University of Glasgow | School of Interdisciplinary Studies

Is biodynamic farming the sustainable agriculture of the future?

DISSERTATION LEVEL 3 – BSC ENVIRONMENTAL STEWARDSHIP

2058279 | Bethan Wood | 5th May 2015 | **Word Count: 11,137**

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1.

Abstract

Biodynamic agricultural is an innovative and potentially sustainable method of farming developed in the 1920's by Dr Rudolph Steiner. It was developed in order to tackle the growing problem of soil erosion that was occurring at the time. The practice incorporates the idea that agriculture is holistic: a collective spiritual, ethical and ecological approach to the production of our food. Biodynamic farming disallows the use of chemical pesticides and fertilisers and instead opt to use something very unique: preparations. These preparations are made up of totally natural substances which are usually sourced from the farm itself. The application of these preparations to the farm follows a strict calendar that incorporates growing seasons, and lunar and cosmic cycles.

The objects of this work was to define sustainability and assess how sustainable biodynamic farming is in relation to the definition. To investigate the effects of preparations on soil quality, and assess whether it would be feasible for biodynamic farming to be the sustainable agricultural practice of the future.

The research found that in terms of sustainability biodynamic agriculture is one of the most sustainable agricultural practices in modern day farming. It has no adverse effects on the environment, produces no waste, as everything that would typically be deemed as waste, is recycled to other parts of the farm. Generally, most biodynamic farms are run as a community effort and tend to run alongside residential schemes that aim to support the needs of individuals with a wide range of learning difficulties and mental health issues. Running a farm in this manner incorporates many factors of social sustainability. The only issue found with biodynamic agriculture's overall sustainability is its economic standing. Most biodynamic farms run on a charity basis to fund their therapeutic residential schemes, in doing so there is then a potential to lose their grants and donation funding from third party providers. Thereby, if funding is cut, this can then be of a massive loss to the farm as it may no longer be able to support its residents or run at a profit. This study found that preparations 500-508 do have beneficial effects on the soil and its quality. The main findings were that compost treated with biodynamic preparations contained 10% less Carbon Dioxide (CO_2), had a higher ratio of dehydrongenase enzyme to CO_2 production and had increased microbiological movement. Additionally it was also found that the treated compostswere typically of a higher average temperature and increased organic matter content. All of these findings are factors which enable decomposition to occur faster, which produces a greater quality of soil. If soil is of good quality then the quality of crops grown in the soil will also be better. The final section of this research focuses on how we can sustainably meet our worlds food demand. This study found that we still need to rely on conventional agriculture to meet our global food demand. This is because currently, our alternative options are just not sustainable enough yet and need more time to develop. overall, biodynamic

farming could be a feasible option for the future. However in order for this to happen, additional measures must be taken in order to make biodynamic agriculture more sustainable. Moreover, more information surrounding the practice needs to be made public, as people will not have faith in a practice that is known to be secretive.

Chapter 1 - Introduction

1.0 Introduction

1.1 Background

Over the past century agricultural researchers have widely recognised that sustainable agricultural production systems are becoming increasingly more important as land becomes more scare and population increases. This highlights that there is a need to develop more suitable methods and definitions to measure sustainability within the agricultural field (Pacini *et al*., 2003). The development of "cleaner" and "low input" methods of farming are required in order to produce enough food for the world's population in accordance with conserving land and habitats. Currently only 4% of the UK's land is farmed based on the concept of sustainability (Pacini *et al.,* 2003).

Presently, the human population is increasing. As it increases the demand for food will also rises in direct correlation. It is estimated that the global food demand will double over the next 50 years (Tilman *et al.,* 2002). This could result in substantial environmental damage, a study by Carpenter *et al.,* (1998) states that, agriculture can lead to the loss of natural ecosystems and adds globally significant and environmentally harmful amounts of nitrogen and phosphorus to terrestrial ecosystems. The damaging impacts caused by agriculture has led to the desire for sustainable farming systems to increase in accordance with the movement to protect wildlife, prevent land degradation and to decrease environmental harm caused by farming practices [CITATION Eur06 \l 2057]. Fundamentally, sustainability is based upon three pillars; economic, social and environmental, if one pillar is weak the whole system is deemed unsustainable. A universal definition for sustainable does not currently exist, so for the purposes of this research this definition of sustainable development will be used.
Sustainable development is "*development that meets the needs of the present, without compromising the ability of future generations to meet their own needs*" [CITATION Sus12 \l 1033].
Presently, the UK has the infrastructure in place to start delivering sustainable development, however it lacks the legislative foundation it needs in order for it to be a feasible [CITATION Ros12 \l 1033]. For sustainable agriculture to exist with a universal definition the infrastructure for sustainable development in required.

Currently, there are many different variations and theories to “sustainable agriculture”. For the purpose of this research the definition provided by The Brundtland Commission of the UN (1987) will be used:

“The management and conservation of the natural resource base, and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such development... conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable.”

The development of a universal definition for sustainability would aid agriculturalists all over the world to measure sustainability. This would be of value as the scale of agriculture is increasing to meet food demand. Presently half of global usable farming land is already in pastoral or intensive agriculture (Tilman, *et al.,* 2002); by having a universally agreed and globally recognised sustainability measurement farmers would be able to develop sustainable farm’s. For a universal definition to be established, the implementation of sustainable development needs to occur first.

1.2 Conventional Agriculture

The concept of conventional agriculture was developed in order to justify and provide a comparative foundation for alternative methods of agriculture [CITATION Han96 \l 2057]. “Conventional agriculture is characterised as capital-intensive, large-scale, highly mechanised agriculture with monocultures of crops and extensive use of artificial fertilisers, herbicides and pesticides, with intensive animal husbandry” (Knorr & Watkins, 1984, p. 148). This type of agriculture became very popular during the Second World War. The UK government encouraged its people to utilise land to its full potential when faced with food shortages[CITATION Rob00 \l 1033]. The “Dig for Victory” campaign encouraged people to transform parks, gardens and even ditches into land for the growth of vegetables[CITATION Placeholder1 \l 1033]. This intensive, industrialised farming caused a large amount of degradation to valuable land and contributed to the population decrease of many species of farmland birds[CITATION The09 \l 1033]. The decline of the raptor species *Falco columbarius* (or Merlin) occurred because of the heavy use of organochlorine pesticides during and after the Second World War (Boatman, *et al.,* 2004). These problems are widely associated with “conventional” or “industrial” agriculture, which is perceived to be unsustainable by many researchers [CITATION Dah91 \l 2057]. It is generally understood that this method of agriculture is not a sustainable option because it causes environmental damage, does not aim to conserve habitats, nor does it consider future human needs. Furthermore, a study by Rasul & Thapa (2004) states that this method of farming is known to degrade

land and water resources, in addition to producing smaller yields after chemical fertilisers are used; thereby showing that conventional farming has exceeded the carrying capacity of the land once yields decrease.
Nevertheless, this method of farming (conventional or industrial agriculture) is currently widely used across the world on large-scale farms.

