University of Chester

THE ROLE OF ANAEROBIC DIGESTION IN ACHIEVING SOIL CONSERVATION AND SUSTAINABLE AGRICULTURE FOR SUSTAINABLE DEVELOPMENT IN THE UK

Thesis Submitted in accordance with the requirements of the University of Chester for the degree of Doctor of Philosophy

By

Franklin Ikenna Duruiheoma

December 2015

DECLARATION

I hereby certify this thesis is original and has not been submitted previously in support of any degree qualification or course. However, parts of this thesis have been published as research articles.

Signed: . . . .

ABSTRACT

Franklin I. Duruiheoma: The Role of Anaerobic Digestion in Achieving Soil Conservation and Sustainable Agriculture for Sustainable Development in the UK

The subjection of soils to degradation directly and indirectly from rising world food demand and resultant intensified agricultural production, population growth, and climate change, demand that soils are better protected. The role of AD in addressing this challenge is examined using a pragmatic research paradigm and the questions: *How can we raise awareness of AD in the UK? What factors motivate and hinder farmers towards adopting improved technology and sustainable agricultural practises? What is the perception of farmers about soils? To what extent does sustainable agriculture incorporate soil conservation in theory and practice? What role can legislation and policies play in AD adoption in the UK?*

The research was in two phases; qualitative and quantitative. The qualitative phase involved interviews with 21 AD stakeholder in the UK using electronic mail. The stakeholders who were divided into groups according to their expertise, were interviewed to explore their views on the areas of focus in the UK strategy and action plan regarding raising awareness of the technology, soil conservation, sustainable agriculture and sustainable development. Thematic analysis of interview data was carried out using MAXQDA 11 statistical software. The quantitative phase involved an online survey of 283 UK farmers aided by Yellow Pages directory for UK, Natural England directory, Twitter and electronic mail. Using SPSS 22.0 statistical software, the Chi square test was used to check for relationships between the variables measured at 95% confidence level ($p<.05$). Relationship strength was measured by means of Cramer's V and Phi values.

Answers to the 1st research question showed that: aligning AD with sustainable development goals, community AD and localism, small AD plants, provision of an available market for AD products, building UK skills and diversifying biogas use from AD are positive options for raising awareness of AD. Response to 2nd research question revealed: significant relationships between interests in agricultural technology and gender, level of education, and farm size; between knowledge of what AD is and gender, level of education and farm size; between interest in AD and age; between willingness to invest in AD if it improved soil properties and farm ownership; and between organic farming practice and age, farm type and farm size. Responding to the third research question, farmers' describe soils in abstract, scientific, physical attribute and functional terms; awareness of soil benefits other than crop production was significantly related to age, and farm ownership; educational level was significantly related to familiarity with soil conservation, and opinion on whether soil should be protected like other natural resources. Findings regarding the 4th and 5th research questions showed: limited understanding of soil matters as a key challenge that has restricted the priority given to soil conservation, while level of education, knowledge of soil conservation and sustainable development and understanding of sustainable agriculture were also identified as influencing factors; digestate from AD is the main benefit viewed to contribute to soil conservation; finance, policy and legislation, low awareness and understanding, lack of feedstock and market, land use conflict and inefficiency of AD plants were identified as barriers to AD in the UK; promoting AD, providing finance, minimizing bureaucracy and simplification of AD systems are options for promoting AD adoption.

This thesis also documents the implications of these findings for knowledge, policy and practice, and based on these recommendations are made, some of which are: better engagement of farmers in policy development for AD and soil management; use of small AD plants, demonstration, networking and training for AD adoption; promote soil conservation in theory and practice; and provision of enhanced support for owners, potential investors and farmers through incentives, simplified planning approval process, and available market for AD product.

To Eric and Florence

ACKNOWLEDGEMENT

I will like to thank the University of Chester for giving me the opportunity to embark on this journey, and the Graduate School for the support and guidance received throughout the entire process. I also like thank the International Student Welfare office for their encouragement and financial grant in difficult times.

Special thanks to the Head of Biological Sciences Department Professor Andrew Lawrence for the consecutive award of 50% departmental bursary and the entire academic and non-academic community for their direct and indirect support. My appreciation also goes to the Faculty of Life Sciences for organising conferences for PhD students within the faculty, a very important event that enabled me to network with other researchers and share my research findings.

Very special thanks goes to my supervisors Professors Cynthia Burek, Graham Bonwick and Roy Alexander for going far and beyond in support for my research. For the constructive feedback, close supervision, advises and guidance I say a very big thank you. I could not have completed this research without your support, and consider myself lucky and fortunate to have you all as my supervisors. Also, I want to say thank you for supporting my ambition to have my research published, and The Institute of Food Science and Innovation for sponsoring the publications. To Professor Sarah Andrew and Dr Martin Evans for taken part in my annual progressive reviews, I say thank you.

Special love and thanks to my family and friends for the financial and emotional support, especially my parents Eric and Florence, I owe my academic accomplishments to you both.

Above all, I give thanks to God Almighty for the grace throughout my educational pursuits.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVATIONS

AD- Anaerobic Digestion

DECC- Department of Energy and Climate Change

DFID- Department for International Development

DEFRA- Department of Environment, Food and Rural Affairs

EC- European Commission

EU- European Union

FAO- Food and Agriculture Organization

FiT- Feed in Tariff

GHG- Greenhouse Gas

HDRA- Henry Doubleday Research Association

IUCN- International Union for Conservation of Nature

IUSS- International Union of Soil Sciences

OFGEM- Office of Gas and Electricity Markets

POST- Parliamentary Office of Science and Technology

RASE- Royal Agricultural Society of England

REA- Renewable Energy Association

RHI- Renewable Heat Incentive

ROC- Renewable Obligation Certificate

RTFO- Renewable Transport Fuel Obligation

SNIFFER- Scotland & Northern Ireland for Environmental Research

SWEA- Severn Wye Energy Agency

UN- United Nations

UNEP- United Nations Environment Programme

US- United States

WCED- World Commission on Environment and Sustainable Development

WSSD- World Summit on Sustainable Development

LIST OF APPENDICES

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Box 1.1: Chapter purposes

- To provide a background to the study and an insight into the focus of the thesis;
- To provide a clear statement of the research goals;
- To outline the research questions and establish the rationale for these and for the objectives of the thesis by highlighting gaps in literature that are further elaborated upon in Chapter Two.

Agricultural wastes, especially those from livestock farms, have the potential to cause environmental pollution. The likelihood of such a scenario is exacerbated by world population growth which implies a rise is agricultural production (consequential rise in agricultural waste) to meet food demand. Through research various technologies have been developed to minimize the risk of environmental pollution from agricultural processes and products, in addition to generating revenue from energy production and organic fertilizer as by-products. Anaerobic digestion (AD) is a typical example of such technology. In simple terms, anaerobic refers to the degradation of biodegradable materials which are mainly organic by various groups of microorganisms in an environment void of air. It is similar to what happens in the digestive system of certain mammals like the ruminants such as cows, wherein food substances are broken down by microorganisms in complex but air-free digestive compartment. A major difference between AD in ruminants like cows and AD plants is the level of control over the digestion process. As such, AD plants are easily controlled to yield substantial amounts (depending on the size of the plants) of biofuel mainly biogas and a residual digestate which can serve as a nutrient rich fertilizer (POST, 2011). Wilkinson (2011) described AD as that technology which plays a steadily growing role in renewable energy practices in many countries.

AD technologies are not new in any sense in most parts of the World, and have been in existence for over a century in the UK mainly for sewage sludge treatment (POST, 2011). Similar cases of AD technology utilization have been reported in other parts of

Europe, America and Australia. In developing nations, it has been stated that the presence of AD technologies is linked to strategies for sustainable development with the need to conserve natural resources and achieve regional development (Lei & Haight, 2007; Mao *et al.*, 2015). Certain rural communities in Asia make use of small scale AD plants for the digestion of 'night soil' to provide biogas for cooking and lighting domestic households (Wilkinson, 2011). Night soil here refers to human faecal material which is harmful when applied directly without treatment as manure in farmlands or used for other agricultural purpose as used in the past in some parts of Asia (Bo *et al*., 1993). Some key highlights of the benefits and prospects of AD include:

I. Renewable energy production;
II. Waste recycling and environmental protection; and
III. Nutrient recycling.

These benefits justify the use of the technology. Some authors however, argue that, only a collection of the benefits of AD technologies justifies its development as no single benefit can do so (Bywater, 2011). In terms of raw material inputs, digestible organic materials are not lacking when the number of farms across the UK is taken into account but the issue of installation of AD plants is faced with a number of factors. These factors serve as both drivers and barriers to the enhancement of AD technologies. Wilkinson (2011) classified these factors into four different categories namely: geopolitical factors, nature of farming systems, social factors and economic factors. Each of these factors plays a significant role on an individual basis and collectively, they have affected the establishment of AD technologies over the years. Geopolitical, social and economic factors were also identified to exert their effects across local, national and regional boundaries.

In recent times, AD technology has begun to occupy higher priority in various environmental protection policies and strategies at the international, national and regional level. At the regional and national stage, such policies and strategies represent commitment towards achieving world targets or standards often stipulated in international conventions and protocols. For instance, the European Union (EU) is committed to a 20% reduction in greenhouse gas emission (GHG) by 2020, and the UK has a legal obligation to cut its greenhouse gas emission by 80% by 2050 enshrined in the Climate Change Act 2008 (Tranter *et al.*, 2011). Despite the number of identified benefits of AD as an alternative to traditional agricultural waste disposal, its adoption and full implementation in most parts of the world, including the UK, is still faced with a number of challenges (Frith & Gilbert, 2011). Frith & Gilbert (2011) carried out a gap analysis of AD in the UK, and some of the gaps identified form part of the rationale for this research.

Soils are a very important component of the environment and their potentials outside agricultural uses are yet to be fully recognised. They have been described as key components of natural ecosystem since environmental sustainability depends largely on sustainable soil systems (Adedokun & Ataga, 2007; Adenipekun, 2008). Soils are complex in nature and are closely related to other elements of the environment, biotic and abiotic, providing direct and indirect services to the environment and man. Ritz (2008 cited in; Haygarth & Ritz, 2009) described soils as part of our natural heritage like other aspects of biodiversity and geodiversity and as presumably the most complex systems on Earth. Soils occur in the uppermost layer of the Earth's crust and so affect the nature of landforms, wildlife and vegetation. The capacity of the soil to function continuously as an important part of the ecosystem, maintain biological productivity, enhance air and water quality, and sustain the health of plant, animal and human is known as *soil quality* (Schloter *et al.*, 2003), while *soil productivity* refers to the capacity of soil under a specific management system to produce a particular yield of crops (Blanco-Canqui & Lal, 2009). A combination of human activities such as intensive agriculture, construction, pollution, and natural events like erosion, landslides and flooding, reduces the quality of soils, and this reduction in soil quality according to McOlivers (1984) implies a decline in soil productivity. The consequences of this decline in soil productivity, which affects its ability to deliver ecosystem services and functions, is not fully appreciated, as soils are still subject to various levels of degradation across the world. The conservation of soils in view of rising world population, climate change and food security issues should be a matter of great concern at local, national and international level. In addition to natural and man-made factors causing soil degradation, population growth has some direct and indirect effects on the degradation of soils. The predictions of world population growth and its effects on natural resources as contained in Malthusian theory of population growth have been made manifest in the world today (Satihal *et al*., 2007). The effects of population growth on the degradation of soils emanate from food security concerns which often require intensified agricultural production and the provision of basic amenities for man which reduces available agricultural land. Food security refers to the provision of adequate nutritious, culturally appropriate and safe food produced in a safe environment in a just manner that allows people to make choices on food (FRAC, 2011). It also demands that producers (farmers) earn a living from the food they produce as well. Food security can therefore be thought to have similar elements to sustainable development, as it pursues economic, social and environmental sustainability.

The ability of soils to withstand the pressure of intensified agricultural food production is however, a function of fertility. The United Nations (2004) projected that the world population will reach 8.9 billion in 2050 at an estimated growth rate of 0.77 percent with higher growth rates in developing nations. There are, however, no projections on the capacity of soils to continue to support agricultural production over the same period, thereby stressing the need for effective soil conservation and sustainable agricultural practices. In trying to meet food security goals, various techniques and approaches have been implored to harness agricultural land (soil) resources (Satihal *et al*., 2007; Khanif, 2010). Harnessing soil mainly involves the improvement and maintenance of soil fertility and the use of conventional fertilizers in doing this still prevails. More recently however, attention has been focused on organic inputs as a way of working towards sustainable agriculture.

Indirect effects of population growth arises from its association with infrastructural development, and studies have shown that such development significantly reduces available agricultural land, thereby putting more pressure on what remains (Khanif, 2010). Yet again, it was further stressed that the productivity value of land is often neglected in the development of infrastructure and by so doing fertile land can easily be lost to infrastructural development. These scenarios emphasize the need to incorporate soil conservation practices into sustainable agriculture for overall sustainable development.

In order to understand and appreciate the need for soil conservation the importance of soils needs to be taken into account. The basic assumption here is that, we cannot conserve what we do not appreciate. Figure 1.1 below illustrates the various functions of soil in a given ecosystem.

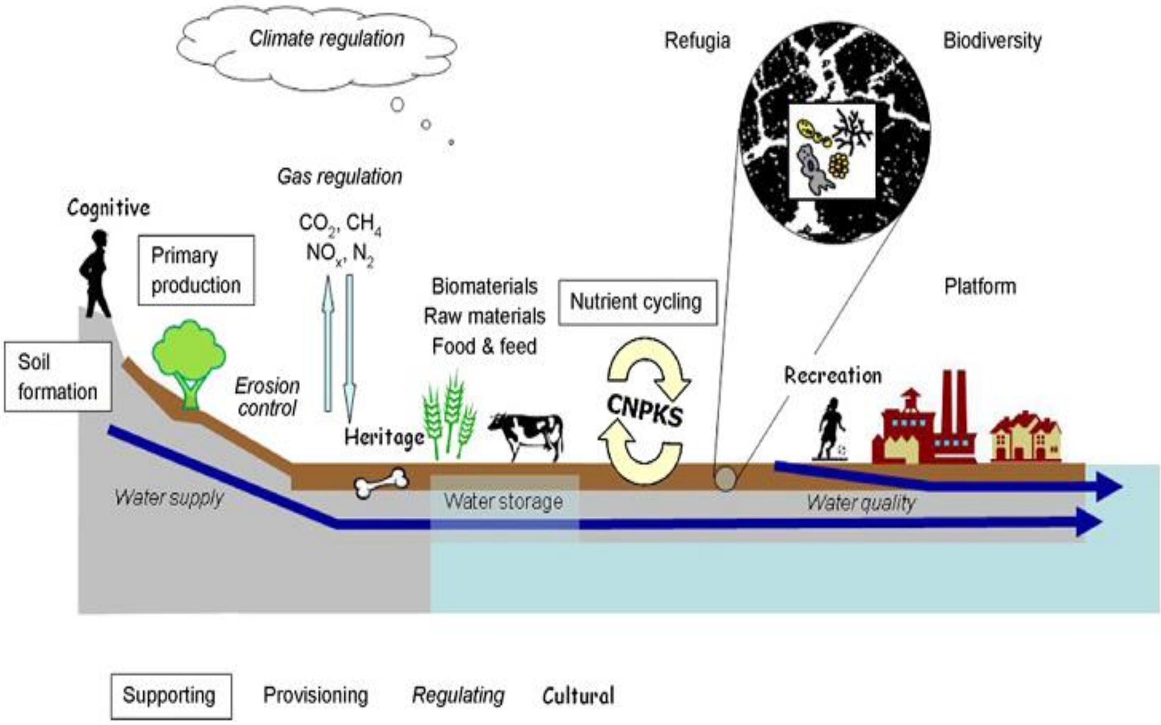

Figure 1.1: Function of Soils in the Ecosystem

© Haygarth & Ritz, 2009

The conservation of soils in the UK over recent decades has been poor in comparison to other aspects of biodiversity and geodiversity. This led to agitations by the International Society Soil Science (ISSS) for soil protection strategies in the late 20th century (Bridges & Catizzone, 1995). According to Towers *et al.* (2005) the difficulty in assessing the nature conservation value of soils is the main challenge for the development of soil protection and conservation strategies. Soils are generally subjected to various agents of manmade and natural degradation in the form of intensive agriculture, pollution, and erosion. The situation is gradually improving as soil is beginning to make headlines in both conservation policies and programmes at the regional and national stage, and this trend can be linked to climate change and food security (Scottish Government, 2009). Examples of this improvement is the presence of different soil protection strategies within the various UK government and this is discussed further in section 2.3 (Chapter 2).

Food is a basic human need, without which survival is threatened. For millennia humans have practised agriculture for the production of food, fur, fibre, fuel and feed, and it is therefore part of humanity. The ability of agriculture continuously to meet these human needs is in doubt in view of population growth, soil/land degradation, climate change, environmental pollution and urbanization. Forecasts for agricultural food production for example, project that food production will have to increase by 70% to meet population demand by 2050 (Leaver, 2011). More so, as man made use of agriculture to meet his needs, over the years; there has been a significant loss and damage to wildlife habitats and valued landscapes especially in rural areas (Ogaji, 2005). How then can agricultural production be sustained? A scenario posted as "producing more food from less land, with lesser environmental impact" (Fowler, 2010:1). These concerns are not new in any sense, and form the basis of the concept of *sustainable agriculture*. However, the interpretation of the concept has been diverse both in theory and practice, thereby raising questions over its achievability in the world today. In fact, the agricultural systems in most developed nations have been criticised for lacking 'sustainability' amidst a level of technological advancement (Hartridge & Pearce, 2001). Sustainable agriculture has been described as agricultural production that utilizes natural resources in such a way that does not deplete the natural resources and still ensures safety for man and environment (Gruhn *et al.*, 2000). A similar view was reported in an FAO report (2002) defining sustainable agriculture as the successful management of agricultural resources to satisfy the needs of man, and at the same time maintain and/or enhance environmental quality and conserve natural resources (biodiversity, geodiversity and soils) for future generations. DFID (2004) gave two distinctive interpretations of sustainable agriculture. Firstly sustainable agriculture based on the type of technology in a given setting especially those that focus on renewable inputs including permaculture, eco agriculture, organic, community-based, farm-fresh, environmentally-sensitive, biodynamic and extensive strategies. The second interpretation, which is the main focus of this research, involves agricultural sustainability in term of resilience and persistence.

Sustainable agriculture covers three key elements, economic, social and environmental sustainability (Gruhn *et al.* 2000; DEFRA 2002). Economic sustainability here is concerned with the income of farmers and the general profitability of the agricultural production, under the basic assumption that for farmers to remain in business, the farming business needs to be viable and profitable. Social sustainability involves the general well-being of the farming community, their health, and access to basic amenities required for normal living. Environmental sustainability involves the reduction in the use of inorganic chemical inputs, pollution mitigation, low fossil fuel consumption, soil nutrient maintenance, sustained crop and animal diversity, on-farm energy production and conservation, community vitality and conservation tillage. These elements of sustainable agriculture, clearly illustrate the linkages with agriculture and the industrial sectors in modern agricultural systems, making use of an array of inputs, which have resulted in some negative effects on the environment (Ogaji, 2005). Organic farming, which is often misconstrued for sustainable agriculture, refers to the farming practices that work in support of nature and not against it, using those techniques that enhance crop yields without causing harm to man and the environment (HDRA, 1998). It is therefore agricultural production that uses zero inorganic inputs in all aspects, and organic farming can thus be considered as part of sustainable agricultural practices.

These background information, suggest a potential role of AD in soil conservation and sustainable agriculture taken into account its highlighted benefits (renewable energy generation, waste and nutrient recycling).

1.2 RESEARCH AIMS AND OBJECTIVES

The aim of this research is to examine how anaerobic digestion (AD) technology can aid soil conservation and sustainable agriculture for sustainable development. The challenges and prospects of AD in the UK and the existing gap between soil conservation and sustainable agriculture in theory and practice is critically examined. Figure 1.2 serves as a guide to the research in terms of the overlaps between AD and Soil Conservation (SC); Soil Conservation (SC) and Sustainable Agriculture (SA), and AD and Sustainable Agriculture (SA) and the nexus culminated in the intersection of Anaerobic Digestion (AD), Soil Conservation (SC) and Sustainable Agriculture (SA).

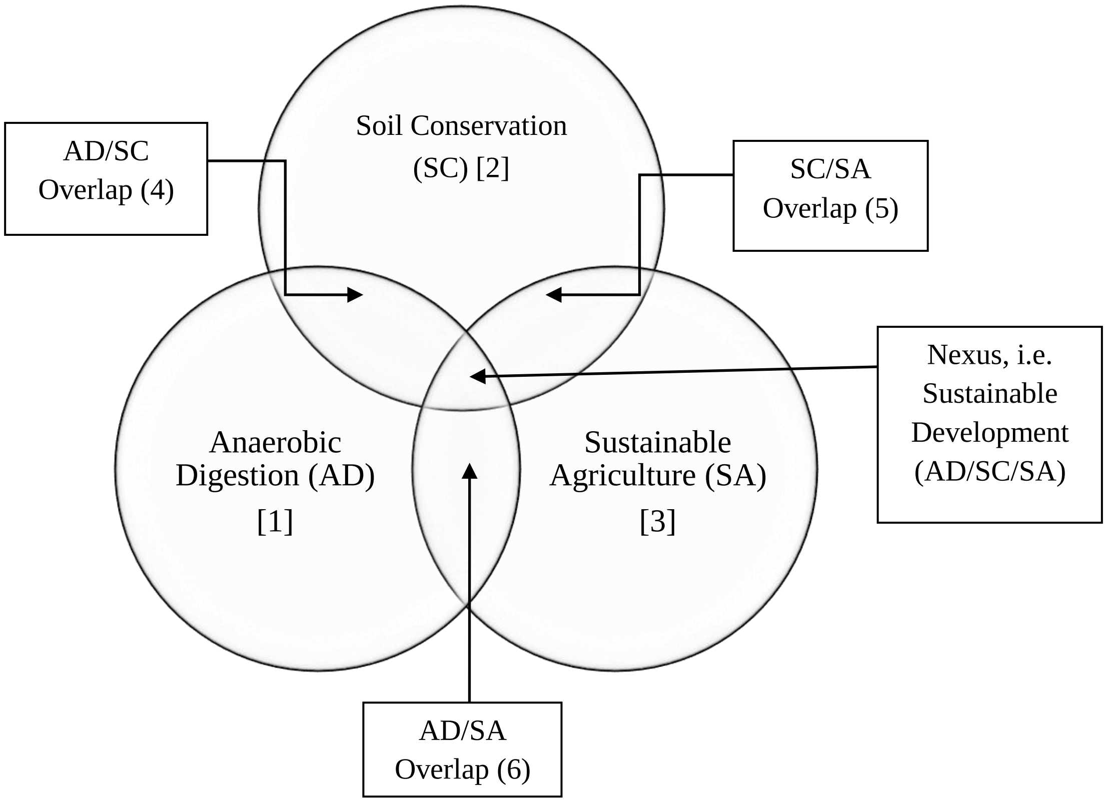

Figure 1.2: The Nexus of Anaerobic Digestion, Soil Conservation and Sustainable Agriculture and their overlaps

For each of the primary areas of interest, that is, anaerobic digestion, soil conservation and sustainable agriculture there is relatively extensive literature. However, the overlaps existing among the three areas of interest are disproportionate and research lacking. The AD and SC overlap (4) and AD and SA overlap (6) are gradually gaining grounds in literature although the latter is often considered as organic farming. The SC and SA overlap (5) is not well established in literature, and the nexus, that is, sustainable development which is the intersection point of the three areas of interest is representative of one of the world's most popularised concepts today, but the combination remains void.

For the purpose of clarity of Figure 1.2, it is important to define what 'void' and 'overlaps' entails here. Void here refers to absence of research in the particular area(s) where the term was used. Overlaps on the other hand represents the interaction between two or more of the areas of interest. This research is aimed at demonstrating these overlaps, thereby filling the voids that currently exists.

1.3 RATIONALE

Even with soil conservation policies and programmes in place to promote soil protection, there seems to be an inherent gap between the concept of soil conservation and sustainable agriculture. The effectiveness of soil conservation policies and programmes for the protection of soils has also been identified as being less effective due to limited coordination, fragmentation and the ad hoc nature of most protection programmes (Scottish Government, 2009). This draws attention to the need to integrate various conservation programmes and policies where possible.

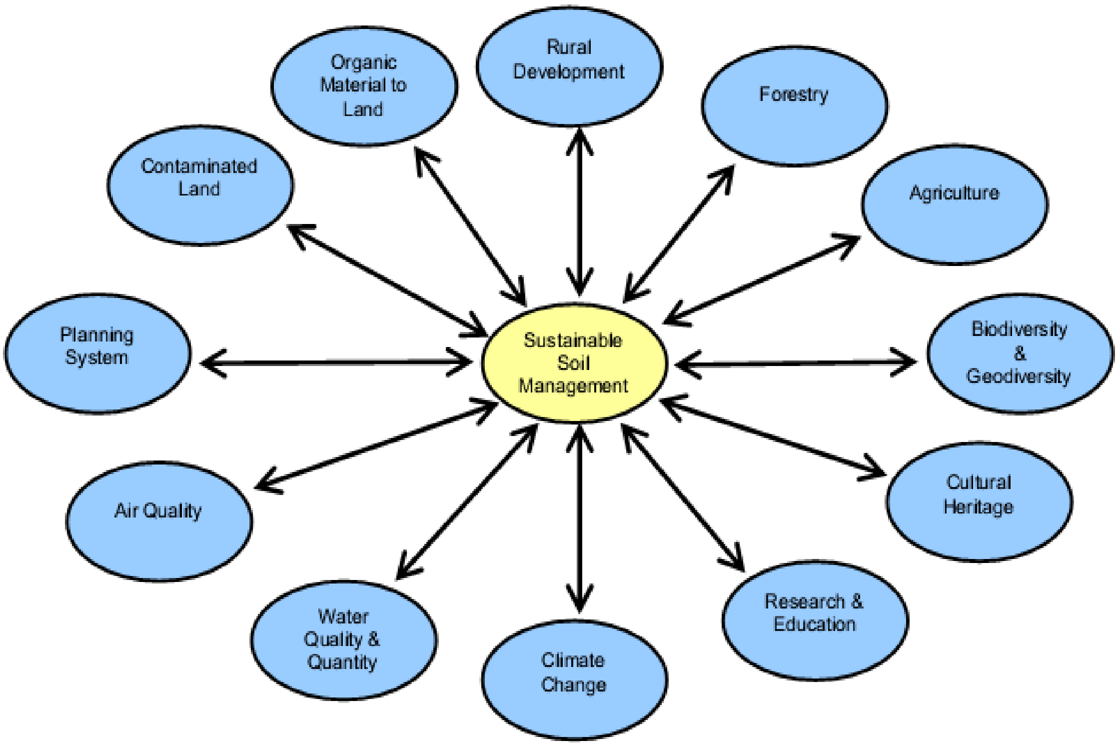

Figure 1.3: Policy Areas Contributing to Soil Protection

© *Scottish Government (2009)*

Brady & Well (2005) defined soil conservation as a combination of all management and land-use methods that safeguard the soil against depletion or deterioration caused by nature and/or humans. The main form of depletion concerned with such management and land-use methods is erosion (Morgan, 2005). Sustainable agriculture on the other hand refers to agricultural production, which utilizes natural resources in such a way that does not deplete them and still ensures safety for humans and the environment (Gruhn *et al.*, 2000). Sustainable agriculture covers three key elements, economic, social and environmental sustainability. Economic sustainability here is concerned with the income of farmers and the general profitability of the agricultural production, under the basic assumption that for farmers to remain in business, the farming business needs to be viable and profitable. Social sustainability involves the general well-being of the farming community, their health, and access to basic amenities required for normal living. Environmental sustainability involves the reduction in the use of inorganic chemical inputs, low fossil fuel consumption, soil nutrient maintenance, sustained crop and animal diversity, on-farm energy production and conservation, community vitality and conservation tillage.

Sustainable agriculture is quite often considered as being synonymous to organic farming as most farmers and soil conservationist focus more on the economic sustainability and environmental protection component of sustainable agriculture (Gruhn *et al.*, 2000; Robertson, 2001; Ingram, 2008; Albuquerque *et al.*, 2012a). This emphasis has created a void between soil conservation and sustainable agriculture, and this research aims to fill this void as shown in Figure 1.2 as the overlap (5) between soil conservation and sustainable agriculture.

Moving from the overlap between soil conservation and sustainable agriculture, the research also aims to establish the significance of the nexus of the three areas of interest also illustrated in Figure 1.2. The rationale here is that, if sustainable agriculture can effectively embrace soil conservation in practice with the addition of the benefits of anaerobic digestion, overall sustainable development can be achieved. The World Commission on Environment and Development (WCED) 1987 gave the definition of sustainable development as that form of development that meets the needs of present generation without compromising the ability of future generations to meet their own needs. The concept of sustainable development traditionally had three indicators namely: economic, ecological and social (Barrow, 2006). These days however, researchers and policy makers tend to include a fourth known as institutional indicator (Ivanovic *et al.*, 2009). Among the basic indicators of sustainable development, Barrow (2006) stated that the ecological indicator mainly concerned with environmental protection is the main propellant of the theory of sustainable development in the 21st century. With focus on the three basic indicators, that is, economic, ecological and social, this research aims to investigate how the benefits of anaerobic digestion (AD) and the integration of sustainable agriculture and soil conservation can achieve sustainable development in the rural community. Some assumptions here that further justify this research are:

I. AD will contribute to economic viability of the rural farming community through on farm energy generation and conservation;

II. AD will help reduce the dependence on inorganic chemical input for soil fertility and pest control thereby meeting the ecological needs of sustainable agriculture and development;

III. AD will contribute to the reduction in fossil fuel consumption and by so doing facilitate a healthier environment which covers the ecological and social indicators of sustainable development;

IV. Integration of soil conservation into sustainable agriculture will reduce various forms of ecological degradation of the environment ranging from soil erosion to environmental pollution;

V. Economic viability of farming business will also be enhanced if products from such farming communities are promoted as being healthier for consumption since they contain lesser or zero chemical residues.

1.4 RESEARCH QUESTIONS

This research contributes at both theoretical and empirical levels to better of understanding the linkage between AD, soil conservation and sustainable agriculture for achieving sustainable development in the 21st century. The main reason for choosing to investigate AD for soil conservation and sustainable agriculture is in view of the established challenges facing AD adaptation and practices in the UK despite its numerous benefits (Frith & Gilbert, 2011) and the gap that exists between soil conservation and sustainable agriculture. The questions listed below have been raised based on notable gaps in literature pertaining to AD, soil conservation and sustainable agriculture.

I. How can we raise awareness of AD in the UK?

II. What factors motivate and hinder farmers towards adopting improved technology and sustainable agricultural practices?

III. What is the perception of farmers about soils?

IV. To what extent does sustainable agriculture incorporate soil conservation in theory and practice?

V. What role can legislation and policies play in AD adoption in the UK?

Box 1.2: Chapter summary

This chapter has;

- Provided a background to the research;
- Provided a rationale to support this research;
- Outlined the research aims and questions.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

Box 2.1: Chapter purposes

- To establish where the thesis is grounded in wider knowledge with respect to anaerobic digestion, soil conservation and sustainable agriculture;
- To clarify the key areas studied 'anaerobic digestion', 'soil conservation', 'sustainable agriculture' and 'sustainable development';
- To identify the gaps in literature that justify the research;
- To establish the links between the areas of research interest;
- To provide the theoretical framework for how anaerobic digestion, soil conservation and sustainable agriculture can contribute to sustainable development.

The previous chapter (Chapter 1) gave a definition of purpose for this research by outlining the research questions, objectives and rationale behind this research which was supported by a brief review of literature. This chapter builds on that foundation with a detailed analysis of literature relevant to the areas of research interest with the overall objective contained in Box 2.1. For further briefing purposes, the chapter will contain some definitions of terms and concepts in the various research areas, link the research areas, clearly open up the gap in literature to support the research questions, and provide a theoretical framework for the research. The concluding section summarizes the rationale for the research questions based on the gaps in literature. Finally, it is important to stress that this chapter also contains some retrospect and prospect analysis in the area of AD technology, sustainable agriculture and soil conservation within the UK. The reason for this is not exclusive to the justification of this research, but also to create room for better understanding of the research objectives and to shed light on other opportunities for further research.

2.2 ANAEROBIC DIGESTION (AD)

Renewable energy technologies represent one of those areas of research geared towards achieving sustainable development mainly through environmental protection and economic sustainability of the practice. In view of this, Astals *et al.* (2012) described AD as one of the most promising renewable energy technologies important for achieving sustainable development. A similar view was earlier reported by Wilkinson (2011) who described AD as a technology with an increasing role in renewable energy in many different countries, even though its full potential is yet to be tapped into. Put more directly, Yeatman (2006) suggested that AD should be seen as a way of unlocking the energy value in wet biomass, just as burning unlocks the energy value in dry biomass.

The need for AD technologies in our society today is further justified by the enormous amounts of biodegradable wastes produced from agricultural systems; mainly livestock systems and the risk posed to the environment if such wastes are not well managed (Alburquerque *et al*., 2012a). Although AD technology has long been identified as a method of energy production in the form of biogas (Banks *et al.*, 2008) it promotion and adoption has often been linked to environmental protection targets and objectives at international and national levels (Zglobiz *et al.*, 2010; Tranter *et al*., 2011). For instance, the European Union is committed to a 20% decrease in greenhouse gas emissions by the year 2020 and renewable energy technologies remain instrumental in achieving such goals. This further stresses the role of AD in contributing towards a safer environment for all.

The agricultural sector represents one of the key aspects of the UK economy and its influence on the environment has long been studied. The levels of organic waste production in UK farms are large and thereby make their renewal an important source of energy production in the light of sustainable development goals (Zglobiz *et al.*, 2010). The bio-wastes used as raw materials in the AD process are adequate in the UK and their quantity has risen greatly over the years. For instance, Dagnall (1995) reported that a total of 1.8 million tonnes of poultry waste and 14 million tonnes of livestock slurry are produced in the UK each year. At that time, AD experience in the UK was poor, mainly due to low biogas yield as a result of inadequate total dry solid in feedstock (Dagnall, 1995). These figures have risen significantly and recent estimates indicate that a total of 90 to 100 million tonnes of slurry (all livestock included) are produced every year in the UK (Juned *et al.* 2014). This increase in biodegradable waste from UK farms shows that the agricultural sector has grown and thus so the need for enhanced waste management because the environment is faced with greater risk now than in the past. Moreover, DEFRA (2011a) reported that some 16 million tonnes of post-farm food and drink waste arises each year in the UK.

Despite the rise in figures, the number AD farms in the UK remains low when compared to organic waste outputs and this disparity has been linked to a number of challenges.

As a member of the EU, the UK is committed to the union's environmental goals and objectives through its various legislation and policies that aim to encourage renewable energy and environmental protection (Zglobiz *et al.*, 2010; POST, 2011). These types of policies and legislation have been instrumental in the promotion of AD technology within the UK (Zglobiz *et al.*, 2010) and other parts of Europe (Wilkinson, 2011). The level of commitment of these polices with regard to stated targets remains questioned as does the feasibility of the targets (Zglobiz *et al.*, 2010). Recent policies however tend to utilise incentives as a means of motivating farmers and investors alike to engage in renewable technologies such as AD (POST, 2011). It also important to stress at this point that the promotion of AD has not strictly been the sole responsibility of the UK government, various organisations and bodies within the UK have been actively involved. For example, DEFRA's target of 1000 AD plants by 2020 has been largely promoted the Royal Agricultural Society of England (RASE) funded mainly by charity organisations like Frank Parkinson Agricultural Trust (Bywater, 2011). As of June 2012, there were a total of 78 AD plants in operation in the whole of UK (DEFRA, 2012). Current figures show that there are over 180 operational plants representing over a 100% increase from 2012 figure (NNFCC, 2015). However this is still a long way behind DEFRA's target by 2020.

2.2.1 Understanding AD

AD has been defined as the process by which organic materials are treated biologically by naturally occurring bacteria in the absence of oxygen to produce biogas which is made up of methane (CH_4) (40-70%), carbon dioxide (CO_2) (30-60%) and other trace gases such as ammonia, hydrogen, hydrogen sulphide and a very useful by-product known as "digestate" in liquid or solid form (Wilkinson, 2011). Similarly, DEFRA (2011a: 5) described AD as

"*A natural process in which micro-organisms break down organic matter in the absence of oxygen, into biogas (a mixture of carbon dioxide (CO_2) and methane) and digestate (a nitrogen-rich fertilizer)"*

It is important to consider from the above definitions that, AD is a natural process, it requires micro-organisms and it takes place in the absence of oxygen. This is therefore similar to the digestion process in the digestive systems of ruminants, and the major difference between the AD in ruminants and that which occurs in AD plants is the degree of control. As such AD plants can be configured to yield substantial amounts (depending on plant size) of biofuel, mainly biogas, and a residual digestate which can serve as a nutrient rich fertilizer (POST, 2011). This is illustrated in Figure 2.1. AD in plants takes place in a controlled environment known as an 'anaerobic digester'. The environment is generally sealed in insulated concrete or steel tanks with some form of agitation, and inside this environment, conditions for anaerobic digestions are created artificially (Mainero, 2012).

It has been argued that an estimated 90% of the energy produced in anaerobic plants from the degradation of biodegradable inputs is retained in the form of methane, resulting in the production of very little excess sludge (Wood *et al.*, 2013). The output from anaerobic digesters however, is largely a function of the operational conditions and design of the digesters (Lawson, 2010; DEFRA, 2011a; Motte *et al.*, 2013). The various technologies available for AD are: the wet and dry, mesophilic or thermophilic, and single or multistage. In England where most of the AD plants in the UK are sited, the most common type of technology in use is the mesophilic, wet and single style types (DEFRA, 2011a).

Mesophilic and thermophilic systems- Mesophilic systems are those with bacteria that perform optimally at temperatures between 35-40^{o}C, and those with bacteria that perform optimally at temperatures between 55-60^{o}C are called thermophilic systems (Lawson, 2010; DEFRA, 2011a; Hollister *et al.*, 2012). As a result of higher temperature requirements, thermophilic systems make use of higher energy inputs, and are therefore more expensive. With the high temperature however, the entire process is faster in thermophilic systems than mesophilic systems (Lawson, 2010).

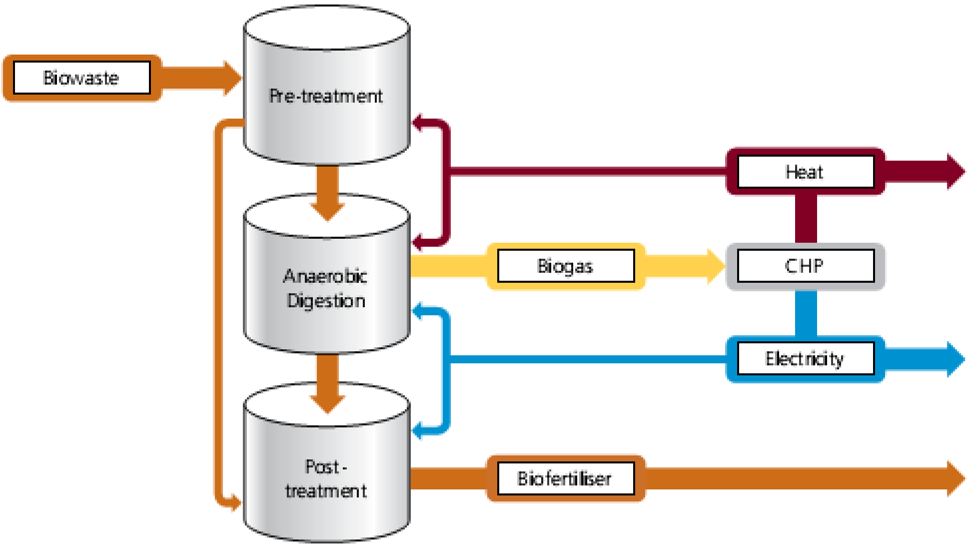

Figure 2.1: An illustration of a configured AD plant
© *DEFRA (2011a)*

Wet and Dry- wet systems are often mesophilic, with the main component as water, and solid components are generally less than 15%, with a residence time of 60-95 days, while dry systems are often thermophilic, with solid components making more than 20% (and can be up to 45%) with a residence time from 9-45 days (Lawson, 2010; Lucas *et al.*, 2014). Dry systems require less mechanical sorting and the process takes place with materials still in solid form, while the raw materials in wet systems need to be in the form of pulp or have a soup-like consistency to facilitate pumping and stirring (Motte *et al.*, 2013). More so, because of the nature of raw material, dry systems process their materials in batches while wet systems do theirs in a continuous flow manner (SWEA, 2011).

Single and Multistage Systems- Single digester systems are those in which biological reactions takes place in individual sealed reactors or holding tanks, while multistage systems comprises of various reactors or holding tanks to optimise the entire reaction (DEFRA, 2011a). Single systems therefore require lower construction costs.

AD plants have also been classified on the basis of type of operation into on-farm AD and centralised AD (CAD). On-farm AD are those with feedstock based on the farm, such as manures, silage and slurries and other by-products such as brewer's grains, while CAD uses wastes that attract gate fees and involves higher cost in terms of the whole project and management in comparison to on-farm plants (Farming Futures, 2009). The CAD plants have earlier been identified as a technology that has the potential of improving the economics of producing biogas since it comprises of a mixture of farm wastes, industrial wastes, sewage sludge and municipal solid waste (Dagnall, 1995). This study however, is more focused on the on-farm AD operations as this is the main type in the UK.

2.2.2 History of AD in the UK

AD technology has been in the UK for up to a century now, but its application to agriculture is still being developed and is not widely applied (Tranter *et al.*, 2011). Attention to agricultural application has been linked to massive consolidation of the agricultural industry over the years and the drive of the European Union towards achieving rural development in member states (Wilkinson, 2011). It was earlier linked to environmental objectives and its synchronisation with farming activities, mainly through agricultural waste management (Dagnall, 1995). The development of AD can be traced as far back as 1859, with the development of an AD plant in Bombay (Monnet, 2003), but the first application in the UK was in 1895 when biogas from a sewage treatment facility powered fuel lamps in the city of Exeter (Monnet, 2003; Bywater, 2011). As part of the benefit of the discovery, in 1922 sewage gas was used to run a Birmingham sewage works (Bywater, 2011). This achievement led to the investigation of the process by a group of scientists in the 1930s and the subsequent identification of the bacteria involved and the conditions that promoted methane production (Monnet, 2003). As a result of this work more advanced and improved methods were introduced, leading to the use of various closed tank, mixing and heating systems to promote AD.

