measure jug, and also avoid spillage.

As the accountability is concern, we are already recording all the necessary data. The stock control is fairly accurate, not 100%, probably 90%. But it is acceptable. I understand a more accurate stock control would help, but it is no necessary. We would have to check the stock even with your system anyway.

This could avoid of wrong chemical. Particularly if you buy from the non major manufactures, the chemical containers and labels are very similar.

This should be integrated with the GateKeeper.

If we end up with more legislation, and we have to record exactly how much we uses and when then this system would help. But we are not there at the moment, and I hope we don't end up there.

**I: Where would you expect to be able to acquire an AACTS from?**

R: I would buy from our sprayer components, sprayers manufacture.



**I: Can you foresee any particular challenges or problems in using the AACTS (explore in detail if any are mentioned)?**

R: Need a bigger hopper, the size of the hopper is already an issue. It makes the hopper even smaller. It is quite difficult to put 10 and 20 litres can and rinse it. Maybe the hopper has to be separated, on the side.

Need to have a bigger read range when the container gets close to the hopper, because if we have 30 or 40 containers we probably will forget to swipe it. The reader should be on the way, closer to where we have to pass the container any way, not where it is now. I know my operator will forget.

Filling the sprayer is taking longer, because we have to triple rinse. This should decrease the time rather than increase. The time to fill the sprayer is crucial, we don't want a system that will increase the time.

With this system there are more area to clean inside the hopper. All the bits will get coated with chemical, and very difficult to wash, this should be either sealed or outside the hopper, or maybe covered with a type o material that the chemical don't stick to it.

If there is residue on the next time we use the sprayer, certain crops are very sensitive and we don't need much to go into the tank to contaminate. If we use only 500 litres on the tank than the amount of contamination can be quite high. This type of chemical we use small amount and don't need very much to do the damage. This is quite big issue, on certain farms, which handle different crops.

**I: Who would be responsible for using the AACTS if you did acquire one?**

R: Myself and the operator.

**I: Would you be able/willing to learn the necessary skills to operate the AACTS?**

R: Yes, we would. The sprayer got already computer, we have to learn new things all the time, it just another thing.

**I: Based on what you have learned today, would you be interested in acquiring an AACTS?**

R: Not at the moment. At the moment the benefits wouldn't be enough to cover the problems of using it. It takes longer and the size of the hopper.

The benefit is to measure the part container, identify we are using the correct chemical and saver. But I don't think it pays for itself. It wouldn't bring a financial benefit at the moment. We are already using some type semi automatic system (PDA). It's save time in the office, but having your system wouldn't be a big step. Maybe for those who don't use it, then the saving time would be greater. Some people are very slow to update the records, your system would help. But we are very good on that anyway.

**I: Would you be prepared to take part in a trial of the system free of charge? If yes, what benefits do you like to achieve?**

R: I would take part to help to improve the system. But the induction hopper has to be bigger.

**I: What would you do with the data generated by the AACTS?**

R: Put into the GateKeeper.

**Interview with respondent ID 25**

**I: Should the use of agrochemicals be carefully monitored (& why / why not)**

R: Yes, to provide safe food.

**I: What problems might a lack of agrochemical traceability cause?**

R: I never experienced any problem. I assume I wouldn't be able to sell my products if I can't prove the chemicals I used.

**I: What methods do you know that can be used to improve agrochemical traceability?**

R: We use SUMM-IT software. It checks what we got on stock and what we put on the field.

**I: Does agrochemical traceability benefit individual farmers (& why / how)?**

R: It more a benefit for the people who buy our products, it helps the farmers to assure people that what they are buying is safe to eat.

**I: How might the AACTS benefit you or your business?**

R: It depend how much it cost. It has potential.

In theory it should help on the stock control, but we shouldn't forget to use it.

We don't use induction hopper. We have a mounted sprayer and we pour straight from the top. But we are looking for change our sprayer for a trailed sprayer.

It could save us some time in the office. At the moment we have a written out spray sheet, we go and do spraying come back and fill it out manually. Then the secretary puts that into the computer.

We are not big farm and I am very closely involved with the spraying process. I actually can't see any directly benefit.

**I: Where would you expect to be able to acquire an AACTS from?**

R: Sprayer manufacture.

**I: Can you foresee any particular challenges or problems in using the AACTS (explore in detail if any are mentioned)?**

R: I never use an induction hopper; I can't see any problem because I am not familiar with that.

We can use 7.5 grams per hectares. Sometime we might have 3 hectares to finish, we need 300 litres of water and 22.5 grams. This system should be accurate enough to weigh that.

**I: Who would be responsible for using the AACTS if you did acquire one?**

R: We have an operator, but I would use it as well.

**I: Would you be able/willing to learn the necessary skills to operate the AACTS?**

R: I don't know. I would have to first learn how to use the induction hopper.

**I: Based on what you have learned today, would you be interested in acquiring an AACTS?**

R: First I need to buy a sprayer with induction hopper then I would consider buying this system. But I wouldn't be the first person to be using it. I would probably wait until the technology mature.