1.2.1 The Green Revolution

From the 1940's to the 1960's, the development of the Green Revolution movement began. The Green Revolution is a series of research, technological advances and high investment into the agricultural sector in an effort to maximise crop yields and decrease diseases susceptibility within crops to combat the risk of human starvation and malnutrition [CITATION Pin12 \l 2057]. "The success of the Green Revolution was caused by the combination of high rates of investment in crop research, infrastructure, and market development and appropriate policy support that took place during the first Green Revolution" (Pingali, 2012, p. 12302). The most notable breakthrough to come from this movement was the invention of genetically modified organisms (GMO's) by Norman Borlaug [CITATION Bri14 \l 2057]. This development of improved agronomy: hybridised high yielding crops and modernised chemicals fertilisers and pesticides [CITATION Int02 \l 2057] greatly aided developed and developing countries all over the world to produce enough crops to feed their population. In some countries such as Mexico, they were able to produce more than what they needed for their population and were able to export to other countries [CITATION Bri14 \l 2057].
Initially, the production levels and crop variety did increase however, it did not take long for people to realise that this was a short-term solution (King, 2008). The three main varieties of seeds: wheat, rice and millet; that were developed for the Green Revolution required heavy irrigation and applications of chemicals fertilisers in order for the crops to be successful [CITATION Seb10 \l 2057]. This meant that if there was decreased access to fertilisers or water supplies then crops failed. India suffered from back-to-back droughts in the 1960's, which caused detrimental effects to their food production [CITATION Pin12 \l 2057].

Conventional agriculture does not prohibit the use of chemical fertilisers or the use of GMO's. In fact chemicals and GMO's are used widespread (Pimentel *et al.,* 2005). In order to achieve higher yields this system requires high-energy inputs, which results in the heavy use of fossil fuels and technological innovations to supplement the required energy needed (Gomiero *et al*., 2011). GMO crops were developed to help increase yields, decrease costs for food production and to help crops become resistant to pests and diseases [CITATION Phi08 \l 2057]. However, a study conducted by Gurian-Sherman, (2009) found that the use of GMO crops does not increase yields. His study showed that the yields of corn and soybeans did increase, although not due to genetically engineered traits but rather traditional selective breeding. Furthermore, conventional farming also requires high- energy inputs to

achieve high yields[CITATION Foo991 \l 1033]. Consequently, The **Common Agricultural Policy (CAP)** was introduced to help “the agricultural sector to meet strategic food requirements and to reduce poverty” (Donald *et al.,* 2002, p.171). Shortly afterwards The **Wildlife and Countryside Act 1981** was introduced to help protect wildlife and habitats from the exploitation that occurred during and after the Second World War. Since these policies introductions, alternative and potentially sustainable agricultural practices have become popular and been developed further; this includes organic, hydroponics and biodynamic agriculture. Biodynamic agriculture will now be considered further.

1.3 Biodynamic agriculture

“Biodynamic agriculture was introduced as a possible solution to farmer’s concerns about their weakening soils and overall well-being of their fields and crops” (McCullough *et al.,* 2012, p. 1364). Biodynamics is an innovative sustainable method of farming which philosopher Dr Rudolph Steiner developed in the 1920’s. It is fundamentally based on his philosophy of “anthroposophy”. Biodynamic farmers view a farm as a “total” organism and attempts to develop a sustainable system where everything within the system is respected and has a proper place (Biodynamic Association, 2014; Mason, 2003:14). The Biodynamic Association (2014), states that biodynamic agriculture incorporates the idea that agriculture is holistic: a collective spiritual, ethical and ecological approach to the production of our food.

Rathore *et al.,* (2014) and Pfeiffer (1940) states that the main principles of Biodynamic Agriculture are:

- To create a diverse and balanced farm ecosystem that can support itself from within the farm[CITATION Mas03 \l 1033]
- To restore the soil through the incorporation of organic matter
- To treat soil as a living system
- To create a system that brings all factors which maintain life into balance
- To encourage the use and importance of green manure, crop rotation and cover crops
- Treat manure and compost in a biodynamic way, and have knowledge of enzymes and hormones.

From these principles it can be recognised that no artificial materials or harmful chemicals are used in the practices of biodynamic agriculture as mentioned in the previous section. This is also stated by Reganold *et al.,* (1993). Instead of chemicals, only natural substances that have been sourced on the farm itself are used in the preparations of fertilisers, sprays and manures. In doing this it allows minimal outside inputs creating a closed system as all the inputs are retrieved from within the farm itself (Carpenter-Boggs, 2011). To ensure stewardship of the Earth is maintained, it is the belief in biodynamic farming that the restoration and

harmonisation of the farm's life forces are reinforced to enhance the quality, flavour and nutrition of the farm's produce [CITATION Mas03 \l 1033]. A study conducted by Woodward-Clyde (2000) highlights that there has been a decline in the public's confidence in modern industrialised farming and processing methods, the study also states that it is due to an increase in the consumer's awareness of food-borne hazards such as pesticides, antibiotics, hormones and artificial ingredients. The public also commonly perceives that organically and biodynamically farmed foods are healthier than the conventional ones, however there is little scientific evidence available to support this theory (Tassoni *et al.,* 2013). Biodynamic farming is viewed as the first alternative method of farming (Chalker-Scott, 2014), which incorporates a sustainable system that can produce quality crops in an organic way, without the use of any harmful chemicals [CITATION App99 \l 1033].