Post World War II experience ignited greater interest in AD technology in Canada, Russia, USA and UK, but the relatively low price of fossil-fuel led to declining interest in the technology (Bywater, 2011). Following the energy crisis of the 1970s interest was reignited and led to further improvement of the technology across parts of Europe, mainly Germany and Denmark, and the development of a small fibreglass digester in the UK. The driving opinion was that AD is the ideal technology for the treatment of slurry, recycling nutrients back to agricultural land and generating energy. The UK government participated in and supported the development in the 1980s through the then Department of Energy (Den) and the Ministry of Agriculture, Fisheries and Food (MAFF), both assessing the technology and its economic potential

(Dagnall, 1995). The assessment revealed that the technology was viable, but economic viability was difficult to ascertain because of the issue of pollution and odour control (Richards & Simms, 1986; cited in Dagnall, 1995). With growing interest in the issues raised, an update review was commissioned in 1990, which according to Mosey (1991, cited in Dagnall, 1995) highlighted the following:

I. on-farm AD application seemed to be cost-optimised;

II. digestate offered some market value that can facilitate offsetting cost of the process;

III. a Non-fossil fuel obligation (NFFO) was in place to support commercial electricity generation from biogas schemes, and projects under the scheme have a guaranteed premium for their electricity for a certain period.

The technology has since grown and in European countries like the UK, there has been a growth and focus on AD owing to higher fossil fuel prices, caused by increasing demand, and more stringent environmental policies and regulations for EU member states (Monnet, 2003).

2.2.3 Benefits of AD in the UK

Although AD technology is still growing, its benefits are numerous favouring its development over the years as identified in the historic trend in the UK. Recent studies also suggest that the technology has some potential benefits that are yet to be tapped into such as market development for its application to soils (Frith & Gilbert, 2011). The benefits already identified in literature include:

I. *Renewable energy* - This is beyond doubt the most established benefit of AD technology that has popularised it over the years (Tranter *et al.*, 2011; Alburquerque *et al.*, 2012a; Astals *et al.*, 2012; Mao *et al.*, 2015). The energy produced is in the form of biogas, which comprises mainly of methane (40-70%), carbon dioxide (30-60%) and other impurities, and the aim of energy production from AD in the UK is to increase the quantity of methane produced and its efficient conversion to electricity, heat or transport fuel (POST, 2011). Renewable energy production from AD plants has been closely monitored, and studies are becoming more focused on enhancing its yield of biogas, for instance the application of glycerol to AD plants aims to improve the biodegradation of agricultural wastes and the resulting by-products (Astals *et al.*, 2012). Issues on the effectiveness on existing AD technologies to harness renewable energy production has also been raised (Ganidi *et al.*, 2009; Kumaran *et al.* 2016).

Important to note here is that renewable energy generation from AD technology is also associated with a lot of other economic benefits such as income generation and cost reduction (Lacovidou *et al.*, 2012). Furthermore, AD rewards the dependent effect that exists between technologies that promote sustainable development through its supply chain and infrastructure especially in waste management (Zglobisz *et al*., 2010).

II. *Recycling waste*- AD makes use of 'waste materials' such as animal slurries, solid manure, food and crop residues and sewage sludge as its feedstock raw materials (Dagnall, 1995; Monnet, 2003; Yeatman, 2006, Granstedt, 2011; Bywater, 2011). This benefit has great importance in the development of AD technology as it supports various environmental protection and regulation programmes across the world (Alburquerque *et al.*, 2012a) and more specifically in the UK (POST, 2011). By making use of the 'waste materials', there is a reduction in the amount of waste going to landfill and therefore a reduced risk of environmental pollution arising from poor waste disposal (Tambone *et al.*, 2010; Alburquerque *et al.*, 2012a). Waste recycling also protects the environments through reduction in air pollution and farm diversification that is environmentally friendly (Bywater, 2011). AD technology should thus be considered as a method of environmental protection in terms of the other benefits it provides. This benefit is well recognised and has even led to the description of AD technology as that which eliminates the term "wastes" (Lacovidou *et al.*, 2012). This claim is arguable taking into account forms and categories of waste especially from chemical industries, but again the quantity of agricultural waste produced in the UK already identified still validates the credit given to AD technology for waste recycling. In the UK, the End of Waste Criteria (EoW) regulation aims to ensure that materials used in AD plants do not cause harm to humans or the environment, and recycled waste meets the PAS 110 specification before being used on land (POST, 2011). The application of AD for treatment of household organic waste have also been reported, as well as the importance of this in overall recycling of municipal waste (Naroznova *et al.*, 2016).

III. *Nutrient recycling*- Returning to the environment what is being taking out of it through waste recycling is a way of recycling nutrients. The digestate from AD is rich in nutrients, and can improve soil qualities in many ways leading to enhanced crop production (Tambone *et al.*, 2010; Alburquerque *et al.*, 2012a; Thomsen *et al.*, 2013; Vaneeckhaute *et al.*, 2013). The digestate, which contains the non-degradable components of the feedstock, is high in vital nutrients such as nitrogen, carbon, potassium and phosphorus. For instance values can range from 5.8 to 42.8 grams per litre (g/L) for total organic carbon (TOC) and 1.4 to 3.9 g/L for total nitrogen (TN) on a fresh weight basis (Alburquerque *et al.*, 2012a). Also, it is estimated that one tonne of digestate from food waste can produce up to 4-6kg of nitrogen (POST, 2011). The agronomic value of biomass treated is therefore raised by AD technology as stated by Tambone *et al.* (2010). Vaneeckhaute *et al.* (2013) described digestate and other bio-based mineral fertilizers as having more ecological and economic benefits than conventional chemical fertilizers when used in modern agriculture. Also the digestate tends to make nutrients more available to plants (Alburquerque *et al.*, 2012a; Johansen *et al.*, 2013), and allows greater nutrient retention by improving soil organic matter content and soil condition (Tambone *et al.*, 2010; Thomsen *et al.*, 2013). The organic matter produced here is less decomposable, thus promoting the ability of soils to further retain nutrients (Sorensen & Moller, 2009; cited in Tambone *et al.*, 2010). Although the nutrient capacity of digestate produced is largely affected by the nature of feedstock used (Wallace *et al.*, 2011; Seadi & Lukehurst, 2012; Thomsen *et al.*, 2013), the level of advancement of the technology in itself can affect this quality as well (Abdullahi *et al.*, 2008). Table 2.1 shows the variation in nutrient content based on two main feedstocks. The treatment, processing and storage of digestate also influence its nutrient content (Wallace *et al.*, 2011; Seadi & Lukehurst, 2012; Bohutskyi *et al.*, 2015). Critics of digestate use for soil nutrient enrichment often base their arguments on the increased nitrogen and methane emissions it can cause, but a study by Meester *et al.* (2012) suggested that these emissions can be reduced by up to 50%. Knowledge of the presence of other micro and macro nutrients in digestate is lacking and this has limited the wide use of digestate for arable crop production. However, the use of digestate for horticultural crop production (e.g. water melon) has shown positive results on yield (Alburquerque *et al.*, 2012b). The use of digestate on soils is largely supported by legislation mainly in the area of waste management which encourages integrated management, as digestate addition to soil provides both agricultural and ecological benefits (Directive, 2008/98/EC; cited in Alburquerque *et al.*, 2012b). Applying these benefits of AD to the conservation of soil is however lagging as the benefits are mainly linked to soil productivity, and this study aims to raise awareness of the issue.

Table 2.1: Some nutrient contents in two types of whole digestate

Source: Wallace *et al.* (2011)

Nutrients (kg per hectare)	Food-based digestate*	Manure-based digestate**
Total N	250	250
Readily Available N	202	145
Total P_2O_5	16.3	77.0
Total K_2O	61.5	199
Total MgO	2.04	42.2
Total SO_3	15.0	73.0

*applied at 34m^3/ha

**applied at 57m^3/ha

IV. *Income generation*- AD technology generates income to its owners. All three aforementioned benefits of AD can effectively generate income for AD plant owners. In the first instance, through renewable energy generation, plant owners can make energy available to local communities while also making use of the same energy (Juned *et al.*, 2014). This is further made lucrative by the rise in alternative energy demand today. Secondly, in terms of waste recycling, ‘gate fees’ paid for recycling food wastes from waste generating companies is an important source of revenue for plant owners, even though this source of income is decreasing in recent years owing to the unwillingness of waste producers to get involved with supply contracts thereby resulting in insecurity of feedstock supply and subsequent decline in income (POST, 2011). Thirdly, through digestate production, AD plant owners can sell digestate to other farmers and generate income. This is particularly significant in the light of sustainable agriculture, food security and sustainable development goals which encourage the use of environmentally safer agricultural inputs (Johansen *et al.*, 2013) and the fact that the advantages of digestate and other organic fertilizers over synthetic fertiliser are becoming more glaring in the agricultural community (Vaneeckhaute *et al.*, 2013).

V. *Soil conditioning and organic matter addition*- The AD process has a biomass yield of up to 90% depending on the type of operation and feedstock (Messter *et al.*, 2012), and this yield also contains significant amounts of fibre, which also varies with the system and feedstock (Moller, 2015). Astals *et al.* (2012) showed that digestate can contain up to 30g/L of fibre, and this fibre can be used to condition soil. The bulky nature of digestate in dried form means its addition to soils can improve resistance to compaction and also improve structure. Furthermore, the organic nature of digestate implies addition of organic matter to soil when applied. The organic matter can improve water-holding capacity of the soil, promote soil aggregate stability, increase soil cation exchange capacity, enhance soil microbial activity and minimize soil compaction. By improving soil aggregate stability and reducing soil compaction, soils are less prone to degradation by erosion. Beni *et al.* (2012) linked the improvement of soil physical properties to aggregate stability and porosity, and observed that digestate had a greater ability to do this than conventional inorganic fertilizers and compost. The direct effects of digestate on field level however, have been reported to be short-term, as are the changes in the activities of soil microorganisms (Moller, 2015).

There are other associated benefits of AD technology that can be linked to the already discussed benefits. For example, improved slurry handling is ensured as they are fed into AD plants, farming business can easily be diversified as energy and income is being generated, agricultural operations can become more sustainable development orientated.

2.2.4 Challenges of AD in the UK

Although the benefits of AD are numerous and crucial in view of sustainable development, the technology is faced with a number of inherent challenges and drawbacks that have limited its development in the UK. Prime among the challenges of AD technology in the UK is the issue of siting an AD plant. Dagnall (1995) suggests AD plants are best located close to required input resource such as feedstock, which will ensure attractive economies of scale. The availability of market for the energy generated is also an important issue that affects the location of AD plants (Allen Kani Associates and Enviro RIS Ltd., 2001; Bywater, 2011). Just like availability for energy utilisation, it is also important that AD plants are sited in proximity to an available market for the digestate produced (Allen Kani and Enviro RIS Ltd., 2001). Another very important issue that affects the siting of AD plants is community acceptability. Khan (2002; cited in Boholm and Löfstedt (Eds.), 2005) stated that, government bodies, corporate organisations, the general public and private individuals tend to welcome the idea of renewable technologies as a form of sustainable development, but their acceptability of renewable energy projects in terms of location is often controversial. Such controversies can effectively hinder the development of AD plants. In the UK, there is a defined procedure for the development of AD plants that is aimed at minimising conflicts of interest and ensuring human and environmental safety (SWEA, 2011).

Cost implications for the establishment of AD plants and the professional advice process are thought to be significant challenges to its widespread adoption and, in most cases, developers and investors are unaware of the funding available (DEFRA, 2011a). Cost issues are not limited to the UK and have the potential to put the viability of AD technology at risk as costs are continually on the rise (Wilkinson, 2011). Although issues associated with capital cost, operational cost and revenue of AD technology have been identified as a challenge in the UK, evidence shows that there is a wide variation in the situation (Frith & Gilberth, 2011). This problem of cost is also well established in the minds of farmers as a recent study conducted by Tranter *et al.* (2011) on the adoption of AD in England revealed that 93.4% of survey respondents considered the cost of establishing an AD plant as being too high. It is estimated that the capital cost for an average AD plant of up to 300 kWh is over £700,000 (Yeatman, 2006), and this clearly shows that the technology is far beyond the financial capacity of most famers within the UK. Various incentives and opportunities are in place to encourage investment by farmers and other stakeholders in the technology, yet again, the issue of type and scale of such incentives represent another basis for debate on the technology (Bywater, 2011).

Another challenge to AD in the UK is the legislation and regulations that guide and monitor AD developments and planning. Over the years, a range of legislation and a variety of regulations have affected AD and these have been interpreted and applied in different ways in the development of AD projects (Bywater, 2011). For the various types of feedstock, residues (digestate) quality, the different digestion capacity and the energy yield in terms of biogas, there are specific regulations and standards to be met (DEFRA, 2011a). Although such regulations are important for the effective management of the renewable energy sector, the regulations themselves can be a barrier to the development of the sector (Wilkinson, 2011). The complexity of regulations and policies for AD development according to Bywater (2011) is more pronounced because AD technology spans a number of disciplines thus involving more regulatory bodies such as European legislation, the Environment Agency, DEFRA, Animal Health, DECC, local planning authorities and so on. The ideal policy and regulatory guide should be that which promotes the use of the technology with incentives that will support small, medium and large scale plants for the overall goal of boosting UK energy and the sustainable development portfolio. Another suggestion elicited by Zglobisz *et al.* (2010) is that policy and regulations should acknowledge the localised nature of AD as a renewable energy option and remain rigidly structured. Gap analysis of AD in the UK shows that these suggestions are being considered by DEFRA as contained in the reports of Frith & Gilberth (2011).

Access to funds in the form of capital grants is another challenge for farmers in the UK. The problem is more predominant with small and medium scale commercial farmers that often require the financing of slurry tanks (Bywater, 2011). The problem is further compounded by the relatively low awareness of the importance of small AD plants and their place in the UK energy portfolio (Zglobisz *et al.*, 2010; Bywater, 2011). In the past, around the late 1980s and 1990s, AD plant owners took advantage of the pollution abatement award which was between 30%-60% and this initiative supported approximately 30 digesters (Bywater, 2011). More recently there are more incentives in place to support farmers and prospective investors interested in AD plants, but access to these incentives remains a challenge. The incentives are even more focused on plant owners rather than prospective owners. There are four financial incentives currently in place for AD development in the UK.

I. Feed in Tariffs (FiTs);
II. Renewable Obligation Certificates (ROCs);
III. Renewable Heat Incentive (RHI); and
IV. Renewable Transport Fuel Obligation (RTFO).

FiTs which is an initiative by the UK government to encourage renewable energy requires that an installation for renewable energy exists and has a certain level of energy generation capacity before the licence can be awarded. The main aim of this incentive is to promote the use of electricity from small-scale renewable generation. The tariff is categorised into different bands in accordance to generation capacity of the plant as shown in Table 2.2. The rates are guaranteed for twenty years for agreed contracts but are subject to increase with inflation each year (Ofgem, 2013). In the case of surplus electricity generation and onward export to the wider distribution network a guaranteed minimum export tariff of 4.64p/kWh can be paid or the energy supplier can negotiate a price. However, the survey carried out by Bywater (2011) shows that the current FiTs are too low to make AD attractive.

Table 2.2: FiT rates for projects approved before 31st March 2014

Source: Ofgem (2013)

Total generating capacity (kW)	Rate (p/kWh)
0 to 250	15.16
>250 to 500	14.02
>500	9.24

ROCs are certificates awarded to eligible renewable electricity suppliers who meet certain annual obligations, and who must use renewable, or contract renewable energy from outside generators mainly AD plants (Juniper, 2007, Ofgem, 2011). These certificates can be traded and as such the subsidy provided to renewable energy generation installations is not fixed unlike the case of FiTs.

RHI is another financial support mechanism to encourage the production of heat, and is very similar to FiTs in the sense that the subsidy is provided on a per kW basis as shown in Table 2.3. DECC (2010) described the RHI as an initiative aimed at reducing carbon emission in the UK. It is however important to state that only heat used for a specific purpose attracts the subsidy.

Table 2.3: RHI rates as of April 2013

Source: REA (2013)

Total generating capacity (kW)	Rate (p/kWh)
0 to 200	7.1

RTFO is a subsidy geared towards the transportation of renewable fuels. It allows for upgrade of biogas as a transport fuel and this is often associated with some fixed costs making the RTFO unsuitable for small-scale AD plants or other small-scale renewable energy generation (REA, 2013).

Issues concerning the understanding of AD and digestates are also factors that challenge AD development in the UK. Low level of knowledge and understanding of

AD plants and consequent poor maintenance are, according to Lukehurst (2007 cited in; Zglobisz, 2010), barriers to AD development and the main reason why only 25% of AD plants installed in the 1990s are still functional. Digestates from AD plants are not fully accepted as a rich source of plant nutrients by farmers (Alburquerque *et al.*, 2012b; Thomsen *et al.*, 2013) and this has greatly affected the available market for digestate.

2.3 SOIL CONSERVATION

The importance of soils has been discussed in the previous chapter and cannot be overemphasised. It has been reported that only an estimated 22% (14,900 million hectares) of the land area on Earth is potentially productive (El-Swaify, 1994; cited in Morgan, 2005; Khanif, 2010). This proportion of land, which in actual sense refers to soils, provides 97% of the World's food, since 3% comes from water bodies (oceans, rivers and lakes) and rising world population will exert even more pressure on the limited resource (Morgan, 2005). Apart from food provision, there is every possibility that development will take up part of this potentially productive land area as world population rises. The total size of the potentially productive land reported in 1994, may therefore be expected to be even less at the moment as Khanif (2010) has suggested. More so, Hannam (1999; cited in Stott *et al.*, [eds.] 2001) stated that global reports show that soils are being used beyond their ecological and physical capacity for agricultural land use. The concerns on the effect of world population on natural resources are not new in any sense, and can be traced as far back as the Malthusian theory of population growth as contained in Malthus's *'Essay on the principle of population growth'* (1798). With regards to depletion of land resource and ensuring food security, various techniques have been employed including, intensive agriculture, development of fast yield and production crops and animal hybrids, land reclamation and use of different forms of fertilizers (Hudson, 1995).

Soil conservation refers to the combination of all management and land-use methods that safeguard the soil against depletion or degradation caused by nature and/or humans (Brady & Well, 2005). Soil degradation here has been defined as a process that reduces the present and or the potential capacity of a given soil to produce goods and services (Hannam & Boer, 2002; Hannam, 2004). The degradation and changes to soil are not limited to human activities, but also natural processes. Population growth basically promotes activities such as intensified agriculture, urbanization and industrialization, deforestation, mineral exploration and land filling leading to erosion, acidification and pollution of the soil resource (Gordon *et al.*, 1995; cited in Taylor *et al.*, [eds.] 1996). The main form of degradation concerned with soil conservation and land-use management is erosion (Morgan, 2005). Soil erosion is defined as that process which makes soil become sediment (Brady & Well, 2005). Erosion remains foremost among soil conservation concerns in view of the level of devastation it can cause on-site and off-site and the financial implications associated therewith. For instance, it is estimated that soil erosion costs the United States of America over US$30 billion annually (Uri & Lewis, 1998; cited in Morgan, 2005). In the UK, POST (2006) reported that about 2.2 million tonnes of topsoil are lost to erosion each year and 17% of the UK's arable land shows evidence of erosion. A similar report estimates the cost of soil degradation in England and Wales to be £0.9 to £1.4 billion per year (POST, 2015). This cost covers GHG emissions, agricultural costs and productivity loss, flooding and water quality, all of which are areas of soil function.

The significance of soil erosion is also made obvious by the fact that it has been a focus of research for many years and even now certain scientific journals are specific to the problem, plus it has even become an independent subject area in universities and research institutes (Boardman *et al.*, 2003). The problem of soil erosion is universally recognised as a significant threat to the well-being of man, and even his existence (Hudson, 1995). As such, soil conservation has constituted an important environmental concern and has been part of considerable nature conservation efforts in some geographical contexts (Hartemink & van Keulen 2005; cited in Ingram & Morris, 2007). Even without the already discussed importance of soils, like other aspects of biodiversity and geodiversity soils also have their own intrinsic value to be conserved as part of the environment.

Various management techniques have evolved over the years for the conservation of soils, but not all such techniques aid soil conservation in practice. Ingram (2008) reported that the failure of certain soil management practices to achieve soil conservation is as a result of low levels of knowledge in addition to lack of experience in the utilization of new technologies and practices mainly on the side of farmers. The ideal management for soil conservation should be based on a number of principles which include: the sustenance of soil structure by maintaining soil organic matter and minimizing the compaction of soil during cultivation, avoidance of overworking and runoff; and maintenance of soil buffering capacity for nutrients by encouraging the effective use of artificial and organic fertilizers (Ingram & Morris, 2007). Espousing these principles in a world where priority is being placed on the enhancement of agricultural production to ensure food security for a rising population in the context of looming effects of climate change is however difficult. More often, management practices for soil conservation are more concerned with raising the productivity by means of artificial nutrient replenishment, that is, fertilizer application. This was justified by Khanif (2010) when he stated that since there is a need to secure food for population growth, total arable land is declining and land is being degraded, the productivity of available land has to be maximised and fertiliser application is a reliable and viable option. To what extent does this practice actually conserve soil? After all the conservation of soils is not limited to maintaining fertility but also includes reducing degradation to the barest minimum. Hannam & Boer (2004) recognised the escalating imbalance in food production to be a function of the gap existing between soil degradation and the rate of soil revitalisation and called for an in-depth reorientation of the attitude of humans to soils and other natural resources. These aspirations, according to them, are embedded in the aims of the International Soil Science Society that is attempting to raise awareness and knowledge on the sustainability of soils with the following main objectives:

I. change human attitude towards the importance of soils;
II. make it clear that soils are an integral part of human physical development and aid the sustainability of societies;
III. promote the status of soils by encouraging the management of soils as non-renewable resources across nations of the world;
IV. establish a network of international specialists to fight against soil deterioration.

Raising awareness of the importance of soils remains a significant step in the conservation of soil (EC, 2006), as it is more difficult to conserve what is not really valued (Towers *et al.*, 2005; Burek & Prosser, 2008). By raising awareness, soils will become more valued, especially to direct users like farmers who often have little knowledge about their soils (Ingram, 2008). The degradation of agricultural soils has also been linked to their unsustainable management by farmers (Boardman *et al.*, 2003). Although soil and environmentally-friendly techniques such as integrated farming, reduced tillage, use of light-weight tractors and organic farming exist, their understanding and effective application remains questionable. Once again, it is necessary for farmers and all stakeholders to be fully knowledgeable on the new and safe ways of promoting soil conservation. For example, in the practice of organic farming, which practically involves the use of organic fertilizers mainly from organic wastes, a thorough knowledge is required to ensure its efficient use in terms of quality and value (Rowell *et al.*, 2001; cited in Tambone *et al.*, 2010), even as the use of such organic inputs can have both positive and negative effects on the soil (Johansen *et al.*, 2013). Furthermore, it is impossible to ensure that farmers are well guided in their various soil management practices without the use of relevant legislation and policies.

2.3.1 Legislation, Policies and Soil Conservation- A Global and UK Perspective

The conservation of natural resources is always associated with one form of legislation or policy and in some cases both, not just within the UK but globally. Such legislation and policy is quite often put in place to meet certain international, regional and national targets often in the form of treaties, directives and recommendations. This has led to the description of legislation and policy as important tools in the conservation of natural resources (Hudson, 1995). Legislations and policy contribute to sustainable land management, forest and vegetation management, endangered species and their habitats, protection of agricultural land, and water and watershed management (Hannam, 1999; cited in Stott *et al.*, [eds.] 2001). Specific to soils, Hannam & Boer (2004) described legislation as a basic element necessary for the sustainability of soils, and the principal aims of legislation for soils are to mitigate erosion, pollution and degradation and to establish soil conservation institutions or authorities. At the international level various conventions and protocols have to some extent embraced the need for soil conservation and their sustainable management. For example, the 1987 Brundtland report, *"The World Commission on Environment and Development- Our Common Future"* is well established for its sustainable development goals and has led to the development of various sustainable development policies. It contains some provision for soil conservation, with the recommendation that policies and legislation for soils should incorporate sustainable development objectives and future legislation should be significantly different from that in the past (Hannam & Boer, 2002). Other important international legislations and programmes that have contributed to the conservation of soils include:

I. UNEP Montevideo Programme III 2000;

II. Millennium Declaration 2000 and Millennium Development Goals;
III. The World Soils Agenda 2002(IUSS);
IV. WSSD Plan of Implementation 2002
V. Committee for the Review of the Convention to Combat Desertification;
VI. UNEP strategy on Land Use Management and Soil Conservation 2004;
VII. Soils and the Global Agenda 2006 (IUSS);
VIII. FAO Global soil partnership 2011;
IX. Transforming our World: The 2030 Agenda for Sustainable Development 2015.

Despite this legislation and programmes for soil conservation, soils are still subject to different forms of degradation (Ingram & Morris, 2007; Boer & Hannam, 2012; Vaneeckhaute *et al.*, 2013). The Resolution of the IUCN World Conservation Congress of 2000 on Sustainable Use of Soil requires that environmental legislation and policies relevant to the sustainable use of soils should "pay attention to the ecological needs of soil and their ecological functions for the conservation of biodiversity and the maintenance of human life" (Hannam & Boer, 2004:12).

The conservation of soils in the UK when compared to other aspects of biodiversity and geodiversity over the past decades has been poor both in policy and industrial terms (Ingram & Morris, 2007). They argued that even though the *Code for Good Agricultural Practice for Soil* has been in place for over two decades, it is not enforced and is voluntary for farmers to practice it. In Europe and the UK obvious threats to agricultural soils have promoted the development of policies for their more sustainable management (Ingram, 2008). A thematic strategy was adopted in 2006 for the identification of threats to and protection of soils among European Union member states (EC, 2006; SNIFFER, 2008; Scottish Government, 2009), but a proposed soil directive for the EU was withdrawn in May 2014. However, the Seventh Environment Action Programme which came into action in January 2014, acknowledges the severity of soil degradation and set a target of sustainable soil management by 2020 (EC 2015). Central to this programme is the minimisation of soil erosion and increase in organic matter content of soils.

In the UK, soil conservation, like other natural resource conservation, is more of a devolved responsibility in view of the different administrations that make up the UK. In England, DEFRA has sole responsibility for soil policies; Scottish Environmental

Protection Agency (SEPA) deals with soil protection in Scotland, The Environment Agency oversees environmental protection in England and Wales and the North Ireland Environment Agency (NIEA) deals with environmental protection in Northern Ireland. The various strategies in place for soil protection in the different countries of the UK are built upon the EU thematic strategy for soil protection. In England, *'Safeguarding our Soils'* strategy (2009) is the action plan in place for soil.

In Scotland *'The Scottish Soil Framework'* of 2009 is the most direct soil protection strategy, which has been developed by the Scottish government in collaboration with key stakeholders (Scottish Government, 2009). The Welsh Assembly also has its own soil protection strategy contained in '*The Welsh Soil Action plan*' and the objectives are similar to those in England and Scotland, while Northern Ireland has no specific action plan for soil protection. Even with these strategies and action plans relevant to soil protection, poor coordination and, their ad hoc and fragmented nature limits soil protection (Scottish Government, 2009). It is thus important for policy makers to integrate soil protection and conservation policies and strategies to ensure their effectiveness while incorporating the two basic principles identified by Boer & Hannam (2012).

2.4 SUSTAINABLE AGRICULTURE IN THE UK

In the UK, it is broadly believed that sustainable agriculture mainly involves an increase in the efficiency of resource use, like harnessing soil quality, minimising nitrogen loss, precision agriculture and a reduction in water use especially for irrigation (Farmers Weekly, 2012). Even when the UK showed commitment to Agenda 21 of the Rio Conference by introducing its own strategy for sustainable development, '*Sustainable Development: the UK strategy'*, the chapter of the report that dealt with agricultural sustainability was more focused on environmentally sensitive farming by setting out to achieve the following objectives as reported by Cobb *et al*. (1999):

I. provision of adequate good-quality food efficiently;
II. minimize the utilization of resources;
III. protect air, soil and water quality; and
IV. preserve biodiversity and landscape quality.

By implication, economic and social sustainability are not really recognised, and only a part of environmental sustainability is incorporated in this general consensus which has lingered for over two decades now, even though the UK has reported some tremendous success in organic farming in the last decade, coming 5th in the production of certified organic foods (Harris *et al*., 2007; cited in Robinson [ed.], 2008). The situation has significantly halted the progress of sustainable agriculture within the UK, a situation even the government recognises. For instance, DEFRA (2002) reported in *'The Strategy for Sustainable Farming and Food- Facing the Future'* that the UK was performing below expectations in the area of social, economic and environmental elements of sustainable agriculture, and this is discussed as follows:

Social elements indicate that agriculture has affected tourism, job creation, income, and health of farmers in the UK. The importance of interdisciplinary collaborations for achieving sustainable agriculture has also been identified by Harris *et al.* (2008) who stated that interdisciplinary linkages are fundamental to answering questions that arise in agro-ecosystems and land use research, and will also meet the needs of non-research stakeholders in sustainable agriculture.

Environmental elements showed that agriculture in the UK has led to more negative impacts than benefits to the environment, costing £1-1.5 billion on the former and £600-900m for the latter per annum. Damages to the environment were mainly in the form of GHG emissions, water pollution and damage to biodiversity. 90% of some 10 million tonnes of raw material used for production is discharged as waste, with packaging waste constituting 12 billion plastic bags and 29 billion drink and food cans. These figures support the call by Fowler (2010) for a technology that will significantly reduce food production waste, and which will ultimately attract market all over the world.

Economic elements revealed that agriculture has not been very profitable. With a fall in the income of farmers, the greatest since the 1930s, overall food production is low at an estimated 20% below world leaders in food production, and poor investment in assets, for example in the food and drink industry where workers had qualifications 20-30% lower than elsewhere in Europe and Japan as well.

On the side of farmers in the UK, Robinson (2008) noted that the challenge of measuring the gain and losses to natural resources has limited sustainable agricultural practices, and that farmers are more concerned with the economic component of sustainable agriculture, with very little consideration for the environment. This goes on to stress the question of how much farmers actually know about their soil and land resource. One might expect that only very little is known as Ingram (2008) reported, and more so, it will be difficult for farmers to fully acknowledge the need to conserve their soil and land resources if they know little about them. Raising awareness of the need to educate farmers on the importance of their soil and land resources beyond the economic benefit and gains is necessary for reorientation of farmers. The use of soil trails is an effective way of informing people about soils and land resources to encourage their conservation and has been promoted by Burek (2005) and, Conway (2010).

2.5 SUSTAINABLE DEVELOPMENT- The Nexus of AD, Soil Conservation and Sustainable Agriculture

The threat to natural resources from population growth, environmental pollution and climate change has made the concept of sustainable development a much popularised one. The concept has heralded most environmental management programmes and policies in most part of the global context for more than two decades. The concept marked an end to traditional ways of resource use in development, where considerations of the needs of future generations were not considered (Golusin *et al.*, 2011). Rogers *et al.* (2008) stated that the concept of 'sustainability', which has now become a slogan in natural resource management, serves as the link between the environment and development. The 1987 report of the World Commission on Environment and Development (WCED), also known as the *Brundtland Report*, gave the definition of sustainable development as that form of development, which meets the needs of present generation without compromising the ability of future generations to meet their own needs. Like most concepts and theories associated with nature conservation and environmental management, sustainable development is still a pursuit in most part of the world due to different interpretations of the concept.

The concept of sustainable development traditionally had three indicators namely: economic, ecological and social indicators (Barrow, 2006; Robinson, 2008). Priorities on these three indicators have been greatly uneven over the years, and have been adjudged to be the main inherent challenge to sustainable development (Robinson, 2008). More recently, researchers and policy makers tend to include a fourth indicator known as an institutional indicator (Ivanovic *et al.*, 2009). Among the basic indicators of sustainable development, Barrow (2006) stated that the ecological indicator mainly concerned with environmental protection is the main propellant of the theory of sustainable development in the 21st century.

From an *economic indicator* point of view, sustainable development is concerned with employment, increased income, poverty reduction, return on investment (profit), reduction in inequality, enhanced production and energy efficiency and access to credit facilities (Mog, 2004). The thesis argues that with anaerobic digestion technology which has the potential of generating income as discussed earlier, poverty will be reduced, energy use will be more efficient, agricultural production can be enhanced, and, to a reasonable extent, employment will be created.

Social indicators of sustainable development include education, health, housing, gender equality, population statistics and rate of growth. Important parameters measured under social indicators according to the reports of the United Nations (2001) are: infant mortality rate, unemployment rate, literacy level, life expectancy from birth, percentage of the population below poverty line, nutritional statistics, crime rate, presence or absence of sewage disposal and access to clean water. In a rural perspective, social indicators anaerobic digestion technology, sustainable agriculture and the conservation of soils can aid the desired figures of the aforementioned parameters. For example anaerobic digestion can create employment and provide income as already discussed; sustainable agriculture with soil conservation will embrace all concerns of the environment thereby promoting clean water supply, and promote health from healthier food using zero inorganic inputs.

Environmental indicators include the minimization of soil and land degradation, minimization of air, land and water pollution, protection of other aspects of biodiversity and geodiversity and the overall retention of ecological integrity according to Mog (2004). These are direct benefits of AD technology, soil conservation and sustainable agriculture.

Last but not the least, *institutional indicators,* which are not always included in most interpretations of the concept, are quite applicable to this study. For instance, Ivanovic *et al.* (2009) identified technological advancement as an indicator of institutional sustainable development, and AD technology is a good example of technological advancement in the area of waste recycling and renewable energy generation. Also, technological advancement is crucial to achieving economic growth and thereby promotes sustainable development.

The most recent sustainable development goals are enshrined in *Transforming our World: The 2030 Agenda for Sustainable Development* report (UN 2015). The report contains 17 sustainable development goals to be achieved by 2030, they are:

- *Goal* 1- End poverty in all its forms everywhere;
- *Goal 2*- End hunger, achieve food security and improved nutrition and promote sustainable agriculture;
- *Goal 3*- Ensure healthy lives and promote well-being for all at all ages;
- *Goal 4*- Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all;
- *Goal 5*- Achieve gender equality and empower all women and girls;
- *Goal 6*- Ensure availability and sustainable management of water and sanitation for all;
- *Goal 7*- Ensure access to affordable, reliable, sustainable and modern energy for all;
- *Goal 8*- Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all'
- *Goal 9*- Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation;
- *Goal 10*- Reduce inequality within and among countries;
- *Goal 11*- Make cities and human settlements inclusive, safe, resilient and sustainable;
- *Goal 12*- Ensure sustainable consumption and production patterns;
- *Goal 13*- Take urgent action to combat climate change and its impacts;
- *Goal 14*- Conserve and sustainably use the oceans, seas and marine resources for sustainable development;
- *Goal 15*- Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss;

- *Goal 16*- Promote peaceful and inclusive societies for sustainable development, provide, access to justice for all and build effective, accountable and inclusive institutions at all levels;
- *Goal 17*- Strengthen the means of implementation and revitalize the global partnership for sustainable development.

While most of these goals may seem unrealistic taken into account the 15-year time frame, it renders much support for this research. Having linked AD to the broad indicators of sustainable development, sustainable agriculture and soil conservation, goals 2, 6, 7, 8, 13, 14 and 15 are directly in line with the overall aims of this research. This is not to say that this research provides all the solution for these particular goals to be achieved in the next 15 years, but rather suggest that this research will contribute to it and is also timely.

2.6 CONCLUSION

The findings of this chapter is summarised in Box 2.2. Concerns on food security issues, rising world population, climate change, environmental degradation and sustainable development goals calls for serious attention in this 21st century. One of those areas demanding attention is alternative technologies for sustainable renewable energy generation, waste recycling and environmental protection. Studies have shown and illustrated beyond reasonable doubt, that AD technology is indeed a reliable technology for waste recycling and renewable energy generation. Although it is yet to attain its full potential in the UK, its prospects abound. The issue of raising awareness remains very important if the prospects of AD technology are to be realised. This issue is highlighted by both the literature and the UK government, even though the question of how to raise such awareness for AD still remains.

The other important challenges to AD discussed are mainly the responsibilities of policy makers, although support from research and other stakeholders is also needed. The lapses in terms of policy and legislation for AD, incentives for renewable energy production and access to capital and funds for AD development need to be improved. The urgency and importance of AD technology is also supported by the rise in energy demand emanating from population growth and the need to achieve sustainable development. Also the potential of small AD plants need to be fully examined and popularised as much as the large and medium scale ones.

Soils are important pillars in every terrestrial ecosystem as a result of the various goods and services they provide. However, recognition of this can be thought to be limited in view of the lower support given to soil conservation when compared to other aspects of biodiversity and geodiversity. Amidst inefficient soil management practices, population growth, climate change and environmental degradation threaten the sustainability of soils to meet food security goals through agricultural production. In the UK, different strategies exist for the conservation of soils, but the level of achievement in ameliorating the degradation of soils remains below par in comparison to other aspects of biodiversity and geodiversity conservation. Stakeholders concerned with soil conservation in the UK, particularly farmers, seem to be more focused on the fertility of soils than their physical degradation; a situation that has been linked to the low conservation value attached to soils. It is also clear that there is a significant gap between the soil conservation practice and sustainable agriculture in strict terms, as the latter fails to fully incorporate the former.

Sustainable agriculture represents one of those approaches aimed towards food security and sustainable development, as human dependence on agriculture is threatened by population growth rates, climate change and environmental degradation. There are however, questions on the understanding of sustainable agriculture and the 'sustainability' of current practices. In the UK, study shows that, there has been an issue with prioritising the various indicators of sustainable agriculture, moving from environmental concerns at the early stage of sustainable development strategy to economic concerns in more recent times. On the side of farmers, the emphasis has always been on economic sustainability of agricultural businesses even though more attention is gradually being placed on organic farming. Although the UK is ranked among the leaders in organically certified food products (Soil Association, 2013), the future of agricultural production is dependent on the ability of policy makers to address the issues raised in this review, and the need to promote the conservation of soils in sustainable agricultural practices also remains a necessity. Achieving success in these three areas will facilitate sustainable development in the UK in the long term, with the recognition of the theoretical framework of their nexus. The research will therefore illustrate how this can be achieved in practical terms and contribute to the theoretical framework for future scenarios.

Box 2.2: Chapter summary

This chapter has;

- Provided a literature review relevant to the research;
- Provided definition of terms and clarity on concepts within the research;
- Provided theoretical framework to link anaerobic digestion, soil conservation, sustainable agriculture and sustainable development.

CHAPTER THREE

METHODOLOGY

3.1 INTRODUCTION

Box 3.1: Chapter purposes

- To locate the research within a philosophical context;
- To outline the research design and further relate it to the research questions raised;
- To illustrate the suitability of the research approach for investigation in the area of anaerobic digestion technology, soil conservation, sustainable agriculture and sustainable development;
- To describe the various research instruments used, the nature and type of data generated and analytical method for the data;
- To elucidate the various ethical considerations undertaken as part of the entire research process;
- To provide a framework for subsequent chapters that will present and discuss data generated and analysed using this methodology.

This chapter will outline and provide justification for the methods used in answering the research questions raised in Chapter one, in addition to other aims as summarized in Box 3.1. The chapter begins by positioning the research within a pragmatic philosophy and describing the exploratory approach used. It goes on to show that the exploratory approach is necessary to demonstrate a new approach to sustainable development. The research design, which takes a mixed methods approach, is then expatiated vis-à-vis the research questions for purposes of clarity. The suitability and justification for the methods used is also discussed. As stated in Box 3.1, a documentation of ethical issues is provided in this chapter, together with a concluding section to set the foundations of subsequent chapters that make up the main empirical and analytical part of this work.

3.2 POSITIONING THE RESEARCH

The analogy of the layers of an onion has been used to describe research processes (Saunders *et al.*, 2003, 2006). According to the model shown in Figure 3.1, the outer layer influences inner layers in an orderly manner up to the innermost layer. As such, the outer layer which according to the model refers to the *philosophical position*, exerts influence on the next layer, which is the *research approach;* this in turn affects the next layer *the research strategy*; and further influences *the time horizons* which then ultimately determines the *data collection method* represented in the innermost layer.

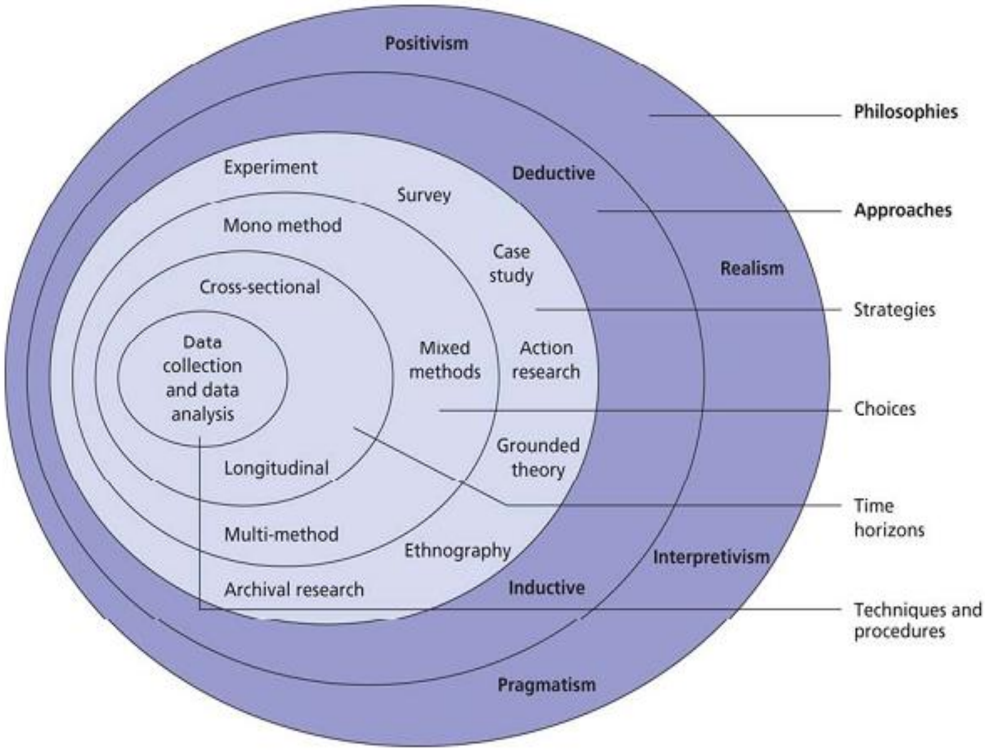

Figure 3.1: Schematic Representation of the 'Onion' view of Research Process

Wahyuni (2012) argued that even though the philosophical position of most research remains implicit, it affects research practices in various fields of study. Questioning the research paradigm is therefore a necessity to enable others to posit the research and create room for assessments of the research findings. By way of clarity, the philosophical position, research approach, research design, data collection and analysis method of this research will simultaneously raise and answer questions on the paradigm of the research.

