SOIL MANAGEMENT IN ORGANIC AGRICULTURE

A CASE STUDY OF DENMARK

By
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EXECUTIVE SUMMARY

The research work in this thesis is based on the review of empirical studies on soil degradation and soil conservation in both organic and conventional agriculture conducted in Denmark and published in international/Danish journals and other sources. This provides a scientific support to the methodology in general and to the findings in particular. The findings are not based on assumptions or expectations but on proved scientific information.

The methodology adopted for this thesis includes two comparative studies. One is the comparative study of organic and conventional agriculture for soil degradation. The other one is the comparative study of organic and conventional agriculture for soil conservation. To carry out both of the comparative studies, certain parameters, which are quality attributes, have been selected separately for soil degradation (Table No. 1, page 39) and soil conservation (Table No. 10, page 74). The selected parameters of soil degradation are the same for both of the farming systems. Similarly, the selected parameters of soil conservation are the same for both of the farming systems.

The selection of the parameters plays a pivotal role in determining the status of soil degradation or soil conservation in both the farming systems. Therefore, great care has been taken in selecting parameters, depending on the agro-climatic conditions and agricultural practices that are relevant to and applied in Danish agriculture. The justification for using the selected parameters is provided in ‘Chapter 5 Discussion and Critical Analysis’ of the thesis.

It is important to conduct both comparative studies due to the fact that there is an inverse relationship existing between soil degradation and soil conservation. If soil degradation is high, then soil conservation is low and vice versa. Soil degradation in Denmark can be understood and measured from the levels (high, medium and low) of soil degradation and soil conservation separately.

Three possible dimensions of soil degradation have been taken into account in the comparative study of farming types for soil degradation. These are physical soil degradation, chemical soil degradation and biological soil degradation. Each soil

degradation dimension has its own list of parameters. In a similar way, three possible dimensions of soil conservation have been taken into account in the comparative study of farming types for soil conservation. These are physical soil conservation, chemical soil conservation and biological soil conservation. Each soil conservation dimension has its own list of parameters.

To figure out whether organic farming reduces soil degradation in Denmark through its soil management, the results of the comparative study of farming types for soil degradation have been quantitatively analysed using the ‘Chi-Square Fisher Exact Test of Independence’ statistical test. This test statistically determines if there is any association existing between the two farming types and three levels of soil degradation. In a similar manner, the results of the comparative study of farming types for soil conservation have been quantitatively analysed using the same statistical test to determine if there is any association existing between the two farming types and three levels of soil conservation.

The case study of Denmark is divided into two portions. The case study part 1 includes two comparative studies. As mentioned earlier, one is of organic agriculture and conventional agriculture for soil degradation and the other is of organic agriculture and conventional agriculture for soil conservation. From these two comparative studies, it is determined, in light of the empirical studies, if organic agriculture can help in reducing soil degradation in Denmark through its proper soil management.

The case study part 2 provides support to case study part 1. The case study part 2 provides an insight into the development, situation and regulation of organic agriculture in Denmark, which also puts light on how soil degradation is reduced in organic agriculture.

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CHAPTER 1

INTRODUCTION

1.1 Background and Pre-Understanding:

Denmark is a country where agricultural production has been carried out very efficiently and effectively, after the Green Revolution of the 20th century, and hence a few decades ago, agriculture was highly valued for its capability to produce many kinds of food that were cheaply available. This production was based on the conventional agricultural practices, where hazardous chemicals and heavy machinery on the soil were primarily used as a result of the industrialization of agriculture. Other factors that contributed to this were scientific achievements, access to affordable energy and other technological achievements that reduced the time and manpower required for agricultural production. However, the fact remains the same that conventional agricultural systems carried the main responsibility for the acute environmental degradation that Denmark experienced throughout the 1960s and 1970s. Particularly, the presence of nitrate and pesticides in drinking water that leached from the soil, residues of pesticides in foods, eutrophication of marine, fresh water and terrestrial ecosystems.

The notion that foods have been produced cheaply, which was one of the main aims of agriculture, is no longer sufficient. This is due to the fact that the public, the private sector and the government all have developed environmental awareness, in agricultural production, in the last couple of decades. Therefore, currently, there are certain expectations and demands from the agriculture system. The indispensable components of such demands are; environmental impacts of agricultural systems, use of natural resources, animal well-being, landscape aesthetics, bio-ethics and food purity.

The type of agricultural production system that addresses all these and other vital issues is *organic agriculture*. Hence, both consumers and farmers have developed a strong and unrelenting interest in certified organic foods and their production methods. This change from conventional to organic agriculture took Denmark quite some time due to the fact that it came up against several socio-economic obstacles within the agricultural systems. These obstacles are either soft or hard. Some examples of soft obstacles are farming attitudes, varying market prices and sale of agricultural products, while those of hard obstacles are conversion of arable land and diary farms, investments in construction and agricultural machinery, and large scale agricultural productions.

In Denmark, organic farming is gradually gaining appreciation as an environment friendly production system due to its basic theme and practices. The basic theme of organic farming differs from the conventional theme where no due consideration is given to the environmental components or natural resources such as soil, groundwater, flora, fauna, and microbes. Ever increasing public attention in Denmark is now being paid to the impact of agriculture on the nature and environment. Hence there is a need to elaborate the farming types that are practiced in Denmark and provide an account of their impacts on the nature and environment. These two major farming types are conventional farming and organic farming.

The basic ideology of organic agriculture differs from conventional agriculture. At the practical level, the difference is that organic agriculture must live up to the expectations and aims of taking special regard to the environment and nature as a whole. This further leads to the concept of agricultural sustainability. The periphery of organic farming is not only restricted to agricultural production but it has a holistic approach. Due to this approach, organic farming is considered as a highly relevant tool that has the potential to contribute in finding solutions simultaneously to a range of problems pertaining from agricultural production to the environment. Organic agriculture aims at creating an environmentally sustainable form of farming which emphasizes on a self-sustaining biological system rather than providing external inputs. That is why such a system is termed as a low-input farming system.

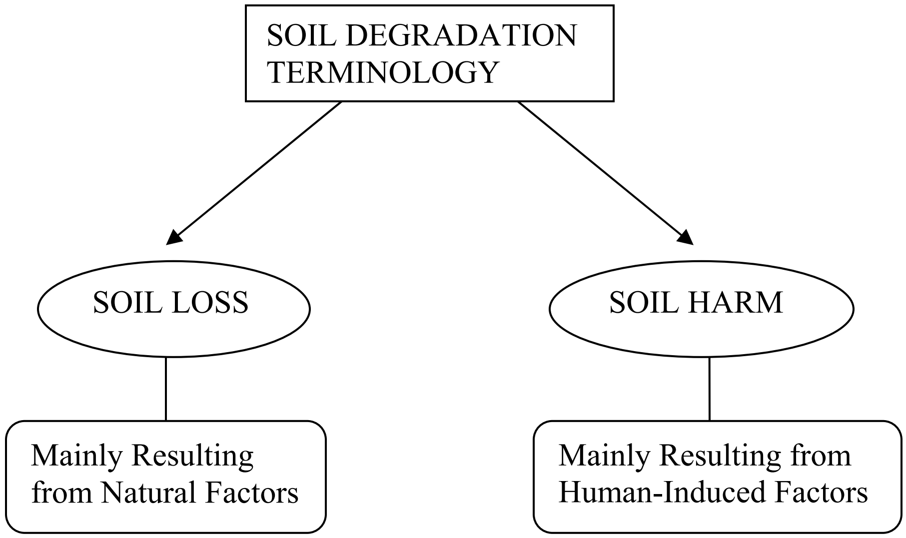
The crux of organic farming and its management practices is its approach to finding solutions to agricultural problems keeping in view environmental protection. This approach is antagonistic to the approach of conventional farming. Organic farming addresses problems in a preventive manner, which relies on long-term solutions, giving due regard to nature and our environment. For example, crop rotations are designed for nutrient cycling, integrated pest management is applied for the prevention of pests, reduced tillage is carried out for soil conservation, etc. Conversely, conventional farming has a reactive approach to the problems and relies on short-term solutions, e.g., application of chemical pesticides and inorganic artificial fertilizers.

Soil is of paramount significance in Danish agriculture. This is due to the fact that the landscape of Denmark is plain and a major portion (60%) of the total land is utilized for cultivation. The total Usable Agricultural Area (UAA) is 2.5 million hectares. UAA is the area of a country that is suitable for agriculture purposes, as compared to its total land area.

Soil is a precious natural resource and in Denmark there is an ever increasing awareness of the declining soil quality. To inhibit this decline, soil conservation has been given due consideration in organic farming in the country. One of the basic aims of soil management in Danish organic agriculture is the reduction of soil degradation as a whole. Soil management in organic farming assures the reduction of soil degradation through its holistic approach. The term soil degradation covers several environmental problems associated with soil at different spatial and time scales. These include acidification (change in the chemical composition of soil), eutrophication (change in the chemical composition of water), atmospheric deposition of heavy metals, persistent organic pollutants, conventional agricultural practices that are harmful to the soil, etc.

Soil conservation is the essence of soil management. To conserve means ‘to protect from loss and harm’. Hence soil conservation means to protect the soil from both loss and harm. *'Soil Loss'* and *'Soil Harm'* are two different unique terms/categories, with reference to soil degradation, that have been introduced separately (in this thesis) to comprehend soil degradation. *Soil Loss* implies soil degradation that occurs naturally e.g. erosion and other factors are responsible for the loss of soil. *Soil Loss* can occur in the three basic dimensions of loss, i.e. physical, chemical and biological. Conversely, *Soil Harm* implies soil degradation that is anthropogenic in nature, i.e. induced by mankind e.g. chemicals and mechanics are responsible for the harm of the soil. Physical, chemical and biological dimensions of harm can take place in *Soil Harm*. With this background, organic farming practices propagate soil conservation by reducing both *Soil Loss* and *Soil Harm.*

Schematic Diagram No. 1; Presenting the soil degradation terminologies that have been introduced in this thesis, depending on the different resulting factors.