1.3.1 Preparations

Biodynamic agriculture shares many practices with organic methods of farming, including soil-building, crop rotations, and composting[CITATION App99 \l 1033]. However, the key aspect of biodynamic agriculture is to work closely with nature with the use of special *"preparations"* that are applied to the soil, crops and composts (Reevea *et al*,. 2010). They are considered to be the most important feature of biodynamic farming and are probably the most difficult part of biodynamics to understand [CITATION Ell10 \l 2057]. The preparations themselves as shown in *Table 1* are unique to biodynamic agriculture and only consist of specific minerals or plants, which are treated or fermented with animal organs, water, and/or soil [CITATION Ste74 \l 1033]. The preparations are applied to the farm in the form of manures, and sprays in accordance to a strict planting calendar. This calendar incorporates lunar and cosmic cycles as well as the seasons, planting and spraying in relation to this will increase the growing capability of the crops [CITATION Thu15 \l 2057]. It is thought that the use of preparations "produce compost that develops faster with less loss of nitrogen, fewer odour problems, and greater nutrient holding capacity, by stimulating organisms present in the feedstock" (Klett, 2006, p. 34). The preparations are conveyed as having a positive impact on the environment in terms of energy use and efficiency (Turinek *et al.,* 2009).

Primarily, the purpose of these preparations is not to add nutrients to the soil but to stimulate the soil's natural process of energy and nutrient cycling (Carpenter-Boggs *et al*., 2000b). There is some research that suggests that the soil quality of a biodynamic farm is greater than that of a conventional farm because of the preparations used. Reganold *et al.,* (1993) found that soils from biodynamic farm's had a higher biological and physical quality in addition to a considerably greater organic matter content and microbial activity than that of soil from conventional farm's. This study concluded that the use of preparations on the soil decreases the soil density, which increases penetrability, and the thickness of the topsoil is also greater.

Table 1 – Preparations used in Biodynamic Agriculture (Steiner, 1974)

Preparation	Main ingredient	Use
500	Cow (*Bos taurus*) manure	Field spray
501	Ground silica from quartz or feldspar	Field spray
502	Yarrow (*Achillea millefolium* L.) blossoms	Compost additive
503	Chamomile (*Matricaria recucitata* L.) blossoms	Compost additive
504	Stinging nettle (*Urtica dioeca* L.) shoot	Compost additive
505	Oak (*Quercus robur* L.) bark	Compost additive
506	Dandelion (*Taraxacum officinale* Weber) flowers	Compost additive
507	Valerian (*Valeriana officinalis* L.) extract	Compost additive
508	Horsetail (*Equisetum arvense* L.)	Field spray

1.3.2 Validity of Biodynamic Agriculture

Biodynamic farming faces a lot of criticism about its credibility, and has been referred to a *pseudoscience* by Turner (2014) and Saltini (2010). A pseudoscience is defined by the Oxford Dictonary as "a collection of beliefs or practices mistakenly regarded as being based on scientific method". A review by Reganold (1995) found that many of the biodynamic agricultural practices were to be of a questionable scientific quality. His study concludes that it is due to the lack of additional secondary reviewing and verification from other scientists, which is a key process in modern scientific research. Preparations, and the effects of the cosmos and lunar cycles are also a cause for criticism. These preparations and the association with the spiritual science of anthroposophy sets biodynamic farming apart from other agricultural practices and is the only agricultural practice that believes that lunar cycles and cosmic forces can influence the whole farm. The creation of the preparation methods were not "developed through scientific methodology, but rather through Steiner's own self-described meditation and clairvoyance" (Chalker-Scott, 2004, p. 1), which means the methodology is not scientifically proven through modern scientific techniques. Currently, the underlying natural science of the preparations is still under investigation (Turinek *et al.,* 2009). Steiner himself believed that his spiritualistic founded methods did not need to be confirmed through traditional scientific reviewing, as they were "true and correct" unto themselves [CITATION Kir94 \l 1033]. In terms of research, Biodynamic farming is still in its infancy, as there is a lack of additional and scientifically reviewed research to suggest that these preparations do have any benefit to the soil and the produce of the farm. Nevertheless, there are thirty published, scientifically certified, peer reviewed studies that suggest that these preparations do in fact have a recognisable impact on the farm, produce and its soil quality (Turinek *et al.,* 2009). For further reading please consult (Carpenter-Boggs *et al.,* 2000a; Rathore *et al.,* 2014; Reeve *et al.,* 2005; Villanueva-Reya *et al.,* 2014). Research has found that there is an increased microbiological movement within the soil, in addition to having a higher level of nutrients and and an increased rate crop development when biodynamic preparation were used in comparison to a conventional farm (Reeve *et*

al., 2010; Reganold *et al.,*1993; Carpenter- Boggs *et al.,* 2000a;Koepf 1993). However in contrast, studys by Carpenter-Boggs *et al.,* (2000b) and Tassoni *et al.,* (2013) found there to be no benefits of using the preparations.

1.3.3 Community Supported Agriculture and Camphill Communities

Another fundemental concept of biodynamic farming is the requirement to partake in Community Supported Agriculture (CSA). The CSA movement was developed in Japan in the 1990's and was incorporated into the Biodynamic movement [CITATION Kin08 \l 1033]. CSA is the direct relationship between a farmer and the people who eat the food the farmer grows [CITATION Soi \l 1033]. This means that the community of people that work on the farm or are shareholders get a direct cut of the farm's produce, therefore sustaining the farm's growth and ensuring a market for its produce [CITATION Con00 \l 1033]. Biodynamic farms can also have other community support systems; these are called Camphill Communities (CC) and the Garvald Movement.

A CC can be a residential care home with education facilities or they can be residential farm that incorporate Steiner's philosophy of anthroposophy by adopting a holistic therapeutic approach to supporting individuals. These individuals may have a range of complex needs such as learning difficulties or mental health issues. These communities aim to help these individuals find purpose in their lives and to develop their social, spiritual and practical skills and overall potential [CITATION Cam14 \l 2057]. For example Loch Arthur biodynamic farm in Dumfries and Galloway is a CC farm (Jardine, 2015, Personal communications). Loch Arthur farm actively recruits members for their community it supports and provides work and residential schemes for young adults.