3.3 PHILOSOPHICAL POSITION

The philosophical position that underpins this research is best described as the *pragmatism paradigm* supported and informed by a number of researchers including Onwuegbuzie & Leech (2005), Pansisri (2005), Greene (2006, 2008), Morgan (2007), Denscombe (2008) and Onwuegbuzie *et al.* (2011) amongst others. It is a research paradigm that is neutral to both positivist and interpretivist philosophies by viewing research as a continuous non-spatial process. By so doing, *pragmatism* embraces axiology, epistemology and ontology in approaching and understanding a particular phenomenon, hence it is often referred to as 'Mixed methods'. Denscombe (2008) stated that, the mixed method is the third major research paradigm, which has distinguished itself with a set ideas and practices in recent years. Thus, the method makes use of both quantitative and qualitative research data for understanding of phenomena or reality often contained in the research questions of the researcher (Wahyuni, 2012) and such questions can be addressed optimally (Onwuegbuzie *et al.*, 2011). It is therefore important to state at this point that the pragmatic paradigm is ideal for such studies as AD, soil conservation, sustainable agriculture and sustainable development which are real world issues. The relevance of this paradigm for this research is elaborated by Onwuegbuzie & Leech (2005) in their discussions on the advantages of the pragmatic researcher.

Firstly, pragmatism allows flexibility in the process of investigation in that it answers the research questions. For example, in this research, the research participants include farmers, conservationist academics, conservationist non-academics, energy/environmental consultants, key figures in farmers' associations, policy makers and retailers. It is therefore important that the technique in use is flexible to ensure that the right information is sourced from the different categories of participants. Also, flexibility is needed to ensure some degree of collaboration across the various participants. Furthermore, the research covers three key areas that are quite related, their combination towards achieving sustainable development is shown in Figure 1.2, and this requires some interdisciplinary flexibility and a holistic approach which pragmatism provides.

Secondly, the mixed nature of pragmatism creates an enabling environment for the researcher to utilize qualitative data to modify quantitative components in a given research. In their example, Onwuegbuzie & Leech (2005) stated that quantitative data equipoise the fact that qualitative data cannot be generalised, and in the same manner qualitative data can give clarity on relationships that may exist from quantitative data. Also, combining quantitative and qualitative components creates a conceptual framework that validates quantitative findings with reference to qualitative phase, and also develop necessary indices from qualitative phase to analyse quantitative data (Madey, 1982 cited in; Onwuegbuzie & Leech, 2005). This is particularly relevant to this study because, the first stage of data collection is qualitative, and information received from this was used to develop the various concepts and wording of the items for a questionnaire for generating quantitative data. The benefit of this approach is contained in the work of Morgan (2007) who stated that the abductive nature of pragmatism i.e. moving back and forth between the qualitative component of the research (induction) and quantitative component (deduction), allows this method to convert observation into theories and validate such theories through action.

Thirdly, a combination of the above two advantages makes pragmatic research paradigms understand the findings relevant to research questions and provide an enabling environment for verification of research findings. For research of this nature, which intends to show how AD, soil conservation and sustainable agriculture can achieve sustainable development, it is necessary to allow for verification of findings and recommendations made. Thus, the research needed to be expansive in all dimensions taking into account the complexity of the sustainable development concept, and pragmatism made this possible.

3.4 RESEARCH APPROACH

As discussed in the previous section the research operated on a pragmatic paradigm combining both a qualitative and a quantitative phase. The research moved from the qualitative phase to the quantitative phase, going back and forth until all the research questions were answered. The qualitative phase determined the items that were included in the quantitative phase. The qualitative phase also explored in depth opinions on some of the research questions raised, while the quantitative phase tested the components of those opinions on a wider group. Conservationist academies, conservationist non-academies, environmental consultants, key figures in farmers' associations, policy makers, and retailers are the groups that make up the qualitative phase, while farmers are the only group in the quantitative phase.

The qualitative phase, which represents the inductive inquiry as given by Morgan (2007), operated as shown in Figure 3.2. It followed a *bottom up* approach where observations led to establishing patterns, these patterns are then classified into tentative answers to research questions, and detailed analysis of these answers leads to theory, which in actual sense represents answers to the research questions. On the other hand, the quantitative, that is, deductive inquiry served as a confirmation to the findings of the qualitative phase under the framework of pragmatism as suggested by Madey (1982 cited in; Onwuegbuzie & Leech, 2005). It therefore follows the *top bottom* approach, moving from the theory developed in the qualitative phase to the tentative answers, which are considered at this stage as potential answers to the research questions. Observations (data collection) are then made and analysed to confirm the theory established in the qualitative phase.

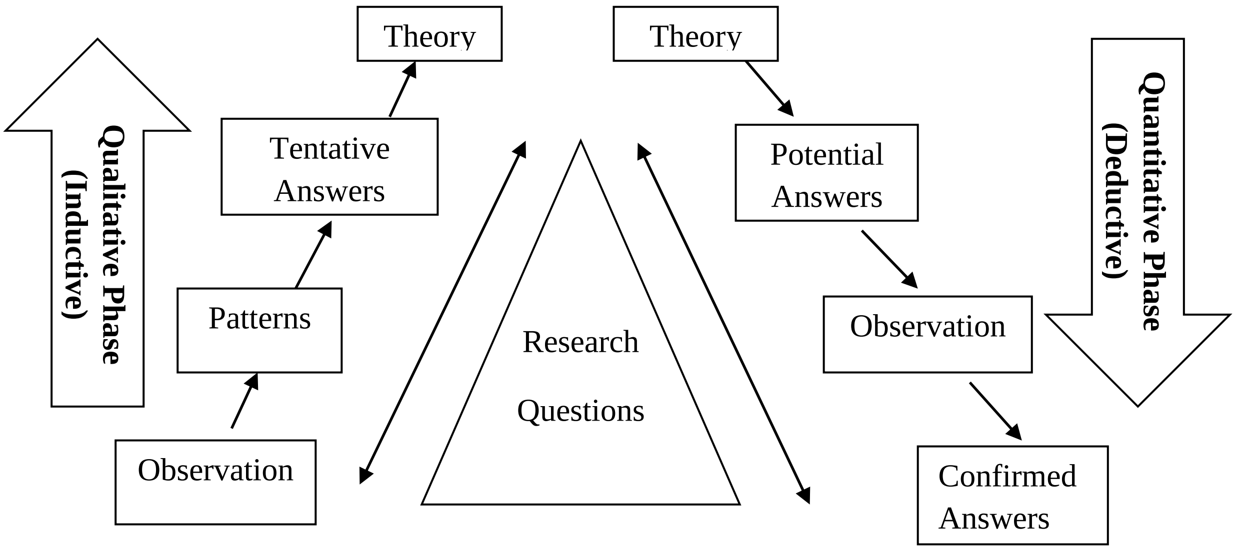

Figure 3.2: Research Approach Framework

The presence of the research questions in the triangle above shows that the process was back and forth until the entire research questions were answered. The entire framework is also an illustration of the *pragmatism paradigm.*

3.5 RESEARCH DESIGN

Having provided the context of the research, discussed its philosophical position and the research approach, the research design will now be discussed. The design in terms of target population, data generation and type is guided by the pragmatic paradigm and as such dependant on the research questions (Onwuegbuzie & Leech, 2005; Greene, 2006, 2008; Morgan, 2007). The research design therefore is driven by the form of research questions in the manner illustrated in Figure 3.2. From the research questions earlier mentioned, the research design involves a survey and case studies. As such, each research question is associated with one or more case study, but not all the case studies are associated with every research question. The survey makes up the quantitative phase of the study, and the case study, the qualitative phase. The various groups of participants are:

Farmers- This covers farmers from across the UK. Both geographical location and type of farmer are considered here. Data from this group is the main component of the quantitative aspect of the research. The main reason for focusing on farmers for the survey is because the research is concerned with soil conservation and sustainable agriculture as possible benefits of AD.

Conservationist Academics: This refers to those with established interest in nature conservation, with emphasis on soil conservation, sustainable agriculture and the use of renewable energy technology such as AD and sustainable development. They are based in institutions of higher learning, mainly universities. They are labelled as group 'A', in this research. Participants in this category were identified through research articles and government publications.

Conservationist Non-academics: Similar to group 'A', in the sense that they have established interests in soil conservation, sustainable agriculture, renewable energy technology like AD and sustainable development. In this case however, they are not based in institutions of higher learning, and do not engage in teaching at universities. They are based in research institutes, and other supporting non-governmental conservation agencies and associations including, British Society of Soil Science, Friends of the Earth, National Trust, Soil Association and Wildlife Trusts. This category is distinguished from group 'A' because their views on issues raised is expected to differ from that of those in the academies. They are labelled group 'B' in this research. This category were also identified though relevant publications and internet searches of the various associations.

Policy Makers: This included those individuals associated with policies relevant to natural resource conservation and renewable energy at the either the European level or the UK or both. The group is drawn from regulatory conservation agencies and societies across the UK including Natural England, Defra, Scottish Natural Heritage, Environment Agency and National Resources Wales. They are presented as group 'C' in this research. The participants here were identified through government publication and relevant websites.

Energy/Environmental Consultants: This group refers to those individuals with expertise in environmental consultancy with specific interest in renewable energy, soil conservation, sustainable agriculture and sustainable development. They are often contributors to environmental policies, and because of this, they are paired with policy makers to answer the same interview questions. They are however separated from policy makers because they do not actually make the policy, and therefore have different views to the issues raised in the interview questions. They are labelled group 'D' in this research, and were identified through internet searches and government papers.

Key figures in farmer's associations: This group refers to those farmers whose 'palms have become soft' due to administrative and political endeavours (Personal communication with an organic farmer, 2013). They are in charge of associations and unions that protect the interests of farmers within the UK. The main associations include: National Farmers Union (NFU), Tenant Farmers Association (TFA), The Royal Association of British Dairy Farmers (RABDF), National Farmers' Retail and Markets Association (FARMA), and National Federation of Young Farmers' Clubs (NFYFC). They are labelled group 'E' in this research, and were identified through the websites of the relevant associations.

Retailers: This group refers to retailers of agricultural produce within the UK. The main participants here are the sustainable development officers, that is, those with the responsibility of making sure their retailing organisation meets with sustainable development goals in terms of food supply, food waste generation, and food waste disposal and recycling. The retailers contacted include: ALDI, ASDA, Co-op, Marks & Spencer, Morrisons, Sainsbury's, Tesco, and Waitrose. This group is included in the study because of their various sustainable development goals and projects, the amount of food waste they generate, and rising demand for healthier food. They are labelled group ‘F’ in this research, and the participants in this group were identified through contact with the relevant press office.

The place of these participants in answering the research questions is shown in the research design in Figure 3.3. The diagram links the participants to the research questions and at the same time provides clarity on the data collection method used for each research question and the phase of research. Also included in the figure is a time frame for answering the research questions.

Different types of questioning were applied for data collection. The main forms of questioning used followed the suggestions of Yin (2003) for the survey part, ‘are, do, how, what?’ type of questions were asked. Examples of questions asked were: *are you aware of the benefits of soil other than crop production, what is farm size, how would rate your overall interest in agricultural technology.* In the case study ‘how, why?’ type of questions were mainly used. Some of the questions asked were *how can we make AD more attractive to farmers other than the use of incentives, why are community AD and localism an important part of the UK’s AD strategy and action plan*. The advantages of this form of questioning are that it creates opportunity for contextual accounts to be generated especially in a case study (Yin, 2003). The full list of questions asked are available as appendix 1 and 2 of this thesis for the case studies and survey respectively.

Case studies were used to generate attitudes, opinions and perceptions towards AD, soil conservation and sustainable agriculture. These attitudes, opinions and perceptions are in turn used to guide information generated from the survey of farmers as described in the research approach. The use of case study in qualitative research is well recognised, as it dominates most qualitative studies (Kumar, 2011; Newing, 2011). Although each case study involves different individuals, they are considered as a single entity as suggested by Kumar (2011) and hence the term ‘case study’. According to Kumar (2011), case studies are best located in a context where little is known about a particular problem or where a holistic approach is taken to make an enquiry, and recalling the aims of this research, case studies are indeed appropriate for this study. Also since the research takes a holistic approach in unravelling the answers to the research questions, using case studies remains appropriate. The case studies are denoted as groups A, B, C, D, E and F.

A *Survey* was conducted to examine the validity of the opinions of the case studies on a wider population (the farmers) on AD, soil conservation and sustainable agriculture. It also aimed at showing the trend in farmers' attitudes towards technological advancement and to examine possible factors that affect such attitudes which are suggested by the case studies. Another important goal was to elucidate how much famers actually know about soils. This exploratory approach exposed present and past trends in farmers' activities, which remain necessary for answering the research questions raised.

Again, for this type of study motive, the use of surveys remains justified as recommended by Kumar (2011) and this strategy has been used for a study of similar nature (For instance Ingram, 2008). Although the use of surveys in research has well defined advantages, a number of challenges, which include getting a reasonable size sample, distributing questionnaires, getting feedback, and misinterpretation of questions by respondents, remain.

3.6 DATA COLLECTION TECHNIQUES

A number of techniques were used for data collection and they include: interviews, questionnaires and literature (i.e. government publications and other relevant literature). The methods were influenced by the research design and research questions. For the case studies, interviews were used to generate data, while questionnaires are used in the survey as shown in Figure 3.3. A continuous review of literature to complement findings from the research using existing data from such publications is categorised as secondary data. The type of data collection techniques used include:

Interviews

Structured interviews were used to generate data in the various case studies. Interviews are used in qualitative studies to get in-depth opinion on various issues arising from the research questions. The interview questions were administered to a number of individuals associated with a particular case study (category). The questions administered to these different categories vary and were made specific to the area of investigation relevant to the particular category. Varying questions to suit a particular case study is supported by Bernard (2006: 216; cited in Newing, 2011) who stated the following:

"*Get people on to a topic of interest and get out of the way*"

However, group A and B were asked the same questions, as were groups C and D.

The interview questions (Appendix 1) were generally structured and open-ended to allow for unsolicited discussions and opinions. Using structured interview questions has the advantage of uniformity in data as opposed to the unstructured case, and this enables comparison of data (Easterby-Smith *et al.*, 2002; Kumar, 2011). Also the need for rigidity of data is necessitated by the tight focus on research questions, which is guaranteed by structured interview questions. Flexibility in conducting the interviews is however encouraged, as the interview process was by electronic mail. The use of email interviewing is well recognised and is known as *asynchronous communication of time and place* (Opdenakker, 2006). Key advantages of this type of approach are time saving, cost reduction and zero physical distraction as associated in face-to-face interview. More so, using email interviews enabled verbatim report of participant response to interview questions, thereby validating the research findings.

In conducting the interviews, the recommendations of Yin (2003) for conducting interviews were followed, which include following a line of appreciative inquiry and asking the main questions without bias in support of the line of inquiry. More importantly responses from the case studies were used to develop wording items in the questionnaires used in the survey phase as indicated in the research approach. The interview process lasted for six months (November 2013 to April 2014).

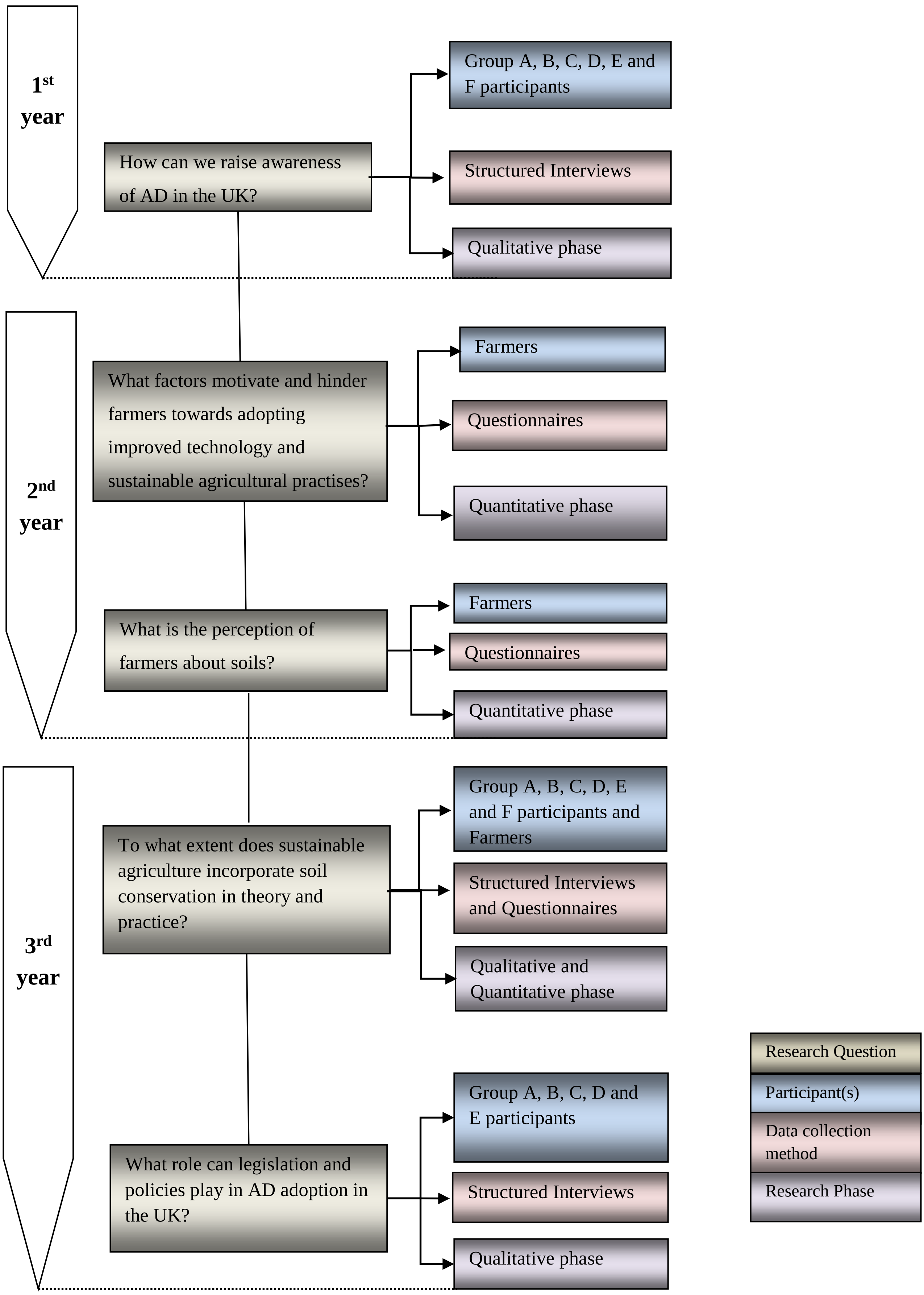

Figure 3.3: Research Design

Questionnaires

Based on the response from case studies, the survey questionnaire (Appendix 2) was developed and was made available online using *SurveyMonkey*. A novel approach to surveying farmers was used. This involved the use of a *Yellow Pages* business directory for the UK, Natural England farms directory, e-mail and Twitter. The directories were used to search for names, contact details (telephone number and e-mail), and addresses of farms across the UK, while e-mail and Twitter were used to send out a survey link to farmers. The use of *Yellow Pages* is recognised for farm surveys (Burton & Wilson, 1999), but this study was not over-reliant on it. In order to use Twitter, a dedicated Twitter account was created and names of farms were searched through the Twitter page *'search option'*. Although the twitter account was originally intended to search for farm names, it also served as a *snow-balling* sampling method, because when one farm or farmer is followed on Twitter, followers of the farmer or farm appear as a suggestion to follow on the Twitter page labelled as *'who to follow'*. In other words, by following one farmer or farm, Twitter automatically suggest another farm or farmer to follow. The reason for using questionnaires for the survey is to reach out to as many farmers as possible within a reasonable period of time as recommended in the literature (Kumar, 2011; Newing, 2011). Also the scattered distribution of farmers across the UK supports the use of questionnaires. The questions were mainly in the form of closed questions but included some open-ended questions. The data types generated here are therefore in the form of categorical data from closed questions and free text from open questions. The questions are all uniformed and standardized for the farmers. The entire survey process lasted for four months (August to November 2014).

Documentations (Secondary data)

In addition to primary data collection through interviews and questionnaires, secondary data was sourced concurrently throughout the research process. From the discussions in Chapter 2 the importance of secondary data, cannot be overemphasized. The documentations used are UK government and international organizations' publications, proceedings and reports of relevant conservation agencies and associations, texts and most importantly peer-reviewed journals relevant to AD, soil conservation, sustainable agriculture and sustainable development. The secondary data was not used or combined in the analysis of primary data but served as reference point to the findings of the research from primary data generated. Care was also taken to ensure that data from secondary sources remained up-to-date and relevant, although past data were included in retrospective analysis of issues arising in the research questions.

3.7 DATA ANALYSIS AND HANDLING

This is without doubt a very important stage of every research process that follows conventional scientific procedure for reporting research. In reality improper analysis and handling of data can ultimately invalidate any given research. All raw data collected was analysed according to type. In line with the philosophical position and research approach, the research questions were answered moving back and forth between the inductive and deductive phase. For each phase however, data were analysed independently. With regards to the philosophical position, the research is not focused exclusively to seeking for regularities or irregularities between the interests' areas (AD, soil conservation, and sustainable agriculture) from the empirical data generated, but are also focused on providing answers for the research questions. The analytical method was geared towards providing a clear description of the basis for synchronising AD, soil conservation and sustainable agriculture to achieve sustainable development and at the same time elucidating the potential structure for achieving that.

During the inductive phase, the analysis is concerned with grounded opinions on current situation associated with the interest areas, ways forward and appreciation of the need to interlink the interest areas to achieve sustainable development. This goal is embedded in the research questions, so, the inductive analysis is concerned with generating tentative answers to the research questions, drawn from conservationist academies, conservationist non-academies, environmental consultants, key figures in farmers' associations, policy makers, and retailers across the UK.

Qualitative data from interviews were analysed in four stages as given by Kumar (2011), even though the overall process is termed the *grounded analysis* as the research is concerned with identifying common and contradicting ideas and patterns relevant to the research questions.

Step 1- Identification of main themes: this involves a thorough reading of the responses to identify the main ideas being communicated, and such ideas are then grouped as broad themes.

Step 2- Coding: After the creation of a hierarchy of emergent themes from the previous step, coding was carried out to help simplify the data and aid focus for analysis. MAXQDA 11 software commonly used for the purpose of storing, coding, recovery and data presentation was used for this process.

Step 3- Classification of responses: here responses were fitted into appropriate themes by referencing participant's response and the appropriate code developed.

Step 4- Integration of themes and responses into research text: having grouped responses into the different themes, the findings were then interpreted and included in the research text.

The deductive phase (survey) involves the analysis of the empirical data to support the tentative answers to the research questions derived from the inductive phase. A similar procedure to qualitative data analysis was used for quantitative data; the only difference is that instead of identifying the main themes in the data, editing is done before coding. The stages are:

Step 1- Editing: the raw data are subjected to scrutiny, looking out for unanswered questions or inconsistency and possible errors to ensure "clean" data are available for analysis.

Step 2- Coding: Although the survey generates mainly quantitative data, elements of qualitative data are also generated at the same time. For example attitudinal scale measurements and open-ended questions are considered as qualitative data. Coding which is done in order to communicate finding to readers (Easterby-Smith *et al.*, 2002; Kumar, 2011; Newing, 2011) involves extracting the main themes in qualitative, categorical and descriptive responses.

Step 3- Analysis: Coded data was subjected to exploratory statistical analysis to check for relationships and patterns. The Chi-square test was used to check for relationship between independent and dependent variables, at 95% confidence level ($p<0.05$) using SPSS version 22.0 statistics software. The test is 2-sided (non-directional), and in each case the null hypothesis (Ho) states that there is no relationship between variables being tested, while the alternate hypothesis (Ha) states that there is a relationship. If the observed p was less than 0.05 the Ho was rejected and Ha accepted, and vice-versa. Phi and Cramer's V were used to measure the strength of relationships, while Fisher's test and Likelihood ratio were used to compare the p value to the rejection level when basic chi-square assumptions were violated (Field, 2009; Pallant, 2013). In the case of categorical data, the software package is used to develop percentages, tallies and charts to describe patterns arising. Word clouds were also used to communicate some quantitative information, particularly farmers' description of soils in Chapter 6 and uses of farm waste in Chapter 7.

3.8 ETHICAL CONSIDERATION

It is believed that the overall quality of research is influenced by ethical concerns mainly in the design and implementation of the research. As such full ethical considerations were taken into account to ensure that the time, effort and personal finance put into the research were not wasted and the research measures up to acceptable standards of the university at this level of research.

As a rule, the university requires that all researchers gain ethical approval for their proposed research prior to data collection. This approval was given by an ethics committee headed by a lead reviewer after a formal application was made with the necessary supporting documents. The application form (Appendix 3) covered the introduction for the researcher, research details, ethical issues and financial arrangements. In summary, the committee aims to ensure that approval is only given to planned research that has the desired credibility and clearly demonstrated potential benefits, whilst ensuring that there is zero or negligible potential to cause harm to all participants including the researcher and put measures in place to reduce the potentials where applicable. In view of the nature of the research, which is focused on AD technology, soil conservation, sustainable agriculture, with potential to contribute to sustainable development, there is no risk or potential harm to participants. This was illustrated from the approach for data collection and analysis, which clearly showed that no vulnerable person, is expected to participate in the study. Although sustainable development is a rather generic topic today, the approach for achieving it in this research offers participants some degree of interest to participate. In other words, the potential wider benefits of the research to sustainable development were assumed to be a contributing factor for participants' cooperation.

Despite the fact that the research embeds no risk or harm to participants, full considerations for type of questions asked were taken into account. The basic assumption is that, although there is no risk of physical harm in this research, asking inappropriate questions has the potential to cause harm not just in this research but every other quantitative and qualitative research. This was avoided by good research practices which involved: making sure participation was voluntary; guaranteeing anonymity of participants, making use of participants' information sheets and ensuring data protection. The issue of sensitivity of participants associated with in-depth interviews was eliminated by the approach for conducting the interviews. Also, in asking questions, personal questions that may seem embarrassing were completely avoided especially in the survey. The participants' information sheet (Appendix 4) served as guide to target participants letting them know the purpose of the study, why they were chosen, time taken to participate, options for withdrawal and making complaints, the benefit of their participation and assurance of anonymity of their identity. This was made available to both interview and survey participants. An 'invitation e-mail' (Appendix 5) was also sent to all participants contacted through e-mail.

With regards to data handling and protection, data were stored and processed with software equipped with password protection. Hard copies were kept out of public view by storing in a secured drawer in a secured office. For the interview responses (transcripts) and summaries, pseudo names were used to ensure that the real identity of participants remain anonymous. In the case of the quantitative components, names were never asked so data generated automatically remained anonymous.

No conflicts of interests exist to create bias in reporting the findings of this research.

3.9 CONCLUSION

A summary of the chapter is provided in Box 3.2. In this chapter it has been stated that the pragmatism paradigm, which uses both qualitative and quantitative components is suitable for investigating the role of AD in achieving soil conservation and sustainable agriculture. This philosophical stance was further justified in the research approach and seconded by the research design presentation. Using qualitative and quantitative approaches has been illustrated to focus the research process on answering the research questions raised in both depth and breath. The suitability and appropriateness of the data collection, analysis and handling techniques applied for this research was also established. This has now set the scene for elaborating on the answers to the research question in subsequent chapters, each providing details and findings of observations at both the qualitative (inductive) and quantitative (deductive) phases of the research. Subsequent chapters (4, 5, 6 and 7) represent responses to the research questions and chapter 8 provides conclusions and recommendations.

Box 3.2: Chapter summary

This chapter has;

- Located the research in a philosophical context;
- Outlined the research design and approach for addressing the research aims and questions;
- Provided the data types, collection technique, and analytical method;
- Outlined the ethical considerations undertaken.

CHAPTER FOUR

RAISING AWARENESS OF ANAEROBIC DIGESTION IN THE UK

4.1 INTRODUCTION

Box 4.1: Chapter purposes

- To provide further literature background relevant to 1st research question;
- To present the interview participants (AD stakeholders) and interview questions dedicated to address the first research question;
- To present part of the interview findings;
- To evaluate these findings in the context of raising awareness for AD;
- To set the scene for the questionnaire survey process and subsequent chapters.

Since the concept of sustainable development was introduced in 1987 by the World Commission on Environment and Development (WCED, 1987), there have been a number of initiatives and policies aimed at ensuring sustainable resource use in different parts of the world. While most policy makers are keen on making decisions that will ensure economic viability, environmental health and social well-being in light of sustainable development goals (Bi & Haight 2007), the rising demand for energy all over the world exerts pressure on some strategic natural resources such as oil and gas, coal, and uranium and concerns grow over the climate impacts of fossil fuel combustion thereby necessitating the need for renewable energy initiatives (Swindal *et al.*, 2010; Kim *et al.*, 2010; Alburquerque *et al.*, 2012a; Browne *et al.*, 2013). Although the rise in renewable energy demand can be linked to economic, environmental and political events across the globe like population growth, food security concerns, need to reduce greenhouse gas emissions and climate change, it also indicates the role of technological advancement in promoting efficient resource use. This was recognised in FAO's definition of sustainable rural development which according to Anon (1989) is the conservation and management of natural resources, and preference for institutional and technological changes that support sustainable development goals. Anaerobic digestion (AD) is a typical example of renewable energy technology that can help to achieve sustainable development goals in the 21st century.

Despite this and the other benefits of AD discussed in chapters 1 and 2, AD remains clearly under-developed in the UK. The UK AD strategy and action plan, published in June 2011 identified the benefits of AD, acknowledged its under-developed status in the UK and outlined the various themes to be addressed with regards to AD (DEFRA, 2011a). The action plan and strategy report however claimed that there is a general awareness of AD in the UK, even when an earlier working document on AD gap analysis in the UK contradicted this and reported low levels of awareness as one of the gaps (Frith & Gilberth, 2011). Another DEFRA (2012) report on AD progress published one year after the introduction of the action plan and strategy clearly stated the need to raise awareness of AD technology and to promote its benefits. Furthermore, the fewer than 200 AD plants in the UK (NNFCC, 2015) indicate a relatively low level of awareness compared to elsewhere in Europe, *e.g.* Germany, has well over 6000 AD plants (POST, 2011).

In addition to Box 4.1, this chapter more specifically aims to identify the various options available for raising awareness of AD in the UK and the ways to address some of the challenges to AD development both in the UK and more generally.

4.2 PARTICIPANTS AND INTERVIEW QUESTIONS

The various groups of interview participants have been discussed in the previous chapter (Chapter 3) as case studies, and were also identified as AD stakeholders. A total of 202 AD stakeholders in the UK were contacted and 21 agreed to be interviewed. The distribution and some characteristics of the participating 21 stakeholders are presented in Table 4.1.

Table 4.1: Characteristics and distribution of AD stakeholders interviewed

Stakeholders	Position	Expertise
Conservationist academics (Group A) *N=8*		
Adam Smith	Professor	Nature conservation and renewable energy
Linda Gold	Senior lecturer	Agriculture and nature conservation
Ken James	Senior lecturer	Renewable resources
Ben Boniface	Senior lecturer	Agricultural technologies
John Barton	Professor	Renewable energy and nature

Mark Price David Brown Eric Stanley	Professor Lecturer and farm manager Reader	conservation Renewable energy and soil conservation Conservation agriculture and agricultural technologies Environmental technologies and nature conservation
Conservationist non-academics (Group B) *N=3* Gordon Nathan Stacey Rowland Armstrong Isaac	 Senior research fellow Research fellow Research fellow	 Renewable energy and soil conservation Nature conservation Renewable energy
Policy makers (Group C) *N=2* Harold Edwards Bryan Cole	 Head Environmental Policy Unit Director Nature Conservation	 Nature conservation and environmental policy Natural resource management
Energy/Environmental consultants (Group D) *N=6* Max Payne Nick Jonathan Joanne Brennan Tricia David Iain Duke Sharon Murray	 Lead consultant Consultant Senior consultant Consultant Principal consultant Consultant	 AD and biogas technology AD AD and environmental technologies AD AD and renewable technology AD and biogas technology
Key figures in farmers association (Group E) *N=1* Paul Andrew	 Regional head	 Agriculture, environmental

		policies and administration
Retailers (Group F) *N=1* Deborah Carter	Head sustainability and agriculture	Sustainable development and agriculture

Note: *N*= number of participants, and all names presented here are pseudo names

The interviews with these stakeholders were structured in the sense that questions asked were informed by themes already identified in the UK AD gap analysis report of 2011 and were varied slightly to suit the participants' group expertise as discussed in Chapter 3. Table 4.2 shows the interview questions used to address the overall aim of this chapter.

Table 4.2: Interview question distribution across participant groups

Interview Questions	Participant Groups
1. How can we ensure that the benefits of AD technology are shared by everyone?	C, D, E and F
2. How can the understanding of AD technology be enhanced by all those associated with AD facilities?	A, B, C, D and E
3. Do you consider community AD and localism have an important role in UK's AD strategy and action plan?	All groups
4. How can we promote community AD projects in view of sustainable development goals?	All groups
5. Do you consider small AD plants as integral to raising awareness for AD?	A, B, E and F
6. How can we ensure that biogas generated from AD plants is diversified in their use?	A,B, C, and D

4.3 RESULTS AND DISCUSSION

4.3.1 Promoting AD projects in view of sustainable development

Figure 4.1 shows a summary of responses received from participants on each theme (interview questions) and sub-theme (shared opinions). The most shared opinion for promoting AD in view of sustainable development was informing people about the benefits of AD. A detailed response that covered the three elements of sustainable development was that of a policy maker who stated:

'By promoting AD as a profitable supplier of renewable energy from waste, a creator of local jobs / skilled labour force and potentially a source of sustainable income for communities to re-invest in their own future. Potential health benefits alongside wider environmental benefits. Furthermore, a by-product of AD could be used as a fertiliser, which can help support the sustainability of rural economies. AD plants themselves potentially offer a focus for engaging communities to think about their energy future and to gain a better understanding of the whole life of food' (March, 2014).

Earlier, Wilkinson (2011) reported that in some developing countries AD is often linked to sustainable development initiatives, natural resource conservation and regional development strategies. In the UK, discussions about promoting AD have been focused on the role of AD in treating biodegradable waste, thereby reducing the amount sent to landfill (Zglobisz *et al.*, 2010). By diverting biodegradable waste from landfill part of the environmental goals of sustainable development is achieved.

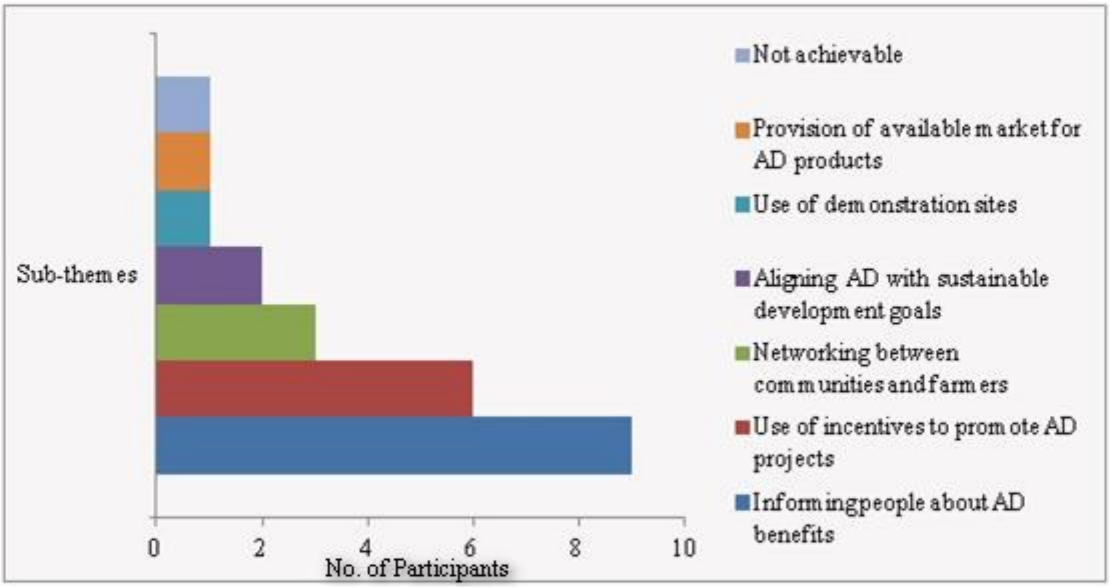

Figure 4.1: Summary of total response across sub-themes under promoting AD projects in view of sustainable development

It is important to note that, even when AD yields sustainable development goals, it could still be unsustainable if residual digested materials are not properly reused, treated or disposed of as this can cause negative environmental impact (Alburquerque *et al.*, 2012a).

Another shared opinion among participants was the use of incentives to promote AD projects. Participants suggesting this option were mainly focused on the role that government has to play in the development of AD projects and how communities can be encouraged to accept such projects. The main suggested role for the government was financial support as one group A participant said *'financing AD at all scales (large, medium and small)'* (November, 2013). There was also a call for networking between communities and farmers. Again, there is a need for government support but in this case non-financial, rather the coordination of the network between farmers and communities, like David Brown, an academic conservationist stated, *'The government need to promote more and encourage communities to work with farmers and not against them'* (November, 2013).

Aligning AD with sustainable development goals was another shared opinion. By aligning AD with sustainable development goals, AD plants should use biodegradable waste rather than emphasize growing energy crops. Other isolated opinions are the use of demonstration sites and the provision of available market for AD products. The use of demonstration sites was suggested by a group D participant, who opined that this would allow more public involvement. The provision of available market for AD products was a suggestion of another group D participant. AD products like the biogas, digestate and energy need to be supplied to the market to make AD sustainable. Lack of available markets for biogas was described as one of the factors that have made AD unsustainable over the years (Wilkinson, 2011). Although most participants made suggestions as to how AD can be promoted in view of sustainable development goals, the group E participant, contradicted this and believes that AD cannot compete with other commercial business as he said '*Difficult, I think commercial business are far better placed to make a success of this technology (AD)'* (April, 2014). Three other participants did not respond to this question.

4.3.2 Community AD, localism and the UK's AD strategy and action plan

Community AD and localism were identified as the main option for raising awareness of AD in the UK AD strategy and action plan, and this gained a wide acceptance among participants in this study. Figure 4.2 shows a total of 17 participants out of the

21 interviewed were in support of community AD and localism. The areas of support were that community AD and localism would promote community acceptance of AD, allow communities to benefit directly from AD and minimise cost.

According to one group A participant, community AD and localism '*will increase the likelihood of public support of AD facilities and remove potential stigma that drives nimbyism*' (February, 2014). Similarly, the direct benefits of AD will give the community a sense of ownership and inevitably their acceptance of AD as suggested by another group A participant, who stated:

> '*Yes since at community level there is a better understanding of the real needs and circumstances of the area, therefore AD treatment can be more targeted and tailored to existing needs. Again, community AD plants promote local 'ownership' of facilities which increases the willingness to participate and 'buy in' to the idea'* (April 2014).

Community acceptance of AD plants was earlier identified as a challenge to the development of the technology (Khan, 2002; cited in Boholm & Löfstedt (Eds.), 2005). Other expected benefits of AD in a local community are job creation, waste management, free power and heat. Community AD projects in Sweden, already feed local households with heat and power (Wilkinson, 2011).

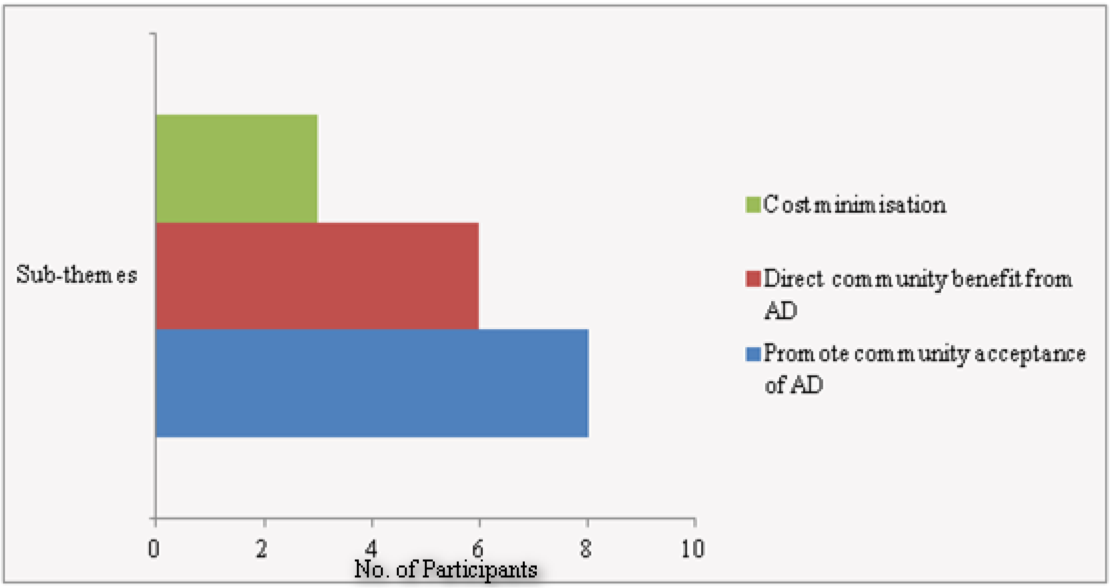

Figure 4.2: Summary of total response across sub-themes under community AD, localism and the UK's AD strategy and action plan

Amidst the wide acceptance of community AD and localism among respondents, some participants identified the potential challenges to achieving this. The challenges identified were environmental pollution and hazards, access to the technology and funding. With respect to environmental pollution and hazards, a group B participant said,

'*At the same time, AD plants are dangerous and have the potential to cause considerable pollution, and having them run by a larger number of people with possibly fewer resources available to invest in training and AD management is likely to increase the risk of serious accidents and pollution incidents'* (December, 2013).