As manifested from experience that *soil harm* has been pre-dominantly higher as compared to *soil loss*. The harm or damage to the soil caused by human induced activities is ever increasing due to factors like conventional agricultural practices, urbanization, industrialization, increasing population, etc. Some of the problems of both *soil loss* and *soil harm* are irreversible, e.g. soil erosion (whether it occurs naturally or as human induced). Whereas, other problems of both *soil loss* and *soil harm* can be dealt with and improved with specialized tactics and measures, e.g. soil leaching can be improved with crop rotations of legumes and catch crops; soil contamination can be alleviated with remediation procedures; etc. Here the soil management practices play a vital role in the soil conservation.

1.2 The Problem:

Soil is one of the natural resources on Planet Earth. Though soil is a renewable natural resource, yet it can become finite, with the passage of time, through its degradation. In Denmark soil degradation is a problem and there are several causes for this. These causes are in fact various factors as a result of which soil degradation takes place. Some of the contributing factors are certain agricultural practices of conventional agriculture. There is a universal acceptance that such agricultural practices degrade the soil. In Denmark, the issue of soil degradation ranges from erosion and contamination of the topsoil to contamination of ground water. Soil degradation is an issue of growing concern in the public.

In Denmark, the excessive use of synthetic chemicals and mechanical methods in conventional agriculture has degraded the soil and their increased use is against soil sustainability in the country. This ultimately goes against the development of overall sustainable agriculture. E.g. the increase of nitrates and other synthetic chemicals, can find their way into the food chain that ultimately affect the human health as well as other living organisms. The presence of these chemicals in the soil may hamper the soil quality itself through soil pollution, which affects the soil sustainability. These synthetic chemicals are also hazardous to other environmental components (e.g. water).
Hence there is a need to conserve the soil and avoid its degradation in order for soil to contribute in the long term development of sustainable agriculture of the country.

The threats associated with consequences of soil degradation are similar to the threats of other long-term environmental problems like global warming and loss of biodiversity. Since these issues are given excessive publicity and coverage, the public are well aware of the global warming problem. Unlike the global warming problem, the public is, generally, not aware of the seriousness of the soil degradation problem.

1.3 Research Area Question/Problem Formulation:

The problem formulation for this thesis is as follows:

> "Can organic agriculture properly manage soil, a natural resource, to reduce its degradation in Denmark?"

At the problem formulation stage, it is better for the reader to comprehend what this study is about. One should not be slipped of the track by the problem formulation (which might sound as a pure soil science research question). This research thesis is not a study of soil science or agriculture neither it is a pure study of the regulation and planning of environmental policies. In fact, this research thesis is based on the concept of inter-disciplinary study encompassing both natural sciences and social sciences so as to derive a basis/understanding for the planning and regulation of environmental policies in the area of agriculture with the emphasis of its impact on the soil environment. This thesis is an attempt to study the knowledge and understanding developed about agriculture and the soil environment.

1.4 Research Methodology:

In order to answer the problem formulation question, the following research methodology is adopted for this thesis. The thesis is carried out with a methodology in light of the problem formulation/research question and therefore, it can be understood better with the help of the following two steps:

Step No. 1:

Firstly, the comparative empirical study of Danish organic and conventional farming for soil management is inevitable in assessing whether organic farming can actually reduce soil degradation through its proper soil management (Chapter 3). In other words, without a comparative empirical study of both the farming types in Denmark, one cannot assess whether organic farming is beneficial to the soil or not in reducing soil degradation.

Moreover, since the problem formulation question seeks reduction of soil degradation through proper soil management in organic agriculture, therefore, soil management includes both reduction of soil degradation and enhancement of soil conservation. Hence, two comparative studies have been conducted. One is the comparative study of organic and conventional agriculture for soil degradation in light of the selected parameters. The other is the comparative study of organic and conventional agriculture for soil conservation in light of the selected parameters. The portion of comparative empirical study, in this thesis, is an attempt to study soil degradation and soil conservation, in both types of farming systems, from a multidisciplinary approach that integrates soil physics, soil chemistry and soil microbiology.

To figure out whether organic farming reduces soil degradation in Denmark through its soil management, it is necessary to measure qualitatively and quantitatively the levels of soil degradation that takes place. This has been achieved in this thesis by first selecting certain parameters of soil degradation and then finding empirical research findings in support of the parameters. In other words a review of the available/published empirical literature for each of the selected parameters separately is compulsory to measure the severity of soil degradation in the analysis.

Similarly, due to the inverse relationship that exists between soil degradation and soil conservation, the level of soil degradation in organic farming can be determined from the level of soil conservation that takes place in organic farming. Therefore, there is another set of parameters of soil conservation and a review of the empirical studies conducted for soil conservation has also been conducted.

Irrespective of the farming types, the inverse proportionality of soil degradation and soil conservation remains constant. The understanding can be developed from the following information:

1) Soil Degradation and Soil Conservation Relationship with Organic Farming

a) If soil degradation is high, then soil conservation is low
b) If soil conservation is high, then soil degradation is low

2) Soil Degradation and Soil Conservation Relationship with Conventional Farming

a) If soil degradation is high, then soil conservation is low
b) If soil conservation is high, then the soil degradation is low

The quantitative analyses are conducted separately for the two comparative studies. This is based on the statistical test of Chi-Square Fisher Exact Test of Independence which determines in light of the review of the empirical studies if there is any association of the two farming types on either soil degradation or soil conservation. In other words, the test determines if there is any effect of farming types on either soil degradation or soil conservation.

To carry out the quantitative analysis for the comparative study for soil degradation, the ranking of all the empirical data for each parameter of soil degradation is tabulated and collectively counted as high, medium and low for the three dimensions, viz. physical degradation, chemical degradation and biological degradation.

In a similar way, the quantitative analysis for the comparative study for soil conservation is conducted where the tabulation of the ranking of all the empirical data for each parameter of soil conservation takes place. The ranking as high, medium and low is collectively counted for the three dimensions, viz. physical conservation, chemical conservation and biological conservation.

Step No. 2:

Secondly, after having this comprehension and assessment whether soil can be properly managed in organic farming in order to reduce its degradation, a thorough presentation of the Danish organic agriculture is given (Chapter 4). This includes a presentation of history, development and the regulatory process of organic farming in Denmark.

Central Point in the Thesis:

The way the empirical data/material is structured is a central point in the thesis. It is important for the reader to properly understand the contribution of the empirical data (in the form of citations) so as to understand the overall thesis. This project is analyses of certain scientific aspects and these aspects are obtained from the scientific literature. The scientific aspects are: the roles which the two farming types play in soil degradation or soil conservation; the impacts of various parameters used for both of these areas; the conclusions derived from the scientific literature; etc.

Author's Role in Citations:

The author's role in this regard is very clear, which is, organizing the data according to the various selected parameters; evaluating the data and extracting knowledge from this organization; conducting the statistical analyses based on the evaluation of the null hypothesis for the comparative study where the existing literature is the data; looking at the impacts of the extracted knowledge on the planning and regulation; analyzing the data so as to answer the problem formulation question.

Role of Citations in the Thesis:

The role of the citations and the role of the knowledge embedded in the literature that has been extensively used under various parameters in this thesis can be understood in the following manner:

An important aspect of the research methodology is to understand the proper role of the citations of the empirical data from literature in all the selected parameters for both soil degradation and soil conservation. It should be clear to the reader that these citations are not the basic substance of the thesis. In fact, these citations provide a strong foundation on which the edifice of the whole thesis is based on, without which the thesis cannot be completed. Following are the major reasons for citations of the empirical data:

- The citations have been presented in the form of boxes, under all the parameters, which underpin the fact that this is not the outcome of this study; rather it is the empirical background for the study, in light of which the outcome is based.
- These citations provide for a background even for the statistical analyses of the null hypothesis that have been conducted in order to comparatively analyze both farming systems for soil degradation and soil conservation.
- The problem formulation question cannot be addressed and answered properly without providing the citations.
- The results of the comparative study are also based on these citations.
- The conclusions of the citations have been used for the determination of the various levels (high, medium, low) of soil degradation and soil conservation under all of the selected parameters.

1.4.1 Organization of the Thesis:

In total there are five chapters:

- The *First Chapter* provides an overview of the background, the problem area identified, the problem formulation question, the research methodology and the objectives.
- The *Second Chapter* discusses soil as a natural resource in agriculture from a global perspective.
- Denmark's case study is divided amongst the subsequent two chapters. The empirical data is provided in *Chapter Three*, from a comparative perspective of organic and conventional farming systems of Denmark, in order to evaluate their impacts on soil and then furthermore assess whether organic farming can reduce soil degradation. This Chapter is divided into two sections.

  In the *first section*, a comparative study of both the farming types is conducted for *soil degradation.* Then the analysis for the comparative study of *soil degradation* is given where the assessment takes place in order to answer the problem formulation, whether organic farming can actually reduce soil degradation through its proper soil management.