The Garvald Home Farm in South Lanarkshire is the only farm to incorporate the Garvald movement (Brett, 2015). This movement is very similar to a CC; it focuses on the social therapy aspect of Steiner's work and applies it to the residents on the farm that can have a range of learning or mental health issues [CITATION Gar14 \l 2057]. However, the Garvald Movement is not restricted to just farming, they have many centres around the world that are open to help people bring structure to their lives CSA communities and CC are different support systems; CSA tends to focus more on a business partnership between farmer and shareholders whereas CC and the Garvald Movement focuses on the therapeutic side of Steiner's work by helping individuals to develop their skills and potential.

1.4 Aims and Objectives

The aim of this dissertation is to analyse and assess whether biodynamic agriculture is a more sustainable than conventional agriculture and evaluate if it can be a sustainable option for the future. This will be achieved by completing the following research questions:

1. To define sustainable agriculture and determine to what extent, biodynamic farming is sustainable.
2. To evaluate the effects biodynamic preparations have on soil quality.
3. To assess whether biodynamic farming is a sustainable option for the future?

Chapter 2 – Methodology

2.0 Methodology

In order to answer the above research questions, this dissertation will be compiled by means of a desk based literature study, which will evaluate the key issues within this subject area, in order to develop a clear understanding of biodynamic farming. I chose to write my dissertation on biodynamic agriculture as it had engaged my interest in class the previous academic year. This interest is also where the research questions chosen stemmed from. During the class the topics that I wanted to know more about the sustainability of the practice, the effect preparations have on the soil quality of farms and finally assess whether or not biodynamics could be the sustainable farming practice of the future. I wanted to research past the misconceptions of biodynamics and find the truth.

This study will be conducted in a number of phases:

2.1 - Phase 1: Initial desk based research and assessments

This will incorporate utilising already existing research to investigate agricultural sustainability and the differences between conventional and biodynamic agricultural practices. In order to achieve well-rounded desk-based research, numerous textual sources will be used. This includes: literature reviews; academic books and journals articles; government publications and policies.
Data will be searched for in a methodical way using the following resources:

- Access to the SRUC Library (Scotland's Rural College Library) though SCONUL access scheme will be sought in order to broaden my access to current agricultural research and publications.
- The University of Glasgow Library Service (online and print books)
- University of the West of Scotland Library Service (online and print)
- Google Scholar
- Science Direct
- Web of Science

When searching for appropriate research the following keywords and phrases will be used in a range of different systematic combinations:

Key Words

- Biodynamic
- Agriculture
- Sustainability
- Environmental
- Conventional
- Farming
- Soil
- Yields
- Policy
- Crops
- Disease
- Management
- Organic
- Profitability
- Scotland
- Alternative
- Quality
- Biodiversity
- Productivity

Key Phrases

- Sustainable Agriculture
- Ecological Systems
- Biodynamic farming
- Soil Quality
- Rudolf Steiner
- Community Supported Agriculture
- Biodynamic Preparations
- Crop Quality
- Conventional agriculture
- Yields per capita
- Rudolf Steiner
- Camphill Communities

The methodical use of keywords and phrases will be used for analysis in these search engines to help with the selection of texts and information. These searches will be in addition to data sourced from elsewhere such as from Non-Government Organisations (NGO's).
Examples of these include the Biodynamic Association, Camphill Community Scotland, The Soil Association, National Sustainable Agriculture Information Service, the Nuffield Farming Scholarship Trust and The Royal Society for the Protection of Birds (RSPB).

2.2 - Phase 2: Review of agricultural practices

Initially this study planned to involve the use of primary research in order to validate and assess data found in the desk-based assessment. After ethical approval was sought and approved, four farmers were invited to take part in the study by means on emails and phone calls. However unfortunately, due to lack of communication between myself and the farmers invited and the strict timescale of the dissertation, this primary research was no longer a plausible option. Nonetheless, this hindrance was foreseen as there is a stigma attached to the biodynamic farming sector that they can be secretive and are not typically willing to talk to outsiders, therefore it was overcome by making the study entirely desk based. I was able to source a biodynamic produce price list from Organic North; this will be used to assess the economic sustainability of a biodynamic farm. The main problems associated with biodynamic farming were found to be the scientific validity of the preparations used and the lack of peer-reviewed published articles.

Chapter 3 – Results and Discussion

The results and discussion will examine the four research questions and attempt to provide answers for each of the questions. Some of my research questions have next to no scientific research to support them, and therefore lack definitive answers.

3.1 Research Question One: To define sustainable agriculture and determine to what extent, biodynamic farming is sustainable.

Sustainability is all about surviving for the long term. This is why the desire for sustainable agriculture is universal, however how to progress towards it remains elusive [CITATION Rig01 \l 1033]. Even with a basic infrastructure for delivering sustainable development, is still difficult to find an agricultural practice that does not deplete natural resources such as soil fertility (Sanchez, *et al.,* 1997). The desire for sustainability is centred on the growing concern and need to develop technologies that enable farming to take place without the depletion of natural resources and accommodates practices that do not have detrimental effects on environmental [CITATION Pre08 \l 2057]. The definition that will be used for agricultural sustainability is one sourced from the FAO (2010):

“The management and conservation of the natural resource base, and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such development... conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable.”

This definition has been used, as it is the most comprehensible in relation to this research. Biodynamic farming is an example of an agricultural practice that is often referred to as sustainable. In its early stages, the practice centred on Steiner’s belief in anthroposophy, that a farm is an entire entity. However, as it developed further agriculturalists realised that this method can achieve sustainability through all three pillars of sustainability and has the ability to be wholly self-sufficient. The question of whether biodynamic agriculture is sustainable or not will now be assessed in relation to the 3 pillars of sustainability:

3.1.1 Environmental Sustainability

For an agricultural practice to be environmentally sustainable, it needs to not have any adverse effects on the environment, maintain and protect the earth’s natural resources for the future (Tilman *et al.,* 2002). Biodynamic agriculture complies with this, as it produces no waste products, as everything that would typically be classed as waste is recycled to other sections of the farm. It is believed that the waste from one part of a farm can be applied to another, creating a vital energy transfer

between sections, thereby resulting in an increase of capacity for self-renewal [CITATION Dem14 \l 1033]. Recycling waste is a process that makes the farm sustainable. As previously stated a basic principle of biodynamics is that they disallow the use of any chemical pesticides and fertilisers (Reganold *et al.,* 1993). By disallowing chemical use this helps it to be a sustainable farming practice as there is evidence to prove that these chemical fertilisers have adverse effects on the environment [CITATION The091 \l 1033].