The main concern about accessing the technology is that AD plants are more complex systems when compared to wind turbines or solar panels. With funding, the group E participant who is not in support of community AD and localism simply responded, *'No- community AD has been difficult due to the logistics and cost of transporting/handling inputs and removing digestate'* (April, 2014). This response is in absolute contrast to the suggestion that community AD and localism will minimize cost.

Some participants also mentioned certain factors that should be considered with community AD. Networking with farmers, proximity to feedstock and size of the digester were the factors mentioned. The suggestions were that farmers would provide the land and most of the feedstock, and so the digesters should be closer to farms. As for the size of the digester, one group D participant stated:

'*We have also looked at these micro digesters for food waste in a village, since it means that there are not huge food waste miles and the digestate could be used locally on a farm or amenity land'* (April, 2014).

Another consideration in developing community AD identified in literature is that such projects should avoid biomass loss in the form of deforestation and also possible soil erosion (Perez *et al.* 2014). A good example of community AD project is that developed by Lower Park Farm Co-operative. The project which lasted for more than 2 years is now operational and was developed through community cooperation, and shares investment (£1 per share).

4.3.3 Small AD plants and awareness of AD

The idea of community AD and localism require the use of small scale AD plants. The question relating to this was not addressed to all participants as shown in Table 4.2, and Figure 4.3 shows the total responses under this theme. From the responses received, small AD plants have economic, environmental and geographical merits. The most shared opinion was on the economic merit. For example, Ken James (group A) simply said, *'economics would stack up to make small scale AD plants economic'* (December, 2013). Reducing transport costs was one of the areas identified to provide economic benefits. Environmental merits identified are same as those with large AD plants, which is the use of farm and food waste thereby minimizing the amount sent to landfill and reduction in greenhouse gas emissions. Geographically, some participants believe that small AD plants can make AD popular at local level. One group A participant shared these three merits of small AD plants when he said:

'*They not only raise awareness but also spread them geographically so that transport costs and associated environmental impacts are decreased'* (February, 2014).

Social merits like social cohesion, improvement in quality of life and values can also be derived from small AD plants (Wilkinson, 2011).

The main challenge to small AD plants identified by one participant was cost, which does not correspond to economic merits identified by other participants. A similar contradiction was noted in the results pertaining to community AD and localism. In this case however, the participant who suggested this challenge did so with a question when he said, *'how much would it cost to set up an on-farm facility, even simply to deal with waste effluents (e.g. from a dairy herd)?'* (February, 2014).

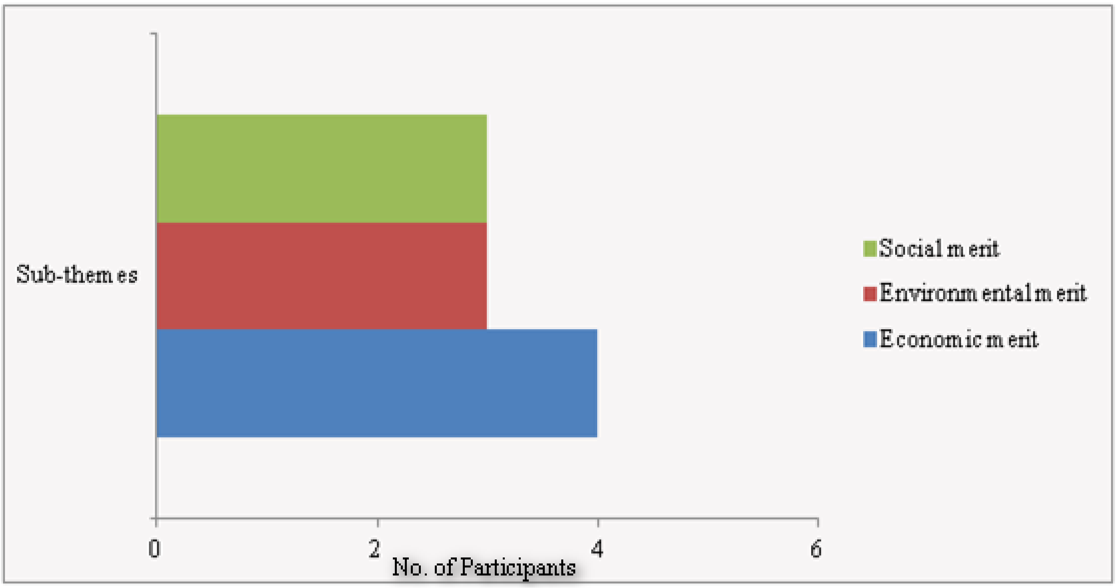

Figure 4.3: Summary of total response across sub-themes under small AD plants and awareness of AD

The contradiction around the issue of cost requires comprehensive economies of scale in deciding the size, type and method for which AD technology can be used, because the arguments of both pro-small AD plants and anti-small AD plant participants remain valid. It is therefore important to address the problem of 'cost' of AD development identified by participants of this study and also in the literature (*e.g.* Zglobisz *et al.*, 2010; Bywater, 2011) as it affects the development of AD at all scales.

4.3.4 Enhancing the understanding of AD technology by those associated with AD facilities

Building UK skills is one of the priority areas of DEFRA as indicated in the AD gap analysis of 2011 and UK AD strategy and action plan. Similarly, Lukehurst (2007 cited in; Zglobisz, 2010) identified inadequate knowledge and skills as one of the challenges that has limited the development of the AD industry in general. This challenge can also impact on the environment, for example Ingram (2008) suggested that poor knowledge and lack of experience in new and complex technologies and practices is one of the constraints to sustainable soil management. The interviews revealed three important methods for enhancing the understanding of AD technology. It also showed the preparedness of AD stakeholders in the UK to move the technology forward, taking into account the number of shared opinions. The interview question relating to this was distributed to all participant groups except group F. The three methods suggested by participants are education (demonstration and training), promoting AD products and sharing experience as illustrated in Figure 4.4. Demonstration and training were paired as a single method because in reality it is difficult to isolate one from the other, and they both share the common goal of educating people. This method was shared by 13 participants cutting across all groups interviewed, and some went on to include factors to be considered before using demonstration or training. For instance, a group D participant explained:

'This could be helped by running small/ large forums, depending on the area targeted and getting the general public and planning authorities involved. This would also cost money in advertising as well as time in doing an analysis and making a careful selection of places to use' (April, 2014).

Based on this explanation, it is important to consider target audience and area, cost and time factors before using the demonstration and training for enhancing knowledge of AD technology. Participants who suggested the promotion of AD products will enhance the understanding of the technology seemed to be concerned with how farmers and investors can be made to develop interest in the technology. Eric Stanley (group A) said, *'Providing the products as convenient and cheap alternatives to artificial fertilisers while promoting their wider benefits will permit farmers to enjoy the feel good factor at no extra cost to them'* (April, 2014).

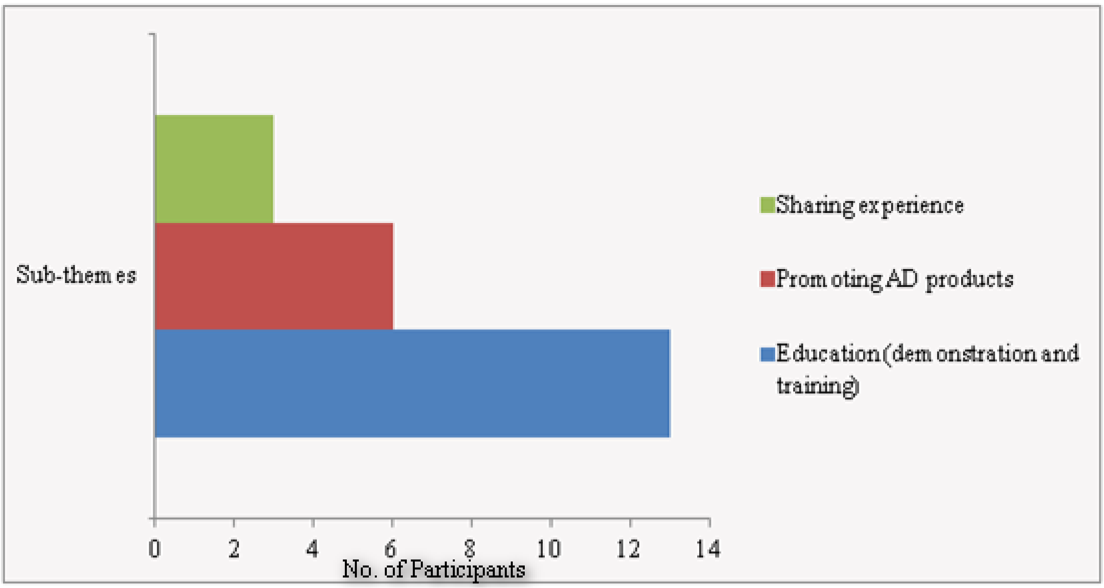

Figure 4.4: Summary of total response across sub-themes under enhancing the understanding of AD technology by those associated with AD facilities

By encouraging farmers and other investors to develop interest in the technology, the next stage will be to educate them on AD through training or demonstration. The promotion of AD products can therefore be seen as a preceding stage to demonstration and training, if the process of enhancing the understanding of AD was to be in stages. Sharing experience is the informal method of the three methods identified for enhancing the understanding of AD. According to one group C participant, it involves *'learning through shared experience in the industry'* (March, 2014). From the responses received, there seems to be a lack of sharing of experience within the UK AD industry as one group A participant explained:

'Those associated with AD facilities should share their experience with other people active in the same sector as well as with the public. Currently the limited sharing and exchanging of information hinders the understanding and improvement of AD technology' (April, 2014).

3 out of the 20 participants neither made any suggestion nor shared any opinion on this issue.

4.3.5 Ensuring the benefits of AD are shared by everyone

The question covering this theme was asked to 10 participants excluding those in group A and B and Figure 4.5 shows the total responses and sub-themes. Despite the low number of participants, there were several opinions expressed on how we can ensure the benefits of AD are shared by everyone, including those who feel this is not achievable. The most shared opinion was using the benefit of AD for general purposes, like a group C participant said, *'grid injection and vehicle usage of biogas, national grid connection to electricity generators'* (March, 2014). With the digestate, a group D participant interestingly suggested that using the digestate as fertilizer for crop production in the UK is a benefit for all. Another option noted was raising awareness, and according to Bryan Cole (group C) '*this should be the main goal of awareness. People should be told about the benefits of AD through awareness programs'* (April, 2014). The environmental benefit of AD can also be shared by all directly or indirectly. The group E participant opined that the reduction in greenhouse gas emissions, especially methane, and its utilization as a renewable energy source is an environmental benefit shared by all. The direct benefit is the use of organic waste as feedstock for AD, and this is being promoted by the government as stated by one group D participant, who said, *'Government and councils have waste collection* *schemes set up so that the public know where their waste is going to and to be used to generate heat/electricity'* (March, 2014). Networking with AD owners to ensure best practice was an isolated opinion by another group D participant. Two participants, both from group D, suggested that it will be difficult to ensure AD benefits are shared by everyone. According to them, the main challenges will be conflict of interest and critics of the technology.

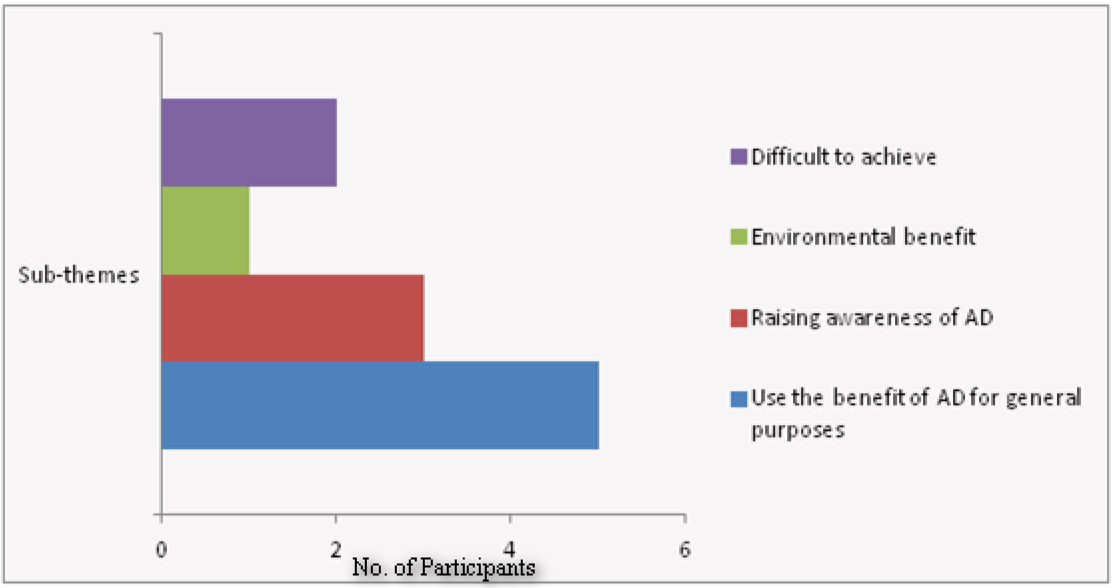

Figure 4.5: Summary of total response across sub-themes under ensuring the benefits of AD are shared by everyone

4.3.6 Diversifying biogas use from AD

Biogas from AD remains the most pronounced benefit of the technology. The importance of this enquiry is that provision of an available market for biogas, mainly methane, and efficiency in its use is a top priority area for DEFRA. In sub-section 4.3.1, the importance of available market for biogas was also discussed. All groups of participants except E and F (Table 4.2) were asked this question. The response distribution is represented in Figure 4.6. Participants who suggested this added that such heat and electrical energy could be used for farm-houses and vehicles, or supplied to the local community. Injection of biogas into the national grid was also identified as an option. One group B participant went on to describe this as the likely most efficient use when he stated *'probably the most efficient use would be if biogas could be connected into national gas grid'* (December, 2013). Some participants also identified the use of biogas from AD in vehicles and other operations that make use of fossil fuels. Biogas from AD can also be used for cooking and refrigeration as seen in most developing nations, but this type of application is less likely in developed nations such as the UK (Surendra *et al.*, 2013).

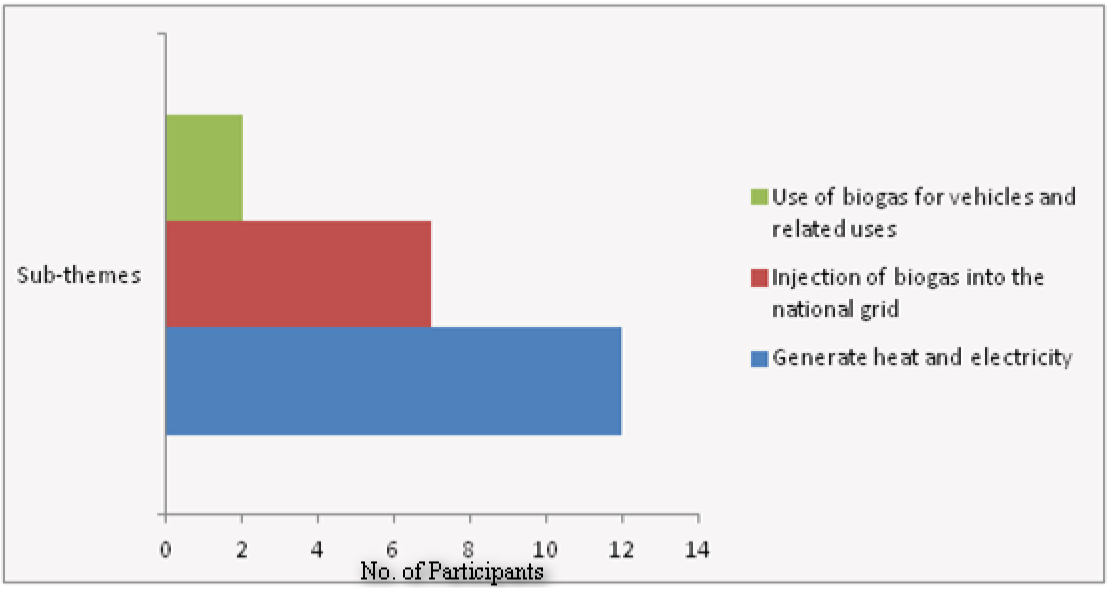

Figure 4.6: Summary of total response across sub-themes under diversifying biogas use from AD

A number of factors to be considered before the biogas from AD can be diversified in its use were also noted by some participants. One such factor is the issue of proximity of AD plants to end users of the biogas, as one group A participant clearly stated: *'currently the setting of AD plants does not normally consider the proximity of potential end users of AD biogas and this restricts its use. Integrated planning is needed to ensure that the maximum benefits are derived'* (April, 2014). Considerations like size of the AD plants and the need for better financial incentives to achieve this were also identified, as contained in the response of a group D participant, who explained:

'Support for AD MUST be separated from other properly renewable energy (RE) technologies, such as solar panels and the fact that it is even included in such an incentive regime illustrates how completely misguided and misinformed policy-makers really are. If we speak of the technology as a renewable energy technology, we subliminally look to it to produce energy, rather than to treat waste in an environmentally responsible manner which is where it is (properly) used and incentivized everywhere else in the world outside Europe. If we regard AD as a RE

technology, there is almost no point in putting low-gas-producing organics into AD plant – and we would have German-style maize monoculture which is what has given rise to ILUC legislation which will hit the British AD industry in a very short time. Thus, unlike the German AD industry which has been able to grow and mature using cheap government loans, big incentives, and unlimited access to high-value feedstock such as maize and large grants for farmers, the British AD industry will not have these advantages and must find another way. I believe that the way forward is small 'appropriately sized' AD' (April, 2014).

The cost of laying gas pipelines and connecting to the national grid were also mentioned as factors to be considered.

4.4 CONCLUSION

This chapter is summarised in Box 4.2. Raising awareness is without doubt the most positive and necessary step in promoting AD in the UK with the recognition of its underdeveloped status. The results of this study show the various options and challenges to raising awareness of AD in the UK. The study also demonstrated the importance of UK AD stakeholders in the development of the AD industry. Therefore it is strongly suggested that there is a need for effective stakeholder engagement for the development of AD industry in the UK. There is an overlap between the benefits of AD technology and sustainable development goals, which further necessitates the development of AD in the UK. Community AD and localism, small AD plants, enhancement of AD skills and understanding, promoting the benefits of AD for everyone and its products are viable options for raising awareness for AD in the UK. However, challenges such as finance need to be addressed, and in doing so, the complexity of AD technology needs to be taken into account. Government role, both financial and non-financial, in the development of the UK AD industry cannot be overemphasized. With respect to finance, there is a need to improve on current renewable energy incentives available to farmers and investors, to make AD more attractive and to emphasize its role in waste treatment rather than just renewable energy. Networking farmers, investors and community is another role the government has to play, to accelerate AD development in the UK. The target of 1000 AD plants by 2020 set by DEFRA is a sign of the UK government's commitment to AD development (Bywater, 2011). However, addressing the issues identified in this research is one way by which this target can stand a chance, even though realistically this is not likely to be achieved.

Box 4.2: Chapter summary

This chapter has;

- Further reviewed literature to strengthen the relevance of this chapter;
- Provided details of interview participants and interview questions;
- Identified how we can raise awareness of AD in the UK.

CHAPTER FIVE

FACTORS INFLUENCING FARMERS' DECISIONS ON AGRICULTURAL TECHNOLOGY ADOPTION AND SUSTAINABLE AGRICULTURAL PRACTICES

5.1 INTRODUCTION

Box 5.1: Chapter purposes

- To provide further literature background relevant to 2nd research question;
- To present the survey participants (Farmers), their demographic and geographic distribution, and the questionnaire variables used for measurements;
- To present part of the survey findings;
- To evaluate these findings in the context of farmers' attitudes towards agricultural technology adoption and sustainable agricultural practices;
- To identify how these findings can influence AD adoption and sustainable agriculture in the UK;
- To set the scene for chapter 6 which looks at farmers' perception of soils.

Population growth and food security concerns have led to agricultural intensification in most parts of the world. The implication of this is an increased pressure on available land resource for agricultural and non-agricultural use, land degradation, loss of biodiversity, technological innovations to enhance agricultural production and provide alternative energy sources and promotion of more environmentally friendly practices like organic farming. Regardless of population growth and food security concerns, agricultural technology use is considered to be part of historic agricultural development (Stone, 1998; Minten & Barrett, 2008; Burgess & Morris, 2009; Birthal, 2013; Pamuk *et al*., 2014). The definition of agricultural technology in the context of this study is the application of science, engineering and management in the production of crops and animals (Burgess & Morris, 2009).While pressure on land resources for agriculture have led to various soil conservation and land use management programmes and policies, the main issue facing agricultural technology innovations is their adoption. Pamuk *et al.* (2014) stated that the main component of most agricultural development schemes is promoting the adoption of innovations. They also reported that agricultural development in poor countries is linked to low level of agricultural technology innovation and adoption. Another issue that has been associated with the adoption of agricultural innovations is ‘friendliness’ of innovations. Harwood (2013) reported that most agricultural technologies are not peasant-friendly and the benefits of their use are mainly experienced in large capitalised farms.

The main aim for the use of technology in modern agriculture is to increase yield and the income of farmers (Stone, 1998). Areas in agriculture that have attracted investment and innovation in developing countries are irrigation and drainage, infrastructures, fertilizer application and institutions (Birthal, 2013). In developed countries like the UK, agricultural innovations have been applied to several aspects of agriculture other than irrigation, fertilizer application and drainage. These include land use changes (Burgess & Morris, 2009), pest control (Sharma *et al.*, 2011), organic farming (Tiffin & Balcombe, 2011) and farm monitoring (Purdy 2011). Innovations in the area of renewable energy like anaerobic digestion (AD) technology, have been extensively used in agriculture for energy generation, source of income and organic fertilizer in some parts of Europe and the Unites States but are not well adopted in the UK (Zglobisz *et al.*, 2010). With organic farming, the main aim is to minimise the negative impacts of intensive conventional agricultural practices, and this idea has gained worldwide support, evidenced in the UK by the presence of EU and national legislation and policies promoting the practice (Hole *et al.*, 2005; Reed, 2009). However, organic food supply to the UK market still falls short of non-organic food supply, with a further 1.5% decrease in sales in 2012 (Soil Association, 2013).

Box 5.1 show the objectives of this chapter, information here can therefore inform the development of policies, legislation and incentives for AD adoption and sustainable agriculture in the UK. In addition, this chapter also aims to illustrate how the demographics of farmers can influence the agricultural technology trajectory in the UK, thereby making the study relevant to policy makers, conservationists, investors and innovators in agricultural technology. Earlier, Tiffin and Balcombe (2011) tried to identify the determinants of technology use in organic farming and computer use among UK farmers using the Bayesian Model Averaging (BMA). While they used models to identify the determinants of technology use in organic farming and computer use, this study focused on direct results from a survey of farmers and subsequent statistical analysis of data.

5.2 SURVEY PARTICIPANTS AND QUESTIONNAIRE VARIABLES

The study was UK focused, covering England, Scotland, Northern Ireland and Wales. Figure 5.1 shows the approximate location (by county) of participating farms. The figure demonstrates a wide distribution of sample farms though with most located within England. Although the points on the map represent the approximate location of farms, not all farmers shared the county where their farms were located. Thus, the map represents only the location of farms where the respondent correctly answered a question pertaining to county location. While eight farmers completely skipped the question on county location, a further 45 wrongly provided answers like 'UK' or 'n/a', and some gave only country names.

Figure 5.1: Distribution of participating farms across the UK

A total of 283 farmers (from an invited sample of more than 500 but less than 600) completed the survey, and the recruitment process, data collection tools and analysis carried out have been reported in Chapter 3. However, extracts from the full questionnaire used to address this chapter's purposes are presented in Table 5.1.

Table 5.1: Questionnaire variables used for this Chapter

Variables	Units
Independent variables	
Gender	1 'Male', 2 'Female'
Age	1 'Less than 30', 2 '30-40', 3 '41-50',4 '51-60', 5 '61-70', 6 'Above 70'
Farm type	1 'Arable', 2 'Livestock (dairy and meat)', 3 'Mixed (arable and livestock)', 4 'Horticulture', 5 'Other'
Education	1 'GCSE or equivalent', 2 'A levels or equivalent', 3 'Diploma', 4 'Degree', 5 'Postgraduate degree', 6 'Other'
Farm ownership	1 'Farm owner', 2 'Manager', 3 'Tenant', 4 'Other'
Farm size (in hectares)	1 'Less than 30ha', 2 '30-60ha', 3 '61-90ha', 4 'Above 90ha'
Farm topography	1 'Upland', 2 'Lowland'
Dependent variables	
Knowledge of what sustainable agriculture means	1 'Yes', 2 'No'
Practice organic farming	1 'Yes', 2 'No'
Overall interest in agricultural technologies	1 'Very low', 2 'Low', 3 'Medium', 4 'High', 5 'Very high'
Knowledge of what AD is	1 'Yes', 2 'No'
Interest in AD (only farmers who	1 'Yes', 2 'No'

know what AD is)	
Willingness to invest in AD if it improved soil properties (only farmers who know what AD is)	1 ‘Yes’, 2 ‘No’, 3 ‘Neither yes or no’
Factors considered in the use of a particular agricultural technology	1 ‘Affordability’, 2 ‘Knowledge of its benefits’, 3 ‘What other people say of the technology’, 4 ‘Simplicity of the technology’, 5 ‘Efficiency of the technology’, 6 ‘availability of government support’

5.3 RESULTS

5.3.1 Characteristics of participants

The characteristics of the farmers and their farms are presented in Table 5.2. The results show that more male farmers participated in the study than females (slightly over 2 to 1, with 195 males and 85 female farmers). Perhaps, the idea of female farmers being seen as ‘invisible farmers’ (Sachs, 1983; cited in Riley, 2009) is now phased out as the ratio of male to female farmers suggests a recognition of the role of female farmers in shaping the UK agricultural sector. When the gender of farmers was compared to farm ownership, 48 female farmers (56.5% of total) said they owned their farms while 106 male farmers (54.6% of total) said the same. The results of the test between gender and forms of farm ownership showed significant relationship between the two variables (chi-square= 8.20, 3 d.f., p= 0.42) and strength of this relationship was small to medium (Cramer’s V= 0.171), suggesting that a higher proportion of female farmers in the UK own their farms. Farm mangers was the second highest category, and had a higher percentage of male (20.1%) than female farmers (12.9%). A similar pattern occurred under ‘tenant farmers’. The percentage response for other categories are presented in Table 5.2. The main groups identified for those indicating ‘other’ under farm ownership, were sons, daughters, and spouses of farmers.

Age was fairly evenly distributed as seen in Table 5.2 except for the age groups ‘61-70’ and ‘above 70’. This might be expected as these two age groups would contain more retired farmers, and they mainly owned their farms. An important observation was the percentage of those 'under 30' (21.9%). This age group was not exclusive to sons and daughters of farmers, as 39.3% of this group said they owned their farms, equalling the number of those that were within the 'other' ownership category. Age showed a significant relationship with farm ownership (Likelihood ratio= 47.42, 15 d.f., *p*=0.0001) and medium to large strength of association (Cramer's V= 0.241) with older farmers being more likely to be owners.

The results revealed a high level of educational attainment amongst UK farmers, with up to 75% of the sample population having at least a diploma. This suggest a rise in educational attainment of UK farmers when compared to study carried out between 1995-6 which showed that only 36% of 196 UK farmers surveyed had a formal Higher/Further education qualification (Gasson, 1998). The highest response on educational level was 'degree' at 42.9%. When this was compared with gender, results showed that 80.9% of female participants had at least a diploma or higher qualification, compared to 77.8% of male participants.

Table 5.2: Characteristics of participant and percentage distribution

Variables	Options provided	Response percentage
Gender	Female	30.4%
	Male	69.6%
Age	Less than 30	21.9%
	30-40	22.9%
	41-50	24.4%
	51-60	20.8%
	61-70	9.3%
	Above 70	0.7%
Farm type	Arable	16.0%
	Livestock (dairy and meat)	42.3%

	Mixed (arable and livestock) Horticulture Other	33.8% 4.6% 13.5%
Level of education	GCSE or equivalent A levels or Equivalent Diploma Degree Postgraduate degree Other	8.4% 9.1% 23.6% 42.9% 12.4% 3.6%
Farm ownership	Owner Manager Tenant Other	55.4% 18.2% 11.1% 15.4%
Farm size	Less than 30ha 30-60ha 61-90ha Above 90ha	15.5% 14.4% 10.8% 59.4%
Farm topography	Upland Lowland	18.5% 81.5%

Since the Chi-square test result also showed a significant relationship (chi-square= 16.74, 5 d.f., p= 0.005) with a small to medium strength (Cramer's V= 0.247) between gender and level of educational attainment, it is less likely that this relationship between gender and level of education among participating farmers happened by chance. Distribution of educational level across age groups showed that those above 70 and those between ages 61-70 were least educated, while those under age group ‘41-50’ were most educated with 84.9% having at least a diploma. The relationship between level of education and age was also significant (likelihood ratio= 41.33, 25 d.f., *p*= 0.021).

Livestock farms were the most common farm type in the sample, while horticulture was the least (Table 5.2). Farm type showed a significant relationship with farm size (likelihood ratio= 52.278, 12 d.f., *p*= 0.0001) and a medium to large strength (Cramer’s V= 0.270). Unsurprisingly, arable farms had the largest farm sizes, with 87.2% being 61ha and higher, followed by mixed farms with 81.2%. Responses also showed that more than half (59.4%) of farms were above 90ha, exceeding the average UK farm size of 77ha as of June 2012 (DEFRA, 2012). The vast majority of the farms surveyed (81.5%) were located on lowlands.

5.3.2 Analysis pertaining to sustainable agriculture

When asked whether they knew what sustainable agriculture means 95.7% of participating farmers answered ‘yes’ and 4.3% ‘no’. Since participants were not asked to define sustainable agriculture this does not necessarily imply that the vast majority that said yes actually know what sustainable agriculture means but rather that they think they know. Responses were tested against the independent variables and no significant relationship was observed. Knowledge of what sustainable agriculture means was further tested with the practice of organic farming and again showed no significant relationship. However, organic farming practice did show a significant relationship with age, farm type and farm size (Figures, 5.2, 5.3 and 5.4 respectively). A total of 80.1% of responses indicated ‘no’ to organic farming practice, while 19.9% indicated ‘yes’.

Organic farming was significantly associated with age (chi-square= 33.09, 5 d.f., *p*= 0.0001) and the strength of association was medium to large (Cramer’s V= 0.350). The results reveal that organic farming was more common for participants aged 61-70 (53.8%), followed by 51-60 (29.8%). It was least common among participants older than 70 followed by those younger than 30.

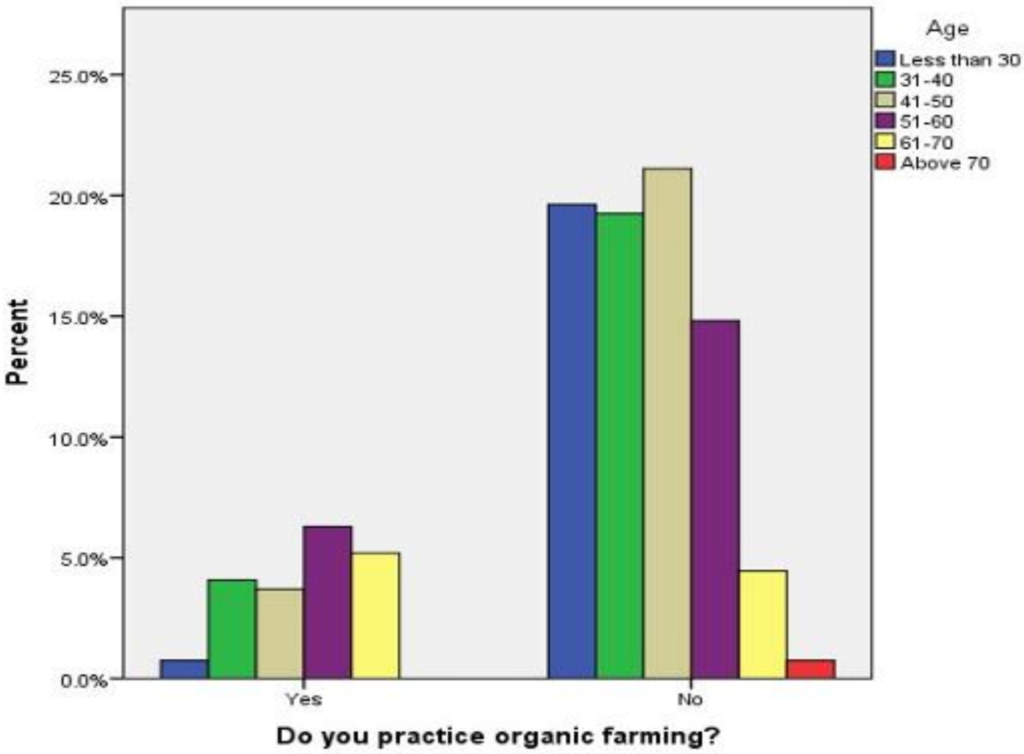

Figure 5.2: Distribution of organic farming practice across age groups

Organic farming was also significantly associated with farm type (likelihood ratio= 22.13, 4 d.f., *p*= 0.0001) with a small to medium strength of association (Cramer's V= 0.281). The basic assumptions of chi-square test were violated since there were non-organic horticultural farmers, and the likelihood ratio was used instead of observed p value. The highest percentage of 'yes' responses came from horticulture farmers (100%), while a 'no' response was most common with arable farmers (97.4%). Organic farming was also more common with mixed farmers (22.8%) than livestock farmers (18.7%).

When tested against farm size, organic farming practice showed a significant association (chi-square= 17.79, 3 d.f., *p*= 0.0001) with small to medium strength (Cramer's V= 0.257). The results suggested that organic farm practice was more prevalent on smaller farms because the percentage of 'yes' responses decreased with increasing farm size.

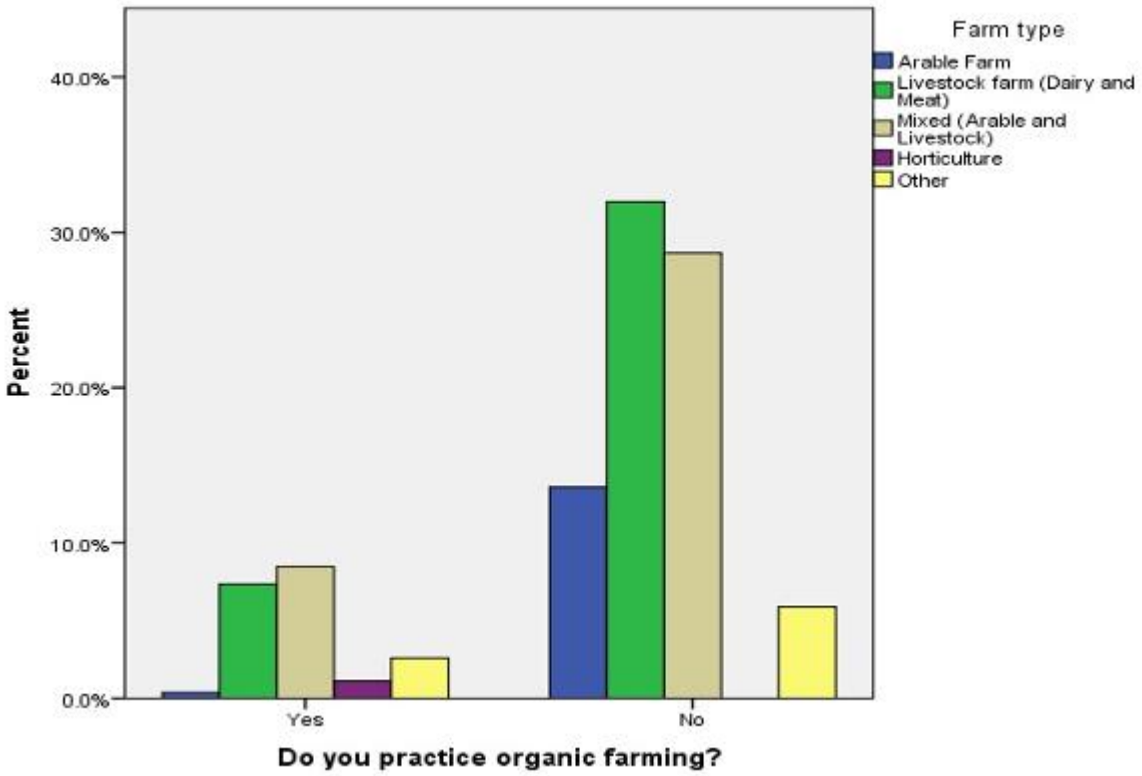

Figure 5.3: Distribution of organic farming practice across farm types

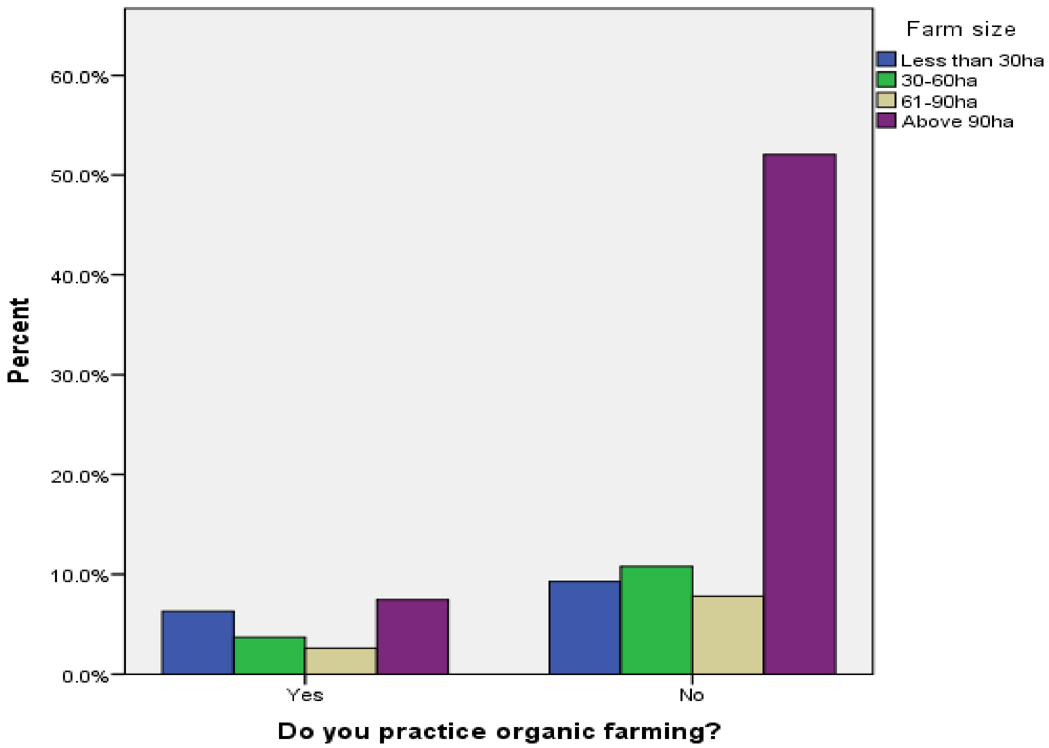

Figure 5.4: Distribution of organic farming practice across farm sizes

5.3.3 Analysis pertaining to agricultural technology and AD

Figure 5.5 shows the overall interest in agricultural technologies among the sample of farmers. 47% indicated ‘High’ interest, while 23.9% and 24.4% said ‘very high’ and ‘medium’ respectively. Table 5.3 shows a significant relationship between overall interest in agricultural technology and gender (chi-square= 22.30, 3 d.f.), level of education (likelihood ratio= 27.06, 15 d.f.) and farm size (likelihood ratio= 25.46, 9 d.f.).

The strength of association with gender is medium to large (Cramers’ V= 0.310) and the distribution across gender showed that 80.6% of male farmers had either a high or very high interest compared to 51.4% in female farmers. So among UK farmers, we can expect a greater interest in agricultural technology in male than female farmers. With level of education, the strength of association is also medium to large (Cramer’s V= 0.188). The distribution across level of education was without surprise because interest in agricultural technology increased with level of education with 75.9% of postgraduate degree holders indicating ‘high’ or ‘very high’ compared to 75%, 58.4% and 56.3% for those with degree, A level or equivalent and GCSE or equivalent respectively.

The value was highest for diploma holders with 80% indicating ‘high’ or ‘very high’ interest, and the reason for this is probably due to the higher percentage of male farmers with diploma than female farmers, recalling that male farmers showed higher interest in agricultural technologies than female farmers. Similarly, farm size showed a medium to large association (Cramer’s V= 0.198) with interest in agricultural technology. The percentage of ‘high’ and ‘very high’ responses collectively increased with farm size, a finding with similarities to Harwood’s (2013) report on the suitability of agricultural technologies with larger farms.

Knowledge of what AD is showed a significant relationship a seen in Table 5.3 with gender (chi-square= 7.88, 1 d.f.), level of education (likelihood ratio 18.61, 5 d.f.), and farm size (likelihood ratio 15.96, 3 d.f.). The association strength with gender is small to medium (Phi= 0.185). More males (96.9%) had knowledge of what AD is than females (87.3%). Overall, 93.9% indicated ‘yes’ to knowing what AD is. This response does not exactly suggest that the farmers who said ‘yes’ know exactly what AD involves but rather that the farmers believe they have an idea of what it is. With respect to education, the strength of association was large (Cramer's V= 0.324). The percentage of those who said 'yes' increased progressively from GCSE or equivalent (75%) to diploma level (98.2%) and declined slightly but remained high at degree (97.9%) and postgraduate levels (93.1%). Association strength with farm size was small to medium and the percentage of 'yes' responses increased with farm size. This trend suggested a relationship between overall interest in agricultural technology and knowledge of what AD is, and test results revealed that there was indeed a significant relationship (likelihood ratio 9.17, 3 d.f.) with a small to medium strength of association (Cramer's V= 0.248).