**I: Would you be prepared to take part in a trial of the system free of charge? If yes, what benefits do you like to achieve?**

R: No.

**I: What would you do with the data generated by the AACTS?**

R: I would put it into my software – sum-it.

**Interview with respondent ID 27**

**I: Should the use of agrochemicals be carefully monitored (& why / why not)**

R: Yes, it definitely should. It ensures food safety and public health.

**I: What problems might a lack of agrochemical traceability cause?**

R: Loss of market, we will not be able to market the crops. It is important to know how much agrochemical has been used on the field, for accounting.

**I: What methods do you know that can be used to improve agrochemical traceability?**

R: I know what everybody used, manual record keeping.

**I: Does agrochemical traceability benefit individual farmers (& why / how)?**

R: There is a financial benefit, we keep the records for accounting.

**I: Do you already use a tracing system (if yes ... what one)**

R: The agronomics sent by email the recommendation I printed it out and give it to the operator. He gives me back after the spray application. I keep it on paper, it is enough for legal purposes. I only type into excel if I for accounting purposes.

**I: How might the AACTS benefit you or your business?**

R: This could help the stock control. As well save time typing the amount we used into the computer.

This can stop the operator using the wrong chemical. Last year we had a problem. We had two jobs on the sheet, one on rape one on beans, two chemicals each. The spray man memories the chemical and he put the mixture for the rape on the beans without look again on the sheet, and he killed 60 acres of beans. If this system is linked with GPS then it will tell you if you are on the right field.

It is quite expensive to get yourself insurance as a contractor, this system could decrease the risk of making a payout. If you could sell this package saying your insurance premium go down by 15% for example. Give them a financial benefit.

**I: Where would you expect to be able to acquire an AACTS from?**

R: I think it should be part of the sprayer as a standard equipment, all integrated.

**I: Can you foresee any particular challenges or problems in using the AACTS (explore in detail if any are mentioned)?**

R: We can't wash big cans with that. This has to be bigger or that has to swing out of the way. Some of the big cans, 20 litres, don't fit on the induction hopper anyway.

Sometimes we have a recommendation for a particular product and we got the generic on the shed, this system has to be able to accommodate that. The software could identify if in the absence of this chemical, this one is the same, give the choice.

This system should to be able to measure 10-20 grams. We use 42 grams per hectares of Ally Max, if we only need to spray a ¼ of a hectare we would need 10 grams.

Couple of the chemicals need a shaker before pouring, because the chemicals settle. Perhaps you can put on the screen "Shake can before weighing" to remind the operator. Sediment.

**I: Who would be responsible for using the AACTS if you did acquire one?**

R: Myself and the spray operator.

**I: Would you be able/willing to learn the necessary skills to operate the AACTS?**

R: Yes, looks very simple to use.

**I: Based on what you have learned today, would you be interested in acquiring an AACTS?**

R: Yes. I would probably buy if it comes as a package on the next sprayer I buy. I wouldn't buy as a separate product. I would pay around £3,500.

**I: Would you be prepared to take part in a trial of the system free of charge? If yes, what benefits do you like to achieve?**

R: Yes, but after the hopper been improved.

**I: What would you do with the data generated by the AACTS?**

R: I would put it into the excel spreadsheet.

## Appendix P. Calculation of the Annual Cost of the AACTS

Operation Cost = (Initial capital cost\*(Depreciation/100))/land area (ha)

Maintenance Cost = (Initial capital cost\*(Maintenance Cost/100))/land area (ha)

Cost of Capital at 7.5% = (0.075\*Initial capital cost)/land area (ha)

Total Cost = Operation Cost + Maintenance Cost + Cost of Capital at 7.5%

Depreciation %	15
Maintenance % of cost new, sprayer	9.5
Maintenance % of cost new, combine	3.5

### AACTS

	data recording system and software package	automatic agrochemical recording system	GPS on Tractor	total costs £
Initial capital cost	1,500	2,000	120	<b>3,620</b>
Depreciation %	15			
Maintenance % of cost new	9.5	9.5	9.5	343.90

land area (ha)	data recording system and software package	automatic agrochemical recording system	GPS on Tractor	maintenance cost	cost of capital @ 7.5 %	total cost, £
<b>730</b>	0.31	0.41	0.02	0.47	0.37	1.59
<b>900</b>	0.25	0.33	0.02	0.38	0.30	1.29

### AACTS and the yield mapping system

	data recording system and software package	automatic agrochemical recording system	Yield Mapping	total costs £
Initial capital cost	1,500	2,000	3,890	<b>7,390</b>
Depreciation %	15			
Maintenance % of cost new	9.5	9.5	3.5	468.65

land area (ha)	data recording system and software package	automatic agrochemical recording system	Yield Mapping	maintenance cost	cost of capital @ 7.5 %	total cost, £
<b>900</b>	0.25	0.33	0.65	0.52	0.62	2.37