Furthermore, the way in which a biodynamic farm treats the land leaves no room for soil erosion or pollution therefore minimising adverse effects on the environment [CITATION Pei04 \l 1033]. Originally, Dr Steiner developed the methodology for biodynamic agriculture due to growing concerns about increased soil erosion and the decrease in soil fertility in the late 1800s and early 1920's [CITATION Eli03 \l 1033]. Even from early days of this agricultural practice it can be seen that it was designed to be sustainable and self-sufficient. Even by modern agricultural standards biodynamics is one of the most feasibly sustainable options.

3.1.2 Economic Sustainability

From a business standing, a biodynamic farm can be both economically sustainable and unsustainable. This is because of the niche market it caters to as not everyone wants to eat biodynamic food and not everybody has the means to pay for certified biodynamic food. Certified organic and biodynamic products are generally more expensive compared to their conventional farmed counterparts, this can be due to many reasons. Loch Arthur Farm Shop supplied a price list from Organic North for the month of March 2015. This price list was used to compare the prices of vegetables grown in a biodynamic way and in a conventional way. The prices for conventionally farmed produced were sourced from a well know local supermarket chain. The comparison of prices is shown in *Table 2.* The data clearly shows that as expected, biodynamic-farmed crops are more expensive per kg than conventionally farmed produce. For example biodynamic-farmed sweet potatoes are 145% more expensive per kg than their conventionally farmed counterpart.

Table 2 - Price Comparison between supermarket produce and biodynamic produce

Biodynamic vs Conventional Price list			
Item	Local supermarket £	Biodynamic £ per/kg	% Difference
Carrots	0.78	1.30	66
Red Onion	0.85	1.17	38
Yellow Onion	0.78	0.97	24
Parsnip	1.29	1.88	46
Sweet Potato	1.25	3.08	146

There is a dramatic difference in the price of crops between these two farming methods for a number of reasons. The most substantial reason is that the majority of the current population have lost faith in modern conventional farming, and have become more aware of food-borne hazards coming from pesticides, hormone treatments and artificial ingredients [CITATION Woo00 \l 1033]. In other words it has become more socially acceptable to be healthier and eat organic and biodynamic food, as it can be traced back to the farm it was grown on. This is the biggest driver to increase the price of biodynamic produce, if there is more demand for “clean grown” produce then it puts more pressure on the farmer to grow it, thereby increasing the prices. There are other contributing reasons why the price of biodynamic crops are more expensive, The Food and Agricultural Organisation for the United Nations (2015) state that it is because:

- The demand of organic/biodynamic food is greater than the supply, which in turn increases prices;
- The production costs can be higher because of greater labour inputs per unit of output;
- Legislation demands the mandatory segregation of biodynamic and conventional produce when being processed and transferred. Due to biodynamic produce being in a smaller quantity this segregation also increases costs;
- The marketing and the distribution chain for biodynamic products is a relatively inefficient system, typically limited to small farm shops and shareholders of farms. Produce rarely makes it to major supermarket chains. This again creates higher costs because of relatively small volumes of produce.

Biodynamic farms are relatively very small scale compared to conventional farms; even so a biodynamic farm still requires more human labour than a conventional farm. Due to the increased human labour, biodynamic produce becomes a more time-consuming process in terms of sowing, fertilising, harvesting and finally handling. This amount of human contact is about triple

that of a conventional farm and this is before its recipients receive the produce. Consequently, all of these factors contribute to the price of biodynamic crops automatically rising in comparison to a conventional farm which mass produces crops, and has the ability to sell them cheaper as they are a greater quantity with less labour as they are mostly mechanised and do not require as much manpower as biodynamic (Koepf, 1986). Being able to sell their produce at a higher cost can greatly benefit a biodynamic farm. Most biodynamic farms, such as Loch Arthur and Garvald Home Farm in South Lanarkshire, choose to stay away from major supermarket contracts in favour of small farm shops catering to a local market (Brett, 2015, Personal Communications; Jardine, 2015, Personal Communications). Mainly, they do this as the farm is there to support the community and not to support the wider population. By staying away from major supermarket contracts the farm untilises the trend to eat locally and the income gained from this is enough to allow them to be economically sustainble [CITATION Bes98 \l 1033].

Fundamentally a farm, no matter how they choose to treat their land is a business. To be economically sustainable, the business must be able to operate without a loss and with a potential margin for profit. This again is where a biodynamic farm can be unsustainable and run at a loss. A CSA run biodynamic farm has more potential to be sustainable as it has shareholders who buy shares in order to automatically receive the farm's produce. This therefore provides the farm with a capital up front inputs that can provide a stable income regardless of how much the farm produces or how well the crops grow in each growing season [CITATION Con00 \l 1033]. In doing this, the competition to gain major supermarket contracts is eliminated and there is no quotas or demands to meet. This decreases the pressure on the farmer to source income from elsewhere and decreases the potential for the land to exceed its own carrying capacity. The shareholders are also the farm's labourers, which also cuts outwards costs in wages. By running the farm in this way, it makes it more economically viable and feasible to be sustainable and self-sufficient.
In contrast however, if a biodynamic farm operates as a CC, then it is mainly operating as a charity that helps to support individuals with a range of disabilities [CITATION htt14 \l 1033]. This is where there can be a potential loss in sustainability. As a charity they base their income mainly on how many people are paying for the use of the farms therapeutic schemes, donations and grant funding. In the case of Loch Arthur Farm in Dumfries, residents have a third party sponsorship to cover the cost of their rent and then they work on the farm in exchange for their food (Jardine, 2015, Personal Communications). This process is instead of basing their income on how many crops they can produce and sell. Overall this creates an inefficient system and can mean that deficit in income may occur if one income factor disappears. For example if their third party sponsorship disappears there may

not be enough workers for the farm or enough income to support the farm. As this creates a loss it can thereby be defined as an unsustainable system.