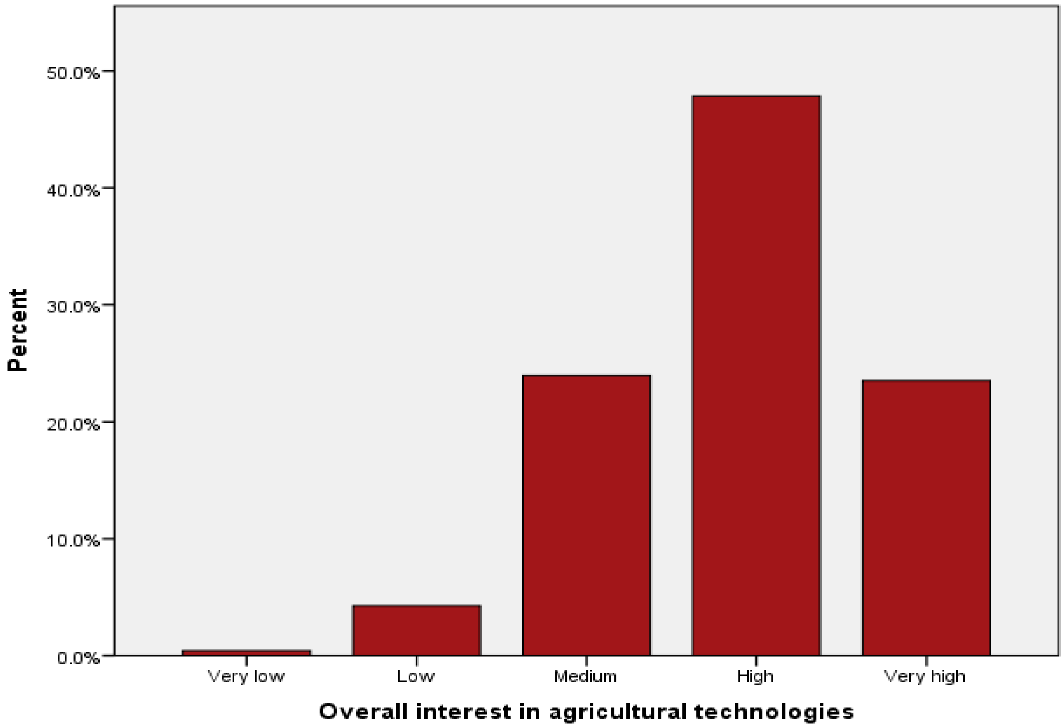

Figure 5.5: Participants' response on overall interest in agricultural technologies

The question on interest in AD was asked only to those farmers who said they had knowledge of what AD is. As seen in Table 5.3, only age shares a significant relationship with interest in AD (chi-square= 11.93, 5 d.f.) and a small to medium strength (Cramer's V= 0.237). The distribution of responses showed that farmers older than 70 had the highest percentage of interest (100%) followed by those under 30 with 82.9%.

Similarly, the question on willingness to invest in AD if it improved soil properties was asked to only those farmers with knowledge of what AD is. 29.4% responded ‘yes’ while 22.5% and 48.2% respectively responded ‘no’ and ‘neither yes or no’. Test results showed a significant relationship between willingness to invest in AD if it improved soil properties and farm ownership (chi-square 15.15, 6 d.f.), with a small to medium strength of association (Cramer’s V= 0.187). Farm managers had the highest ‘yes’ response (50%), tenant farmers the highest ‘no’ response (32%) and those in the ‘other’ category of ownership the highest ‘neither yes or no’ response (52.9%).

Table 5.3: Observed p values for Chi square tests between independent and dependent variables pertaining to agricultural technology and AD

Independent / Dependent	Gender	Age	Farm type	Level of education	Farm ownership	Farm size
Overall interest in agricultural technologies	.0001*	.227	.285	.028*	.944	.003*
Knowledge of what AD is	.013*	.132	.113	.002*	.191	.001*
Interest in AD	.993	.036*	.107	.091	.095	.739
Willingness to invest in AD if it improved soil properties	.723	.162	.324	.851	.019*	.379

*Relationship significant at $p<0.05$

5.3.4 Factors influencing technology use by UK farmers

Farmers were asked to select the factor(s) they considered before engaging in the use of a particular agricultural technology. The options provided and the percentage responses are shown in Table 5.4. The most common factor considered was affordability, followed by knowledge of its benefit, while the least common was what other people say of the technology. Within gender (Figure 5.6), a slightly higher percentage of female farmers considered affordability of a technology than male farmers. The same was observed for other factors with exclusion of simplicity of the technology and efficiency of the technology where male farmers had a higher response percentage.

Table 5.4: Response summary to factors considered in the use of agricultural technology

Factors	Number of responses	% of total response
Affordability of the technology	214	91.8%
Knowledge of its benefits	187	80.3%
What other people say of the technology	47	20.2%
Simplicity of the technology	97	41.5%
Efficiency of the technology	179	76.8%
Availability of government support	101	43.3%

The distribution of response across age groups is illustrated in Figure 5.7 where participants older than 70 had the highest percentage response on affordability (100%), followed by 'less than 30' and '61-70', both with 95.8%. Knowledge of its benefits' was the main consideration of those aged '51-60', and least considered by 'older than 70'. 'What other people say of the technology' was the common choice for farmers under 30, while 'simplicity of the technology' increased progressively in percentage response from the lowest to highest age group. Farmers older than 70 again had the highest percentage response for both 'efficiency of the technology' and 'availability of government support'.

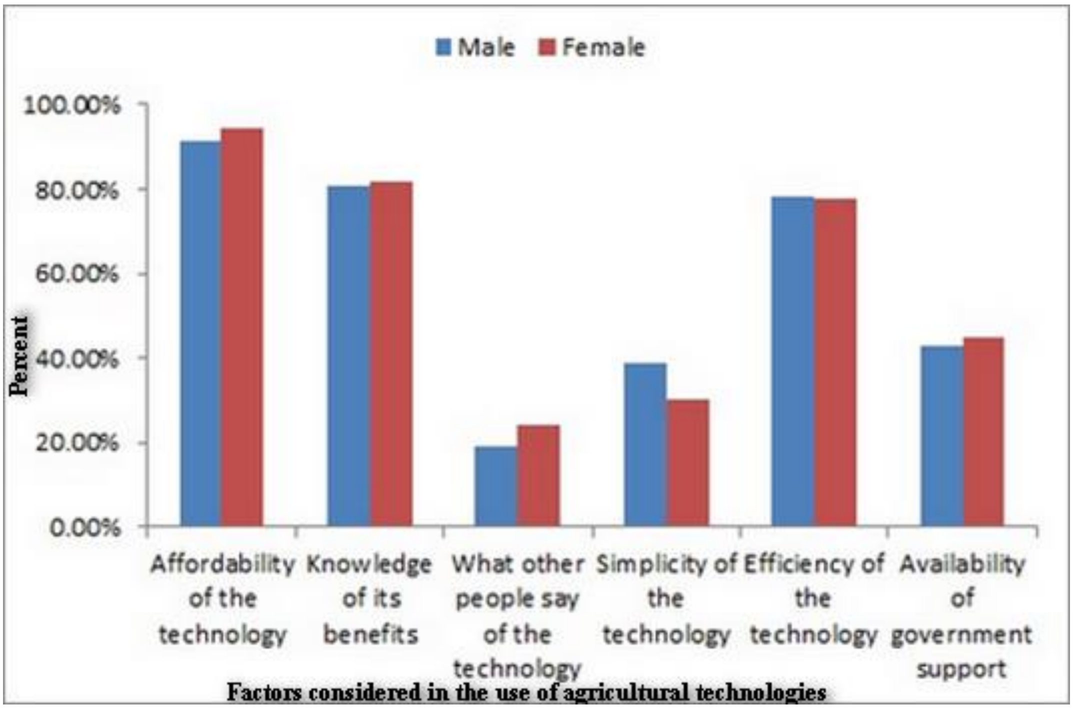

Figure 5.6: Percentage response distribution for factors considered in the use of agricultural technologies across gender

Across all factors provided horticultural farms had highest percentage response, significantly higher on the 'simplicity of the technology' as shown in (Figure 5.8). With education (Figure 5.9), farmers with a postgraduate degree considered 'affordability' and 'efficiency of a technology' more than other levels of education. 'Knowledge of its benefits' was jointly the highest response from farmers with 'A' level or equivalent and degree.

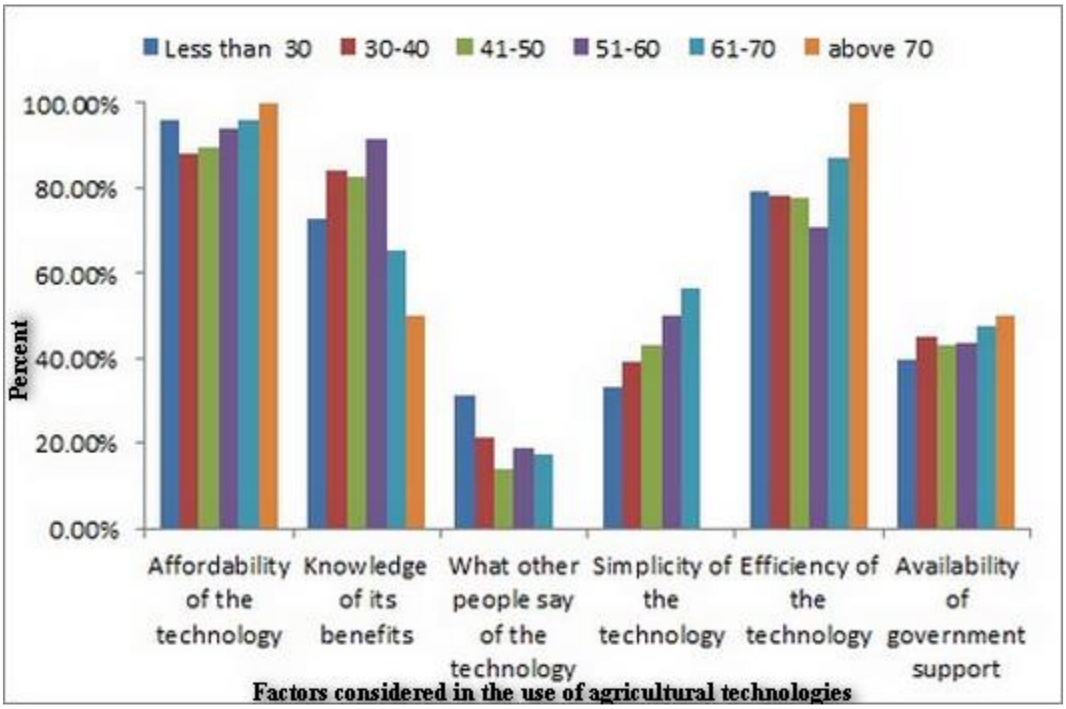

Figure 5.7: <u>Percentage response distribution for factors considered in the use of agricultural technologies across age</u>

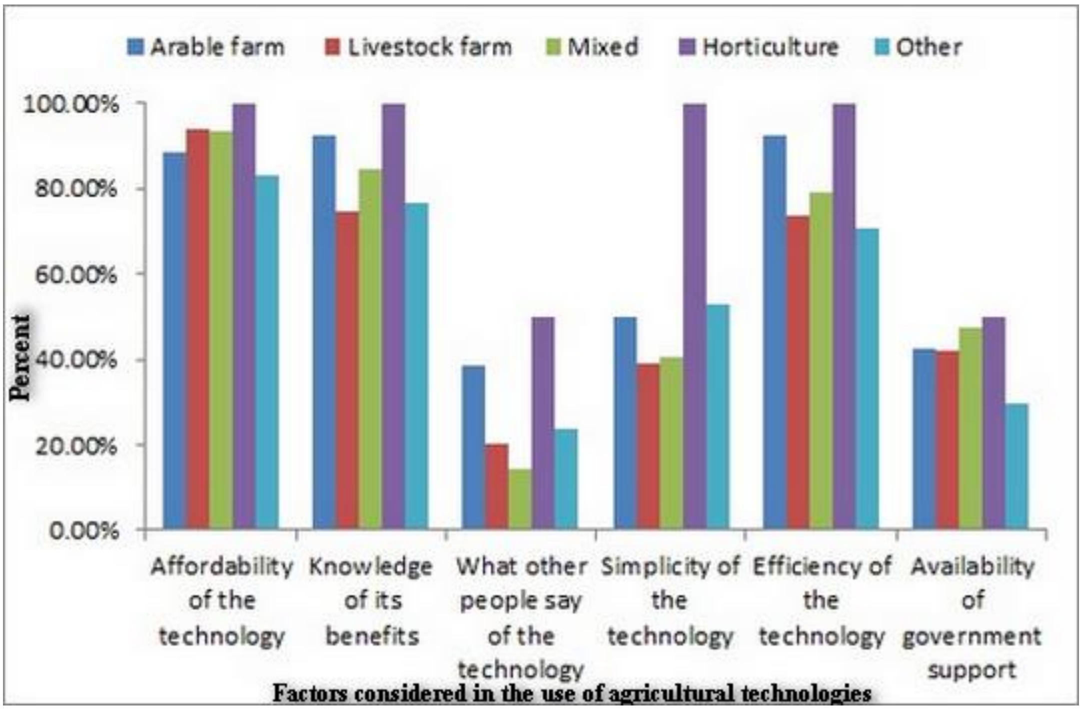

Figure 5.8: <u>Percentage response distribution for factors considered in the use of agricultural technologies across farm type</u>

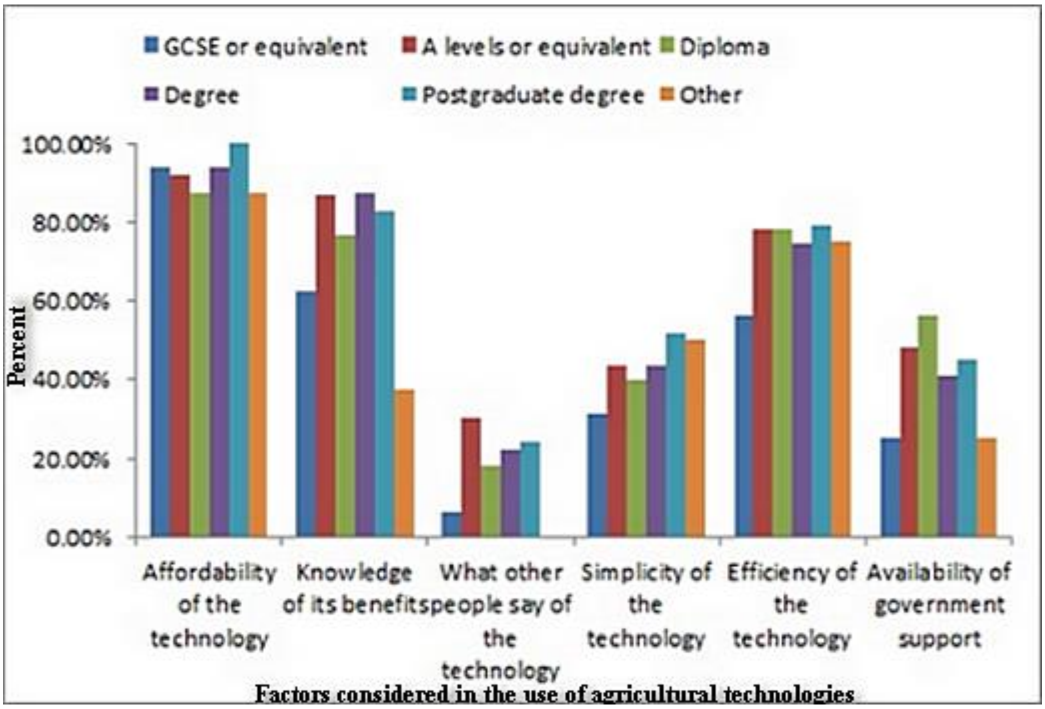

Figure 5.9: Percentage response distribution for factors considered in the use of agricultural technologies across levels of education

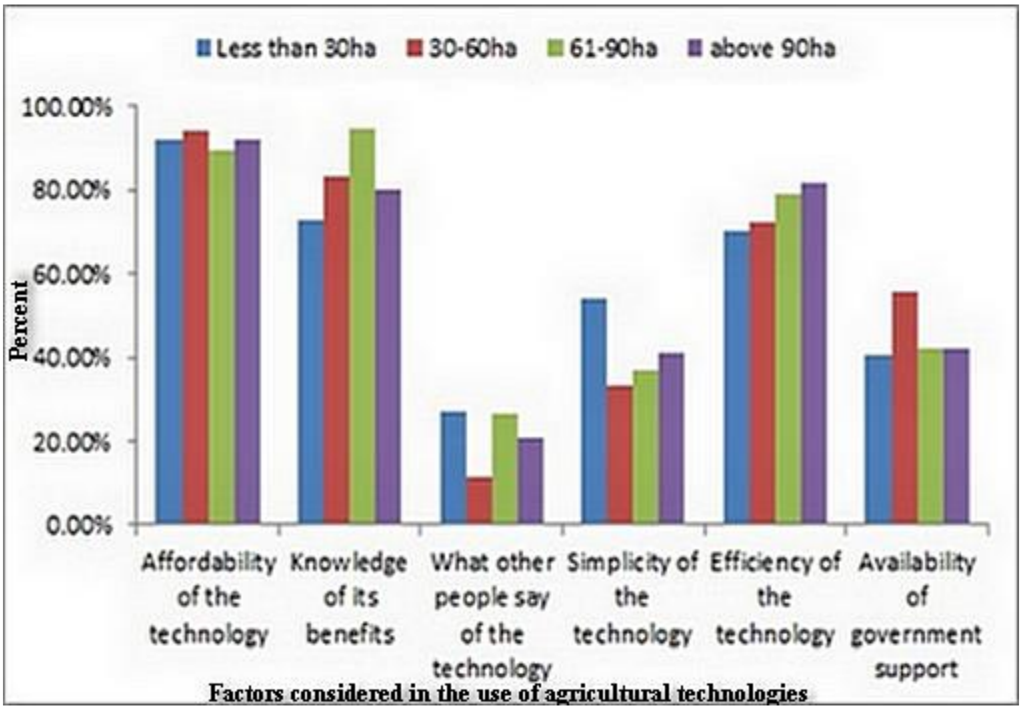

Figure 5.10: Percentage response distribution for factors considered in the use of agricultural technologies across farm sizes

'What other people say of the technology' was mostly considered by farmers with 'A' level or equivalent, while 'availability of government support' was mostly consider by farmers with diploma. The distribution of response across farm size is shown in Figure 5.10. Farm size between 30-60ha had highest response under 'affordability of the technology' and 'availability of government support', while 'knowledge of its benefits' had the highest response from farms between 61-90ha. The smallest farm size showed the highest response for 'what other people say of the technology' and 'simplicity of the technology'. Farm size above 90ha mostly considered 'efficiency of the technology' more than other farm sizes, and the response on this increased progressively with farm size as seen in (Figure 5.10).

5.4 DISCUSSION

5.4.1 Implication of findings for AD adoption in the UK

Interest in agricultural technologies and the level of knowledge of what AD is suggests a high level of awareness of AD technology in the UK, however, existing literature indicates otherwise and this has been identified as one of the limitations to AD development in the UK (Zglobisz *et al.*, 2010; Duruiheoma *et al.*, 2014 and Chapter 4). This can also be an indicator that what the participating farmers actually know about AD might just be a general overview of what it involves. The number of those interested in AD on the other hand, suggests that what some of the participants knew of the technology was enough for them to be interested in it even though it remains under-developed in the UK. Factors considered in the use of agricultural technologies sheds some light on the state of AD development in the UK and interest of farmers in the technology.

Affordability of a given technology was first in the list of factors considered by farmers in this study. Cost associated with AD plants has been identified as one of the generic limitations to its development (Zglobisz *et al.*, 2010; Bywater, 2011). Similarly, Sharma *et al.* (2011) broadly stated that the constraints with technological adoption are usually socio-economic in nature in their study of the determinants of technology adoption among UK cereal farmers. The second most popular factor considered by the farmers was knowledge of its benefits. AD technology has several benefits which include renewable energy generation, organic waste reduction, income source, and fertilizer option in the form of digestate. Whether farmers are aware of these benefits is unknown since no question pertaining to this was asked, but results suggest not. The response on willingness to invest in AD if it improved soil properties supports the call for raising awareness of the benefits of AD (Duruiheoma *et al.*, 2014) since only 29.4% of the sample indicated 'yes' to this factor. The third most considered factor, efficiency of the technology, also supports the importance of educating UK farmers on AD.

Of the three factors considered least important by farmers, availability of government support comes first. The importance of government support in the development of any technology cannot be overemphasised. Support can take the form of incentives, financing options, standardization, and the use of appropriate legislation to promote technology adoption (Purdy, 2011). Although there are incentives for renewable energy generation from AD in the UK such as the feed-in-tariff (FiT) and renewable heat incentive (RHI), they have come under criticism in view of their suitability for larger-scale generation (REA, 2013), thereby discouraging the development of smaller plants. Response to simplicity of technology as a factor, suggests that some farmers will prefer portable and easy to operate technology, making small AD plants more relevant for AD development in the UK. The factor least considered in the use of agricultural technology is what other people say of the technology. Even though this has the lowest percentage, it suggests that networking between technology users, in this case AD plant owners, and non-users might be beneficial increasing adoption.

5.4.2 Implication of findings for sustainable agriculture in the UK

Results of this study suggest a general 'awareness' of the concept of sustainable agriculture amongst UK farmers, however interpretations of this concept may vary significantly in practice. Cobb *et al.* (1999) called for a wider interpretation of farming systems and property rights, both of which were considered to be limitations to sustainable agriculture in the UK. Even though the concept of sustainable agriculture is quite complex and requires an interdisciplinary approach to its understanding and interpretation (Harris *et al.*, 2008), a key message of sustainable agriculture is that; it requires farmers to consider the long-run effect of their practices and how this may interact with the dynamics of agricultural systems (Ogaji, 2005). One of the main practices viewed as sustainable in modern agriculture is organic farming, and some believe both are synonymous (Rigby & Caceres, 2001). This type of farming requires less to zero inorganic input for crop and animal production, soil nutrient replenishment, pest control and other aspects of agricultural production (Lampkin, 2002).

The results on organic farming practice did not conform to expectations based on the level of awareness of sustainable agriculture. The relationship existing between organic farming practice and age, farm type and farm size makes the basis for the arguments made here. With age, the low level of organic farming practice especially within the group younger than 30 and between 30-40 raises concern on the sustainability of the UK's agriculture. Gorp & Goot (2012) identified the importance of the younger generation in promoting and having a positive attitude towards sustainable agriculture. Even though these results are not positive for the future of UK's agriculture, the relationship between age and organic farming is expected, since an earlier study showed that the probability of adopting organic practice increases by 0.03% for every year increase in age (Tiffin & Balcombe, 2011). The low level of organic farming practice observed in the survey conforms to the UK government report on organic farming practice. DEFRA (2015) reported a decline in the total area of land farmed organically from 576,000 hectares in 2013 to 548,000 hectares in 2014, despite a rise in the 7.1% increase in the number of certified organic processors within the same period. The report also showed a decline in registration with organic certification bodies.

In terms of farm type, horticultural producers showed the highest percentage of organic farm practice compared to other types. The results conform to the findings of Tiffin & Balcombe (2011) as they also observed that organic farming was more common with horticultural farmers. They further suggested that the main determinants in adopting organic farming based on their model approach were beliefs of the farmer, their gender and source of information. Although the source of information participant farmers have on organic farming was not asked, there was no significant relationship with gender. Perhaps the belief of farmers was the main influencing factor from the study population in the practice of organic farming. The prevalence of horticultural farmers in farms less than 30ha and arable farmers on farms larger than 90ha, account for the relationship observed between organic farm practice and farm size. The concerning part of this relationship is that, since the vast majority of farms surveyed were large (70.2% were 61ha or more), the long-term negative impact of inorganic or conventional farming systems in the UK is inevitable.

Communication between farmers, policy makers and conservationists is vital for the sustainability of agricultural production (Schoon & Grotenhuis, 2000; Ingram, 2008;

Glenna *et al.*, 2011). The main reason for this is to continually update farmers on the new skills needed to meet the demands of sustainable agriculture (Ingram, 2008). Communication therefore, offers opportunity for improved sustainable agricultural practices in the UK.

5.5 CONCLUSION

This chapter identified the various factors that affect the use of agricultural technology by UK farmers and organic farming, and how this affects AD adoption and sustainable agriculture in the UK (Box 5.2). Overall there is a high level of educational attainment among the farmers surveyed and a high level of interest in agricultural technologies. Interest in agricultural technologies was higher among male farmers, and increased with both level of education and farm size. Large farm sizes dominated the survey, and there was a significant presence of female farmers and young farmers. Farm ownership was more common than other forms of tenure, and livestock farms were more common than any other type. Sustainable agriculture is a popular concept for most of the farmers, but sustainable agricultural practices, such as organic farming, were not as common. This leaves the question of what aspect of sustainable agriculture UK farmers are active in. There is clearly not much concern on the impact inorganic inputs from their agricultural practice has on the environment, not just because of the low number of those who practice organic farming but also, the low number of those willing to invest in AD if it improved soil properties. Affordability, knowledge of the benefits, and efficiency of a technology were the top three factors considered by farmers. These are therefore recommended as key areas in which to focus the promotion of AD technology in the UK, however factors such as 'availability of government support' should not be ignored.

Box 5.2: Chapter summary

This chapter has;

- Further reviewed literature to strengthen the relevance of this chapter;
- Provided the characteristics of farmers surveyed, their distribution and some questionnaire variables;
- Identified the factors that influence farmers' decision on agricultural technology adoption;
- Identified the implication of the chapter findings on AD adoption and sustainable agriculture in the UK.

CHAPTER SIX

FARMERS' PERCEPTION OF SOIL

6.1 INTRODUCTION

Box 6.1: Chapter purposes

- To provide further literature background relevant to 3rd research question;
- To present the questionnaire variables used for measurements in this chapter;
- To present part of the survey findings;
- To evaluate these findings in the context of farmers perception of soils and matters relating to soil;
- To identify how these findings can influence soil conservation and sustainable agriculture in the UK;
- To set the scene for Chapter 7, which examines the final two research questions.

Chapters 1 and 2 identified the importance and various functions of soil and these are examined further here. Box 6.1 gives a summary of the chapter objectives.

Anthropogenic and natural processes like soil erosion, population growth, intensified agriculture, deforestation, and inorganic fertilizer use directly and indirectly cause changes in the biological, chemical and physical properties of soils, leading to a global decline in soil quality (Tesfahunegn *et al.*, 2011). While soil erosion is widely recognised as a major factor in soil degradation and decline in soil quality (Hannam & Boer, 2004; Morgan, 2005), population growth and resulting food security concerns have promoted the need to conserve soils at the international, regional and national scale (Hannam & Boer, 2004; Khanif, 2010; Schneider *et al.*, 2010; Nkegbe, 2013; Sudha, 2015). Population growth decreases available agricultural land through development in the form of soil sealing. It also increases pressure on available agricultural land for food production, thereby leading to intensified agricultural production. Intensification of agricultural production encourages the use of inorganic fertilizers to maintain soil fertility, however, their long term impact on the environment, mainly water contamination which affects human health, make their use less ideal for soils (Schiermeier, 2013).

Soil conservation efforts have taken the form of land policies to encourage good farming practice such as zero tillage (Schneider *et al.*, 2010), less inorganic fertilizer use (Schiermeier, 2013; Karltun *et al.*, 2013) and reduction in those non-agricultural practices that expose soils to degradation such as deforestation. Zero-tillage involves crop production on undisturbed soils using specialised machinery and weed control with herbicides. In this way the soil structure remains undisturbed and susceptibility to erosion is reduced. Legislation and policies relevant to soil conservation within the UK, as well as European and International level have been discussed in Chapter 2. The challenges with such policies and legislation, especially within the UK were also discussed. Although use of policy and legislation is considered an important tool for soil conservation (Hannam & Boer, 2004; Towers *et al.*, 2005), it is inadequate to control the rapid rate of soil degradation globally.

The recognition of the inadequacies in policy and legislation for soil conservation has led to a gradual shift in conservation efforts towards the assessment of knowledge of farmers about soils (Ingram *et al.*, 2010; Karltun *et al.*, 2013; Schiermeier, 2013; Rushemuka *et al.*, 2014), and their soil management practices (Nkegbe, 2013; Kings, 2014; Tesfaye *et al.*, 2014; Sudha, 2015). This shift in soil conservation efforts recognises farmers as primary players in the conservation of soils. Assessing farmers' knowledge of soil is necessary for the development of more effective policies and soil management initiatives (Tesfahunegn *et al.*, 2011). This approach is similar to ethnopedology, which is the study of local knowledge of soil (WinklerPrins & Sandor, 2002), and the main difference is that some studies have been more focused on farmers' soil management practices and therefore lack the full integration of topics covered in ethnopedology.

This chapter, not only looks at farmers' knowledge of soil and its benefits, but also their knowledge of soil conservation, the need to protect soils, and organic fertilizer use. Building on the principles of ethnopedology, this research aims to relate farmers' description of soils to scientific information, and furthermore to relate farmers' knowledge to their individual demographic characteristics. The chapter also builds on earlier report in Chapter 4 and Duruiheoma *et al.* (2014) on the need to raise awareness on the benefits of AD in the UK to encourage its uptake among farmers, but for this to be effective it is critical to understand farmers' perceptions of soils so that messages can be framed appropriately. In addition, recommendations on soil management policies, initiatives and conservation efforts are made based on the relationships observed between farmers' demographic characteristics and their knowledge, and opinions.

6.2 MEASUREMENTS

Survey methodology and analysis have been presented in Chapter 3, and the independent variables contained in the questionnaire were presented in the previous chapter (Table 5.1). Table 6.1 shows the variables used for addressing the research question central to this chapter. These variables are considered dependent variables and were tested against the independent variables and within themselves. Word clouds (Figures 6.1 to 6.5) used to communicate farmers' perception of soils are presented in this chapter. The larger the words in the 'clouds' the more their frequency. The frequency of words used to describe soils are also presented in Appendix 6 of this report.

Table 6.1: Dependent variables used in survey questionnaire

Variables	Units
What 4 key words would you use to describe soils?	Open-ended
Are you aware of the benefits of soils other than crop production?	1 'Yes', 2 'No'
How familiar are you with soil conservation?	1 'Very familiar', 2 'Familiar', 3 'Heard of but could not explain', 4 'Never heard of'
Should soils be protected like other natural resources?	1 'Yes', 2 'No'
Do you think organic fertilizers are good for soils?	1 'Yes', 2 'No'

6.3 RESULTS

6.3.1 Response distribution of variables

Responses revealed that most of the study participants claim to know the benefits of soils other than crop production. Although participants were not asked to mention other benefits of soils they are aware of, their responses suggest strongly that most of the farmers surveyed may have some information on the various functions of soil discussed in the Introduction. In terms of soil conservation, more than 80% of participants were at least familiar with the concept. This percentage also represents those participants that believe they can explain what soil conservation means. Similarly, a large majority of participants agree that soils should be protected like other natural resources, which is in line with the level of awareness of the other functions of soils and soil conservation. The use of organic fertilizers also gained wide support from participants.

Table 6.2: Dependent variable distribution

Variables	Options provided	Response percentage
Are you aware of the benefits of soils other than crop production?	Yes No	83.8% 16.2%
How familiar are you with soil conservation?	Very familiar Familiar Heard of but could not explain Never heard of	25.3% 56.8% 15.3% 2.6%
Should soils be protected like other natural resources?	Yes No	92.7% 7.3%
Do you think organic fertilizers are good for soils?	Yes No	91.4% 8.6%

6.3.2 Soil descriptions

A total of 213 (75.3% of all participants) farmers responded to the question on four key words to describe soils, although this percentage declined slightly and progressively from the first to fourth key word. 208 participants provided first and second key words, 204 first to third key words, and 194 provided the complete four key words. The responses show a diversity of words that can be used to describe soils. Figure 6.1 shows the common first key words used to describe soil. The words used here are more abstract with words like ‘essential’ being the most popular first key word. Other popular key words, like ‘alive’, ‘vital’, ‘heavy’ and ‘fertile’ also suggest a broad view of soils shared by the farmers. The second (Figure 6.2) and third (Figure 6.3) key words used indicated that participants have some ‘scientific’ knowledge of soils with ‘clay’, ‘humus’, ‘structure’, ‘nutrients’, ‘organic’ and ‘pH’ more common. A closer look at Figure 6.2, also shows that most of the common second key words used are associated with soil physical characteristics. In addition to showing some ‘scientific’ knowledge about soil, the third key words covered both soil functions and abstract descriptions.

The fourth key words (Figure 6.4) consisted mainly of a mixture of abstract and scientific terms with words like ‘loam’, ‘productive’, ‘structure’, ‘organic matter’, ‘essential’ and ‘complex’ being most popular. Overall (Figure 6.5), the words used to describe soil fall into four categories, namely: abstract, scientific, physical soil attributes, and soil function.

6.3.3 Interactions between variables

Table 6.2 shows the results of the test between dependent and independent variables. Gender, farm type and size had no significant relationship with any of the dependent variables. The closest to a significant relationship with gender (p= 0.073) was observed on opinion on whether soils should be protected like other natural resources. The results, though not significant, showed that a greater percentage of female participants answered ‘yes’ to the question. A similar relationship was observed with farm size, with the highest percentage of ‘yes’ coming from participants with farm size between ‘61-90ha’, again this is not significant (p= 0.095).

Age showed a significant relationship with awareness of the benefits of soils other than crop production (likelihood ratio= 17.75, 5 d.f., p= 0.003), and this association has a small to medium strength (Cramer’s V= 0.272). The results showed that the percentage of farmers aware of the benefits of soils other than crop production increased progressively with age.

Figure 6.1: First key words used to describe soils

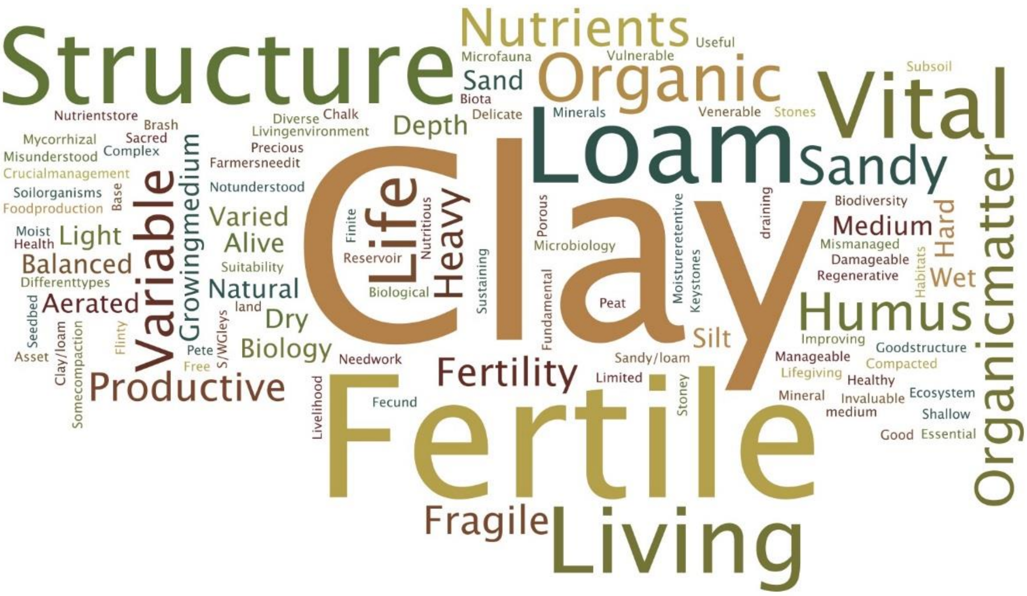

Figure 6.2: Second key words used to describe soils

Figure 6.3: Third key words used to describe soils

Figure 6.4: Fourth key words used to describe soils

Figure 6.5: Overall key words used to describe soils

A similar trend was observed with opinion on whether soils should be protected like other natural resources. The main difference here was that, famers with 'GCSE or equivalent' had the highest 'yes' percentage.

Farm ownership was significantly related to awareness of the benefits of soil other than crop production (chi-square= 14.49, 3 d.f, Table 6.3) with a small to medium strength (Cramer's V= 0.252). Results showed that farm owners were more aware of these benefits, followed by tenant farmers.

Level of education showed (Table 6.3) a significant association with both familiarity with soil conservation (likelihood ratio= 28.51, 15 d.f.) and opinion on whether soils should be protected like other natural resources (likelihood ratio= 13.87, 5 d.f.). The strength of association in both cases was medium to large (Cramer's V= 0.19 and 0.252 respectively). Percentage familiarity with soil conservation increased with educational level. However, farmers with 'A level or equivalent' were least familiar with soil conservation followed by those with 'diploma'.

Table 6.3: Observed p values for test between dependent and independent variables

Dependent \ Independent	Gender	Age	Farm type	Level of education	Farm ownership	Farm size
Awareness of the benefits of soils other than crop production	.523	.003*	.330	.216	.002*	.857
Familiarity with soil conservation	.408	.123	.104	.019*	.794	.540
Opinion on whether soils should be protected like other natural resources	.073	.865	.431	.016*	.465	.095
Opinion on whether organic fertilizers are good for soils	.996	.068	.858	.482	.914	.609

***** Relationship significant at p<0.05

Significant relationships were observed both between awareness of the benefits of soil other than crop production and familiarity with soil conservation (chi-square= 58.24, 3 d.f., *p*= 0.0001) and between opinion on whether soils should be protected like other natural resources and opinion on whether organic fertilizers are good for soils (chi-square= 5.226, 1 d.f., *p*= 0.045). Figure 6.6 shows that the more familiar farmers are with soil conservation the more likely they are to be aware of the benefits of soils other than crop production and vice versa. The strength of this association is large (Cramer's V= 0.508). For opinions on whether soils should be protected like other natural resources against whether organic fertilizers are good, the results showed that participants who agreed with one were more likely to agree with the other, and the association was small to medium, with (Phi value= 0.154).

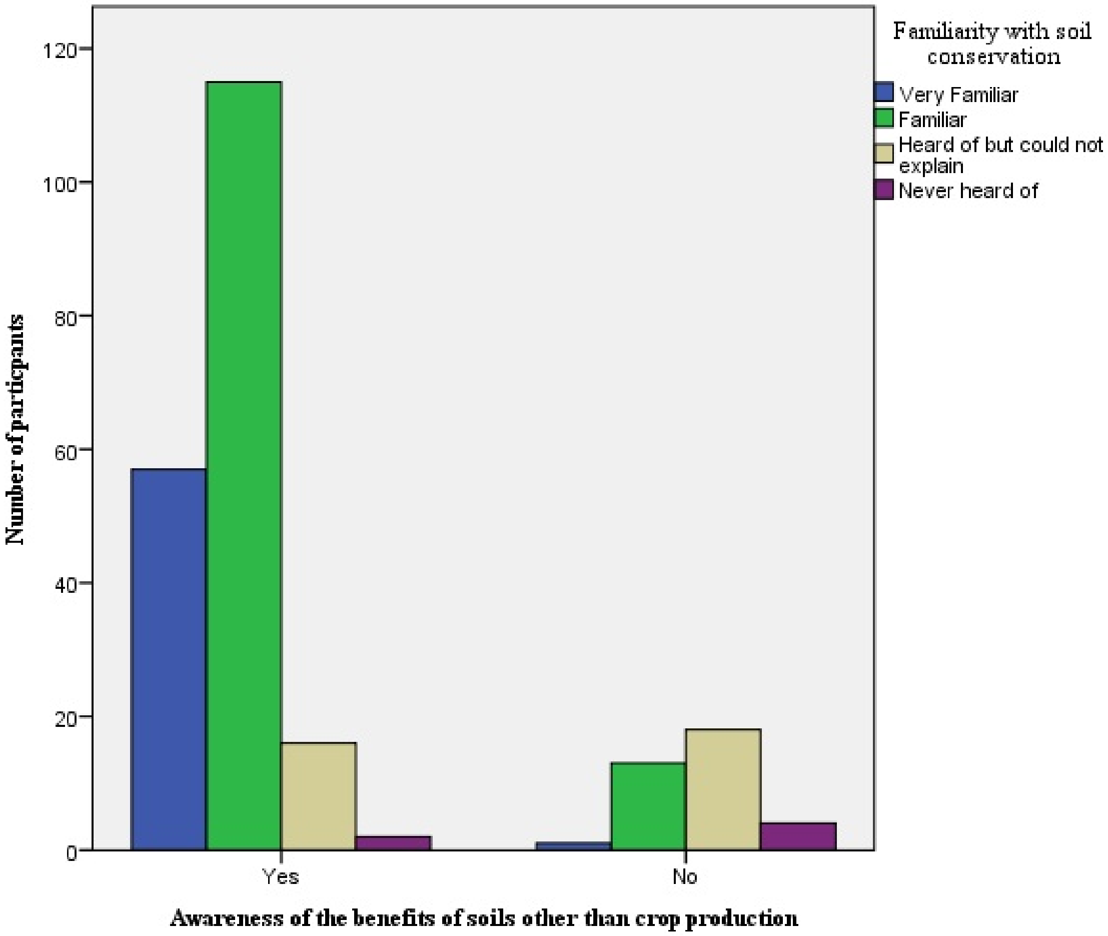

Figure 6.6: Distribution of responses between awareness of the benefits of soils other than crop production and familiarity with soil conservation

All significant relationships observed in this analysis suggest that the type of associations detected between variables did not happen by chance as a result of sampling, and similar relationships can be expected from a wider sample of the UK farming population with a 95% confidence level.