  The *second section* comprises of a comparative study of both the farming types for *soil conservation.* Then the analysis for the comparative study of *soil conservation* is given where the assessment takes place in order to answer the problem formulation, whether organic farming can actually reduce soil degradation through its proper soil management.
- *Chapter Four* provides a detailed situation of the geographical distribution, soil types, organic farming, soil management practices and the regulatory process that is carried out in Denmark.
- *Chapter Five* comprises of discussion, conclusion and critical analysis.

1.4.2 Procedure:

The main procedure that has been adopted in this thesis is that several important parameters have been selected, keeping in view the agro-climatic conditions of Denmark, for both organic and conventional agricultural systems. These parameters are basically indicators of either soil degradation or soil conservation. There are separate sets of parameters in each of the three dimensions (physical, chemical and biological) for soil degradation. Similarly, there are separate sets of parameters in each of the three dimensions (physical, chemical and biological) for soil conservation. There are instances where a parameter is found in both the comparative studies. In other words, in both farming types a common parameter is found which on one hand indicates the severity of soil degradation and on other indicates the severity of soil conservation.

Various parameters have been selected in each comparative study in order to estimate the overall respective soil degradation and soil conservation. The selected parameters of soil degradation are also indicators that reflect on the severity of soil degradation in Denmark. Similarly the selected parameters of soil conservation are also indicators that reflect on the severity of soil conservation in Denmark. The selected parameters play a pivotal role in the findings of this thesis.

Once these parameters are identified, then the basic idea is to dig out the respective empirical research conducted in Denmark. From a statistical point of view, the collection of data in the review is similar to sampling which is done in a random manner. Upon collecting samples for each of the parameters within the areas of soil degradation and soil conservation, the data is analysed quantitatively using a statistical test. The statistical test has been selected depending on the null hypothesis, the sampling procedure and conclusions to be determined.

From the conclusions of the gathered experimental data, the references are classified into three various levels; high, medium and low. These levels are for both of the comparative studies. The levels are taken into consideration because soil degradation and soil conservation can be observed in these three levels high, medium and low in Denmark. This information is used later on in the analysis to determine if any association exists between the farming types and the levels of soil degradation and soil conservation.

The question arises, what is the importance of the selected parameters in this thesis? This question is addressed in 'Chapter 5 Discussion and Analysis' where a detailed account is given to each of the selected parameters in both the categories of soil degradation and soil conservation.

This quantitative analysis aids in answering the problem formulation question whether organic farming can help in reducing soil degradation in Denmark. Though the conclusions of the statistical test are based on the samples of empirical data collected for each parameter in both of the comparative studies, yet it is also possible to derive an understanding from the qualitative evaluation of the empirical data gathered, whether organic agriculture can help in reducing soil degradation in Denmark.

In order to figure out if organic farming can help in reducing soil degradation in Denmark we want to determine;

a) If there is any association present between organic agriculture and three levels of soil degradation.
b) If there is any association present between conventional agriculture and the three levels of soil degradation.
c) If there is any association present between organic agriculture and the three levels of soil conservation.
d) If there is any association present between conventional agriculture and the three levels of soil conservation.

The first two associations are addressed in the first comparative study. This is a comparative study of organic and conventional farming for soil degradation. This means that the three dimensions of soil degradation are observed in light of the empirical data conducted in Denmark within the selected parameters.

The last two associations are addressed in the second comparative study. This is a comparative study of organic and conventional farming for soil conservation. This means that the three dimensions of soil conservation are observed in light of the empirical data conducted in Denmark within the selected parameters.

1.4.3 The Basic Method:

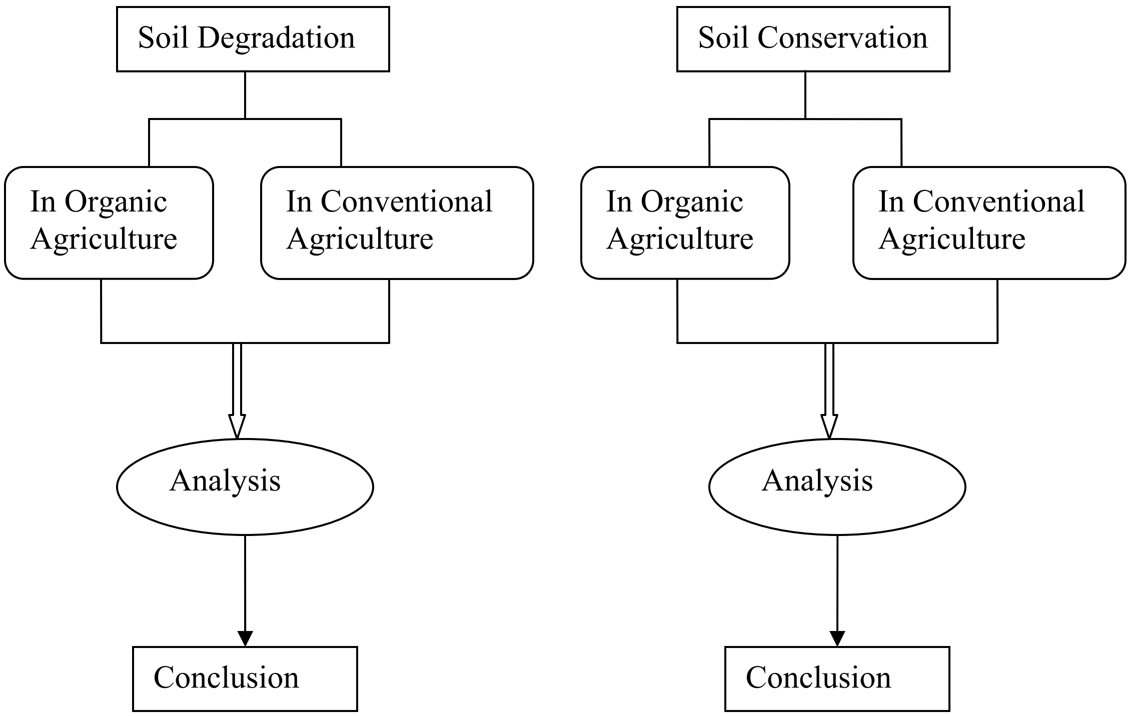
The question arises, how can it be determined if organic agriculture can manage soil to reduce its degradation in Denmark?

In order to determine if organic agriculture can manage soil and reduce soil degradation in Denmark, *firstly*, there is a need to properly define the two different farming systems, i.e., organic and conventional agriculture, from Denmark's point of view in a comparative study. Then elaborate the basic notions and practices of each of the farming systems to differentiate easily between the two types in light of the selected parameters.

Secondly, in light of the specialist empirical studies conducted in Denmark, it can be determined which of the two kinds of farming systems has proved to be detrimental to soil and degrades it. To accomplish this task, the *basic method* applied is to gather data from both types of farming systems for soil degradation and at the same time for soil conservation in the three dimensions; viz. physical, chemical and biological. In other words, there is a need to perform a comparative empirical study of organic and conventional agriculture of Denmark showing both the soil degradation and soil conservation in the three dimensions; viz. physical, chemical and biological. The qualitative and quantitative analysis will reveal further on which of the two types has proved to be harmful to the soil.

The following schematic diagram elaborates the basic method:

Schematic Diagram No. 2; Showing the *basic method* applied to gather empirical data for both soil degradation and soil conservation in organic and conventional agriculture. This *basic method* is implemented in Chapter 3.



1.4.4 Scope:

The scope of this thesis is vast globally yet limited to Denmark. On one hand, from a global perspective, soil is studied as a natural resource in agriculture, whereas on the other, the scope of the thesis is limited to Denmark's case study only.

1.4.5 Research Methods:

The empirical data collection approach in the case study has been relied exclusively to secondary-research. The search, for collection of required relevant data, was conducted from various sources such as;

- Books and articles
- International electronic journals available at Roskilde University's Library
- Internet resources of Danish governmental and non-governmental organizations and other interest groups

1.4.6 Definitions:

1.4.6.1 Conventional Farming:

Conventional farming is also called traditional farming. The major practices include: soil tillage (both inversion and vertical), application of artificial mineral fertilizers, and application of chemical pesticides. The detrimental effects of conventional farming on the soil environment are commonly well known, particularly, the effects of soil tillage. The original structure of the soil is drastically changed; it buries the residues of previous crops; the bare and loose soil is left unprotected and is exposed to the action of wind and water as erosion; the soil organic matter is reduced; and the biodiversity content is reduced.

1.4.6.2 Organic Farming:

The type of agriculture which does not use any synthetic pesticides or artificial fertilizers and uses conservation tillage practices is known as organic farming. In organic farming, due consideration is given to the natural state of the environment hence it is basically natural farming.

The Danish Research Centre for Organic Food and Farming (DARCOF) in Denmark has defined organic farming as, “Organic farming describes a self-sustaining and persistent agro-ecosystem in good balance. As far as possible, the system is based on local and renewable resources. It builds on a holistic view that incorporates the ecological, economical and social aspects of agricultural production in both the local and global perspectives. In organic farming nature is considered as a whole with its own innate value, and man has a moral obligation to farm in such a way that cultivated landscape constitutes a positive aspect of nature.”[1]

1.4.6.3 Soil Management:

The branch of soil science that deals with enhancing the soil fertility and reducing soil degradation to a minimum through various practices ensuring soil conservation such as tillage/planting procedures, cropping systems, fertilizer inputs, irrigation methods and other necessary treatments conducted on a soil for the production of crops is known as ‘Soil Management’.

1.5 Objectives of this Thesis:

1. To study and understand how soil degradation is reduced/prevented through organic agriculture in Denmark
2. To study how organic agriculture conserves the soil through its practices in Denmark
3. To find out statistically if there is any association between the two farming types (organic and conventional agriculture) and the three levels (high, medium and low) of soil degradation.
4. To find out statistically if there is any association between the two farming types (organic and conventional agriculture) and the three levels (high, medium and low) of soil conservation.
5. To study the regulatory process of organic agriculture in Denmark.