Each biodynamic farm is unique and there are certain differences in the way that each farm operates their business. Consequently, this means that there is not a definite answer to whether or not this farming practice can be wholly economically sustainable. It is entirely dependable on the individual farm in question.

3.1.3 Social Sustainability

In a social standing, biodynamic agriculture encompasses the main principles of social sustainability, cultural diversity, social equity and above all acceptance of everyone [CITATION Hod09 \l 1033]. This is achieved by building communities that support individuals with a range of complex needs such as physical or mental disabilities; these individuals can sometimes require specialist help. For the purpose of a CC, they aim to help people develop their character and confidence, improve their life skills, provide them with structured day and enable a safe learning and working environment [CITATION Cam13 \l 1033]. The farm and their shops are used as the medium to bring the people of the community together by providing a social and working environment. It has been shown that by living in a socially stimulating and active way can greatly improve people's quality of life [CITATION Fis04 \l 1033]. This highlights that a CC run biodynamic farm is indeed run in accordance to social sustainability.

Overall, biodynamic farms have the potential to be wholly sustainable and self-sufficient. Their biggest hindrances is how sustainable they can be economically, as they mainly operate as a charity there is always the chance that the farm can run at a loss due to the withdrawals of third party funding, sponsorship and grants. In terms of social and environmental sustainability biodynamics is sustainable; there are no adverse effects on the environment and all waste produced is recycled to other parts of the farm. Socially sustainable communities are equitable, diverse, connected and democratic and provide a good quality of life. A biodynamic farm incorporates each of these principles in it day to day running, therefore making it feasibly sustainable.

3.2 Research Question Two: To evaluate the effects biodynamic preparations have on soil quality.

This question is the highest debated topic within biodynamic farming. Scientists have researched for years to find out whether or not biodynamic unique preparations alter soil quality or not. Unfortunately, there is still no definitive answer

as some research states that the preparations have a great effect on the soil and others state that there is no significant difference between soils treated with preparations and soils that have not been. There is also a lack of peer-reviewed articles discussing the efficiency of the preparations and whether they have any effect on the soil (Reeve *et al.,* 2010). As I was unable to conduct the planned primary research surrounding soil quality, this question will be answered by the comparison of four peer-reviewed research articles.

The first article assessed by Carpenter-Boggs *et al.,* (2000a) investigated the effects of preparations 502-507 on compost over a 13 month trial. Untreated compost was used as the control. Overall the study found that preparation treated compost to be of a greater quality than the untreated control. The study found that the biodynamic treated compost contained 10% less Carbon Dioxide (CO_2) and had a higher ratio of dehydrongenase enzyme to CO_2 production. As there is more CO_2 being produced this means that the decomposition within the compost is more complete. Furthermore, this higher ratio also suggests that the compost supports more efficient bacterial communities or a larger proportion of anaerobic metabolism. The treated compost was also significantly higher in temperature and this is typically caused by more microbiological activity which also contributes to faster decompostion oand greater control over weeds and pathogens. It was also found that the treated compost contained 65% more nitrate that the control which suggests that this compost was more mature, meaning it had more access to Nirtogen (N_2), allowing more complete decomposition to occur. This study found significant differences between the treated and untreated composts', in particular the biodynamically treated compost to be of a greater qualty.

A second study by Carpenter-Boggs *et al.,* (2000b) investigated the effects of preparations 501-508 over the course of two years. The soil in the control group was not treated at all. Overall this study found that there were no significant differences between the treated soils and untreated soils. The only minor difference found was a small influx in fatty acids in the treated soils in the first year of the study, however this was rendered negligible. Now, this is an interesting result as the previous study by Carpernter-Boggs published in the same year did find significant differences between the treated and untreated soils as previously stated. This is an example of why this question is very hard to provide a definitive answer for as the research itself does not come to a definitive conclusion.

The third study analysed by Reganold *et al.,* (1993) observed the effects of preparations 500-508 had on soil over two biodynamic farm's. This was compared against the soils of two conventional farm's. In this study some differences between the two were found. The preparation treated soil had a better structure and more readily broke down to a seedbed. The drainage and aeration of the treated soils were better which is better for crop and grass growth. The soil was also of a lower bulk density in comparison to the conventional soil. The article stateds that this is beneficial as it allows machinery to pass over more easily and also makes it easier

for roots to grow through. The treated soil was also found to have a greater organic matter content and materialised nitrogen content. The higher amounts of organic matter within a soil is a good thing, it means more nutrients for the crops, which means more growing potential[CITATION Lew02 \l 1033]. Nonetheless despite all of these significant difference between the two soils, Reganold *et al.,* (1993) found that there was no differences in soils below 20cm from the surface.

The final study examined is by Reeve *et al.,* (2010), this study analysed the effects of biodynamic preparations on a mixture of grape pomace and manure over a period of two years two years. The water extracts of the composts where then used to fertigait wheat seedlings, with and without inorganic fertilisers. The control group is the untreated mixture. This experiment found that there was a slightly higher dehydrongenase enzyme activity in the preparation treated soil. It is suggested that this change is due to a higher microbiological content which can contribute to a higher rate of decomposition.

The observations of all four studies are consistent in establishing that biodynamic preparations do have a small effect on soil quality. The general consensus between articles is that the use of preparations provide the soil with increased organic matter content, contributing to higher concentrations of dehydrongenase enzyme activity, which results in higher decomposition rates. All four of these studies have similar contributing authors, as they are the only experts in this field of agriculture. Even still the results are not biased and vary considerably.

3.3 Research Question Three: To assess whether biodynamic farming is a sustainable option for the future?

This section will discuss the feasibility of biodynamic agriculture being one of the sustainable options for the future. There is very little research and published material for this subject therefore it will be based entirely on my own observations.