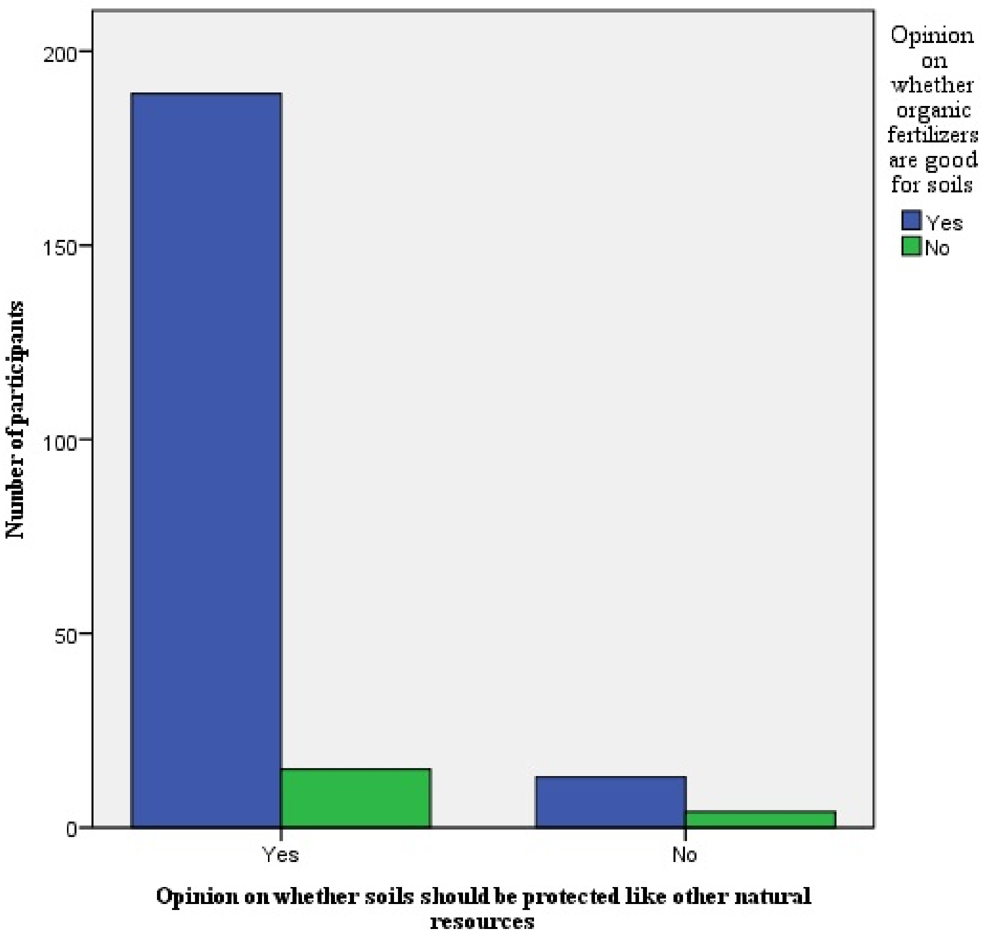

Figure 6.7: Distributions of responses between opinions on whether soils should be protected like other natural resources and whether organic fertilizers are good for soils

6.4 DISCUSSION

The description of soils given by farmers in this study suggest that farmers have some knowledge about soils. The study also shows that not only do farmers have a different knowledge of soils from scientists (Ingram *et al*., 2010), but that there is a difference among farmers themselves looking at the number of words used to describe soils. The findings of the study are not limited to differences in the perception of soils among farmers, but also include certain similarities in their perception of soils. This is particularly relevant considering the diversity in the farmers' age groups, educational level, farm type and other independent variables that had significant associations with the dependent variables.

The words used to describe soils, which have been categorised into abstract, scientific, physical, and soil function descriptions were closely linked to responses on the dependent variables. For instance, the description of soils as 'essential' very much suggest that farmers may actually know the various functions of soil other than crop production. Other descriptions of soils, such as 'organic matter', also suggest why most famers agreed that organic fertilizers are good for soils. Similarly, descriptions of soil as 'important', 'vital', 'living' and 'essential' make responses on opinions on whether soils should be protected like other natural resources less surprising. There is no doubt farmers possess good knowledge of their local soils, as various studies have suggested (Ingram *et al.*, 2010; Schiermeier, 2013; Rushemuka *et al.*, 2014; Tesfaye, 2014), the main question is how this knowledge can be translated into effective soil conservation practices for sustainable agriculture. Although results showed a high level of awareness of the benefits of soils other than crop production, its association with age and farm ownership suggest the need to effectively engage farmers in knowledge exchange networks for the overall benefit of soil conservation. With higher awareness of the benefits of soil in older farmers and 'farm owners', a possible knowledge transfer network between farmers can involve the older farmer and 'farm owners' sharing their knowledge about soils. Farmers within these categories can also be positioned to serve the interest of farmers in the development of soil conservation policies in the UK. Other authors have reported, the need for farmers' participation in soil conservation (Sudha, 2015) and sustainable agriculture (Harris *et al.*, 2008) policies, particularly involving those farmers with more awareness of the benefits of soil in such activities. However, participation should go beyond stakeholder engagement as such farmers could make significant contributions to policy development.

High levels of familiarity with soil conservation were also reported in the results and, while it remains unclear whether or not farmers actually know what soil conservation entails, the association observed between it and educational level offers opportunity for soil conservation and sustainable agriculture in the UK. Since farmers were not asked to define soil conservation, it is not certain how familiar they are, however previous studies (Ingram, 2008; Ingram *et al.*, 2010; Kings, 2014) and results from this study, especially the medium to large association with educational level, suggest that UK farmers might indeed be familiar with soil conservation. With the expectation that the more educated farmers will be more familiar with soil conservation, highly educated farmers can play a leadership role in soil conservation networks between farmers. Opinion on whether soils should be protected like other natural resources also shared a medium to large association with education and therefore supports the role for highly educated UK farmers in soil conservation.

Although opinion on the use of organic fertilizers on soils did not share a significant association with any independent variable, it had a significant association with opinions on whether soils should be protected like other natural resources and there was an overall high support for organic fertilizer use on soils. Duruiheoma *et al.* (2015a) identified the importance of anaerobic digestion (AD) technology in promoting soil conservation and sustainable agriculture. Rich organic fertilizer called the digestate is one of the benefits of AD reported, and the support for organic fertilizer on soils here shows that informing UK farmers of the benefits of AD can promote its development, thereby supporting sustainable agricultural production.

6.5 CONCLUSION

Building on the principles of ethnopedology, this chapter has shown the perception UK farmers have of soils and how this can influence soil conservation and sustainable agriculture. The results show that UK farmers have scientific knowledge of soils, awareness of the various benefits of soils and are quite aware of soil conservation. Age, farm ownership and level of education shared significant association with some dependent variables, and these associations can be useful in efforts to promote soil conservation and sustainable agriculture in the UK. The association between opinion on the need to protect soils like other resources and support for organic matter use on soils as well as their response distribution supports the promotion of AD technology in the UK.

Box 6.2: Chapter summary

This chapter has;

- Further reviewed literature to strengthen the relevance of this chapter;
- Provided some questionnaire variables;
- Identified farmers' perception of soil;
- Identified how knowledge of farmers' perception of soil can be used to develop policy aimed at influencing influence soil conservation and sustainable agriculture in the UK.

CHAPTER SEVEN

PROMOTING SOIL CONSERVATION WITHIN SUSTAINABLE AGRICULTURE AND ANAEROBIC DIGESTION ADOPTION

7.1 INTRODUCTION

Box 7.1: Chapter purposes

- To provide further literature background relevant to 4th and 5th research questions;
- To present the variables used for measurements in this chapter;
- To present the rest of the interview and survey findings;
- To evaluate these findings in the context of promoting soil conservation within sustainable agriculture in the UK;
- To identify the limitations and options for promoting AD adoption in the UK.

Food security in light of world population growth and a resulting rise in food demand, is an important issue facing policy makers in developing and developed nations (UN, 2013). Demand for food has also risen due to increases in income and wealth which are associated with preferences for a more varied diet (Godfray, 2015). Sustainable agricultural production is central in addressing global food security concerns. Achieving sustainable agricultural production is however, faced with a number of challenges which include among other things: the interpretation, understanding and acceptance of the term 'sustainable', effect of policy and legislation pertaining to it, meeting food demand without negative environmental impact; and challenges at both institutional and individual (farmer) level. While the term 'sustainable' is arguably relative, it is mostly accepted that sustainable agriculture incorporates economic, social and environmental sustainability as driven by the concept of sustainable development. White *et al.* (2014) defined sustainable agriculture as the ability of a given agricultural system to maintain steady production quality and level without economic or environmental compromise. While this definition is clearly incomplete as it fails to mention the social aspect of sustainable agriculture which is concerned with well-being, health and availability of basic amenities, it covers the aspect of sustainable agriculture that is of interest to farmers (economic profitability) and policy makers (environmental protection). This definition also supports a recently popularised concept known as *sustainable intensification.* Godfray (2015) described sustainable intensification as a process that involves increasing agricultural production while minimizing the effects on the environment.

Irrespective of the variations in the definition and interpretations of sustainable agriculture, the fact remains that soils are central to agricultural production, and are more prone to degradation with intensified food production. Apart from their ecological and environmental benefits, soils provide direct and indirect economic benefits. In the UK for instance, it has been estimated that the total income from soil is worth around £5.3 billion (National Statistics, 2012) and POST (2015) estimated the cost of soil degradation in England and Wales to be between £0.9 and £1.4 billion per year. Within the concept of sustainable agriculture soil conservation is considered a part of the environmental sustainability aspect, the main concept that fully recognises the soil conservation is the concept of conservation agriculture. Conservation agriculture is focused on soil improvement to increase and sustain agricultural production and at the same time conserve soil water and air (Carvalho & Lourenco, 2014). Conservation agriculture encourages practices like zero tillage to ensure minimal soil disturbance, use of cover crops and their residues to conserve water and control soil temperature, crop rotation, and integrated fertilization and pest control techniques (Lal, 2010). Farmers are therefore very important for soil conservation to be achieved.

The chapter builds on an earlier study on raising awareness of AD in the UK (Duruiheoma, 2014; Chapter 4), farmers' perception of soils, and how this may inform policies on soil conservation and sustainable agriculture in the UK (Duruiheoma *et al.*, 2015b; Chapter 6), and the role of anaerobic digestion in achieving soil conservation and sustainable agricultural development in the UK (Duruiheoma, 2015a; Chapter 2).

7.2 MEASUREMENT

Table 7.1 show the interview questions used in this chapter to address the fourth and fifth research questions. Details of the interview process are discussed in Chapter 3. The characteristics and distribution of the interview participants are presented in Table 4.1.

Table 7.1: Interview questions used in this chapter

Interview Questions	Participant Groups
Why is soil conservation often not considered a top priority in natural resource conservation?	A, B, C and D
Are current sustainable agricultural practices in the UK in line with sustainable development goals?	A, B, C and D
How can we ensure that sustainable agriculture takes soil conservation into account?	A, B and E
How can the conservation of soils be promoted among farmers?	A, B and E
Do you believe AD has a role to play in soil conservation?	All groups
To what extent can digestate from AD plants promote the conservation of soils?	A and B
What is your opinion about current regulatory framework for AD plants?	C and D
What are the barriers to on-farm AD plants?	C, D and E
How can we make AD more attractive to farmers other than through the use of incentives?	C, D and E
How can policies reduce risk and promote access to finance for AD plants at all scales from banks and other sources?	C and D

Extracts from survey questionnaire (Table 7.2) were also used address the objectives of this chapter. The characteristics and percentage distribution of farmers surveyed is shown in Table 5.2.

Table 7.2: Questionnaire variables and their units

Variables	Units
How familiar are you with concept of sustainable development?	1 'Very familiar', 2 'Familiar', 3 'Heard of but could not explain', 4 'Never heard of'
How would you describe the profitability of your farm?	1 'Increasing', 2 'Decreasing', 3 'Neither increasing nor decreasing'
What do you do with your farm waste?	Open-ended

7.3 PROMOTING SOIL CONSERVATION WITHIN SUSTAINABLE AGRICULTURE

7.3.1 Prioritizing soil conservation

There have been several debates on the level of priority being given to soil conservation amongst policy makers globally, even though policy and legislations alone are considered inadequate to prevent soil loss and degradation (Tesfahunegn *et al.*, 2011; Karltun *et al.*, 2013; Rushemuka *et al.*, 2014; Sudha, 2015). The interview question on the priority associated with soil conservation received a variety of responses from participants. The most popular response suggested that low levels of awareness and understanding of soil matters are to blame for the low priority given to soils. This was clearly identified by one policy maker who stated:

'*Soil conservation effort per se is not supported by explicit soil conservation/protection legislation in Europe/UK/Wales, therefore soil loses out to other environmental media (air, water) and biodiversity etc. objectives when prioritising work allocation of resources. There is a general lack of awareness to the importance of soil function and its fundamental role in most ecosystem services . . .'*
(March, 2014)

A response from an environmental consultant was quick to attribute the lack of priority for soils to the amount of research devoted to other natural resources and the way this has influenced policy makers while at the same time suggesting a shift in the situation by stating:

'I agree with this. Generally people are more aware of biodiversity and geodiversity because of the amount of research and awareness that has been put into them. This has therefore attracted policy makers more than soils. However, soil protection is no longer over looked' (April, 2014).

Three other possible reasons behind the priority associated with soils are low attractiveness of soils, issues surrounding soil conservation benefits and soil degradation processes. Some stakeholders argued that soils are not as attractive as other aspects of biodiversity and geodiversity and therefore less appealing to conserve; this point was even more relevant coming from a policy maker who responded:

' . . ., soil has a lack of colourful, charismatic or emblematic biological species associated with it, which could appeal to public, and from a scientific viewpoint there is little interest in the diversity of soil types, compared to say other aspects of geodiversity' (March, 2014).

Like attractiveness of soils, their benefits are not so popular, hence making them less appealing to conserve. One conservationist (non-academic) participant recognised this alongside the other recurrent theme on soil degradation processes in stating:

' . . . I believe that this is due to the time required to either cause noticeable harm to soils, and the time required before the benefits of remedial actions are seen. So, in the UK, where we have a temperate climate, the process of soil degradation tends to occur by small increments, year-on-year, and it can take 25 to 50 or even 100 years before the impacts are appreciated by the land manager. In addition, actions taken to reverse soil degradation, e.g. changing tillage operations, including livestock in the rotation, adding organic materials, requires considerable effort and cost, but the benefits are seen only incrementally over the longer term. This 'return on investment' makes it difficult for land managers to prioritise beneficial soil management practices. Another point to consider here is that the benefits of good soil management can be difficult to quantify. For example, if a farmer achieves a high crop yield, was it the new seed that was used that year, the new insecticide that the agronomist advised, or the reduced tillage that was adopted five years ago?' (December, 2013).

While most stakeholders were able to point out the possible reason behind the low level of priority in soil conservation, 3 of the 19 did not accept that soils are given low priority. For instance a conservationist (academic) replied:

'I think this is to some extent a thing of the past now. Current holistic approaches to nature conservation rightly position soil conservation alongside other natural resources' (November, 2013).

Whether or not soil conservation is now top in the priority of policy makers, both sides of the arguments suggest a neglect in soil conservation, at least in the past. The benefits of soils and the factors that limit soils to deliver their benefits discussed in Chapter 1 and 2 necessitates the need for greater attention to soil conservation. Also, like other aspects of biodiversity and geodiversity, the intrinsic value of soils support the need for their conservation.

7.3.2 Sustainable agricultural practices and sustainable development goals

The most recent sustainable development goals have been cited in Chapter 2 of this thesis, some of which were also linked to the aims of this research. Interview participants were asked whether what is considered as sustainable agricultural practices in the UK is in line with sustainable development goals. Since the current sustainable development goals were published after the interview process, 'goals' used in the question refers to the fundamental indicators of sustainable development (economic, environmental and social). 11 out of 16 participants who responded to this do not believe that current agricultural practices in the UK favour sustainable development goals. The main themes arising from this are the issues of economic unsustainability and inevitable environmental impact from agricultural production. This according to a conservationist (academic) participant is also linked to the rise in world population:

'In economic terms the current structure of agriculture within the UK is unsustainable because it continues to rely on subsidies under the Common Agricultural Policy. I worry about world population growth and the rising demand for agricultural products. This does put enormous strains on the environment; and worldwide it seems to me there is evidence of detrimental effects: pollution, global warming, extinctions and loss of biodiversity, etc. . . .' (February, 2014).

Another important theme shared by two participants concerns the issues of interpretation of both concepts. While one of them simply described the term sustainable as varied, the other participants was more detailed providing examples of varied interpretations in stating:

'. . . From the agricultural industry perspective sustainable agricultural practices tend to focus on the economic. Many farmers would claim they are practising sustainable agriculture, in that they are stewarding the land for the next generation. From the perspective of those who have a different set of values/principles e.g. Soil Association sustainable agricultural practices such as organic farming are in line with the 3 principles of SD, whereas they see current conventional practices as not sustainable. The term sustainable agriculture is highly contested, agric. industry and policy promote the notion of sustainable intensification while others believe sustainable agriculture needs to be founded on a different set of principle and values' (December, 2013).

The view reported by Ingram and Morris (2007) that agricultural policies and legislation are not enforced in the UK, thereby reducing their effectiveness as a tool for environmental protection was identified as one of the limitations to aligning sustainable agriculture with sustainable development by a conservationist (non-academic). The response was:

'. . . The UK government has some guidelines for farmers which are supposed to encourage environmental protection including soil conservation. The problem can be thought to be the issue of enforcement and this will be very difficult to achieve, as we are dealing with farmers here' (March, 2014).

A response from one of the five participants who believe that UK agricultural practices are in line with sustainable development goals pointed out the various ways this is supported stating that:

'Sustainable agricultural practices align with sustainable development goals in terms of achieving environmental preservation, protecting public health and sustaining communities. Also they assist energy conservation and reduced emission of greenhouse gases' (April, 2014).

Survey results revealed that more than 85% of farmers were familiar with the concept of sustainable development, and this was significantly associated with educational level of farmers, awareness of soil conservation (likelihood ratio= 79.03, 9 d.f., p= 0.0001) and sustainable agriculture (likelihood ratio= 25.24, 3 d.f., p= 0.0001). With education, observed p= 0.003, 15 d.f., and likelihood ratio= 33.96, and the strength of the association is medium to large (Cramer's V= .199). The strength of association with knowledge of what sustainable agriculture means is medium to large, and large for soil conservation with Cramer's V of 0.390 and 0.360 respectively. The results also revealed that even from an economic sustainability perspective, more than half of the farms' surveyed are economically unsustainable with only 34.4% of respondents considering their farms' to be profitable. While it may not be appropriate to associate farm profitability to any other variable measure since no significant relationship was identified, this result suggests an unsustainable agricultural system in the UK. This result conforms to DEFRA (2016) forecasts of a fall in farm incomes of all farm types except poultry, mixed farms and grazing livestock farms on lowland. The main reasons for the predicted fall is reduction in output due to a decline in prices.

7.3.3 Promoting incorporation of soil conservation into sustainable agriculture among farmers

By incorporating soil conservation into sustainable agriculture, we consider an agricultural system that both meets sustainable development goals and protects soils from degradation, and therefore take a different view from the conservation agriculture defined by Carvalho & Lourenco (2014). DEFRA (2011b) levels of annual soil loss indicate that there is a gap in practice suggest even though farmers and policy makers may be aware of what both soil conservation and sustainable agriculture mean. Some of the AD stakeholders were asked about ways in which this gap can be filled, and a number of suggestions were provided. The most popular was raising awareness of soil benefits and the need to conserve them. A detailed response given by a conservationist (academic) stated that:

'Food production levels are directly affected by soil quality. Informing farmers of the potential benefits they will gain from preventing soil degradation will form a major part of ensuring that sustainable agriculture takes soil conservation into account. Farmers are already aware that soil quality will ultimately affect their production quality, but are currently accustomed to adding artificial fertilisers to supplement any

deficiencies, and this in itself brings problems such as runoff and pollution of watercourses. Education in more holistic practices is essential' (April, 2014)

Retailers were also identified as having a role to play in promoting soil conservation within sustainable agriculture as one participant noted:

'Remove barriers to good soil management such as pressure on land managers for cheap produce at specified times from supply chain (retailers, processors etc)' (December, 2013).

This is in line with another response from a conservationist (non-academic) who suggested collaboration between famers and retailers:

'Work with retailers and other food purchasers to obtain their commitment to better soil management practices, which will benefit them by managing supply chain risk, and include good soil management practices in crop assurance schemes. On rented farmland, particularly shorter term leases, farmers have little incentive to adopt expensive soil management practices and the land will tend to be degraded over time. This will affect the rental or capital value of the land and will, consequently, have a negative financial impact on the landowner. This situation sounds like an ideal case for a benefits sharing arrangement, which provides financial benefits to both the tenant and the landowner' (December, 2013).

The use of incentives to encourage better soil management and commitment to such practices was also suggested. For instance farmers can get economic reward for good soil management practice. In the Netherlands, a system where farmers get reward in the form of product grading with better pricing for higher product grades, and agricultural input incentives from the government for reducing their environmental load has been reported (Staats *et al.*, 2011). This type of approach can therefore inform policy makers on how to encourage soil conservation within agricultural practices among UK farmers.

Figure 7.1: Various uses of farm waste

This is also linked to the last but not the least suggestion on how to incorporate soil conservation into sustainable agriculture, which is the use of policy tools. Although this suggestion was an isolated one, it was quite detailed on areas through which such policy tools can be applied including:

'Set bench marks with soil protection policies and codes of practice
Ensure advisors/agronomists have sufficient skills and knowledge
Target all land managers including large estates, contracts farmers, farm management companies as well as those in the supply chain (i.e. high value crops like potatoes are very damaging to soil but farmers often contract out their production or have to respond to processor requirements)' (December, 2015).

Demonstration, training, and public media were identified as ways of spreading the word for good soil management practice to farmers. However, survey results suggest that most farmers are engaged in sound environmental practices that are good for soils, based on the uses of their farm waste (Figure 7.1). While some farmers have a single use for their farm waste for instance 'recycle', other have multiple use like 'fertiliser/recycle/burn'. Among the practices identified, recycle and fertiliser were the most common uses of waste, although others, such as disposal and landfill were listed.

7.4 PROMOTING AD ADOPTION IN THE UK

7.4.1 AD and soil conservation

Duruiheoma *et al.* (2015a) identified anaerobic digestion (AD) as a technology that offers opportunities for soil conservation, sustainable agriculture and overall sustainable development. To support this, AD stakeholders were asked if they believed AD has a role to play in soil conservation, and 19 of the 21 participants were positive that AD has a role to play in soil conservation. Most of the responses attributed this potential role of AD to the digestate derived from AD process. For instance one conservation (non-academic) stated:

'Digestate from AD plants are good nutrient sources for soils. This can help with improves soil structure and stability, so yes AD can help soil conservation' (January, 2014).

Some others identified the role AD plays in recycling nutrients and how this favours the environment and ultimately soils. This was clear when an energy/environmental consultant responded:

'Yes, because it effectively recycles nutrients, removing volatile carbon as energy and returning macro- and micro-nutrients to the soil, as well as slow release (sequestered) carbon' (April, 2014).

Even though most participants were positive about the role of AD in achieving soil conservation, some of the participants were still skeptical of this as they identified several challenges that need to be addressed. Some of the challenges reported include unavailability of market and acceptance of the digestate, lack of market for energy from AD, acceptance by retailers, heavy metal contamination of soil, transportation, and structural damage to soil. One response that covered most of these challenges was that of a conservationist academic, who replied:

'Well it sounds like a good idea, but when I investigated the topic some years ago a series of practical considerations came into play including legal definitions of waste, including what one could do with the digestate, and whether supermarkets would accept the practice. How these discussions have progressed I do not know' (February, 2014).

Three participants were not in agreement that AD has a role in soil conservation. Two of the responses for an energy/ environmental consultant and a conservationist non-academic respectively are given below:

'No. AD is currently seen by farms as a mean to earn income. Most farms have no interest in soil conservation when considering AD' (February, 2014).

'In general, digestate contains a lot of water, some very useful nutrients, and a very little organic matter. However, the dry matter content of digestate is typically very low (<5%) and it will supply very little organic material to land.
In the case of the AD of slurries or crops, the organic matter content of the feedstock materials could have been returned to land directly, and putting them through a digester will have done nothing to enhance them.
Where crops are used as a feedstock, it could be argued that this increases pressure on farmland and soils, which might be degraded more rapidly than otherwise.
For these reasons, I believe that AD has little or no role to play in soil conservation' (December, 2013).

Some participants were further asked to what extent they think digestate can promote soil conservation. Three areas were identified: nutrient addition to soil, lesser contamination of soil and surrounding ecosystems, and soil conditioning. One conservationist academic who identified nutrient addition also added that rising fertilizer price will increase demand for digestate, the response was:

'Massively. They contribute both carbon and nutrients, both of which are vitally needed for sustainable production. Demand of digestate will increase considerably over time as fertiliser costs become prohibitive' (February, 2014).

Another response that covered aspects of soil conditioning and minimized contamination was that of a conservationist academic who gave the following response:

'AD Digestate can be a valuable soil conditioner and improver and contributes to the conservation of soils. The application of digestate to land closes the loop by recycling organic material, and also reduces the need for application of artificial fertiliser with all its inherent runoff problems' (April, 2014).

One the participants who earlier disagreed on the role of AD in soil conservation, also believed that digestate are unsuitable for soils.

7.4.2 Limitations to AD growth in the UK

Findings from literature suggest that the AD industry is faced with a number of challenges as reported in Chapter 2 and Duruiheoma (2015a). Two questions that pertain to this were asked to some group of participants to see if their response conforms to finding from literature. The first question was what are the barriers to on-farm AD plants? Several barriers were identified by participants and the most popular was the issue of finance. Other barriers identified in order of popularity were policy and legislation, feedstock availability, low awareness and understanding, availability of market, land use conflict, and inefficiency of AD plants. The most detailed response that identified finance as a barrier was provided by an energy/environmental consultant who further criticised current incentives available to AD plant owners by stating:

'. . . access to finance. FIT degression may affect the 250-500kWe digesters now, since the Government's ridiculously small sub-500 capacity limits have meant a 20% degression. Talks and lobbying continue. The further way that over 500kWe plants can 'FIT-rob' this small capacity (the Extensions rule) exacerbates this. And, finally, pre-accreditation does NOT mean actual capacity and degression is erroneously based on pre-accreditation and not installed capacity which is also not helpful and not the way it was designed. Smaller, manure based plants (remember that a large dairy farm would be 400 cows (say) – which is only 40kWe) also suffer from this unfair FIT degression, but also suffer from lack of access to finance, as 'payback' under current FITs is not considered acceptable to most banks and banks seem to regard AD as an 'industrial' addition, rather than a pollution mitigation and nutrient recycling technology which is what it is at an appropriate scale' (April, 2014).

Even though policy and legislation was the second most shared opinion with 4 participants identifying it, no participant gave detailed explanation on this. For example one participant simply said *'policy and legislation'* another responded *'regulatory framework'*. These types of responses were also received from those participants who identified feedstock, and low awareness and understanding of AD as a barrier. Some of the responses received were *'supply of raw material'*, *'feed stock availability'*, '*low awareness'*, and *'the gaps in our knowledge and understanding of the operation of AD on farms'*.

Available market, inefficiency of AD systems and land use conflict were isolated opinions.

Having identified the current regulatory framework for AD as a barrier to AD development in literature, some stakeholders were asked about their opinion on this.

The responses received were in two categories, those who believed the current regulatory framework is a challenge to AD development, and those who did not see it as a challenge considering the underdeveloped status of AD in the UK. Most of those who viewed it as challenging to AD development described it as complex and confusing, a demonstration of lack of understanding on the side of policy makers. Of specific interest is the response from a policy maker who stated:

'It poses a number of challenges for AD regulators, planners and developers/operators in understanding the process that control its use and in achieving the right balance between encouraging growth of the industry and the requirement to protect human health and the environment. Given that the technology is still in its infancy and that there have been cases of AD plant failures, some of which high-profile and of an explosive nature, one can argue that the regulatory current burden on business is necessary and that discussions on how much regulation is required needs to be based on risk, taking into account the environmental, social and economic benefits that regulation itself provides' (March, 2014)

An energy/environmental consultant attributed the lack of understanding on the side of policy makers as the reason why most AD development applications are rejected. His response was:

'I feel that most planning authorities seriously lack understanding of AD plants and take the easy way out by simply rejecting most applications' (April, 2014).

One of the responses suggesting that the current regulatory frame work is not a challenge to AD development was provide by a policy maker stating that:

'We are getting there. Current regulatory frameworks are not perfect, but remember AD industry in the UK is still underdeveloped' (April, 2014).

7.4.3 Options for promoting AD

In the UK, the use of incentives is the main means by which the government has shown support for AD development. Some of the incentives available have been discussed in Chapter 2, and even when these incentives are considered inadequate there are suggestions that the UK government plans to cut down on some of them. Earlier Duruiheoma *et al*. (2015c) identified the various factors farmers consider before using a particular technology and 43.3% said government support. Although government support was not the most popular factor considered, the figure shows how significant availability of government support is with technologies like AD. In view of this, some stakeholders were asked how AD can be promoted without the use of incentives, and the following options were identified:

I. Promoting the benefits of AD
II. Providing finance
III. Minimizing bureaucracy
IV. Simplifying AD technology

Promoting the benefits of AD was the most shared option which suggests that farmers and other investors will be interested in AD technology if they know more about it. An energy/environmental consultant indicated this by replying:

'Making farmers aware and understand the technology and the benefits it can bring to farming' (March, 2014).

While incentives have some financial benefits, finance identified by participants here refers mainly to capital cost associated with developing AD plants. One participant even suggested a form of collaboration with farmers and investors were farmers provide land and feedstock, and the investor provides the fund to develop the plant. The response that raised this idea is that of another energy/environmental consultant by stating that:

'Offer farms fully funded AD in which the AD is owned by investors and the farm earns 20 year land lease income combined with a 20 year feed stock contract and low cost heating/electricity' (February, 2014).

Having identified the complexities associated with policies and legislations relevant to AD, and the current regulatory framework as challenges to AD development, minimising bureaucracy is an expected option to promoting AD. The last but not the least, simplifying technology was an isolated opinion, and is linked to reducing cost of AD. The response that identified this option suggests that making AD systems less complex will lower the cost of AD plants. Although this may not be likely in the short term since simpler systems are likely to be high technology (often pricey) to ensure efficiency, the long term view of AD development in the UK makes this a viable suggestion. The response was:

'. . . simpler and therefore lower cost technology . . .' (April, 2014).

One participant considered the use of incentives as inevitable taking into account historic AD development, environmental commitment and energy prices. The response, which was quite detailed states that:

'We have been in this business for 40 years and there was one digester a month being built when there were 50% grants, AND they were built for the right reasons. Then there were no incentives so, coupled with cheap energy prices and no 'sticks' to reduce GHGs and pollution from the production, storage and handling of manures and slurries, there were NO digesters built within a period slightly longer than 10 years. The fact of the matter is that if we wish to reduce the environmental impact of farming, especially where manures and slurries are concerned, AD needs to be incentivized somehow: through carbon reduction programs, through full-cost accounting for food – in some way. Also, all organics (food processing waste, food waste, etc) comes from the land and it needs to go back onto the land in the most environmentally friendly way, so the regulatory and incentive framework does need to somehow incentivize such small farm-based, appropriately-scaled systems' (April, 2014).

To reduce the risk associated with and promote access to finance through policies, the responses suggest that policy can promote access to finance by reducing interest charged on AD plants by banks, increase the incentives of AD to make banks more willing to offer loans, and promote collaboration between banks and retailers. One policy maker however suggested that an overall favourable policy will address this issue, by stating that:

'Policies that contribute to feedstock, supply chain security, promote digestate as a resource (waste management/regulation), biogas use, and provide some certainty around the financial incentives that are in place to encourage AD and other types of renewable energy generation. Planning reform, carbon offsetting, transport and energy policies – barriers to fuel switching in fleet vehicles, road haulage trucks, subsidies for biogas etc. Occupational standards, qualifications, operator competence, and accreditation schemes for AD operations and process. H and S regulations relevant to AD and associated training' (March, 2014).

7.5 CONCLUSION

This chapter has identified the need to raise the priority given to soil by policy makers to promote its conservation. While policy and legislation alone are not considered adequate for soil conservation, it is important for policy makers to consider enforcing policies that will promote sustainable soil management among UK farmers. Also, raising awareness of the benefits of soil conservation, and using economic incentives have been identified as important tools for promoting better soil management practices. Where sustainable agriculture as a whole is concerned, the findings from this study suggest that promoting soil conservation among farmers is likely to result in them engaging in more sustainable practices. The association between educational level and knowledge of what sustainable agriculture means suggests that the use of farming networks, with more educated farmers acting as leaders, may help to increase general awareness of sustainable agriculture built on the concept of sustainable development. Although the findings raise questions concerning the economic sustainability of UK farms, such an approach will encourage farmers to look beyond the short-term economic sustainability of their farms and to embrace environmental and social sustainability.

Response from AD stakeholders in this chapter supports the role of AD in achieving soil conservation. The limitations to on-farm AD development and options for promoting AD were also discussed. Another important finding from this chapter is the importance of UK government in promoting AD development. Government has a significant role in addressing the limitations to AD development in the UK. The key areas in need of intervention are: favourable regulatory framework to speed up applications approval and make the whole process of AD plant development less complex, better access to finance from banks through policies and enhancement of incentives, and funding of research to develop simplified AD systems. The options for raising awareness of AD in the UK has been detailed in Chapter 4 and Duruiheoma (2014).

Box 7.2: Chapter summary

This chapter has;

- Further reviewed literature to strengthen the relevance of this chapter;
- Provided the rest of the interview questions and questionnaire variables;
- Identified how to promote soil conservation within sustainable agriculture in the UK;
- Identified the limitations and option for promoting AD adoption in the UK.

CHAPTER EIGHT

CONCLUSION

8.1 INTRODUCTION

Box 8.1: Chapter purposes

- To relate the findings of this research with reference to research questions;
- To review the role of AD in achieving soil conservation and sustainable agriculture;
- To identify the relevance of this research to practice, knowledge and policy;
- To reflect on the strengths and limitations of this research;
- To suggest future opportunities and areas for research.

Prior to this research, there was no study linking anaerobic digestion to soil conservation and sustainable agriculture in the UK nor elsewhere. There was little documentation on the benefits of digestate for agricultural purpose with most focusing on the physiochemical characteristics of the digestate and how it interacts with soil, and its application in agronomy and horticulture. There was also little documentation on the role of AD in sustainable agriculture none of which took a holistic view as reported in this thesis. Although AD is reported to have been in the UK for up to a century (Tranter *et al.*, 2011), this study is the first of its kind to use pragmatic approach to study the benefits of AD. Given the lack of research in the role of AD in achieving soil conservation and sustainable agriculture, it is no surprise that no single study has been dedicated to raising awareness of the benefits of AD as reported in Chapter 4 and by Duruiheoma *et al.* (2014).

This research and the various papers produced from it (Duruiheoma *et al.*, 2014; 2015a, 2015b, 2015c) has examined the benefits of AD in the UK, particularly in the area of soil conservation and sustainable agriculture. In doing this, this research has opened avenues for further work on the applications of AD, while addressing the research questions established at the outset. The aims of this chapter are presented in Box 8.1, and, to achieve these, it is divided into four parts. Firstly the role of AD in achieving soil conservation and sustainable agriculture is reviewed by revisiting the research questions that have guided this research process and the documentation in this thesis. Secondly, the relevance of this research to policy, practice and contribution to knowledge is discussed. Thirdly, the strengths and limitations of the research are discussed, and finally, suggestions for future research are outlined.

8.2 REFERENCE TO RESEARCH QUESTIONS

This research has been driven by five research questions as outlined in Chapter 1, and the research design used is illustrated in Figure 3.3. The research questions were partly derived from the review of AD gap analysis in the UK (Frith and Gilbert 2011). The first research question looked at *how we can raise awareness of AD in the UK* and the findings which broadly supported low level of awareness of AD in the UK, are discussed in Chapter 4 and in Duruiheoma *et al.* (2014). This research question utilised data from interviews with 21 AD stakeholders in the UK. The findings showed:

- Informing people of the benefits of AD was the most shared opinion by participants;
- Community AD and localism are important in popularising AD under the UK's AD strategy and action plan because they promote the acceptance of AD, enable communities to benefit from AD and assist cost minimisation;
- Small AD plants as the main option for promoting localism of AD systems, their economic, environmental and social benefits;
- Enhancing the understanding of AD technology by those associated with it can promote awareness of AD, and this can be achieved through sharing experience between stakeholders, plant owners and farmers, promoting AD products, and education (demonstration and training);
- While it may be difficult to ensure that the benefits of AD are shared by everyone, promoting the benefits of AD (environmental, social, and economic) and using any such benefits for general purposes, is capable of raising awareness of AD. Again, this relates to community AD and localism;
- Diversifying biogas use from AD is one of the ways to use AD benefit for general purposes. Three options were identified: use of biogas for vehicles and other related uses, injection into the national grid, and heat/ electricity generation. Proximity to end users, size of AD plant and the costs associated with creating channels for linking AD biogas to national grid were identified as key factors here.

The above findings indicate that, intervention is needed to raise awareness of AD mainly in terms of popularising its benefits and thereby making it attractive to investors and farmers, government financial support (funds and incentives), promoting small AD plants, and educating those associated with AD facilities.

The second research question, *what factors motivate and hinder farmers towards adopting improved technology and sustainable agricultural practices*, was addressed with data derived from the survey of farmers, and this is presented in Chapter 5 and in Duruiheoma *et al.* (2015c). In addressing this research question, its relevance to AD adoption and sustainable agriculture in the UK was also documented. Overall, survey results showed a significant presence of female farmers, young farmers (< 30 years old), high level of education among UK farmers, and low level of organic farming practice. With reference to the second research question, Chapter 5 shows:

- High level of interest in agricultural technology among farmers surveyed with up to 70% of all participants indicating a high interest in agricultural technology. The interest in agricultural technology was significantly associated with gender, level of education, and farm size. The most popular factor considered by famers in the use of agricultural technology is 'affordability' followed by 'knowledge of its benefits' and 'efficiency of the technology';
- knowledge of what AD is was significantly associated with gender, level of education and farm size, while interest in AD was significantly associated with age;
- A significant association between willingness to invest in AD if it improved soil properties and farm ownership; and
- Sustainable agriculture is a popular concept among farmers surveyed. While knowledge of what sustainable agriculture means did not share any significant association with any of the independent variables, organic practice was significantly associated with age, farm type and farm size.

These findings clearly suggest that farmers are more likely to invest in AD if it is more affordable, and if they are aware of AD benefits and efficiency. Similarly, farm owners are likely to invest in AD if it can improve soil properties. Another suggestion is that farmers are keen on sustainable agricultural practices. Overall the findings suggest that interventions are needed to:

- Make AD more affordable, improve its efficiency and, as earlier mentioned, promote its benefits ;
- Demonstrate to farmers how digestate can improve soil properties and serve as an alternative to inorganic fertiliser use;
- Create farmers' networks that will allow knowledge exchange in areas of technology use, and sustainable agricultural practices.

The third research question which investigated *the perception of farmers about soil*, is addressed in Chapter 6 and in Duruiheoma *et al*. (2015b). It looked at how farmers value soil and how this can inform soil conservation and sustainable agricultural practices, with the overall aim of promoting the relevance of AD technology. Like the second research question, this was mainly dependant on farmers' survey data. The following findings were made:

- Farmers' are generally familiar with soil, describing it in abstract, scientific, physical attribute and functional terms;
- Awareness of soil benefits other than crop production was significantly related to age, and farm ownership;
- Educational level was significantly related to familiarity with soil conservation, and opinion on whether soil should be protected like other natural resources;
- Even though opinions on whether organic fertilisers are good for soils did not have any significant association with any other variable, over 90% of farmers were in agreement on the use of organic fertilisers for soils.

For these findings to be relevant to soil conservation and sustainable agriculture in the UK, the following interventions are needed:

- A participatory approach that will involve farmers should be considered in the development of agricultural programmes on soil conservation and sustainable agriculture in the UK and elsewhere.
- Farmer knowledge transfer networks focused on 'soil matters' can be constituted to foster soil conservation in the UK targeting older farmers and more educated farmers as key figures within such networks.

The fourth and fifth research questions investigated *what extent sustainable agriculture incorporates soil conservation in theory and practice* and *what role policies can play in the adoption of AD* respectively using both qualitative and quantitative data. The findings, which are documented in the previous chapter

(Chapter 7), further necessitated the need for promoting AD by exploring the gap between soil conservation and sustainable agriculture in theory and practice, and also identifying key aspects where policies and legislation can promote AD growth in the UK. The following evidence was gathered while addressing the fourth question:

- Although soil conservation is gradually getting recognition in policy terms, most stakeholders still see soils conservation as low in priority when compared to other aspects of geodiversity and biodiversity;
- Sustainable agriculture is mostly viewed as not being in line with sustainable development goals, and one of the reasons is because it fails to embrace soil conservation. Also the concept of sustainable development is popular among farmers and even though this was significantly associated with their awareness of what sustainable agriculture and soil conservation means, more than 60% of farmers reported that their farms were economically unsustainable;
- Soil conservation can be promoted within sustainable agriculture by promoting the benefits of soil, cooperation between farmers and retailers, incentivising good soil management practices, use of enforcing policies and educating people about soil;
- Farmers surveyed appear to be environmentally conscious considering their use of farm waste;

The evidence listed above strengthens the need for AD adoption in the UK, if the right interventions are considered accordingly as reported in Duruiheoma *et al*. (2015a). Evidence gathered in addressing the fifth research question shows:

- AD is acknowledged to have a role to play in soil conservation mainly due to the availability of digestate as a by-product of the AD process;
- Finance, policies and legislation, lack of understanding and awareness of AD, lack of feedstock, absence of available market for AD products (digestate and biogas), land use conflict and efficiency of AD systems are viewed as limitations to AD growth in the UK;
- Government policy is identified to have a role to play in addressing these limitations, and most stakeholders including policy makers were critical of current regulatory framework for AD.