[1] DARCOF, Available at: http://www.darcof.dk/organic/index.html

CHAPTER 2

SOIL AS A NATURAL RESOURCE IN AGRICULTURE

2.1 NATURAL RESOURCES:

Natural resources are naturally occurring substances on Planet Earth, such as water, air, land, forests, fish, wildlife, soil, minerals etc. that are considered valuable and useful to humans in their relatively unmodified natural form. Natural resources are classified as renewable and non renewable resources.

Renewable resources are those natural resources whose quantity (stock) can increase over time, for example oxygen, fresh water, solar energy, timber, and biomass. Renewable resources can restock themselves and be used indefinitely if they are used sustainably. However, they can become non-renewable resources if used at a greater rate than the environment's capacity to replenish them.

Non-renewable resources are those natural resources which cannot be regenerated or remade on a scale comparative to its consumption and hence at a time will be depleted. In summary, a renewable resource can be used and a non-renewable resource can be used up.

Though soil is one of the important natural resources necessary for life on Planet Earth, yet its relationship to the agricultural industry is somewhat different in comparison to relationships of other natural resources to their respective industries. For example, the industries of mining, petroleum, natural gas, fishing, forestry, etc. are generally considered as 'natural-resource industries', whereas the agricultural industry is not. This is due to the fact that the 'natural-resource industries' are associated with primary activities of extraction and purification of existing natural resources, while the agricultural industry, on the contrary, does not extract or purify the soil but actually is associated with production and creation through the soil. Hence a unique relationship exits between soil as a natural resource and the agricultural industry.

2.2 NATURAL RESOURCES MANAGEMENT:

In the contemporary world, managing natural resources for optimal benefits to mankind is essential for their sustainable use. This has led to a global phenomenon of a proper utilization for a sustainable future. Of the various natural resources, soil management has its own significance. It is a dilemma that such a precious natural resource is overlooked.

2.3 SOIL DEFINITION:

Soil has been defined in several ways depending on the context and perspective of the study. A broad definition which the Council of Europe[2] adopted in 1990 states: "Soil is an integral part of the Earth's ecosystems and is situated at the interface between the Earth's surface and the bedrock. It is subdivided into successive horizontal layers with specific physical, chemical and biological characteristics and has different functions. From the standpoint of history of soil use, and from an ecological and environmental point of view, the concept of soil also embraces porous sedimentary rocks and other permeable materials together with the water which these contain and the reserves of underground water."

2.4 SOIL AS A LIMITED NATURAL RESOURCE:

There is no doubt in the fact that Planet Earth's naturally occurring resources are vital for existence and development of mankind. Therefore, proper management of these natural resources is obligatory for the survival of future generations. Some of these natural resources are non-renewable or finite, meaning, once they have been exhausted, they are exterminated e.g. minerals, species, habitats, fossil fuels, etc. Others are renewable such as water, wood, air, etc.

Soil is a naturally occurring resource. From nature's point of view, soil is considered to be a renewable natural resource due to the fact that there is a very slow natural process of soil regeneration with regards to the time scale. However, "Lal (1994)

[2] Council of Europe, 1990, European Conservation Strategy, Recommendation for the 6th European Ministerial Conference on the Environment, Council of Europe, Strasbourg

reviewed the estimates of rates of soil formation for a number of soil types and concluded that most soils can be considered a non-renewable resource within the human life span."[3]

The soil degradation that is taking place currently worldwide is for all reasons irreversible because of the fact that it can take hundreds or thousands of years to regenerate most soils. In this regard soil is also considered to be a non-renewable or a limited natural resource. Similarly The Tutzing Project[4] (1998) highlights that, "Soil formation is slow, requiring 500 years on average for only 2.5 cm of soil…"

Hence due consideration needs to be given to the environmental concern of soil degradation; due to the limitation of soil resource on Planet Earth and the increasing imbalance of soil due to the great difference in the rate of soil degradation and the rate of its regeneration.

2.5 CHARACTERISTICS OF SOIL:

- Soil may be the most complex system known to science.
- In comparison to air and water, soil is a more complex medium.
- It is the medium which supports life in its broadest sense and has a large number of living organisms
- Soil is composed of inorganic and organic compounds
- It also has all the three states of matter, i.e. solid, liquid and gaseous forms
- It shows great variability in space and time
- Unlike the systems of air, water and biota, which are mobile systems, soil is site-specific
- It is also more stable than the other three systems of air, water and biota

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2.6 FUNCTIONS OF SOIL:

The soil functions can be categorized according to different perspectives. Following are its functions from an ecological perspective:

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[3] Schjønning, P.; Elmholt, S. and Christensen, B.T. (2004), Soil Quality Management - Concepts and Terms, Managing Soil Quality: Challenges in Modern Agriculture, Chapter 1, page 1-16, CABI Publishing, Wallingford, UK

[4] The Tutzing Project "Time Ecology", Preserving Soils for Life, Proposal for a "Convention on Sustainable Use of Soils" 1998, Available at: http://www.zeitoekologie.de/Bodenkonv_engl.doc

- To protect the aquatic ground environment against pollution
- To provide essential nutrients for the germination and subsequent development of a plant
- Soil is the medium for the production of biomass by agriculture
- The soil acts as a geo-membrane by mechanically filtering and buffering organic and inorganic compounds.
- It is a source of raw materials and water
- It is a habitat for living organisms where numerous organisms and micro-organisms can live and be protected
- It provides the proper environment for mineralization, i.e. transformation and decomposition of organic matter

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2.7 SOIL LINKAGE:

An important aspect of soil, as a natural resource, is that it is interconnected with other natural resources, such as the air, water, fauna and flora. Like soil, these natural resources are also essential for human life. Soil is very closely related to agriculture, so if the soil is well managed through various agricultural practices, the other natural resources (air, water, fauna, flora etc.) would be in a better state. On the contrary, if agriculture badly manages soil, this will have a direct effect on other natural resources and hence they will also be deteriorated. Therefore, there is a need for proper soil management in agriculture. Due to its linkage with other natural resources and environmental components, an important aspect of soil is its crucial link to other global environmental problems. Soil is profoundly associated with these problems in some way. They are:

a) Desertification
b) Water Management
c) Climate Change
d) Loss of Biodiversity

Amongst these problems, desertification is mainly associated with soil degradation. The United Nations Convention to Combat Desertification (UNCCD, 1997) has defined desertification as “Land degradation in arid, semiarid and sub-humid areas resulting from various factors, including climatic variations and human activities”[5]. Desertification is a process of land degradation as a result of which soil is deteriorated, where consequently the soil nutrients and soil fertility is lost and ultimately devegetation occurs. Various factors that contribute to desertification are climate variations, droughts and human activities like, excessive cultivation, deforestation, overgrazing, inadequate irrigation practices, etc. Desertification affects the ability of soil to produce crops.

2.8 SOIL AND AGRICULTURE:

Soil is one of the major environmental components that has a direct correlation with agriculture. All forms of agriculture disturb the equilibrium state of native soil ecosystems. Hence, the soil needs to be sustainable in order for mankind to continue its utilization. Soil sustainability is an integral component of agricultural sustainability. Therefore, without soil sustainability, agricultural sustainability cannot be achieved. In order to achieve soil sustainability, soil conservation practices have to be carried out in agriculture worldwide. Organic agriculture has high regard for soil conservation. In order to achieve the goal of sustainable crop and livestock production, organic farming uses complex and integrated biological systems.

Sustainable agriculture focuses on improving the long term quality and quantity of farming for mankind without increasing the use of natural resources beyond the capacity of the environment to supply them indefinitely. In order to have sustainable productivity in agriculture, it is essential for the soil to be fertile. Hence it is the soil fertility that determines the productivity in agriculture. The ability of soil to supply essential nutrients (NPK) and other micro-nutrients to the crops is known as *soil fertility*.

Soil fertility contributes in the reduction of natural *soil loss* e.g. loss by erosion. Douglas (1994) has demonstrated that soils with high organic matter levels and good physical structure are more resistant to erosion than those in which biological and physical soil degradation takes place.

Soil fertility primarily results from a combination of all three major compositions of soil, i.e. biological composition, chemical composition and physical composition. Soil

[5] UNCCD Interim Secretariat, 1997, United Nations Convention to Combat Desertification in those Countries Experiencing Serious Drought and/ or Desertification, Particularly in Africa, Text with Annexes, Geneva, Switzerland

fertility is a complex phenomenon and it cannot be understood without the detailed study of all the three major compositions of soil. E.g. in the biological composition of soil, a copious microbial life indicates that the soil fertility is high and relatively permanent in nature, and hence sustainable. The level of microbial activity can be estimated from the soil respiration rate. In the soil, microbes and multicellular organisms produce carbon dioxide, one of the products of respiration, and this process is known as soil respiration. The higher active the soil population is, the higher it respires and higher amounts of carbon dioxide is produced. So, higher rates of soil respiration reflect the higher active soil population.

2.8.1 Soil Resource Management:

Soil resource management is a broader area covering several management practices which enhance soil conservation. One of these practices is the soil fertility management. In organic farming, this is generally a longer term strategic process.