Currently, there is an ever-growing range of sustainability claims and indicators. Collectively however, all fail to establish operational and practical ways to understand what sustainability actually means, and to deliver it effectively (Guttenstein *et al.,* 2010). As previously stated, it is estimated that the global food demand will double over the next 50 years (Tilman *et al.,* 2002). This means more land will need to be utilised for farming. However, it is reported that half of our planets terrestrial farmland is already being used to its full potential (Carpenter *et al.,* 1998; Tilman *et al.,* 2002). Land shortage is one of the biggest issues surrounding the eminent increase in food demand. How humans choose to use land has a great impact on environmental quality and the state of ecosystems and socio-economic development. Generally, land use is considered to be sustainable if the

environmental pressures of human activities do not exceed the ecological carrying capacity (Ruggiero *et al.,* 2012). The majority of the earth's farmland is exploited due to the industrialised nature of our modern farming practices. Once land has been used beyond its carrying capacity, the soil very rarely regenerates back to a fertile state, leaving it barren and useless[CITATION Bro95 \l 1033]. Exploitation on this scale cannot continue to occur. Our already existing farming land needs to be treated in a more sustainable way. If we nurture our land, instead of exploiting it, the likelihood of it being able to farm it for years to come increases.

This is where biodynamic agriculture can be of a massive advantage to the agriculture sector. Unlike most modern agricultural techniques, this practice is entirely environmentally and socially sustainable. As previously discussed in Section 3.1, farming in a biodynamic manner generates no waste products, is very self-sufficient and does not harm the environment at all; therefore it is incredibly sustainable in an environmental sense. A study by Tavernier & Tolomeo (2008) states that sustainable agriculture is an approach that needs to clearly maximise economic and social benefits while at the same time maintaining environmental quality. Again, this is where biodynamic agriculture is a forward thinking movement. Even in its early days of development biodynamic agriculture incorporated the main principles of social sustainability. The way in which biodynamic farms are typically run includes a strong presence in community life, supporting individuals with learning difficulties, encouraging social equity and cultural diversity. All of these factors contribute to a socially sound sustainable environment [CITATION Hod09 \l 1033]. Despite all of these good sustainable qualities it is not believed that we would be able to rely on biodynamic agriculture solely to produce enough food to meet the demand. Even in a perfect world, being sustainable and self-sufficient is not efficient enough as even the most developed countries in the world do not have to the ability to introduce the infrastructure and legislation to guide the introduction of sustainable development [CITATION Ros12 \l 1033]. Without the foundation for sustainable development, there is no footing for a wholly sustainable agricultural practice to exist. This highlights how much research and planning that still needs to occur for feasible sustainable agricultural practice to exist.

Some researchers believe that a "large-scale shift towards organic farming would not only increase the world's food supply, but might be the only way to eradicate hunger" [CITATION Hal06 \p 1 \l 1033]. This is surprising to most as many assume that organic yields are less than that of a conventional farm. However this is not the case, a seven-year study from Maikaal District in central India involving 1,000 farmers found that average yields for cotton, were as much as 20% higher on the organic farms in comparison to the nearby conventionally managed ones (Eyhorn, Mäder, & Ramakrishnan, 2005). Organic farming is similar to biodynamic farming, as both practices ban the use of GMO's , synthetic chemical fertilisers and pesticides [CITATION Org13 \l 1033]. The only differences between the two practices is biodynamic's holistic approach to food production and their incorporation of lunar

and cosmos cycles. With the similarities in mind would it then be possible for a large-scale shift towards biodynamic farming?

Personally, after reviewing the research used in this dissertation, I do not believe it would be wise to conduct a widespread shift to one agricultural practice across the world. This is because not all agricultural practices can support all of the different types of crops and livestock that humans require for food. Also not all climates can support every type of farming. This is why agricultural diversity is needed; a world where several sustainable agricultural practices that can produce enough for the global food demand needs to exist. Furthermore, for biodynamic agriculture to exist as one of our future sustainable options more research would need to be conducted and more information needs to be made open to the public. The world of biodynamic agriculture is still a very closed community; and because of this the public can still be very sceptical and wary of it. Until more is know about biodynamic farming, it cannot be a sustainable option for the future as there will be little faith in its capabilities. Nevertheless, we cannot keep relying on conventional agriculture when it causes so much damage to our fragile planet. Even still, right now it is practical to continue in this way, as it is the main supplier of our food. Until we have the ability to rely on sustainable methods for farming, we need conventional agriculture to meet our global food demand.

3.4 Limitations and Ethics

The anticipated limitations of this research included the planned primary research. Ethical approval was initially declined, for a small security alteration. This delayed my research considerably due to the processing period for resubmission. Once my ethics form was approved, my research was hindered further. Biodynamic farmers can be very secretive about their agricultural practices as in the past they have received a lot of scrutiny and criticism. This delayed my research further, as the biodynamic farmers invited to partake in this study were not inclined to discuss methods, preparations, and yields. Furthermore due to miscommunication and the strict time scale of the dissertation, I was unable to conduct any primary research I had planned. However as this was foreseen issue the dissertation was changed to a desk based literature study, which brings me to my next limitation. Obtaining sound peer-reviewed literature was difficult, as biodynamic agriculture is still a relatively new agricultural practice and is widely un-researched. Due to the lack of peer-reviewed articles available some information sourced could be relative and incorrect.

Chapter 4 – Conclusion

4.0 Conclusion

Biodynamic agriculture has been around since the 1920’s, however it is still very much in its infancy. Everyday it is being developed and is slowly becoming

incorporated into the modern agricultural world. Despite the mystery and criticism that surrounds biodynamic agriculture, the practice itself is as sustainable and self sufficient as you can get in this current era.

The research taken place in this dissertation has shown that biodynamic agriculture is indeed a very sustainable agricultural practice. Where this practice lacks in economic sustainability, it makes up for in environmental and social sustainability. It is one of the most environmentally friendly farming practices in the world and is well on its way to being one of the sustainable options for the future. From literature analyses it was found that biodynamic preparations 500-508 do have beneficial effects on the soil quality (Carpenter-Boggs *et al.,* 2000a; Reeve *et al.,* 2010; Reganold *et al.,* 1993). The benefits identified were increased microbiological movement, higher organic matter content and higher concentrations of dehydrogenase enzyme activity. Finally the research highlighted that there is a need for more sustainable agriculture to exist and that a large-scale move to sustainable agriculture may be the way forward. Nonetheless, the world still lacks the basic foundation for delivering sustainable development. Until this changes the world will still need to rely upon conventional agriculture in order to meet the current and further food demand.