The research questions reported in this thesis have systematically provided support for the role of AD in achieving soil conservation and sustainable agriculture for sustainable development in the UK. Responses to the first research question looked at how AD can be promoted in the broad sense within the UK. Responding to the second research question this research positioned AD as an agricultural technology, and identified the various factors that farmers consider in their adoption of agricultural technologies. Similarly, answers to the third research question explored the perception farmers have about soil and soil matters, to assess how their perception can inform the promotion of AD taking into account its potential in promoting soil conservation. The fourth research question was more direct, and response to this revealed the gaps in practice of soil conservation under the concept of sustainable agriculture and development. Here AD is positioned to be capable to fill this gap, as suggested in Figure 1.2. Having rightly positioned AD as an important technology for soil conservation and sustainable agriculture, response to the fifth research question was complementary to the overall objective of this research and took a more specific approach to identifying and addressing the challenges of AD in the UK.

8.3 IMPLICATIONS OF THIS RESEARCH

8.3.1 Implications for Knowledge

This research has documented how to raise awareness of AD in the UK, the factors that motivate and hinder farmers towards the adoption of agricultural technology, farmers' perception of soils, the extent to which sustainable agriculture incorporates soil conservation in theory and practice, and the role of policy in promoting the adoption of AD in the UK. In documenting these findings, this research has also contributed to the body of knowledge in the following ways:

- *Recognition of AD potential*- this research is the first documentation to look at the benefits of AD in the broader spectrum of soil conservation and sustainable agriculture simultaneously, therefore adding to what is already known about digestate from AD.
- *Farmers' attitudes towards technology use*- this research has provided some reasons why farmers respond to the use of certain technology in a particular way, by identifying the relationships between farmers' attitudes towards agricultural technology, sustainable agricultural practices and their demographic characteristics.
- *Contribution to ethnopedology*- findings from this research have added to the body of knowledge on ethnopedology by demonstrating that UK farmers have

both scientific and general knowledge of soils. It can therefore serve as a starting point for future ethnopedology research in the UK.

- *Position of soil conservation*- another important contribution from this research is the position of soil conservation within sustainable agriculture in the UK. Apart from the absence of soil conservation in the definitions of sustainable agriculture reviewed, the lack of association in the knowledge of what sustainable agriculture means and soil conservation further suggested a gap in farmers' knowledge of the two concepts.
- *Methodology*- the methodology used in this research contributed to the pragmatic research paradigm and the use of Twitter in conducting the survey highlights the opportunities of social media in agricultural and environmental research.

8.3.2 Implications for policy and practice

The bulk of this research documentation has direct implications for policy and practice. In addition to areas of interventions outlined earlier, the implications for policy and practice according to the research questions addressed are:

- *Awareness of AD*- This research serves as a practical guide to policy makers on how to address the issue of awareness of AD in the UK. The possible options, challenges and possible solutions to these challenges are documented in this thesis.
- *Promoting technological adoption among farmers*- response to the second research questions informs policy makers, investors, innovators and researchers alike on areas of focus in promoting the adoption of AD and other agricultural technology.
- *Promoting soil conservation*- this was addressed accordingly by the third research question. By informing conservationists, policy makers and other relevant stakeholders of famers' perception of soil and attitudes towards soil matters, this research identifies the areas for policy intervention and soil management advice for farmers. In addition, this research suggests better consideration for soil conservation practices within those agricultural practices that are viewed as 'sustainable', as well as in definitions of sustainable agriculture.
- *Policy to make AD technology more attractive*- the areas of intervention identified and findings reported can impact on the UK's approach to encouraging the uptake of AD among farmers and investors.

Based on the above implications, the following recommendations are made to actualise the benefit of AD in soil conservation and sustainable agriculture:

I. Include farmers and investors directly in stakeholders' engagement on policy development for AD, as this will allow their concerns on such policy to be addressed.

II. Small AD plants should be encouraged since they can help popularise the technology and are less expensive to build.

III. Demonstration, training, networking between farmers, plant owners and retailers should be used to spread information and awareness about the benefits of AD.

IV. For innovators, affordability, efficiency and a mechanism for informing people of the benefits of a technology should be top in priority.

V. Policy makers should capitalise on the popularity of sustainable agriculture and soil conservation amongst farmers to promote AD adoption.

VI. Government should promote farmers involvement in soil policy planning and implementation on soil management, taking into account their close association with and understanding of soils.

VII. In promoting sustainable agricultural practices, conservationist, policy makers and other relevant stakeholders should highlight soil conservation as an important aspect.

VIII. Soil degradation should not be ignored just because it happens over a long period of time, and should therefore be given as much priority as other aspects of geodiversity and biodiversity. More so, the slow process of soil degradation should be considered an advantage, since it is inexpensive to control at early stage with minimal effort, for example digestate addition to condition soil.

IX. Farmers should be encouraged to engage in good soil management practices through incentives either in the form of product grading or farm input discount.

X. Having documented the role of AD in achieving soil conservation and sustainable agriculture, it is recommended that the government addresses the issue of access to finance, simplifies the AD planning approval process, encourages acceptance of AD on the side of retailers, creates markets for AD biogas, supports further research on digestate quality that will ultimately enhance its market acceptance and finally, improves the current incentives available for plant owners.

8.4 RESEARCH PROCESS, STRENGTHS AND LIMITATIONS

The entire research process documented in this thesis was faced with a number of challenges. However, these were not unexpected considering the fact the area of research is uncommon and part of the methodology used is novel. At the same time new areas of research were exposed and questions other than those already documented in this thesis arose. The strength of the research which enabled its timely completion and authenticated the evidence gathered, is also presented here.

A personal reflection on the entire research process is presented in Box 8.2. This looks at the entire research process, the methodology used and satisfaction of the findings vis-à-vis the original research aims and questions. In hindsight, Box 8.2 also documents areas that could have been done differently and more efficiently, especially the research methodology. Nevertheless, every element set to be achieved at the start of the research was accomplished.

Box 8.2: Reflections on the research process

The research process has been characterised by ups and downs, not to mention how long it feels. I however feel accomplished with the findings of the research and the fact there has been no significant deviation from the original research plan especially the research question. Indeed some minor adjustments were made in the methodology, but these were necessary to achieve the desired goal.

Looking back to when I thought of this research idea, coined the topic, and raised the research questions I must say that both my bachelor's degree which was in Soil Science and Technology and Master's degree in Environmental Management were very useful. Their usefulness was not limited to knowledge acquired in soil and environmental issues but also include others like knowledge and experience in research methodology, research writing and public relations skills. This is not to say that during the research process I did not get relevant training and support, rather my educational background made me more confident with the entire research process, and sometimes over ambitious.

My plan to use a pragmatic research paradigm came with a lot of doubts. I wondered how I would recruit participants, if I would get a 'reasonable' sample size, and how long it would take me to complete the data collection process. As discussed in Chapter 3, I started out with the qualitative phase recruiting interview participants with electronic mail. While it seemed so quick and easy the number of people I could reach out to with the research invitation, their responses were by far not as quick. Some participants were even sent 'gentle' reminders fortnightly until they sent back their response, and even with this, it took some up to 2 months to respond.

With a total time frame of 10 months for data collection 6 months for qualitative and 4 months for quantitative, the interview process ended with 21 participants in total. The quantitative phase started slowly as well when I was using only electronic mail, until I introduced Twitter in the 2nd month of the process. Twitter, which was not initially part of the plan, accelerated the response rate so rapidly I even raised my target survey sample size from 250 to 500 participants. I however ended up with 283 participants. So in hindsight, I should have raised the time for qualitative data collection to 7 months instead of 6, and reduce that for quantitative phase from 4 to 3. Also I should have considered Twitter as an option from the very beginning.

In terms of the wording used for the interview and survey questions, participants seemed to have understood the questions since only 2 of the 283 farmers contacted me to clarify aspects of the survey questions. While this suggests that questions were well understood, some farmers still provided the wrong response to the question on location of their farms, with responses like 'England, UK . . .' when asked about the county where their farms were located. In some cases, the response from interviewee were short, so looking back I wonder if it would have been different had it been face-to-face interview.

Data handling and analysis was quite interesting especially the quantitative data. No doubt the use of statistical software (MAXQDA and SPSS) made things a lot easier, although I needed to acquire more skills through training to be comfortable with the software packages.

Writing up this thesis is perhaps the most interesting part of the whole research process. Again my original plan of addressing my research questions in form of publications, and putting out the overall research aim out there in form of a review paper made the whole writing up process easier. The review of literature was however arduous, as it was continuous through the whole process, updating information as necessary. Another benefit I derived by presenting this research in publications is that my overall writing skills improved.

As a researcher, there was always a feeling of excitement and high expectations at seminars, conferences, public lectures and training, and even among my company of friends. In all the process has been worthwhile, and is without a doubt the peak

With Box 8.2, it is clear that this research is characterised by both strengths and limitations, mostly in the methodology used to address the research questions. The strengths of this research are:

- Asynchronous communication of time and place allowed flexibility in the research process, making it possible to contact multiple potential participants within a short space of time. The methodology used is therefore useful for a time-bound research process like a PhD.
- For the interviews, the method used was very helpful as it eliminated the need for transcription since verbatim response were received. Again this saved time and made it easier to input data into the statistical software. Similarly, for the survey process data were summarised by the online survey tool (Survey Monkey). This made it straightforward to code the data and to identify important aspects of the results.
- Randomisation of sampling was enable by the method used especially for the survey process.
- The pragmatic research paradigm allowed this research to focus on actions and changes contained in the research question, which is the empirical focus of the whole research process. It also demonstrates the constructive nature of this research and my role as researcher focused on change. In all, the combination of qualitative and quantitative data validates the findings documented in this thesis.
- Most of the findings documented in the chapters of this thesis have been scrutinised by peers, through peer reviews as part of publication process.

The *limitations* identified are:

- Although the use of Twitter had a number of advantages, a critical look at this technique raise questions of the quality of farmers' survey. As a social media network, there is a likelihood that the quantitative sample comprises mainly of more educated farmers. However, this may not be the case considering the popularity of Twitter and the presence in the sample of farmers with low educational levels.

- The use of structured interview questions is thought to have limited the responses received, as is the case for closed questions. This was however beneficial for the data handling and analysis process.
- The time gap between actual data collection and presentation of findings is considered a limitation even though this was inevitable. For example, the interviews were held between November 2013 and April 2014, and the findings from this are now documented in this thesis creating a gap of over a year from data collection to actual presentation of results. It can be argued that the views shared by interviewees might be different now, however all research questions and their implications are documented which is the most important thing.
- Though the research method is credible as the findings reported, the sample sizes limits some of the general assumptions here especially with the survey sample size, considering the number of farms in the UK.
- The recommendations made in this thesis are based on the evidence gathered, however, dynamics in the UK government policies may make some of the recommendations less valid.

8.5 FUTURE LINES OF ENQUIRY AND CLOSING REMARKS

Having addressed the research questions raised at the start of this research, and all the evidence documented in this thesis, the following lines of enquiry are opened for future research:

- *Digestate quality*: this research has identified digestate as the most important benefit of AD that can influence soil conservation, however, this research did not make any primary contribution to the issues surrounding digestate quality in soil conservation, thereby making this an important area of research.
- *Market for AD products*: availability of markets for AD products (digestate and biogas) have been identified as challenges to AD development in the UK, however this research did not address the issues of market for AD products, but rather provided information that can serve as a framework for such research.
- *Social media in environmental/agricultural research*: this thesis has documented a novel approach to surveying farmers, thereby exposing the opportunities that abound in social media for environmental and agricultural research.

- *Farmers' perception on agricultural technology, soil, sustainable agriculture and sustainable development*: while this may seem to be a duplication of this research, it is included as a future line of enquiry in view of the sample size documented in this thesis. A larger sample size will complement the findings here and make them more applicable and transferrable.

Closing remarks

This thesis has shown that if soil is to meet the challenges of rising food demand and consequential intensification of agricultural production, population growth and climate change, then more needs to be done to protect soils and minimise their degradation. Considering the importance of soils, this thesis has made clear the role of AD in achieving soil conservation and sustainable agriculture for overall sustainable development in the UK. A holistic approach and view is needed to integrate soil conservation into sustainable agriculture both in theory and practice and AD offers that opportunity, and this thesis can serve as a working document. AD in itself is faced with several challenges as documented in this thesis, but the evidence gathered in this thesis has systematically outlined how AD can help achieve soil conservation and sustainable agriculture, and how this can contribute to sustainable development in the UK. This thesis is by and large, therefore, an important document that will contribute to the actualisation of some of the 2015 sustainable development goals by 2030.

REFERENCES

Abdullahi, Y. A., Akunna, J. C., White, N. A., Hallet, P. D. & Wheatley, R. (2008). Investigating the effects of anaerobic and aerobic post-treatment on quality and stability of organic fraction of municipal solid waste as soil amendment. *Bioresource Technology*, 99: 8631-8636.

Adedokun, O. M., & Ataga A. E. (2007). Effect of amendments and bioaugmentation of soil polluted with crude oil, automotive gasoline, and spent engine oil on the growth of cowpea (*V. unguiculata*) L. walp. *Science Research Essay* 2(5): 147-149.

Adenipekun, C. O. (2008). Bioremediation of engine oil polluted soil by Pleurotus tuber-regium singer, a Nigerian white rot fungus. *African Journal of Biotechnology,* 7(1): 55-58.

Alburquerque, J. A., Fuente, C., Campoy, M., Carrasco, L., Najera, I., Baixauli, C., Caravaca, F., Roldan, A., Cegarra, J. & Bernal, M. P. (2012a). Agricultural use of digestate for horticultural crop production and improvement of soil properties, *European Journal of Agronomy*, Vol. 43: 119-128.

Alburquerque, J. A, Fuente, C. & Bernal, M. P. (2012b). Chemical properties of anaerobic digestates affecting C and N dynamics in amended soils. *Agriculture, Ecosystems and Environment*, 160: 15-22.

Allen Kani Associates and Enviros RIS Ltd (2001). *Implications of Different Waste Feed Streams (Source-Separated Organic and Mixed Waste) on Collection Options and Anaerobic Digestion Processing Facility Design, Equipment and Costs*. WDO Study, December 2001.
Available at: http://www.nerc.org/documents/toronto_report.pdf

Anon, K.A. (1989). *Sustainable development and natural resources management*, Conference Twenty-fifth Session. Rome: FAO

Astals, S., Nolla-Ardevol, V. & Mata-Alvarez, J. (2012). Anaerobic co-digestion of pig manure and crude glycerol at mesophilic conditions: Biogas and Digestate. *Bioresource Technology*, Vol. 110: 63-70.

Banks, C., Chesshire, M., & Stringfellow, A., (2008). A pilot-scale comparison of mesophilic and thermophilic digestion of source segregated domestic food waste. *Water Science and Technology*, Vol. 58: 1475-1481.

Barrow, C. J. (2006). *Environmental Management for Sustainable Development, 2nd edition*. London: Routeledge.

Beni, C., Servadio, P., Marconi, S., Neri, U., Aromolo, R. & Diana, G. (2012). Anaerobic Digestate Administration: Effect on Soil Physical and Mechanical Behavior. *Communications in Soil Science and Pant Analysis*, 43: 821-834. DOI: 10.1080/00103624.2012.648359

Bernard, R. (2006). Research Methods in Anthropology*;* cited in: Newing, H. (2011) *Conducting Research in Conservation.* London and New York: Routledge

Bi, L., & Haight, M. (2007). Anaerobic digestion and community development: A case study from Hainan province, china. *Environment, Development and Sustainability*, 9(4): 501-521. http://10.1007/s10668-006-9034-7

Birthal, P. S. (2013). Application of Frontier Technologies for Agricultural Development, *Indian Journal of Agricultural Economics*, *68*(1), 20-38.

Blanco-Canqui, H. & Lal, R. (2009). Crop Residue Removal Impacts on Soil Productivity and Environmental Quality. *Critical Review in Plant Science*, Vol. 28: 139-163. DOI: 10.1080/07352680902776507

Bo, L., Ting-xin, D., Zhi-ping, L., Lou-wei, M., Zhu-xuen, W. & An-xiu, M. (1993). Use of night soil in agriculture and fish farming. *World Health Forum*, Vol. 14: 67-70.

Boardman, J., Poesen, J. & Evans, R. (2003). Socio-economic factors is soil erosion and conservation. *Environmental Science & Policy*, Vol. 6: 1-6.

Boholm, Å. & Löfstedt, R. (Eds.) (2005). *Facility Siting: Risk, Power and Identity in Land-Use Planning*, London: Earthscan

Bohutskyi, P., Chow, S., Ketter, B., Betenbaugh, M. J., & Bouwer, E. J. (2015). Prospects for methane production and nutrient recycling from lipid extracted residues and whole *Nannochloropsis salina* using anaerobic digestion. *Applied Energy*, Vol. 15: 718-731.

Brady, N. C. & Weil, R. R. (2005). *The Nature and Properties of Soils, 13th edition*, India: Pearson Education.

Bridges, E. M. & Catizzone, M. (1996). Soil science in a holistic framework: discussion of an improved integrated approach, *Geoderma*, Vol. 71: 275-287.

Browne, J. D., Allen, E., & Murphy, J. D. (2013). Evaluation of the biomethane potential from multiple waste streams for a proposed community scale anaerobic digester. *Environmental Technology*, 34(13-16): 2027-2038. http://10.1080/09593330.2013.812669

Burek, C. V. (2005). England's first soil trail. *Earth Heritage*, Issue 24: 12.

Burek, C. V. & Prosser, C. D. (2008). *The History of Geoconservation.* The Geological Society, London, Special Publications, 300.

Burgess, P. J., & Morris, J. (2009). Agricultural technology and land use futures: The UK case, *Land Use Policy*, *26S*, S222-S229. http://10.1016/j.landusepol.2009.08.029

Burton, R. J. F., & Wilson, G. A. (1999). The Yellow pages as a Sampling Frame for Farm Surveys: Assessing Potential Bias in Agri-environmental Research, *Journal of Rural Studies*, *15*(1), 91-102.

Bywater, A. (2011). *A Review of Anaerobic Digestion Plants on UK Farms-Barriers, Benefits and Case Studies* A report prepared with financial support from the Frank Parkinson Agricultural trust. Warwickshire: RASE

Carvalho, M. & Lourenco, E. (2014). Conservation Agriculture- A Portuguese Case Study. *Journal of Agronomy and Crop Science*, Vol. 200: 317-324.

Cobb, D., Dolman, P. & O'Riordan, T. (1999). Interpretations of sustainable agriculture in the UK. *Progress in Human Geography*, 23, 2: 209-235.

Conway, J. S. (2010). A Soil Trail?- A Case Study from Anglesey, Wales, UK. *Geoheritage*, Vol. 2: 15-24.

Dagnall, S. (1995). UK Strategy for Centralised Anaerobic Digestion. *Bioresource Technology*, Vol. 52: 275-280.

DEFRA: Department for Environment, Food and Rural Affairs (2002) *The Strategy for Sustainable Farming and Food- Facing the Future*. London: DEFRA
Available at: http://archive.defra.gov.uk/foodfarm/policy/sustainfarmfood/documents/sffs.pdf

DEFRA: Department for Environment, Food and Rural Affairs (2011a). *Anaerobic Digestion Strategy and Action Plan- A commitment to increasing energy from waste through Anaerobic Digestion.* London: DEFRA
Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69400/anaerobic-digestion-strat-action-plan.pdf

DEFRA: Department for Environment, Food and Rural Affairs (2011b). *The Total Cost of Soil Degradation in England and Wales*. London: DEFRA

DEFRA: Department for Environment, Food and Rural Affairs (2012). *Anaerobic Digestion Strategy and Action Plan- Annual Report on Progress 2011/2012, July 2012*. London: DEFRA
Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69566/pb13788-ad-2012-progress.pdf

DEFRA: Department for Environment, Food and Rural Affairs (2015). *Organic Farming Statistics 2014*. London: DEFRA

DEFRA: Department for Environment, Food and Rural Affairs (2016). *Forecasts of Farm Business Income by Type of Farm in England- 2015/16*. London: DEFRA

Denscombe, M. (2008). Communities of practice: a research paradigm for the mixed methods approach. *Journal of Mixed Methods Research,* 2(3): 270-283.

DECC: Department of Energy & Climate Change (2010). *Feed-in Tariffs- Government's response to the Summer 2009 Consultation*. London: DECC.
Available at: http://www.fitariffs.co.uk/library/regulation/100201FinalDesign.pdf

DFID: Department for International Development (2004) *Agricultural Sustainability*. London: DFID. Available at: http://dfid-agriculture-consultation.nri.org/summaries/wp12.pdf

Duruiheoma, F. I., Burek, C., Bonwick, G., & Alexander, R. (2014). Raising Awareness of Anaerobic Digestion in the UK- Views of Key Stakeholders. *Journal of Environment and Ecology*, 5(2), 258-275.

Duruiheoma, F. I., Burek, C., Bonwick, G., & Alexander, R. (2015a). The role of anaerobic digestion in achieving soil conservation and sustainable agricultural development in the UK. *Journal of Environment and Ecology* (2015), Vol. 6 (2): 13-37.

Duruiheoma, F. I., Burek, C., Bonwick, G., & Alexander, R. (2015b). Farmers' Perception of Soil: Implications for Soil Conservation and Sustainable Agriculture in the UK. *Global Journal of Agricultural Research*, Vol. 3(3): 11-24.

Duruiheoma, F. I., Burek, C., Bonwick, G., & Alexander, R. (2015c). Farmers' Interest in Agricultural Technology and Organic Farming: Implications for AD Adoption and Sustainable Agriculture in the UK. *Environmental Management and Sustainable Development* (2015), Vol. 4(1): 242-263.

Easterby-Smith, M., Thorpe, R. & Lowe, A. (2002). *Management Research- An Introduction*, 2nd edition. London, Thousand Oaks, New Delhi: SAGE

EC: European Commission (2006). *The Thematic Strategy for Soil Protection*. Communication from the commission to the council, the European Parliament, The European Economic and Social Committee and The Committee of The Regions. Brussels: EC

EC: European Commission (2015). Soil. Brussels: EC, available at: http://ec.europa.eu/environment/soil/index_en.htm

El-Swaify, S. A. (1994). State of the art for assessing soil and water conservation needs and technologies, cited In: Morgan, R. P. C. (2005) *Soil Erosion and Conservation, 3rd edition*, Oxford: Blackwell publishing

European Commission Directive (2008/98/EC), cited In; Alburquerque, J. A., Fuente, C., Campoy, M., Carrasco, L., Najera, I., Baixauli, C., Caravaca, F., Roldan, A., Cegarra, J. and Bernal, M. P. (2012) Agricultural use of digestate for horticultural crop production and improvement of soil properties, *European Journal of Agronomy*, Vol. 43: 119-128.

FAO: Food and Agriculture Organization (2002). *Soil Biodiversity and Sustainable Agriculture*. Paper prepared as a background paper for the Ninth regular Session of the Commission on Genetic Resources for Food and Agriculture (CGRFA) FAO-Rome, 14-18 October 2002. Rome: FAO. Available at: http://www.fao.org/fileadmin/templates/nr/images/resources/pdf_documents/CGRFA_SoilBiodSustAg.doc

Farmers Weekly (2012). *What is sustainable agriculture?* Rural Living Articles, Monday 16 April 2012 [Online Resource] Available at: http://www.fwi.co.uk/articles/16/04/2012/132441/what-is-sustainable-agriculture.htm#.UdAhBPl4LWg

Farming Futures (2009). Climate Change: be part of the solution; Focus on: farm anaerobic digestion. *Fact Sheet*, Vol. 17. Available at: http://www.farmingfutures.org.uk/sites/default/files/casestudy/pdf/FF_FS17_REV_OCT09[4].pdf

Field, A. P. (2009). *Discovering statistics using SPSS: And sex and drugs and rock 'n' roll, 3rd edition.* London: SAGE.

Fowler, C. (2010). Conserving Diversity: The Challenge. *Global Crop Diversity Trust*, Rome: FAO

FRAC: Food Research and Action Center (2011). *Food Insecurity and Obesity: Understanding the Connections*. Spring 2011 Brief: Washington: FRAC. Available at: http://frac.org/pdf/frac_brief_understanding_the_connections.pdf

Frith, P. & Gilbert, J. (2011). Anaerobic Digestion Evidence Availability and Gap Analysis *Report to Defra*, project number WR1311.

Ganidi, N., Tyrrel, S. and Cartmell, E. (2009). Anaerobic digestion foaming causes- A review. *Bioresource Technology*, Vol. 100: 5546-5554.

Gasson, R. (1998). Educational attainment levels of UK farmers- a review, *European*

Journal of Agricultural Education and Extension, *4*(4), 231-243. http://dx.doi.org/10.1080/1389224988530006

Glenna, L. L., Jussaume, R. A., & Dawson, J. C. (2011). How farmers matter in shaping agricultural technologies: social and structural characteristic of wheat growers and wheat varieties, *Agriculture and Human Values*, *28,* 213-224. http://10.1007/s10460-010-9275-9

Godfray, H. C. J. (2015). The debate over sustainable intensification. *Food Security*, Vol. 7: 199-208.

Golusin, M., Ivanovic, O. M. & Teodorovic, N. (2011). The review of the achieved degree of sustainable development in South Eastern Europe- The use of linear regression method. *Renewable and Sustainable Energy Reviews*, Vol. 15: 766-772.

Gordon, J.E., Gubbins, N., Taylor, A.G. & McKirdy, A.P. (1995). Soils and Sustainability: A Natural Heritage Perspective. In: Taylor, A.G., Gordon, J.E. and Usher, M.B., (eds) (1996) *Soils, sustainability and the Natural Heritage.* Scottish Natural Heritage, Edinburgh: HMSO

Gorp, B., & Goot, M. J. (2012). Sustainable Food and Agriculture: Stakeholder's Frames, *Communication, Culture & Critique*, *5*, 127-148. http://10.1111/j.1753-9137.2012.01135.x

Granstedt, A. (2011). On Farm Biogas production with solid manure in organic farming. *Evaluation of the two stage dry anaerobic biogas plant production and recycling on Skilleby experimental farm in Jarna 2004-2010, Final report December 2011*.

Greene, J. C. (2006). Toward a Methodology of Mixed Methods Social Inquiry. *Research in The Schools,* Vol. 13, No. 1: 93-98.

Greene, J. C. (2008). Is mixed methods social inquiry a distinctive methodology? *Journal of Mixed Methods Research,* 2(1): 7-22.

Gruhn, P., Goletti, F. & Yudelman, M. (2000). Integrated nutrient management, soil fertility and sustainable agriculture: current issues and future challenges. *Food, Agriculture and the Environment Discussion paper 32*, Washington: International Food Policy Research Institute

Hannam, I. (1999). Ecologically Sustainable Soil: The Role of Environmental Policy and Legislation, In: Stott, D. E., Mohtar, R. H. & Steinhardt, G. C. (eds.) (2001) *Sustaining the Global Farm.* Selected papers from the 10th International Soil Conservation Organization Meeting held May 24-29, 1999 at Purdue University and the USDA~ARS National Soil Erosion Research Laboratory.

Hannam, I. & Boer, B. (2002). *Legal and Institutional Frameworks for Sustainable Soils: A Preliminary Report*. Gland, Switzerland and Cambridge, UK: IUCN. xvi + 88 pp.

Hannam, I. D. (2004). Progress Towards an Improved International and National Legal Strategy for Sustainable Use Of Soil: Partnership Between the Soil Science Community and The World Conservation Union. *ISCO 2004-13th International Soil Conservation Conference- Brisbane, July 2004.* Conserving soil and Water for Society: Sharing Solutions.

Hannam, I. & Boer, B. (2004). *Drafting Legislation for Sustainable Soils: A Guide.* Gland, Switzerland and Cambridge, UK: IUCN. x + 100 pp.

Hannam, I. & Boer, B. (2012). RIO+20: What Ambition for the Environment? *A Background Paper for World Conservation Congress IUCN commission on Environmental Law Workshop on a Soil Convention, 6 September 2012- Third Worldwide Conference of Environmental Law NGO and Lawyers*. Gland, Switzerland and Cambridge, UK: IUCN.
Available at: https://portals.iucn.org/2012forum/sites/2012forum/files/paper-soil-protocol-cidce-limoges-rio-20-symposium-final-25-august-2011-1.pdf

Hartemink, A., & van Keulen, H. (Eds.) (2005). Soil degradation in Sub-Saharan Africa; In: Ingram, J. and Morris, C. (2007) The knowledge challenge within the transition towards sustainable soil management: An analysis of agricultural advisors in England. *Land Use Policy*, 24: 100-117.

Hartridge, O. & Pearce, D. (2001). *Is UK Agriculture Sustainable? Environmentally Adjusted Economic Accounts for UK Agriculture.* CSERGE-Economics, University College London. Available at: http://www.cserge.ucl.ac.uk/AGNNP.FINALFINAL.pdf

Harris, F., Robinson, G. M. & Griffiths, I. (2007). A Study of the Motivations and Influences on Farmers' Decisions to leave Organic Farming Sector in the United Kingdom, In: Robinson, G. M. (ed.) (2008) *Sustainable Rural Systems: Sustainable Agriculture and Rural Communities- perspective on rural policy and planning*, Ashgate publishing.

Harris, F., Lyon, F. &s Clarke, S. (2008). Doing interdisciplinary: motivation and collaboration in research for sustainable agriculture in the UK. *Area*, Vol. 41, No. 4: 374-384.

Harwood, J. (2013). Can agricultural technology be 'peasant-friendly'? *Appropriate Technology*, *40*(2), 17-18.

Haygarth, P. M. & Ritz, K. (2009). The future of soils and land use in the UK: Soil systems for the provision of land-based ecosystem services. *Land Use Policy*, Vol. 26S: S187-S197.

HDRA: Henry Doubleday Research Association (1998). *What is Organic Farming?* Coventry: HDRA. Available at: http://www.infonet-biovision.org/res/res/files/488.OrgFarm.pdf

Hole, D. G., Perkins, A. J., Wilson, J. D., Alexander, I. H., Grice, P. V., & Evans, A. D. (2005). Does organic farming benefit biodiversity? *Biological Conservation*, *122*, 113-130.

Hudson, N. (1995). *Soil Conservation, 3rd edition.* Ames: Iowa State University Press

Hollister E.B., Forrest, A.K., Wilkinson, H.H., Ebbole, D.J., Tringe, S.G., Malfatti, S. A., Holtzapple, M. T., & Gentry, T. J. (2012). Mesophilic and Thermophilic Conditions Select for Unique but Highly Parallel Microbial Communities to Perform Carboxylate Platform Biomass Conversion. *PLoS ONE* 7(6): e39689. doi:10.1371/journal.pone.0039689

Ingram, J. & Morris, C. (2007). The knowledge challenge within the transition towards sustainable soil management: An analysis of agricultural advisors in England. *Land Use Policy*, Vol. 24: 100-117.

Ingram, J. (2008). Are farmers in England equipped to meet the knowledge challenge of sustainable soil management? An analysis of farmer and advisor views, *Journal of Environmental Management*, Vol. 86: 214-228

Ingram, J., Fry, P. & Mathieu, A. (2010). Revealing different understandings of soil held by scientists and farmers in the context of soil protection and management, *Land Use Policy*, 27, 51-60.

Ivanovic, O. D. M., Golusin, M. T., Dodic, S. N. and Dodic, J. M. (2009). Perspectives of sustainable development in countries of Southeastern Europe, *Renewable and Sustainable Energy Review,* Vol. 13: 2079-2087.

Johansen, A., Carter, M. S., Jensen, E. S., Hauggard-Nielsen, H. & Ambus, P. (2013). Effects of digestate from anaerobically digested cattle slurry and plant materials on soil microbial community and emission of CO_2 and N_2O. *Applied Soil Ecology,* Vol. 63: 36-44.

Juned, S., Woollacott, M., Bywater, A., & Alcock, R. (2014). *Refuelling the Countryside- The prospects for low carbon farm and rural transport fuels*. Warwickshire: RASE

Juniper (2007). *Commercial Assessment Anaerobic Digestion Technology for Biomass Projects*. Prepared by Juniper for Renewable East, BIOREGEN, Juniper Consultancy Services Ltd June 2001. Available at: http://www.biomassenergycentre.org.uk/pls/portal/docs/PAGE/RESOURCES/REF_LIB_RES/PUBLICATIONS/GUIDANCE/RENEWABLES%20EAST%20-%20ANAEROBIC%20DIGESTION%20(FULL%20REPORT).PDF

Karltun, E., Lemenih, M. & Tolera, M. (2013). *Comparing Farmers' Perception of Soil Fertility Change with Soil Properties and Crop performance in Beseku*, *Ethiopia*, Land Degradation & Development, 24, 228-235.

Khan, J. (2002). Siting conflicts in renewable energy projects: A biogas case study, cited in; Å. Boholm and R. Löfstedt (Eds.) (2005) *Facility Siting: Risk, Power and Identity in Land-Use Planning*, London: Earthscan

Khanif, Y. M. (2010). Improvement of soil carrying capacity for better living. *J. ISSAAS*, Vol. 16, No. 1: 1-7.

Kim, W., Lee, S., Lee, C., Shin, S. G., Hwang, S., & Hwang, K. (2010). Methanogenic community shift in anaerobic batch digesters treating swine wastewater. *Water Research,* 44(17), 4900-4907. http://dx.doi.org/10.1016/j.watres.2010.07.029

Kings, D. (2014). Farmers' Understanding of Weeds and Herbicide Usage as Environmental Influences on Agricultural Sustainability, *Journal of Environmental Protection*, 5, 923-935.

Kumar, R. (2011). *Research Methodology- a step-by-step guide for beginners, 3rd edition* London, Thousand Oaks, New Delhi: SAGE

Kumaran, P., Hephzibah, D., Sivasankari, R., Saifuddin, N. & Shamsuddin, A. H. (2016). A review on industrial scale anaerobic digestion systems deployment in Malaysia: Opportunities and challenges. *Renewable and Sustainable Energy Reviews*, Vol. 56: 929-940.

Lacovidou, E., Ohandja, D. & Voulvoulis, N. (2012). Food waste co-digestion with sewage sludge – Realising its potential in the UK. *Journal of Environmental Management*, 112: 267-274.

Lal, R. (2010). A dual response of conservation agriculture to climate change: reducing CO_2 emissions and improving the carbon sink. *Proceedings of the European Congress on Conservation Agriculture*. *Towards agro-environmental climate and energetic sustainability*, Madrid, Spain, page 3-19.

Lampkin, N. (2002). *Organic Farming*. Ipswich: Old Pond

Lawson, T. (2010). Overview of Anaerobic Digestion and Digesters. *North East Biogas; Clean Energy for Life.* New York: Environmental Protection Agency (EPA) Available at: http://www.epa.gov/region2/webinars/pdfs/3-24-10_1.pdf

Leaver, J. D. (2011). Global food supply: a challenge for sustainable agriculture. *Nutrition Bulletin*, Vol. 36: 416-461.

Lei, B. & Haight, M. (2007). Anaerobic Digestion and Community Development: A Case Study from Hainan Province, China. *Environmental Development Sustainability*, Vol. 9: 501-921.

Lucas, F. S., Therial, C., Gonclaves, A., Servais, P., Rocher, V. & Mouchel, J. M. (2014). Variation of raw wastewater microbiological quality in dry and wet weather conditions. *Environ Sci. Pollution Res Int.* Vol. 21(8): 5318-28.

Lukehurst, C., (2007). Esbjerg—Denmark, AD on the move—United Kingdom 2007, cited in: Zglobisz, N., Castillo-Castillo, A., Grimes, S. and Jones, P. (2010) Influence of UK energy policy on the deployment of anaerobic digestion. *Energy Policy*, vol. 38: 5988-5999. http://dx.doi.org/10.1016/j.enpol.2010.05.054

Madey, D. L. (1982). Some benefits of integrating qualitative and quantitative methods in program evaluation, with some illustrations; cited In: Onwuegbuzie, A. J. & Leech, N. L. (2005) On Becoming a Pragmatic Researcher: The Importance of Combining Quantitative and Qualitative Research Methodologies. *Int. J. Social Research Methodology*, Vol. 8, No. 5: 375-387.

Mainero, D. (2012). Integrated anaerobic-aerobic systems for solid waste treatment. *Rev Environ Sci Biotechnology*, 11: 343-352. DOI 10.1007/s11157-012-9300-0

Mao, C., Feng, Y., Wang, X., & Ren, G. (2015). Review on research achievements on biogas from anaerobic digestion. *Renewable and Sustainable Energy Review*, Vol.45: 540-555.

Mcolivers, J. U. (1984). Productivity of arable lands associated with contamination of crude-oil. *American Society of Agronomy*, Madison WL pp 89-113.

Meester, S., Demeyer, J., Velghe, F., Peene, A., Langenhove, H., & Dewulf, J. (2012). The environmental sustainability of anaerobic digestion as a biomass valorization technology. *Bioresource Technology*, 121: 396-403

Minten, B., & Barrett, C. B. (2008). Agricultural Technology, Productivity, and Poverty in Madagascar, *World Development*, *36*(5), 797-822. http://10.1016/j.worlddev.2007.05.004

Mog, J. M. (2004). Struggling with Sustainability- A comparative Framework for Evaluating Sustainable Development Programs. *World Development*, Vol. 32, no.12: 2139-2160.

Moller, K. (2015). Effects of anaerobic digestion on soil carbon and nitrogen turnover, N emission, and soil biological activity. A review. *Agronomy for Sustainable Development*, Vol. 35 (3): 1021-1041.

Monnet, F. (2003). An Introduction to Anaerobic Digestion of Organic Wastes. *Final report.* EU: Biogasmax Available at: http://www.biogasmax.eu/media/introanaerobicdigestion__073323000_1011_24042007.pdf

Morgan, R. P. C. (2005). *Soil Erosion and Conservation, 3rd edition,* Oxford: Blackwell publishing

Morgan, D. L. (2007). Paradigms Lost and Pragmatism Regained: Methodological Implications of Combining Qualitative and Quantitative Methods. *Journal of Mixed Methods Research*, Vol. 1, No. 1: 48-76.

Motte, J, Trably, E., Escudie, R., Hamelin, J., Steyer, J., Bernet, N., Delgenes, J. & Dumas, C. (2013). Total solids content: a key parameter of metabolic pathways in dry anaerobic digestion. *Biotechnology for Biofuels*, 6: 164.

Naroznova, I., Moller, J., Larsen, B. & Scheutz, C. (2016). Evaluation of a new pulping technology for pre-treating source-separated organic household waste prior to anaerobic digestion. *Waste Management*, Vol. 50: 65-74.

National Statistics (2012). *Agriculture in the United Kingdom*. National Statistics

Newing, H. (2011) *Conducting Research in Conservation.* London and New York: Routledge

Nkegbe, P. K. (2013). Soil Conservation and Smallholder Farmer Productivity: An Analytical Approach, *Journal of Management and Sustainability*, 3(2), 92-99.

NNFCC: National Non-Food Crops Centre (2011). *Farm-Scale Anaerobic Digestion Plant Efficiency*. York: NNFCC

NNFCC: National Non-Food Crops Centre (2015). *Anaerobic Digestion Deployment in the United Kingdom, 2nd annual report*. York: NNFCC

Ofgem (2011). *Renewables Obligation: Guidance for generators*. Ofgem E-Serve, May 2011. London: Ofgem. Available at: https://www.ofgem.gov.uk/ofgem-publications/58150/ro-generator-guidance-may-2011-final.pdf

Ofgem (2013). *Feed-in Tariff Payment Rate Table for Non-Photovoltaic Eligible Installations for FIT Year 4 (1 April 2013 to 31 March 2014)*. Ofgem E-Serve. London: Ofgem.
Available at: https://www.ofgem.gov.uk/ofgem-publications/58940/fit-tariff-table-1-april-2013-non-pv-only.pdf

Ogaji, J. (2005). Sustainable Agriculture in The UK. *Environment, Development and Sustainability*, 7: 253-270.

Onwuegbuzie, A. J. & Leech, N. L. (2005). On Becoming a Pragmatic Researcher: The Importance of Combining Quantitative and Qualitative Research Methodologies. *Int. J. Social Research Methodology*, Vol. 8, No. 5: 375-387.

Onwuegbuzie, A. J., Johnson, R. B. & Collins, K. M. T. (2011). Assessing legitimation in mixed Research: a new framework. *Qual Quant*, Vol. 45: 1253-1271.

Opdenakker, R. (2006). Advantages and Disadvantages of Four Interview Techniques in Qualitative Research. *Forum: Qualitative Social Research*, vol. 7(4), Art. 11.

Pallant, J. (2013). *SPSS survival manual: A step by step guide to data analysis using SPSS, 5th edition*. Maidenhead: Open University Press/McGraw-Hill Education.

Pamuk, H., Bulte, E., & Adekunle, A. A. (2014). Do decentralized innovation systems promote agricultural technology adoption? Experimental evidence from Africa, *Food Policy, 44*, 227-236. http://dx.doi.org/10.1016/j.foodpol.2013.09.015

Pansiri, J. (2005). Pragmatism: A Methodological Approach to Research Strategic Alliance in Tourism. *Tourism and Hospitality Planning & Development*, Vol. 2, No. 3:191-206.

Perez, I., Garfi, M., Cadena, E., & Ferrer, I. (2014). Technical, economic and environmental assessment of household biogas digesters for rural communities, *Renewable Energy*, 62: 313-318. http://dx.doi.org/10.1016/j.renene.2013.07.017

POST: Parliamentary Office of Science and Technology (2006). UK Soil Degradation. *Postnote, No. 265*, London: POST

POST: Parliamentary Office of Science and Technology (2011). Anaerobic Digestion. *Postnote, No. 387*, London: POST

POST: Parliamentary Office of Science and Technology (2015). Securing UK Soil Health. *Postnote, No. 502*, London: POST

Purdy, R. (2011). Attitudes of UK and Australian farmers towards monitoring activity with satellite technologies: Lessons to be learnt, *Space Policy*, *27*, 202-212. http://10.1111/j.1477-9552.2010.00272.x

Richard, K. M. & Simms, R. (1986). The potential for biogas on farms in the UK, In: Dagnall, S. (1995). UK Strategy for Centralised Anaerobic Digestion. *Bioresource Technology*, Vol. 52: 275-280.