The essence of soil management is to basically control the supply of nutrients to crops. If proper soil management techniques/practices are implemented, crops will receive optimal amounts of the nutrients which will ultimately end up in humans as a result of the food chain. Despite the fact that soil has been extensively utilized for agricultural production worldwide since the dawn of civilization, there is a possibility of it being exterminated, due to its *loss* and *harm*. Therefore, it is of pivotal significance that the soil management concept is practically implemented in order to not only maintain soil fertility but also increase it in all possible ways. These soil maintenance practices are fallowing, manuring, crop rotation, chemical fertilizer application, terracing, stone diversion, tree planting, contour plowing, etc.

The question arises; what are the management practices which can be carried out in organic farming so as to maintain and develop soil fertility? The most important management practices are mentioned briefly as follows:

2.8.1.1 Management of Crop Residues:

Soil fertility can be increased when the stubble of the harvested crops are left on the fields. This management practice in agriculture ensures the biological degradation of the dead organic residues of crops. As a result of the mineralization process, where the organic matter is converted into inorganic matter due to decomposition by biological agents (microbes), the soil receives the essential nutrients for the germination and development of crops. One important management practice is to use shallow rather than deep ploughing. This helps in the retention of crop residues near the topsoil, where its degradation and decomposition occurs rapidly. Hence management of crop residues not only maintains the soil fertility but also enhances it.

2.8.1.2 Management of Crop Rotations:

Crop rotation is a management practice where different plants are grown in a recurring and defined manner. In organic agriculture crop rotations are the main mechanism for nutrient supply to the crops via soil. The crop rotations primarily include a mixture of leguminous and catch crops. The leguminous crops are the soil fertility building crops. Through a naturally occurring process, soil maintains its fertility via crop rotations but human intervention is necessary from the management point of view.

2.8.1.3 Management of Manure Application:

Manures are supplementary nutrients that are imported into the soil in organic farming. Manures contain a high amount of nitrogen essential for plant growth. Application of organic manures to organic fields is an important management practice that ensures adequate supplementation to the existing fertility of the soil.

2.8.2 EFFECTS OF SOIL MANAGEMENT PRACTICES ON SOIL:

Effects of the adoption of specific soil management practices are as follows:

2.8.2.1 Increasing Soil Organic Matter Levels:

This can be accomplished by:

a) Application of animal manures and compost
b) Incorporation of crop residues
c) Leaving crop residues to decompose in-situ, etc.

2.8.2.2 Replacing Lost Soil Nutrients:

Soil nutrients are lost due to several natural factors (leaching, topsoil erosion, etc) and human induced factors (use of heavy machinery, removal in the harvested products). The replacement of lost soil nutrients can be accomplished by:

a) Use of nitrogen fixing crops (legumes)
b) Crop rotations and intercropping
c) Enriched fallows, etc.

2.8.2.3 Maintaining and Enhancing Topsoil Structure:

This can be accomplished by:

a) Reduced or minimum tillage
b) Leaving crop stumps and roots to decompose in-situ
c) Enriched fallows
d) Incorporation of animal manure, compost and crop residues, etc.

2.9 SOIL DEGRADATION:

When soil resource management does not occur by non-implementation of the soil management practices (mentioned in sub-sections of 2.8.1) in agriculture, the soil is subject to degradation. There are also other factors both agricultural and non-agricultural which contribute to soil degradation. Hence, soils are prone to degradation when both '*soil harm*' and '*soil loss*' take place. The dimensions of soil degradation are physical, chemical and biological.

Soil conservation means to protect the soil from loss and harm. While being utilized, if soil is not conserved then either it is lost or harmed; in both cases it is degraded. The nature and type of action of various factors that act on the soil, determine whether the soil is lost or harmed. In what ways can the soil be degraded?

2.9.1 Soil Degradation Types:

When soil degradation takes place, a number of detrimental changes take place in the soil. This in turn affects the germination and development of crops which ultimately lead to reduced yields per acre. These detrimental changes are briefly mentioned as follows:

2.9.1.1 Physical Loss of Soil:

The physical loss of soil from the land affects the physical characteristics of the soil. Better physical qualities like soil aggregation and soil strength are badly affected due to physical loss. This primarily occurs due to soil erosion. Erosion can take place due to wind, water and other factors.

2.9.1.2 Sorption of Chemicals to Soil Particles:

Pesticide applications to crop fields allow the sorption of hazardous chemicals to the soil resulting in reduced soil fertility. Certain pesticides are retained in the soil for longer periods where the natural degradation rate is slow. In such circumstances, the soil particles cannot perform their functions in an optimal manner.

2.9.1.3 Loss of Soil Fertility:

The decrease in organic matter of the soil leads to the loss of soil fertility. There are various factors which lead to the decrease in organic matter. One such factor is the unsustainable agricultural practices, e.g. conventional tillage practices are the main cause of the loss of carbon dioxide from the soil to the atmosphere and in the long run this reduces the organic contents of the soil ultimately leading to loss of fertility. As a result of the soil fertility loss, crops do not get the required level of nutrients for their growth and hence the total yield per acre is drastically reduced. Such agro-climatic conditions then entail the application of artificial fertilizers (unnatural inputs to the soil) for attaining the required production levels of crops.

2.9.1.4 Loss of Soil Biological Activity:

The soil environment is a haven for all the soil fauna and flora. The soil biota are classified into three categories depending on the location of their biological activities; above or on the soil surface such as birds; in the soil-atmosphere inter phase such as reptiles and mammals; and in the soil medium. As a result of soil degradation, the soil biodiversity is negatively affected and this in turn affects the overall soil productivity because it is the soil biota that are responsible for various chemical and biological reactions that increase and maintain the soil fertility.

2.9.1.5 Soil Salinization:

The accumulation of free salts in the soil to such an extent that it leads to the soil degradation is known as soil salinization. This is a naturally occurring process resulting from high levels of salt in the soils. Soil salinization is responsible for high levels of soil degradation at the global scale.

2.9.1.6 Soil Acidification:

The re-depositing of toxic emissions from vehicles, industries, power stations and natural bio-chemical cycles on the soil surface is known as soil acidification. The two major methods of re-depositing are rainfall and dry deposition on the soil surface. Soil acidification alters the naturally occurring chemical environment of the soil thus contributing to soil degradation.

2.9.1.7 Toxic Contamination:

The heavy metal contamination takes place as a result of high concentrations of trace elements that are present in the soil. These trace elements are mercury (Hg), lead (Pb), cadmium (Cd) and arsenic (As). They function as micro nutrients to plant growth. Increased concentrations of these elements change the natural state of nutrient supply to the plants resulting in impaired development.

2.9.1.8 Nutrient Excess:

The elements of nitrogen (N), phosphorous (P) and potassium (K) are essential for plant growth and development. In order to improve the soil fertility, these elements are added as fertilizers to the soil. However, the over-application of fertilizers with high contents of nitrogen or phosphorous can have adverse impacts on the soil e.g. the nutrient supply capability of the soil to the plants is affected. Nutrient accumulation results in soil becoming saturated which consequently increases nutrient leaching from the soil or simply being washed off into the ground water or even the coastal systems causing eutrophication.

CHAPTER 3

CASE STUDY – PART 1

A COMPARATIVE STUDY OF ORGANIC AND CONVENTIONAL AGRICULTURE IN DENMARK

3.1 INTRODUCTION:

The main objective for carrying out the comparative study is to figure out if organic agriculture can reduce soil degradation as mentioned in the problem formulation. To accomplish this task, it is essential:

a) to weigh organic and conventional agriculture for *soil degradation* in Denmark
b) to weigh organic and conventional agriculture for *soil conservation* in Denmark

Hence, the first part of the case study comprises of a comparative study between organic and conventional farming types in light of the specialist research findings from Denmark. The results of empirical studies help to determine which type of agriculture conserves the soil more and reduces its degradation. Hence the judgment is made according to the available research findings.

Soil degradation and soil conservation are strongly interlinked to each other. This is evident from the fact that soil degradation is inversely proportional to soil conservation. If soil degradation is high/more, soil conservation is low/less and vice versa. Therefore, it is essential to include both soil degradation and soil conservation specialist research findings in Denmark in the comparative study.

For an easy comprehension, this chapter is divided into two major sections; Section A which is a thorough comparative study and analysis of organic and conventional farming for *soil degradation* and Section B which is a thorough comparative study and analysis of organic and conventional farming for *soil conservation*. The organization of this chapter is based on the procedure explained in the ‘Methodology’ in Chapter 1, in accordance with the ‘Schematic Diagram No. 2’ (Page 24).

SECTION A:

THOROUGH COMPARATIVE STUDY AND ANALYSIS FOR SOIL DEGRADATION

A1 NULL HYPOTHESIS FOR SOIL DEGRADATION:

To determine if organic farming *degrades* the soil, the obvious system to compare it with, is its counterpart farming system– conventional farming. So, it is deemed necessary to compare the *soil degradation* in organic farming with conventional farming in Denmark. The farming type that *degrades* the soil more will *conserve* the soil less; so the relation is inversely proportional. Hence statistically, the null hypothesis is that ‘no association exists between organic and conventional farming types and *soil degradation* levels’. The soil degradation levels taken into consideration in this thesis are; high soil degradation, medium soil degradation and low soil degradation. In the analysis of this comparative study, the various empirical findings, under the various ‘selected parameters’ mentioned in the following Table No. 1 (Page 39), are ranked according to these three levels of soil degradation in order to find if any association is present.

This null hypothesis is *accepted* if there is clear evidence from existing Danish empirical literature that ‘no association between farming types and soil degradation levels exists’. Conversely, if the evidence is available that the association is present, then the null hypothesis is *rejected* and it will be concluded that ‘association exists between organic and conventional farming types and *soil degradation* levels’.