4.1 Further Research

Biodynamic agriculture is still an area of agriculture that very little research has been conducted. What little research that has been published has not all been peer-reviewed. I suggest that further peer-reviewed research needs to be conducted in order to prove the validity of biodynamic preparations and the effect they have on the soil and crops. In addition to this, more research in to how agricultural sustainability can be used to achieve world food demand should be taken place. Then the results of this research can be directly applied to biodynamic agriculture and how it can progress towards being a global farming option.

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Appendices

Costs and timescale

Costs

This section details the financial cost of producing this research and the timescale of which it aims to be achieved.

Table 2 - Travel costs
Visit to local Scotland's Rural College Library: Barony College and farms around Dumfries and Galloway over a five-week period.

Item	Rate per week
Travel	£22

Table 3 – Costs per week

Item		
Travel	5 weeks @ £22	£110.00
	Total cost	£110.00

Table 4 - 17 week time scale of research

Timetable

Below is a Gantt chart timetable detailing the intended duration of this research. The chart details days from the start of semester two, which has been set as 12 January 2015. The date for final submission is **5 May 2015**. The contingency plan for this research can be found in the appendix.

Task List	w/b Jan 26	w/b Feb 2	w/b Feb 9	w/b Feb 16	w/b Feb 23	w/b Mar 2	w/b Mar 9	w/b Mar 16	w/b Mar 23	w/b Mar 30	w/b Apr 6	w/b Apr 13	w/b Apr 20	w/b Apr 27	w/b May 4
Initial Research															
Draft research proposal															
Final research proposal															
Proposal submission															
Supervisor															

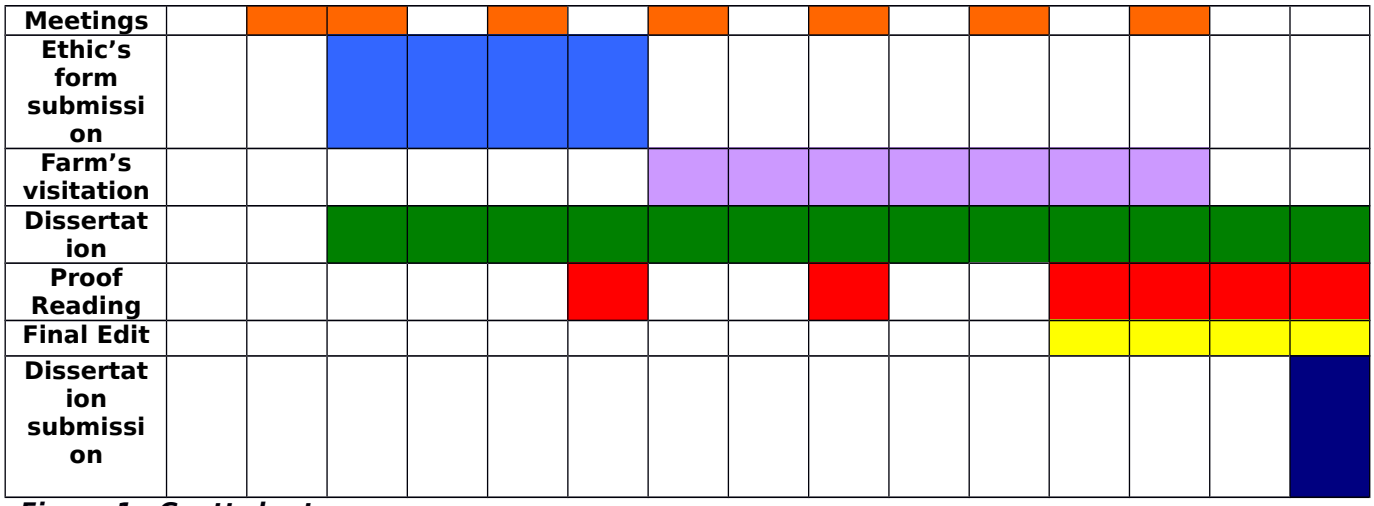

Figure 1 - Gantt chart

Furthermore the following table demonstrates the completion dates of the final report.

Task	Completion Date
Introduction	20th February 2015
Materials and Methods	23rd March 2015
Results	13th April 2015
Discussion	30th March 2015
Conclusion	20th April 2015
Abstract	15th April 2015
Draft Edit	26th April 2015
Final Submission	5th May 2015

Table 5 - Completion dates for Final Report

Contingence plan

Below is a table of foreseen obstacles that could hinder progress. This contingency plan will help in planning processes in order to tackle problems and stay on track with research and writing.

Obstacle	How Much impact	Measures	Who could help	How far to plan ahead
Writers block	Could lose valuable days' worth of	Dog walking, reading, moving on to	Google, talking with Bethan Wood	Cannot plan for this

	writing	different subject	(Supervisor)	
Unforeseen circumstances	Major/minor meltdown	Improve and adapt	Bethan Wood (Supervisor) and course convener	Plan for wasted days
Exhaust dissertation topics	Causes writers block and not being able to meet word counts	Meet with supervisor and peers for support	Meet with Bethan Wood (Supervisor) and peers for support	Meet with supervisor regularly
Technical issues	Lose time and possibly word counts	Seek professional help from IT, back up regularly on numerous media	IT support	Leave time at end and always have back ups
Support system breaks down	Lose direction and focus	Actively seek out other support	Bethan Wood	Create an emergency plan
Ethics form not approved	Delays research considerably	Double check before submission	Bethan Wood	Have additional forms ready for editing in case first form is not approved
Adverse weather conditions	Restricts farm visitations which can hinder research	Checking weather forecasts before planning visits	Weather mediums, peers	Weather is only predictable by two weeks in advance, so planning will have to occur weekly.
Farmers not wanting to be interviewed	Hinders fieldwork, may have to change dissertation to desk based study.	Meet with supervisor and peers for support	Meet with supervisor for support and directional help	Meet with supervisor on regular basis.

Table 6 - Contingency Plan