REA Biogas: Renewable Energy Association Biogas (2013). *Increasing Deployment of Small-Scale, On-farm Anaerobic Digestion Plants.* Small scale AD Roundtable Background paper, April 29, 2013. London: REA
Available at: http://www.biogas.org.uk/images/upload/events_51_Small-scale-AD-Roundtable-background-paper-v4-1.pdf

Reed, M. (2009). For whom? – The governance of organic food and farming in the UK, *Food Policy*, *34*(3), 280-286. http://10.1016/j.foodpol.2009.03.003

Rigby, D., & Caceres, D. (2001). Organic farming and the sustainability of agricultural systems, *Agricultural Systems*, *68*, 21-40.

Riley, M. (2009). Bringing the 'invincible farmer' into sharper focus: gender relations and agricultural practices in the Peak District (UK), *Gender, Place and Culture*, *16*(6), 665-682. http://10.1080/09663690903279138

Ritz, K. (2008). Soil as a paradigm of complex system; In: Haygarth, P. M. and Ritz, K. (2009) The future of soils and land use in the UK: Soil systems for the provision of land-based ecosystem services. *Land Use Policy*, Vol. 26S: S187-S197.

Robinson, G. M. (2008). Sustainable Rural Systems: An Introduction, In: Robinson, G. M. (ed.) *Sustainable Rural Systems: Sustainable Agriculture and Rural Communities- perspective on rural policy and planning*, Ashgate publishing.

Robertson, G. A. (2001). Soil management for sustainable agriculture, *Resource Management Technical Report No. 95*, government of Western Australia

Rogers, P. P., Jalal, K. F. & Boyd, J. A. (2008). *An Introduction to Sustainable development*. UK and USA: Earthscan

Rowell, D.M., Prescott, C.E., & Preston, C.M., (2001). Decomposition and nitrogen mineralization from biosolids and other organic materials: relationship with initial chemistry; In: Tambone, F., Scaglia, B., D'Imporzano, G., Schievano, A., Orzi, V., & Adani, S. F. (2010) Assessing amendment and fertilizing properties of digestates from anaerobic digestion through a comparative study with digest sludge and compost. *Chemosphere*, Vol. 81: 577-583.

Rushemuka, N. P., Bizoza, R. A., Mowo, J. G. & Bock, L. (2014). Farmers' soil knowledge for effective participatory integrated watershed management in Rwanda: Toward soil-specific fertility management and farmers judgemental fertilizer use, *Agriculture, Ecosystems and Environment*, 183, 145-159.

Sachs, C. E. (1983). The invisible farmers: women in agricultural production, In: Riley, M. (2009) Bringing the 'invincible farmer' into sharper focus: gender relations and agricultural practices in the Peak District (UK), *Gender, Place and Culture*, *16*(6), 665-682. http://10.1080/09663690903279138

Satihal, D. G., Vaikunthe, L. D. & Bhargava, P. K. (2007). Impact of Population Growth on Agricultural Land Utilization in Karnataka, India. *Princeton Papers* Available at: http://uaps2007.princeton.edu/papers/70762

Schoon, B., & Grotenhuis, R. (2000). Values of Farmers, Sustainability and Agricultural Policy, *Journal of Agricultural and Environmental Ethics*, *12*, 17-27.

Scottish Government (2009). *The Scottish Soil Framework.* Edinburgh: Scottish Government.
Available at: http://www.scotland.gov.uk/Resource/Doc/273170/0081576.pdf

Schiermeier, Q. (2013). Farmers dig into soil quality, *Nature*, vol. 502, 607.

Schloter, M., Dilly, O., & Munch, J. C. (2003). Indicators for evaluating soil quality. *Agriculture, Ecosystems and Environment*, Vol. 98: 255-262.

Schneider, F, Ledermann, T., Fry, P. & Rist, S. (2010). Soil conservation in Swiss agriculture-Approaching abstract and symbolic meanings in farmers' life-worlds, *Land Use Policy*, 27, 332-339.

Seadi, T. & Lukehurst, C. (2012). *Quality management of digestate from biogas plants used as fertiliser*. IEA Bioenergy: Task 37-Enrgy from Biogas.

Sharma, A., Bailey A., & Fraser, I. (2011). Technology Adoption and Pest Control Strategies among UK Cereal Farmers: evidence from Parametric and Nonparametirc Count Data Models, *Journal of Agricultural Economics*, *62*(1), 73-92. http://10.1111/j.1477-9552.2010.00272.x

SNIFFER (2008). Strategic Environmental Assessment DRAFT- Practical Guidance for Practitioners on How to Take Account of Soil, *SECTION 2- SOIL*, Edinburgh: SNIFFER

Soil Association (2013). *Organic market report 2013*. Soil Association, Bristol, Edinburgh: Triodos Bank.

Sørensen, P. & Møller, H.B. (2009). Fate of nitrogen in pig and cattle slurries applied to the soil-crop system, In; Tambone, F., Scaglia, B., D'Imporzano, G., Schievano, A., Orzi, V., & Adani, S. F. (2010) Assessing amendment and fertilizing properties of digestates from anaerobic digestion through a comparative study with digest sludge and compost. *Chemosphere*, Vol. 81: 577-583.

Staat, H., Jansen, L., & Thogersen, J. (2011). Greening the greenhouse grower. A behavioural analysis of a sector-initiated system to reduce the environmental load of greenhouses. *Journal of Environmental Management*, 92: 2461-2469.

Stott, D. E., Mohtar, R. H. & Steinhardt, G. C. (eds.) (2001) *Sustaining the Global Farm.* Selected papers from the 10th International Soil Conservation Organization Meeting held May 24-29, 1999 at Purdue University and the USDA~ARS National Soil Erosion Research Laboratory.

Stone, B. (1998). Developments in Agricultural Technology, *The China Quarterly*, *116*, 767-822. http://10.1017/S0305741000037954

Sudha, S. C. R. (2015). Investment, adoption, attitude and extent of participation of farmers in soil conservation projects in Western Ghats of India, *International Journal of Social Economics*, 42(3), 251-275.

Surendra, K. C., Takara, D., Jasinski, J., & Khanal, S. K. (2013). Household anaerobic digester for bioenergy production in developing countries: Opportunities and challenges. *Environmental Technology*, 34(13-16): 1671-1689. http://10.1080/09593330.2013.824012

SWEA: Severn Wye Energy Agency (2011). Country Specific Conditions and Barriers to Implementation for Anaerobic Digestion Plants in England and Wales. *Promotion of bio-methane and its market development through local and regional partnerships, A project under the Intelligent Energy- Europe programme.* Available at: http://www.swea.co.uk/Bio-methaneRegions/downloads/framework_EW.pdf

Swindal, M. G., Gillespie, G. W., & Welsh, R. J. (2010). Community digester operations and dairy farmer perspectives. *Agriculture and Human Values*, 27(4): 461-474. http://10.1007/s10460-009-9238-1

Tambone, F., Scaglia, B., D'Imporzano, G., Schievano, A., Orzi, V., & Adani, S. F. (2010). Assessing amendment and fertilizing properties of digestates from anaerobic digestion through a comparative study with digest sludge and compost. *Chemosphere*, Vol. 81: 577-583.

Taylor, A.G., Gordon, J.E. 7 Usher, M.B., [Eds] (1996). *Soils, sustainability and the Natural Heritage.* Scottish Natural Heritage, Edinburgh: HMSO

Tesfahunegn, G. B., Tamene, L. & Vlek, P. L. G. (2011). Evaluation of soil quality identified by local farmers in Mai-Negus catchment, northern Ethiopia, *Geoderma*, 162, 209-218.

Tesfaye, A., Negatu, W., Brouwer, R. & Van Der Zaad, P. (2014). Understanding Soil Conservation Decision of Farmers in the Gedeb Watershed, Ethiopia, *Land Degradation & Development*, 25, 71-79.

Thomsen, I. K., Olesen, J. E., Moller, H. B., Sorensen, P. & Christensen, B. T. (2013). Carbon dynamics and retention in soil after anaerobic digestion of dairy cattle feed and faeces. *Soil Biology & Biochemistry*, Vol. 58: 82-87.

Tiffin, R., & Balcombe, K. (2011). The determinants of technology adoption by UK farmers using Bayesian model averaging: the cases of organic production and computer usage, *The Australian Journal of Agricultural and Resources Economics*, *55*, 579-598. http://10.1111/j.1467-8489.2011.00549.x

Towers, W., Malcolm, A. & Bruneau, P.M.C (2005). Assessing the nature conservation value of soil and its relation with designated features, *Scottish Natural Heritage Commissioned Report No. 111 (ROAME No. F03AC104).*

Tranter, R. B., Swinbank, A., Jones, P. J., Banks, C. J., & Salter, A. M. (2011). Assessing the potential for the uptake of on-farm anaerobic digestion for energy production in England, *Energy Policy*, vol. 39: 2424-2430

United Nations (2001). *Indicators of Sustainable Development: Guidelines and Methodologies.* Division for Sustainable Development. New York and Geneva: UN

United Nations (2004). *World Population to 2300*. Department of Economic and Social Affairs, Population Division, New York: UN

United Nations (2013). *World population prospects, the 2012 revision.* Department of Economic and Social Affairs, Population Division, New York: UN

Uri, N. D. & Lewis, J. A. (1998). The dynamics of soil erosion in US agriculture, In: Morgan, R. P. C. (2005) *Soil Erosion and Conservation, 3rd edition,* Oxford: Blackwell publishing

Vaneeckhaute, C., Meers, E., Michels, E., Buysse, J., & Tack, F.M.G. (2013). Ecological and economic benefits of the application of bio-based mineral fertilizers in modern agriculture. *Biomass and Bioenergy*, Vol. 49; 239-248.

Wahyuni, D. (2012). The Research Design Maze: Understanding Paradigms, Cases, Methods and Methodologies. *JAMAR*, Vol. 10, No. 1: 69-80.

Wallace, P., Frederickson, J., Chambers, B., Taylor, M., Longhurst, P., Tyrrell, S., Gale, P., Goddard, A. & Litterick, A. (2011). *Digestates: Realising the fertiliser benefits for crops and grassland.* Guidance document: Wrap (Cymru)

WCED: World Commission on Environment and Development (1987). *Our Common Future*. Brundtland report. Oxford: Oxford University Press for WCED.

White, P. J., Crawford, J. W., Alvarez, M. C. D., & Moreno, R. G. (2014). Soil Management for Sustainable Agriculture 2013. *Applied and Environmental Soil Science* (Editorial).

Wilkinson, K. G. (2011) A comparison of the drivers influencing adoption of on-farm anaerobic in Germany and Australia *Biomass and Bioenergy*, vol. 35: 1613-1622

WinklerPrins, A. M. G. A. & Sandor, J. A. (2002). Local soil knowledge: insights, applications and challenges, *Geoderma*, 111, 165-170.

Wood, B. M., Jader, L. R., Schendel, F. J., Hahn, N. J., Valentas, K. J., McNamara, P. J., Novak, P. M., & Heilmann, S. M. (2013). Industrial symbiosis: Corn ethanol fermentation, hydrothermal carbonization, and anaerobic digestion. *Biotechnology and Bioengineering*, 110(10), 2624-2632. doi:10.1002/bit.24924

Yeatman, C. O. (2006). *The Profitable use of Anaerobic Digestion (AD) on UK Farms*. A 2005/2006 Nuffield Farming Scholarship Study. Available at: http://www.nuffieldinternational.org/rep_pdf/1226661015Yeatman,_Owen.pdf

Yin, R. K. (2003). *Case study research: Design and methods 3rd edition*. Thousand Oaks: Sage

Zglobisz, N., Castillo-Castillo, A., Grimes, S. & Jones, P. (2010). Influence of UK energy policy on the deployment of anaerobic digestion. *Energy Policy*, vol. 38: 5988-5999.

APPENDICES

APPENDIX 1

Interview Questions

1. How can we ensure that the benefits of AD technology are shared by everyone?
2. How can the understanding of AD technology be enhanced by all those associated with AD facilities?
3. Why are community AD and localism an important part of the UK's AD strategy and action plan?
4. How can we promote community AD projects in view of sustainable development goals?
5. What are those factors that influence farmers' attitudes towards new technologies?
6. What are the barriers to on-farm AD plants?
7. How can we make AD more attractive to farmers other than the use of incentives?
8. How can we ensure that biogas generated from AD plants is diversified in their use?
9. Do you consider small AD plants as integral to raising awareness for AD?
10. Why is soil conservation not often considered top priority among natural resource conservation when compared to biodiversity and geodiversity?
11. How can we ensure that sustainable agriculture takes soil conservation into account?
12. Are current sustainable agricultural practices in the UK in line with sustainable development goals?
13. To what extent can digestate from AD plants promote the conservation of soils?
14. What is your opinion about current regulatory framework for AD plants?
15. How can we make policies reduce risk and promote access to finance for AD plants of all scales from banks and other finance houses?
16. How can we promote the conservation of soils among farmers?

APPENDIX 2

Survey Questionnaire

1. Pleas indicate your gender, Male ☐ Female ☐
2. Age (Please tick), Less than 30☐ 30-40 ☐ 41-50 ☐ 51-60 ☐ 61-70 ☐ above 70 ☐
3. What type of farm do you have? (please tick)
   I. Arable farm ☐
   II. Livestock farm (Dairy and meat) ☐
   III. Mixed (arable and livestock) ☐
   IV. Horticulture ☐
   V. Other ☐ Please specify . . . .
4. Please indicate your level of education
   I. GCSE or equivalent ☐
   II. A levels or equivalent ☐
   III. Diploma ☐
   IV. Degree ☐
   V. Postgraduate degree ☐
   VI. Other ☐
5. Are you the farm Owner ☐ Manager ☐ Tenant ☐ Other☐ please specify……………
6. What is your farm size? Less than 30ha☐ 30-60ha☐ 61-90ha ☐ above 90ha ☐
7. Would you say your farm is an upland☐ or lowland ☐ farm?
8. In which county is your farm located? . . . .
9. How familiar are you with concept of sustainable development? (Please tick)
   I. Very familiar ☐
   II. Familiar ☐
   III. Heard of but could not explain ☐
   IV. Never heard of ☐
10. Do you know what sustainable agriculture means? Yes ☐ No ☐
11. Do you practice organic farming? Yes ☐ No ☐
12. How would you describe the profitability of your farm? (Please tick)
    I. Increasing ☐
    II. Decreasing ☐
    III. Neither increasing nor decreasing ☐

13. What do you do with your farm waste? . . . .

14. What 4 key words would you use to describe soils?

1.	2.
3.	4.

15. Are you aware of the benefits of soils other than crop production? Yes☐ No ☐

16. How familiar are you with soil conservation? (Please tick)

I. Very familiar ☐

II. Familiar ☐

III. Heard of but could not explain ☐

IV. Never heard of ☐

17. Should soils be protected like other natural resources? Yes ☐ No ☐

18. Do you think organic fertilizers are good for soils? Yes ☐ No ☐

19. How would you rate your overall interest in agricultural technologies? (Please tick)

I. Very low ☐

II. Low ☐

III. Medium ☐

IV. High ☐

V. Very high ☐

20. Do you know what Anaerobic Digestion (AD) is? Yes ☐ No ☐ If 'No' please go to question 23

21. Are you interested in such technologies as AD? Yes ☐ No ☐ If 'No' please state why

. . . .

22. If AD can improve your soil properties will you be keen on investing in it? Yes ☐ No ☐ Neither yes or no ☐

23. Which of these factor(s) will attract you to use a particular technology for your farming? Please tick as many as applicable

I. Affordability of the technology ☐

II. Knowledge of its benefits ☐

III. What other people say of the technology ☐

IV. Simplicity of the technology ☐

V. Efficiency of the technology ☐

VI. Availability of government support ☐

APPENDIX 3

Ethics Application Form

University of Chester

For office use: FREC reference number ______________________

Lead reviewer ______________________

Faculty of Applied Sciences
Research Ethics Committee

Application for Ethical Approval of a Proposed Research Study

Applicant name:

Department/Centre:

Programme of study:

New application: ☐ or **Resubmission:** ☐ (Please X in appropriate box)

Title of study:

Application version:

Date of application:

Date of FREC meeting to which application is being submitted:

Please tick this box if you would like to attend the meeting: ☐

- Students are advised to discuss their proposal with their supervisor before submitting an application for ethical review. All applicants are advised to read the accompanying guidance notes before completing this application form; these can be found on IBIS.
- Once you have completed your application form, and it has been signed by you and your supervisor/line manager, please submit **ONE** paper copy of your application (including a complete reference list and **all** appendices) to: FREC Secretary, Dean's Office, Faculty of Applied Sciences, Molloy 106, University of Chester, Parkgate Road, Chester, Cheshire, CH1 4BJ, United Kingdom.
- In addition, an electronic copy of the application (including a complete reference list and **all** appendices) must be emailed to frec@chester.ac.uk by the submission deadline.
- Please **DO NOT** staple your application form and appendices as they will need to be photocopied – use a paper clip.

University of Chester

Faculty of Applied Sciences
Research Ethics Committee

Signatures

Applicant's signature

I confirm that:

- The information in this application is, to the best of my knowledge, accurate and I take full responsibility for it;
- I undertake to abide by the ethical principles embodied in the good practice guidelines identified in this application;
- If the research is approved, I undertake to adhere, without deviation, to the study as outlined in the application;
- I am aware of my responsibility to be up-to-date and compliant with the requirements of the law and relevant guidelines relating to data security; and
- I understand that personal data about me as a researcher and this application will be held by the Faculty Research Ethics Committee and that this will be managed according to the principles established in the Data Protection Act.

Name:

Signed: ______________________________

Date:

- Please ensure that your academic supervisor/line manager has seen and agreed to support this proposal; they must sign this form to indicate they are happy for the proposal to be submitted.
- All relevant signatures must be obtained **before** submitting this application. **Failure to have all the required signatures will result in your application being returned to you**, which may delay your review.
- Applicants should note that it is their responsibility to submit their proposal in sufficient time, particularly when working to tight/strict deadlines. This includes allowing adequate time prior to submission for the supervisor/line manager to read the proposal, provide feedback, and review any amendments before agreeing to support the proposal and signing the application form overleaf.

Approval from Academic Supervisor

I confirm that the applicant has discussed their research proposal with me, and that I have read and agree to support this application.

Name:

Signed: ______________________________

Date:

OR

Approval from Line Manager

I confirm that the applicant has discussed their research proposal with me. I understand the purpose of the research and am aware of all the implications (including time) that conducting this research may have. I am in agreement with the research and support this application.

Name: **Insert line manager's name here**

Signed: ______________________________

Date:

University of Chester

Faculty of Applied Sciences
Research Ethics Committee

Applicant's Checklist

Title of Study:	
Lead researcher:	

- **This document MUST be completed and submitted as part of the application form. Please ensure ONE copy of each document, as detailed below, is attached as an appendix to this application form. ALL appendices MUST have dates and version numbers clearly marked.**
- **Indicate 'yes/no' as applicable, and continue your document list on a separate continuation sheet if necessary.**

Document	Enclosed?	Appendix №	Version №	Date
FREC application form	**Mandatory**			
List of references	**Mandatory**			
Summary C.V. for lead researcher	**Mandatory**			
Letter(s) of invitation to participants	Y ☐ / N ☐			
Participant Information Sheet(s) [PIS]	Y ☐ / N ☐			
Participant consent form(s)	Y ☐ / N ☐			
Information sheets / letters to other relevant personnel	Y ☐ / N ☐			
Written permission(s) from relevant personnel (eg. to use facilities)	Y ☐ / N ☐			
Interview schedule(s) or topic guide(s)	Y ☐ / N ☐			
Validated questionnaire(s)	Y ☐ / N ☐			
Non-validated questionnaire(s)	Y ☐ / N ☐			
Copies of advertisement material(s)	Y ☐ / N ☐			
Risk Assessment form(s)	Y ☐ / N ☐			
Other documents (Please specify below, as necessary)	Y ☐ / N ☐			
	Y ☐ / N ☐			
	Y ☐ / N ☐			
	Y ☐ / N ☐			
	Y ☐ / N ☐			
	Y ☐ / N ☐			
	Y ☐ / N ☐			
	Y ☐ / N ☐			
	Y ☐ / N ☐			
	Y ☐ / N ☐			
	Y ☐ / N ☐			
	Y ☐ / N ☐			

University of Chester

Faculty of Applied Sciences
Research Ethics Committee

Application Form

Part 1: Introduction

1. Title of research project

2. Lead researcher (the applicant) NB. The lead researcher must submit a copy of their current CV (max. 2 sides of A4) with this application.	
Name of applicant	
Status (eg. MSc student; PhD student; staff researcher; other – please specify)	
Address for correspondence	
Contact telephone number	
Contact email address	
Qualifications	
Experience of research methods	

3. Other individuals who may work on the research project NB. If there are more than two additional researchers, please note their details on a separate sheet and append to this application. A summary CV (max. 2 sides of A4) for each additional person must accompany this application.	
Name	
Status (eg. student; tutor / supervisor; researcher; statistician)	
Institution	
Contact telephone number	
Contact email address	

Name	
Status (eg. student; tutor / supervisor; researcher; statistician)	
Institution	
Contact telephone number	
Contact email address	

University of
Chester

4. Academic supervision

Postgraduate students (taught or research) of the University of Chester must state who will act as academic supervisor(s) for their project. Some projects may also be supervised by experts external to the University of Chester. External supervisors should also be listed, and a brief summary CV of their **relevant** qualifications, training and experience should be appended to this application. You do not need to submit a CV for your University of Chester supervisor(s).

Primary supervisor
(University of Chester):

Additional supervisor(s)
(University of Chester and/or External):

5. Good research practice

Please confirm that the research will be carried out in accordance with the University of Chester's guidelines as outlined in the Research Governance Handbook.

☐ *I agree to undertake the proposed research, as outlined in this application, in accordance with the University of Chester's Research Governance guidelines.*

Please state which other professional codes of conduct you will abide by (if applicable):

Type your statement of practice here

6. Confirmation of exclusivity

☐ *I confirm that this application has NOT been submitted for ethical review by any OTHER Research Ethics Committee*

If this is a resubmitted application to FREC, please indicate your FREC reference number and the date at which your original (1st submission) application was first reviewed:

***FREC reference number*:** 000/00/AA/AAAA

***Date of 1st review*:**

University of Chester

Part 2: The research

1. Type of research proposed
Please indicate whether the proposed research is:
☐ Quantitative ☐ Qualitative ☐ Both

2. Outline of the research
Please provide a brief outline of the proposed research under the sub-headings below.

i. **Aims and objectives**

ii. **Hypotheses and/or research question(s) to be addressed**

iii. **Rationale, to include a *brief* synopsis of the background to the research**

iv. **Study design, to include recruitment and sampling strategy, inclusion/exclusion criteria, sample size and justification**

v. **Proposed method(s) of data analysis**

vi. **Description of site(s) / facilities required**

3. Ethical issues
Please summarise what you think are the ethical issues inherent in this study. The questions that follow will give you the opportunity to demonstrate how you will manage these issues in the conduct of your research.

i. **Are there any potential risks or adverse effects to participants?**
As well as any physical risks or adverse effects, you should consider the potential for discomfort, distress, inconvenience or change in lifestyle for the participants, and explain how these will be managed.

ii. **Are there any particular requirements or abstensions that will be imposed on participants?** *(Eg. multiple attendance sessions; abstention from alcohol, tobacco, etc.).*

iii. **Are there any potential benefits to participants, or to the wider society?**

iv. **Are there any potential risks or adverse effects to *researchers themselves*?**

v. **Please indicate whether participants will receive payment or reimbursement for taking part in the research study** *(including reimbursement of expenses).* **If so, what amount?**

vi. **Please state the relationship, if any, which may/will exist between the researcher(s) and potential participants.** *(Eg. will any of the participants be students, subordinates or colleagues of the investigator, or staff members of the University?)*

4. Informed consent

Will informed consent be obtained from the research participants?

☐ Yes ☐ No

If 'YES', please give details of who will obtain consent and how this will be done, including how long participants will have to decide whether or not to take part. If 'NO', please explain why not.

Type your response here

Children

Can you confirm that, where the participant is 16 years old or over, consent to participate in the research will be obtained from the young person themselves.

☐ Yes ☐ No

Can you confirm that, where the participant under 16 years of age but is judged to have the maturity and capacity to understand the nature of the research, consent to participate in the research will be obtained from the young person themselves.

☐ Yes ☐ No

Please state the manner in which any apparent objection to participation by a minor will be handled.

Type your response here

Please state whether and how parental consent, or consent of the legal guardian or order/declaration of the court, will be sought in relation to the participation of minors.

Type your response here

NB. Copies of the consent form(s) and Participant Information Sheet(s) to be used in the research ***must*** *accompany this application.*

5. How will participants who may not adequately understand verbal explanations or written information given in English be enabled to consent?

6. Please state what measures will be taken to ensure that participants are able to withdraw from the research at any time without explanation and without fear of reprisal should they so wish

7. **Confidentiality of data**

What measures will be taken to protect the confidentiality of participants' data?
You should consider data in hard copy, electronic and audio/audio-visual form. You should explain how the anonymity of participants is protected during the data collection process, during data analysis and at the end of the research project. (Applicants are advised to consult the University of Chester's Research Governance Handbook for further information).

Who will have control and act as custodian of the data used in / generated by the research?

Type your response here

Can you confirm that the data will be retained in accordance with the University of Chester's Research Governance Handbook, which states that "data generated in the course of research should be kept securely in paper or electronic format, as appropriate, for a minimum of ten years from the date of final publication"?

☒ *Yes, I confirm that data will be stored securely and confidentially for a minimum of 10 years.*

8. **Vulnerable groups**

Are you *specifically recruiting* participants from any of the following groups?

Children under 16	☐
Pregnant women	☐
The elderly	☐
Persons suffering from mental disorder	☐
Adults with learning disabilities	☐
Prisoners	☐
Young offenders	☐
Other vulnerable groups	☐

Please explain why it is necessary to conduct research involving such participants, and whether the required data could be obtained by any other means.

Type your response here

Please state what special or additional arrangements, if any, will be applied, particularly in relation to Participant Information Sheets and gaining informed consent, to safeguard the interests of such participants.

Type your response here

Please state whether, and if so, how participation in the proposed research may/will be of personal benefit to individual participants.

Type your response here

9. Disclosure statement

If you are working with vulnerable adults or minors (under the age of 18 years old), please state whether or not you have applied for and/or received a disclosure statement from the Criminal Records Bureau (CRB) *[or equivalent, in the case of research conducted outside of the United Kingdom].*

☐ Yes ☐ No

If 'YES', please give the disclosure number and date this was made.

Disclosure number:

Date of disclosure:

Part 3: Financial and other arrangements

1. **Please state any financial or other interests (including any conflicts of interest) that the Applicant, their Department/Centre, supervisor(s) or employer has in relation to the conduct of this research.**

2. **Please state the amount of payment, if any, that will be paid to the researcher(s) *[over and above their normal salary].***

3. **What additional costs will be incurred by the University of Chester through the conduct of the research, and how are these to be met? Please state the details of any funding which has been secured for the research.**

4. **Please confirm that the necessary arrangements have been, or will be made to comply with the requirements of the UK Data Protection Act (DPA) 1998 with regard to computer storage and processing of participants' personal information, and that generally the data supplied and generated during the course of the study will remain confidential.**

   ☐ *Yes, provisions have been, or will be made to comply with the DPA.*

5. **What arrangements are in place for monitoring the conduct of the research, and dealing with any issues, complaints or adverse effects which may arise from the research?**
   [Note that, in the first instance, complaints should be addressed to the Dean of the Faculty of Applied Sciences, Professor Sarah Andrew.]

APPENDIX 4

Participants Information Sheet (For Interviewees)

Participant information sheet

The role of Anaerobic digestion in achieving soil conservation and sustainable agriculture for sustainable development

You are being invited to take part in a research study. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

Thank you for reading this.

What is the purpose of the study?

The aim of the proposed research is to examine how anaerobic digestion (AD) technology can aid soil conservation and sustainable agriculture for sustainable development. The challenges and prospects of AD in the UK and the existing gap between soil conservation and sustainable agriculture in theory and practice will be critically examined.

Why have I been chosen?

You have been chosen because your profession and position is relevant to the research aims and objectives. Your expertise, experience and interest will contribute to the research aims and objectives.

Do I have to take part?

It is up to you to decide whether or not to take part. If you decide to take part you will be given this information sheet as an attachment in a formal invitation email, and you will be expected to keep it. If you decide to take part you are still free to withdraw at any time and without giving a reason. A decision to withdraw at any time, or a decision not to take part, will not affect you in any way.

What will happen to me if I take part?

If you decide to take part, you will be given this information sheet to keep and you will answer some questions. The questions will be sent to you by email as an attachment and your response will be received through the same means. The questions will take between 30-45 minutes to answer. The response I get from you and the other participants will be kept securely and false names will be used to protect your identity.

What are the possible disadvantages and risks of taking part?

There are absolutely no disadvantages or risk in taking part.

What are the possible benefits of taking part?

By taking part, you will be contributing to the use of renewable energy, soil conservation and sustainable agriculture, and overall sustainable development.

What if something goes wrong?

If you wish to complain or have any concerns about any aspect of the way you have been approached or treated during the course of this study, please contact Professor Sarah Andrew, Dean of the Faculty of Applied Sciences, University of Chester, Parkgate Road, Chester, CH1 4BJ, 01244 513055.

Will my taking part in the study be kept confidential?

All information which is collected about you during the course of the research will be kept strictly confidential so that only the researcher carrying out the research will have access to such information.

What will happen to the results of the research study?

The results will be written up as part of my PhD and may be published. Individuals who participate will not be identified in any report or publication.

Who is organising the research?

The research is conducted as part of the requirement for the award of PhD within the Department of Biological Sciences at the University of Chester. The study is organised with supervision from the department, by Franklin Duruiheoma, a PhD candidate.

Who may I contact for further information?

If you would like more information about the research before you decide whether or not you would be willing to take part, please contact:

Franklin Duruiheoma- 1224822@chester.ac.uk

Thank you for your interest in this research.

Participant's Information Sheet (For Farmers)

University of Chester

Participant information sheet

The role of Anaerobic digestion in achieving soil conservation and sustainable agriculture for sustainable development

You are being invited to take part in a research study. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

Thank you for reading this.

What is the purpose of the study?

The aim of the proposed research is to examine how anaerobic digestion (AD) technology can aid soil conservation and sustainable agriculture for sustainable development. The challenges and prospects of AD in the UK and the existing gap between soil conservation and sustainable agriculture in theory and practice will be critically examined. This section of the work involves gathering information on the perception of AD among UK farmers.

Why have I been chosen?

You have been chosen because you are a farmer in the UK, and this makes you relevant in this study.

Do I have to take part?

It is up to you to decide whether or not to take part. If you decide to take part you are still free to withdraw at any time and without giving a reason. A decision to withdraw at any time, or a decision not to take part, will not affect you in any way.

What will happen to me if I take part?

If you decide to take part, you will answer some questions. Answering the questions will take about 10 minutes of your time. The response I get from you and the other participants will be kept securely and your identity will remain anonymous.

What are the possible disadvantages and risks of taking part?

There are absolutely no disadvantages or risk in taking part.

What are the possible benefits of taking part?

By taking part, you will be contributing to the use of renewable energy, soil conservation and sustainable agriculture, and overall sustainable development.

What if something goes wrong?

If you wish to complain or have any concerns about any aspect of the way you have been approached or treated during the course of this study, please contact Professor Sarah Andrew, Dean of the Faculty of Life Sciences, University of Chester, Parkgate Road, Chester, CH1 4BJ, 01244 513055.

Will my taking part in the study be kept confidential?

All information which is collected about you during the course of the research will be kept strictly confidential so that only the researcher carrying out the research will have access to such information.

What will happen to the results of the research study?

The results will be written up as part of my PhD and may be published. Individuals who participate will not be identified in any report or publication.

Who is organising the research?

The research is conducted as part of the requirement for the award of PhD within the Department of Biological Sciences at the University of Chester. The study is organised with supervision from the department, by Franklin Duruiheoma, a PhD candidate.

Who may I contact for further information?

If you would like more information about the research before you decide whether or not you would be willing to take part, please contact:

Franklin Duruiheoma- 1224822@chester.ac.uk

Thank you for your interest in this research.

APPENDIX 5

Invitation E-mail to Participants (For Interviewees)

Subject: PhD Research Project Help

Dear (name)

My name is Franklin Duruiheoma, a PhD student in the department of biological sciences at the University of Chester, working on “The role of AD in achieving soil conservation and sustainable agriculture for sustainable development”. I am writing to you, to seek help by participating in the qualitative phase of my research.

I have attached to this email a participant information sheet (PIS) that will provide all the necessary information you need concerning the research, such as research objective, why you have been chosen, what will happen if you participate, who to contact if something goes wrong, benefit of taking part, and how confidentiality will be ensured.

I will be much obliged to provide additional information on this study, please email me or call me on 07521294252. Also, you can contact any member of my supervisory team and they will be happy to give additional information. The team is:

- Professor Cynthia V. Burek (Principal Supervisor) - Department of Biological Sciences University of Chester, Parkgate Road Chester, CH1 4BJ. Email- c.burek@chester.ac.uk
- Professor Graham Bonwick (Co-supervisor) - Department of Biological Sciences University of Chester, Parkgate Road Chester, CH1 4BJ. Email- g.bonwick@chester.ac.uk
- Professor Roy Alexander (Co-supervisor) - - Department of Geography University of Chester, Parkgate Road Chester, CH1 4BJ. Email- r.alexander@chester.ac.uk

If you will like to participate in this research, please to this email and I will forward the interview questions to you.

Many thanks.

Kindest regards,

Franklin.

Invitation E-mail to Participants (For Farmers)

Subject: PhD Research Project Help

Dear (name)

My name is Franklin, a PhD student in the department of Biological Sciences at the University of Chester, working on "The role of Anaerobic Digestion in achieving soil conservation and sustainable agriculture for sustainable development in UK". I am writing to you, to seek help by participating in my survey. Please ignore if you have already participated.

The link to the survey is: https://www.surveymonkey.com/s/QKCQQKS

It will only take between 5-10 minutes or less to complete. The first page of the above link will give you a better understanding of what the research is about and other possible questions you may want to ask. Your identity and that of the farm will remain ANONYMOUS.

I will be much obliged to provide additional information on this study, please email me or call me on 07521294252. Also, you can contact any member of my supervisory team and they will be happy to give additional information. The team is:

1. Professor Cynthia Burek (Principal Supervisor) - Department of Biological Sciences University of Chester, Parkgate Road Chester, CH1 4BJ. Email- c.burek@chester.ac.uk
2. Professor Graham Bonwick (Co-supervisor) - Department of Biological Sciences University of Chester, Parkgate Road Chester, CH1 4BJ. Email- g.bonwick@chester.ac.uk
3. Professor Roy Alexander (Co-supervisor) - Department of Geography University of Chester, Parkgate Road Chester, CH1 4BJ. Email- r.alexander@chester.ac.uk

Many thanks in anticipation of your response.

Kindest regards,
Franklin.

APPENDIX 6

Key Words Used to Describe Soil

1st key words	*N*	2nd key words	*N*	3rd key words	*N*	4th key words	*N*
Heavy	15	Vital	7	Water	2	Vital	4
Vital	10	Habitats	1	Vital	2	Habitats	1
Sand	1	Biodiversity	1	Decomposing	1	Important	5
Life-giving	1	Fertility	3	Important	5	Irreplaceable	1
Calcareous	1	draining	1	Lifeline	1	Unknown	1
Important	5	Asset	1	Potential	1	Fertility	2
Irreplaceable	1	Chalk	1	Fertility	1	Challenging	2
Limestone	1	Suitability	1	Nurture	1	Difficult	1
Critical	1	Regenerative	1	Free draining	2	Asset	2
Dry	1	Nutritious	1	Asset	4	Hidden	1
Compaction	2	Keystones	1	Foundation	2	Chalk	1
Essential	23	Hard	2	Chalk	2	Erosion	1
Heavy clay	1	Loam	8	Exploited	1	Stability	1
Fertility	2	Biological	1	Anchoring	1	Cold	1
Ecosystem	4	Varied	2	Fascinating	1	Susceptibility	1
Light	1	Peat	1	Valuable	3	Valuable	1
Mouldy	1	Fecund	1	Fertilized	1	Loam	9
Free draining	2	Balanced	2	Biological	1	Air	1
Versatile	1	Life	5	Loam	3	Teaming	1
Alluvial loam	1	Useful	1	Longevity	1	Biological	1
Thin	1	Need work	1	Air	1	Varied	2
Clay	9	Wet	2	Varied	1	Peat	1
Valuable	1	Venerable	1	Cycle	1	Stiff loam	1
Organic	4	Reservoir	1	Land	1	Analysis	1
Friable	1	Biology	2	Flexible	1	Life	1
Resource	5	Minerals	1	Chemical	1	Profitable	1
Brown earths	1	Natural	2	Aggregates	1	Useful	1
Loam	6	Depth	2	Life	3	Endangered	1
Air	1	Complex	1	Alkaline	1	Growth	1
Deep	1	Shallow	1	Useful	2	Wet	2
Peat	1	Humus	4	Nutrient	1	Reservoir	1
Care	1	Fragile	3	Wet	2	Unstable	1
Land	1	Fundamental	1	soil	1	Texture	3
Chemistry	1	Different types	1	Minerals	1	Contrasts	1
Mixed	1	Silt	2	matter	1	Complex	4
Medium	1	Invaluable	1	Natural	1	Interesting	1
Undervalued	1	Structure	8	Depth	1	Fundamental	1
Sandy/sandstone	1	Mineral	1	Complex	1	Humus	1
Life	2	Pete	1	Drained	1	Fragile	2
Soil	1	Damageable	1	Top/sub	1	Permeable	1
Profitable	1	Living	7	Fragile	3	Silt	2
Farm reserve	1	Precious	1	Humus	1	Sensitive	1
Crucial	2	Fertile	13	managed	1	Mystery	1
Key	1	Alive	2	Silt	3	Structure	6
Brown	1	compaction	1	Sensitive	1	Dirty	1
Growth	1	Subsoil	1	Bacteria	1	retention	1
Earthy	1	Heavy	3	Structure	3	Nature	1

Wet	3	Aerated	2	Worms	1	Precious	1
Living organism	1	Sand	2	Mineral	1	Fertile	3
Long-term	1	Life giving	1	Cycling	1	Alive	2
Natural	1	Soil organisms	1	Precious	2	Carbon	2
Texture	1	Biota	1	Living	3	Susceptible	1
Depth	1	Dry	2	Tricky	1	Growing	1
Complex	1	Essential	1	Fertile	6	Well drained	1
Earth	4	Mismanaged	1	Exciting	1	Cold/wet	1
Medium loam	1	Ecosystem	1	Carbon	2	Managed	2
Brash	1	Light	2	Damaged	2	Heavy	1
Shallow	1	Sacred	1	Red	1	Aerated	1
Fragile	3	Mycorrhizal	1	Type	1	Sand	1
Fundamental	1	Clay	20	Evolving	1	Renewable	1
Nutritive	1	Finite	1	Growing	1	Saturated	1
Silt	1	Organic	5	Yield driver	1	Dirt	1
Nutrients	2	Free	1	Yield	1	Cultivatable	1
Rich	1	Living	1	Vary	1	Critical	1
Structure	3	Diverse	1	Managed	1	Dry	1
Compact	1	Medium	2	Heavy	4	Compaction	1
Healthy	1	Variable	4	Sand	3	Essential	4
Worms	1	Vulnerable	1	Dry	1	Depleted	1
Mineral	1	Microbiology	1	Compaction	1	Stony	1
Topsoil	1	Flinty	1	Grass	1	Easy going	1
Poor	1	Delicate	1	Warm	1	Aerobic	1
Living	5	medium	1	Essential	3	Light	3
Precious	2	Limited	1	Stony	1	Ecosystem	1
Productive	2	Brash	1	Microorganisms	1	Bog	1
Stable	1	Microfauna	1	Light	3	Lovely	1
Sandy	5	Compacted	1	Ecosystem	1	Finite	1
Alive	9	Sandy/loam	1	Primary	1	Clay	1
Fertile	10	Nutrients	4	Recycling	1	Organism	1
Permeability	1	land	1	Thin	3	Unappreciated	1
Carbon	1	Clay/loam	1	Versatility	1	Glacial	1
Organic matter	3	Manageable	1	Testing	1	Organic	3
Type	2	Healthy	1	Clay	12	Moisture	2
Growing medium	3	Good structure	1	Finite	1	Priority	1
Abused	1	Health	1	Filtration	1	Clover	1
Wonderful	1	Livelihood	1	well-drained	1	Resource	1
Well-drained	1	Productive	3	Organic	2	Cloggy	1
Resilient	1	Sandy	4	Resource	2	Preserve	1
Good	2	Seedbed	1	Dense	1	Diverse	3
Managed	1	Improving	1	Fungi filled	1	Improvable	1
		Stoney	1	Diverse	2	Non-fertile	1
		Sustaining	1	Medium	2	Dark	2
		Base	1	Environment	1	Undervalued	1
		Crucial	1	Balance	1	Waterlogged	1
		Porous	1	Cleansing	1	Undulating	1
		Organic matter	4	Free draining	1	Brown	1
		Not understood	1	Variable	3	Vulnerable	2
		Growing	2	Vulnerable	2	Delicate	2
		Stones	1	Well	1	Medium	1
		Moist	1	Delicate	1	Content	1

		Food production	1	Earth	2	Brash	1
		Misunderstood	1	Compacted	2	Compacted	1
		Good	1	Assets	1	Quality	1
		Nutrient store	1	Nutrients	1	Rich	3
				Rich	2	Boggy	1
				Remediation	1	Magical/diverse	1
				Draining	1	Draining	1
				Healthy	1	Manageable	1
				Textured	1	Regenerating	1
				Carbon storage	1	Unpolluted	1
				Chalky	1	Nutrition	1
				Sandy	3	Productive	5
				Stoney	2	Sandy	1
				Drainage	2	Hungry	1
				Organic matter	2	Rewarding	1
				PH	5	Organic matter	4
				Abused	1	Drainage	2
				Sustainable	1	PH	1
				Good	1	Workable	1
						Abused	1
						Decreasing	1
						Misunderstood	1
						Dying	1
						Fight	1
						Good	1