The quantitative results obtained after the statistical analysis, to identify any association between the farming types and soil degradation levels, would determine if a comparative statistical analysis can be conducted to find any difference, if any, between the two farming types for soil degradation.

A2 LIST OF SELECTED PARAMETERS OF SOIL DEGRADATION:

Following is the list of selected parameters of soil degradation for the comparative study. The parameters have been selected in light of the agro-climatic conditions and farming practices in Denmark. All the empirical data, in the comparative study for soil degradation, have been distributed according to the selected parameters of soil degradation. In other words, the empirical data have been gathered depending on these important parameters that determine the severity of soil degradation in Denmark.

Table No. 1; Showing the Selected Parameters in the Comparative Study of both Farming Systems for Soil Degradation.

Dimension of Degradation	**Serial No.**	**Selected Parameters**
Physical Degradation	1.	Soil Compaction
	2.	Water Erosion
	3.	Tillage Erosion
	4.	Tillage
Chemical Degradation	1.	Sewage Sludge
	2.	Ash from Biomass Combustion
	3.	Flora Parts Mineralization
	4.	Nitrogen Losses
	5.	Sulphate Leaching
	6.	Potassium Leaching
	7.	Pesticide Application
	8.	Sorption of Pesticides
	9.	Soil Contamination due to Chemicals
	10.	Pesticide Leaching
Biological Degradation	1.	Soil Biota (including various bio-indicators)

The above selected parameters have been used in the following comparative study for each dimension of soil degradation. These various dimensions have been presented separately in each of the farming types so as to provide a clear and better understanding of the soil degradation in their respective selected parameters.

A3 SOIL DEGRADATION IN ORGANIC FARMING:

The Danish empirical literature found in the category of soil degradation in organic farming is only restricted to the risks associated with chemical degradation of the soil, whereas no literature was found for any physical and biological degradation.

A3.1 CHEMICAL DEGRADATION OF SOIL:

A3.1.1 Application of Sewage Sludge:

Sewage sludge is used as a fertilizer in organic farms. Sewage sludge is the chemically treated municipal waste, rich in organic compounds, that is added to the fields in organic farming to increase the soil organic matter. Organic compounds, present in the sewage sludge, can be harmful to the soil. There is a possibility for these organic contaminants, to leach through the soil, to ground water. H. de Jonge *et al.* [6] (2002) conducted column experiments and reported,

"Municipal sewage sludge is often used on arable soils as a source of nitrogen and phosphorus, but it also contains organic contaminants that may be leached to the ground water. Di(2-ethylhexyl)phthalate (DEHP) is a priority pollutant that is present in sewage sludge in ubiquitous amounts. Column experiments were performed on undisturbed soil cores (20-cm depth x 20-cm diameter) with three different soil types: a sand, a loamy sand, and a sandy loam soil. Dewatered sewage sludge was spiked with ^{14}C-labeled DEHP (60 mg kg^{-1}) and bromide (5 g kg^{-1}). Sludge was applied to the soil columns either as five aggregates, or homogeneously mixed with the surface layer. Also, two leaching experiments were performed with repacked soil columns (loamy sand and sandy loam soil). The DEHP concentrations in the effluent did not exceed 1.0 μg L^{-1}, and after 200 mm of outflow less than 0.5% of the applied amount was recovered in the leachate in all soils but the sandy loam soil with homogeneous sludge application (up to 3.4% of the

[6] H. de Jonge, L. W. de Jonge, B. W. Blicher and P. Moldrup, Transport of Di(2-ethylhexyl)phthalate (DEHP) Applied with Sewage Sludge to Undisturbed and Repacked Soil Columns, Journal of Environmental Quality, November-December 2002, Volume 31, Issue 6

applied amount recovered). In the absence of macropore flow, DEHP in the leachate was primarily sorbed to mobilized dissolved organic macromolecules (DOM, 30.3 to 81.3%), while 2.4 to 23.6% was sorbed to mobilized mineral particles. When macropore flow occurred, this changed to 16.5 to 37.4% (DOM) and 36.9 to 40.6% (mineral particles), respectively. The critical combination for leaching of considerable amounts of DEHP was homogeneous sludge application and a continuous macropore structure."

A3.1.2 Application of Ash:

Ash from biomass combustion is applied to agricultural fields in Denmark as fertilizers for increasing the soil fertility. This is due to the fact that ash from biomass combustion contains high content of macronutrients and has a potential liming capacity. But on the other hand, this ash contains toxic cadmium, a heavy metal, in high amounts which is hazardous to the soil. The Danish Environmental Protection Agency has given the limiting values of the toxic heavy metal cadmium for agricultural utilization. Hence there is risk associated with the application of ash from biomass combustion.

However, Anne Juul Pedersen[7] (2003), in her electrodialytic remediation experiments showed that the amount of cadmium can be reduced to a greater extent. She reported,

"……under optimized remediation conditions using a mixture of ammonium citrate (0.25 M) and NH_3 (1.25%) as an assisting agent, more than 70% of the initial Cd could be removed from the wood fly ash. The results also indicated that a continuous out-separation of Cd from the aqueous process solutions is possible. Thereby, recycling of the (nutrient rich) process solutions as well as of the remediated ash seems achievable."

A3.1.3 Flora Parts Mineralization:

Organic soil layers that are formed due to decomposition of plant products, play an important role in the fertilization of the topsoil due to its rich nutrients. However, there

[7] Anne Juul Pedersen, Characterization and Electrodialytic Treatment of Wood Combustion Fly Ash for the Removal of Cadmium, Biomass and Bioenergy, Volume 25, Issue 4, October 2003, Pages 447-458

can be instances where these plant parts may contain toxic substances. Lars H. Rasmussen *et al.*[8] (2003) has mentioned,

> "Bracken (*Pteridium aquilinum* (L.) Kuhn) is a common fern found on all continents except Antarctica. It is under suspicion of causing cancer among people who utilizes it as food. The main carcinogenic compound is thought to be the water-soluble compound ptaquiloside. Ptaquiloside-uptake may occur not only through food, but also via drinking water as ptaquiloside might leach from plant material. The purpose of the study was to identify environmental parameters that correlate with the ptaquiloside-content in fronds, and to quantify the amount of ptaquiloside in the soil environment. The ptaquiloside-content in fronds, Oi/Oe-, and Oa/A-horizons was quantified at end of the growth season at 20 sites in Denmark. The fronds had ptaquiloside-contents between 108 and 3795 μg g^{-1}. The Oi/Oe-horizons had contents between 0.09 and 7.70 μg g^{-1}, while Oa/A-horizons had contents between 0.01 and 0.09 μg g^{-1}. The ptaquiloside-content in the standing biomass, which could be transferred to the soil by the end of the growing season, ranged between 10 and 260 mg m^{-2}, with nine sites having ptaquiloside loads over 100 mg m^{-2}. The carbon-content in the O-horizon, the precipitation, the amount of Bracken-litter, the turnover rate and the size of Bracken-stands determined the ptaquiloside-content in the soil materials while the content in fronds was found to be a function of the frond-height and the light-exposure in the ecosystem."

A3.1.4 Nitrogen Losses:

Nitrogen losses to the soil environment can result in the reduction of soil fertility. One of the characteristics of organic farming is its relatively high reliance on internal nitrogen cycling. The lower import of nitrogen to the soil should reduce the potential for nitrogen losses, but higher organic inputs and nitrogen turnover rates may have the opposite effect. Generally, organic farming practices reduce the loss of nitrogen but J.

[8] Lars H. Rasmussen, Stine Kroghsbo, Jens C. Frisvad and Hans Christian B. Hansen, Occurrence of the Carcinogenic Bracken Constituent Ptaquiloside in Fronds, Topsoils and Organic Soil Layers in Denmark, Chemosphere, Volume 51, Issue 2, April 2003, Pages 117-127

Berntsen *et al.*[9] (2006) have shown that under certain conditions on organic dairy farms, sandy soils are vulnerable to nitrogen losses. They reported,

> “Organic farming is considered an effective means of reducing nitrogen losses compared with more intensive conventional farming systems. However, under certain conditions, organic farming may also be susceptible to large nitrogen (N) losses. This is especially the case for organic dairy farms on sandy soils that use grazed grass–clover in rotation with cereals. A study was conducted on two commercial organic farms on sand and loamy sand soils in Denmark. On each farm, a 3-year-old grass–clover field was selected. Half of the field was ploughed the first year and the other half was ploughed the following year. Spring barley (*Hordeum vulgare* L.) was sown after ploughing in spring. Measurements showed moderate N leaching during the pasture period (9–64 kg N ha^{-1} $year^{-1}$) but large amounts of leaching in the first (63–216 kg N ha^{-1}) and second (61–235 kg N ha^{-1}) year after ploughing. There was a small yield response to manure application on the sandy soil in both the first and second year after ploughing. To investigate the underlying processes affecting the residual effects of pasture and N leaching, the dynamic whole farm model farm assessment tool (FASSET) was used to simulate the treatments on both farms. The simulations agreed with the observed barley N-uptake. However, for the sandy soil, the simulation of nitrate leaching and mineral nitrogen in the soil deviated considerably from the measurements. Three scenarios with changes in model parameters were constructed to investigate this discrepancy. These scenarios suggested that the organic matter turnover model should include an intermediate pool with a half-life of about 2–3 years. There might also be a need to include effects of soil disturbance (tillage) on the soil organic matter turnover.”

A3.1.5 Sulphate Leaching:

It is necessary for an effective crop production and better yield to maintain the natural supply of sulpher for a long term period in organic farming. Denmark, during the last decade, has witnessed a reduction in the emissions of sulpher containing atmospheric

[9] J. Berntsen, R. Grant, J. E. Olesen, I. S. Kristensen, F. P. Vinther, J. P. Mølgaard & B. M. Petersen, Nitrogen Cycling in Organic Farming Systems with Rotational Grass–clover and Arable Crops, Soil Use and Management, Volume 22 Issue 2 Page 197 - June 2006

pollutants due to strict regulations. Consequently, atmospheric deposition of sulpher on the soil has been reduced. At the same time, sulphate leaching is a naturally occurring process that takes place in the soil. Hence, better yield in low input farming systems such as organic farming, may be at stake in the long run as a result of the deficiency of sulpher in the soil. J. Eriksen *et al.*[10] (2000) at the Department of Crop Physiology and Soil Science, Danish Institute of Agricultural Sciences, Tjele, Denmark, studied sulphate leaching on sandy soil in Denmark and stated,

> "Sulphate leaching losses may reduce the long-term possibility of maintaining the S supply of crops in low input farming systems. Sulphate leaching and S balances were investigated in an organic dairy/crop rotation (barley [*Hordeum vulgare*] → grass-clover [*Lolium perenne*/*Trifolium repens*] → grass-clover → barley/pea [*Pisum arvénse*] → winter wheat [*Tritucum aestivum*] → fodder beet [*Beta vulgaris*]) from 1994 to 1998. The importance of climatic conditions and use of different organic manure types at different application rates for sulphate leaching were investigated and related to the concurrent nitrate leaching. As an average of years, sulphate leaching from the crop rotation was 20 kg S ha^{-1}, which was equivalent to 60% of the total input to the rotation. Sulphate leaching was highly variable over the years (4–45 kg S ha^{-1} for the same crop) and closely related to the annual drainage volume ($r^2 = 0.99$; $P < 0.01$). The same relationship between drainage and nitrate leaching was not significant. No differences were observed in sulphate leaching between the organic manure types or the application rates, but significant differences were found in sulphate leaching between the different crops in the rotation. In the year with the largest drainage volume, there was a significant correlation between the S input in irrigation and sulphate leaching ($r^2 = 0.69$; $P < 0.05$). The S balance was slightly positive when averaged over the four years, as more S was imported than removed. Thus, immediate S deficiency may not occur, but in the longer term a negative S balance must be expected in this crop rotation. However, even with a positive overall S balance, the S input is not necessarily synchronised with plant needs. In order to maintain a sufficient S supply in the future when further reductions in the atmospheric deposition are expected, it is important to reduce leaching losses of sulphate."

[10] J. Eriksen and M. Askegaard, Sulphate Leaching in an Organic Crop Rotation on Sandy Soil in Denmark, Agriculture, Ecosystems & Environment, Volume 78, Issue 2, April 2000, Pages 107-114

A3.1.6 Potassium Leaching:

Being one of the essential elements of soil fertility and plant nutrition, along with nitrogen and sulpher, is potassium. Potassium leaching can reduce the availability of potassium in organic farming systems in a similar manner as nitrogen and sulpher leaching. Olesen[11] (1999) highlighted the high risk of potassium leaching in particular situations in organic farming in Denmark, for example with grazing sows. Moreover, Johnston[12] (1998) showed that there is a high risk of potassium leaching in fields that produce or receive sources of organic matter such as manure, clover-grass, catch crops, etc. These sources raise the mobility of potassium in the soil medium.

[11] Olesen, J.E., 1999, Tab af Næringsstoffer, Natur, Miljø og Ressourcer i Økologisk Jordbrug, FØJO Rapport 3, Forskningscenter for Økologisk Jordbrug, pp. 17–33

[12] Johnston, A.E., 1998, Phosphorus: Essential Plant Nutrient, Possible Pollutant, In: Phosphorus Balance and Utilization in Agriculture Towards Sustainability, Kungl. Skogs- och Lantbruksakademiens Tidsskrift 135 (7), 11–22

A4 SOIL DEGRADATION IN CONVENTIONAL FARMING:

In the Danish conventional farming, soil degradation has taken place in all the three major dimensions. This statement is supported from the available literature which is presented in this section of the chapter according to the three dimensions which are:

a) Physical Degradation of Soil
b) Chemical Degradation of Soil
c) Biological Degradation of Soil

Hence the soil degradation study in conventional agriculture is classified into the above three major sections which are presented in detail as follows:

A4.1 PHYSICAL DEGRADATION OF SOIL:

A4.1.1 Soil Compaction:

Soil compaction occurs both to the topsoil and to the subsoil in Denmark. The topsoil compaction is not persistent while subsoil compaction is. All aspects of soil quality are affected by subsoil compaction in conventional farming. Many soil properties and processes are influenced due to the compaction of topsoil and subsoil. Soil compaction takes place as a result of the mechanization in conventional farming. The severity of subsoil compaction is higher due to wheel loads.

Several experiments and studies have been conducted, in Denmark, in order to show the impact of heavy machinery on soil, thus resulting in soil compaction. In one such study Munkholm *et al.*[13] stated,

> "Subsoil compaction caused by heavy traffic has been highlighted as the biggest threat to soil quality in modern agriculture. This concern is even more relevant in organic farming, as poor crop growth conditions can not be compensated for by the use of mineral fertilizers or pesticides. Subsoil compaction has been shown to severely hamper root development, limit rooting depth, reduce utilization of nutrients and water and reduce crop yield. Subsoil compaction may also cause increased impact on the environment due to increased risk of erosion, nitrogen leaching and denitrification. Even

[13] Lars J. Munkholm & Per Schjønning, Compacted Subsoils in Organic Farming, Mechanical Loosening and the Risk of Recompaction, Department of Agroecology, Danish Institute of Agricultural Sciences, Available at: http://www.darcof.dk/enews/sep03/soil.html, Archived at http://orgprints.org/00003365

though subsoil compaction is a widespread and serious concern, subsoiling of compacted subsoils often gives discouraging results. In many cases this has been related to a traffic-induced recompaction of the loosened soil, which is highly prone to recompaction. It is thus a key issue in organic farming, whether mechanical loosening should take place and how recompaction should be avoided."

A4.1.2 Water Erosion:

Erosion is a process where the gradual detachment of soil fragments, by natural factors like water, wind, ice and by human induced factors like mechanical, chemical or biological forces, takes place. The following table explains only water erosion losses in Denmark by highlighting the different water erosion types and rates:

Table No. 2; Types of water erosion processes in Denmark and typical soil erosion rates, from Veihe *et al.*[14] (2003).

Erosion types	Soil erosion rates (t/ha)	References
Sheet erosion	Bare soil (0.42) Winter wheat across contours (0.95) Winter wheat, contours (0.62)	Schjønning et al., 1990
	Catchments (0-0.14)	Hasholt, 1990
	Permanent ryegrass (0.03) Spring barley followed by rye grass during winter, ploughed in spring (0.13-0.42) Spring barley, ploughed in autumn (0.45-2.69) Winter wheat drilled up and down slope, ploughed in autumn (1.17-12.79) Winter wheat drilled across the slope, ploughed in autumn (0.49-11.08) Fallow, ploughed in spring and harrowed from time to time to remove weeds (5.93-10.87)	Sibbesen et al., 1994b
Rill erosion	Plots (0.58-26.2) Slopes (0.35-18.6)	Hasholt, 1995
	2.4	Kronvang et al., 2000b
Tillage erosion	Net erosion rate approximately 6.00	Heckrath, 2000
Bank erosion	0.020 m^3/m stream reach	Laubel et al., 1999
	0.023 m^3/m stream reach	Laubel et al., 2000

[14] A. Veihe, B. Hasholt and I. G. Schiøtz, Soil Erosion in Denmark: Processes and Politics, Environmental Science & Policy, Volume 6, Issue 1 , February 2003, Pages 37-50

A4.1.3 Tillage Erosion:

The physical loss of topsoil particles due to tillage practices is known as tillage erosion. Tillage erosion is common in conventional agriculture due to the use of heavy machinery on the farms. Prior to the development of organic farming in Denmark in the 1980s and the rapid growth in the 1990s, all the fields were cultivated with the use of heavy machinery. Hence in addition to soil compaction, erosion of the soil occurred due to these tillage practices. In an experiment, G. Heckrath *et al.*[15] (2005) investigated the detrimental effects of tillage erosion on soil properties and crop yield. They studied the implication of tillage erosion on soil organic content (SOC);

> “Tillage erosion had been identified as a major process of soil redistribution on sloping arable land. The objectives of our study were to investigate the extent of tillage erosion and its effect on soil quality and productivity under Danish conditions. Soil samples were collected to a 0.45-m depth on a regular grid from a 1.9-ha site and analyzed for ^{137}Cs inventories, as a measure of soil redistribution, soil texture, soil organic carbon (SOC) contents, and phosphorus (P) contents. Grain yield was determined at the same sampling points. Substantial soil redistribution had occurred during the past decades, mainly due to tillage. Average tillage erosion rates of 2.7 kg m^{-2} yr^{-1} occurred on the shoulderslopes, while deposition amounted to 1.2 kg m^{-2} yr^{-1} on foot- and toeslopes. The pattern of soil redistribution could not be explained by water erosion. Soil organic carbon and P contents in soil profiles increased from the shoulder- toward the toeslopes. Tillage translocation rates were strongly correlated with SOC contents, A-horizon depth, and P contents. Thus, tillage erosion had led to truncated soils on shoulderslopes and deep, colluvial soils on the foot- and toeslopes, substantially affecting within-field variability of soil properties. We concluded that tillage erosion has important implications for SOC dynamics on hummocky land and increases the risk for nutrient losses by overland flow and leaching. Despite the occurrence of deep soils across the study area, evidence suggested that crop productivity was affected by tillage-induced soil redistribution. However, tillage erosion effects on crop yield were confounded by topography–yield relationships”

[15] G. Heckrath, J. Djurhuus, T. A. Quine, K. Van Oost, G. Govers and Y. Zhang, Tillage Erosion and Its Effect on Soil Properties and Crop Yield in Denmark, Journal of Environmental Quality, Volume: 34 Issue: 1, January-February 2005

A4.1.4 Tillage:

The soil is physically degraded with various conventional tillage types. Tillage and practices that change the soil organic matter content are foremost among the many practices that influence soil structure. Henning Petersen[16] (2002) reported that a group of Danish scientists conducted a study of the effect of different tillage methods on the soil system and crop yield in organic farms.

> "In this paper, the reaction of the collembolan community to two kinds of primary soil tillage in the autumn, i.e. deep tillage with a non-inverting tine subsoiler (modified Dutzi method) vs. conventional ploughing, is compared. A surprisingly high mean number of Collembola, i.e. more than 100,000 m^{-2}, were present in the field before soil tillage. The abundance of total Collembola was strongly reduced 1 week after tillage with both methods and the sum of populations in four strata between the soil surface and 32 cm in depth showed no significant difference between the two tillage treatments. Conventional ploughing reduced the collembolan population more than the non-inverting tillage in the uppermost 4 cm stratum, while in the deepest stratum the immediate effect was opposite. When the whole soil horizon is considered, the two tillage treatments resulted in similar population changes for most collembolan species whereas significant differences were observed in individual strata. Especially strong effects were observed in epedaphic and hemiedaphic species."

The topsoil structure is extremely susceptible to degradation as a result of intensive tillage. Under wet conditions this situation is aggravated and the resilience (recovery of soil) period is elongated which goes against the basic notion of soil conservation.

[16] Henning Petersen, Effects of Non-inverting Deep Tillage vs. Conventional Ploughing on Collembolan Populations in an Organic Wheat Field, European Journal of Soil Biology, Volume 38, Issue 2, April-June 2002, Pages 177-180

Munkholm *et al.*[17] (2004) of Department of Crop Physiology and Soil Science, Danish Institute of Agricultural Sciences, Research Centre Foulum, Tjele, Denmark, reported;

"Sustainable soil management requires that the structural degradation is balanced or exceeded by regeneration. Our objective was to investigate the vulnerability of topsoil structure to stress exerted by intensive tillage or traffic. The study addressed the short-term stability to disturbance as well as the recovery (resilience) within a year. A field experiment was conducted in a randomised block design on a humid sandy loam in 1997–1999. Each year, either compaction from a heavy tractor (PAC) or puddling by intensive rotary cultivation (PUD) produced a severe impact on topsoil structure. The PAC and PUD treatments were carried out on wet soil in early spring. The mechanical treatments were referenced by plots (REF), which were left undisturbed until the soil had dried to a friable condition and ready for seedbed preparation. The PAC and PUD treatments were prepared for sowing at the same time as the reference plots. Penetration resistance was recorded in the spring of 1998 and 1999 to a depth of 200 mm. Soil was sampled from the 0–40 mm layer in May 1998 and in March, May and November 1999. The soil was air-dried and separated into four aggregate size fractions. The aggregates were subjected to tensile strength and density measurements. The penetration resistance in the 0–200 mm layer ranked in the order PAC>>PUD>REF. Both mechanical treatments significantly increased the density of 4–8 mm aggregates. One or 2 months after the mechanical treatments, they had increased tensile strength relative to REF by 44 and 33% in 1998 and by 13 and 33% in 1999 for the PAC and PUD treatments, respectively. Thus, our result showed substantial topsoil degradation when exposed to the PAC and PUD treatments, i.e. the sandy loam showed low stability. In November 1999, the PUD-treated aggregates were still markedly stronger than those found in the REF soil. Hence, the PUD-treated soil showed little resilience within a 6-month summer period. There was no significant difference in aggregate tensile strength between the treatments in March 1999 after a winter with cycles of freezing and thawing and a mouldboard ploughing operation

[17] Lars J. Munkholm and Per Schjønning, Structural Vulnerability of a Sandy Loam Exposed to Intensive Tillage and Traffic in Wet Conditions, Soil and Tillage Research, Volume 79, Issue 1, September 2004, Pages 79-85

in early spring. Our results thus imply that soil degradation induced by soil compaction or intensive rotary cultivation early spring may reduce the ease of tillage in the following autumn, whereas little residual effect can be expected in the following spring."

They concluded as:

"The sandy loam topsoil displayed low structural stability when exposed to soil compaction and intensive rotary cultivation in wet conditions. The topsoil showed very little recovery of structure within season but our results indicated a relatively high resilience after a winter and a spring ploughing. The poor within season resilience has practical implications under Danish conditions where the establishment of winter crops in the autumn shortly after the harvest of summer crops is very common.
Further studies are needed to elucidate especially the effects of intensive cultivation, which is less well described than compaction. There is reason to believe that problems associated with intensive cultivation on wet soil are increasing. In modern agriculture, the combined use of tractors with increased traction power and low-pressure tyres has enabled tillage at wetter conditions and with higher intensity than ever before."

The naturally occurring process in the soil medium where the conversion of organic forms of nitrogen (e.g. proteins in dead plant material) into inorganic forms of nitrogen (e.g. ammonium and nitrate) takes place in the presence of soil microbiota is termed as *nitrogen mineralization*. If the fertility of soil is high, the rate of nitrogen mineralization will also be high and crops will uptake nitrogen for longer periods. The major sources of nitrogen mineralization are manure, crop residues and the soil organic matter. This process is an important step in the N-cycle. As a result of this step, crops take up this inorganic form of nitrogen for growth. In order to meet the crop nitrogen demand, the synchronization between soil nitrogen mineralization and crop nitrogen uptake is of pivotal importance. However, I. K. Thomsen *et al.*[18] (2006) have shown that tillage does not improve the synchronization between the soil N mineralization and crop N demand. They reported,

[18] I. K. Thomsen & P. Sørensen, Interactions between Soil Organic Matter Level and Soil Tillage in a Growing Crop: N Mineralization and Yield Response, Soil Use and Management, Volume 22 Issue 2, Page 221 - June 2006

"Four levels of soil organic matter (SOM) had been established on a coarse sandy loam after application of four combinations of mineral fertilizer, animal manure, straw incorporation and catch crops for 12 years. Soil tillage was carried out in a growing spring barley crop (*Hordeum vulgare*) to examine the potential for improving the synchrony between soil N mineralization and crop N demand. Tillage raised soil nitrate concentrations temporarily but did not influence barley dry matter (DM) yield. At maturity, both grain DM yield and N uptake were largest on soil with the highest OM level. The previous OM applications had a pronounced influence on crop development and N availability, but soil tillage did not significantly improve the synchrony between soil N mineralization and crop N demand."

A4.2 CHEMICAL DEGRADATION OF SOIL:

Chemical degradation is the term used when the soil is chemically deteriorated. This can take place primarily in several ways;

- Sorption of chemicals to soil particles
- Soil contamination due to chemicals
- Loss of soil fertility
- Increase in the nitrate leaching

A4.2.1 Pesticide Application:

The Danish Environmental Protection Agency (EPA) states, “The use of pesticides has a number of undesirable environmental and health impacts”[19]. One of these is undesirable effects on soil, an essential component of the environment.

In Denmark fungicides are used in conventional agriculture for the control of fungi in various crops. There is a greater risk of soil contamination and, subsequently, ground water contamination associated with the use of fungicides in Denmark.

Maneb and Mancozeb are the two major kinds of fungicides that have been extensively used in Danish conventional farming. According to the Danish EPA[20] (1993), in 1992 alone, Maneb and Mancozeb contributed to 46% (or 615 ton/year) of the total use of fungicides in Denmark.

“Maneb is an ethylene(bis)dithiocarbamate fungicide used in the control of early and late blights on potatoes and tomatoes and many other diseases of fruits, vegetables, field crops, and ornamentals. Maneb controls a wider range of diseases than other fungicides. It is available as granular, wettable powder, flowable concentrate, and ready-to-use formulations.”[21] Also, Mancozeb which also belongs to the chemical class ethylene(bis) dithiocarbamate, is used in a similar way. “Mancozeb is used to protect many fruit, vegetable, nut and field crops against a wide spectrum of fungal diseases, including potato blight, leaf spot, scab (on apples and pears), and rust (on roses). It is also

[19] Pesticide Action Plan II 2000, Danish Environmental Protection Agency, available at: http://www.mst.dk/chemi/Pesticider/02020100.doc

[20] Kjølholt, J., COWIconsult AS, Landbrugets pesticidanvendelse i 1992, Danish EPA, 1993

[21] http://extoxnet.orst.edu/pips/maneb.htm

used for seed treatment of cotton, potatoes, corn, safflower, sorghum, peanuts, tomatoes, flax, and cereal grains. Mancozeb is available as dusts, liquids, water dispersible granules, as wettable powders, and as ready-to-use formulations. It may be commonly found in combination with zineb and maneb."[22]

Helle Johannesen *et al.*[23] (1996), at the Danish Institute of Plant and Soil Science, Department of Weed Control and Pesticide Ecology, Flakkebjerg, Slagelse, in an experiment reported,

> "Ethylenethiourea (ETU) is one of several degradation products from the ethylenebisdithiocarbamate (EBDC) fungicides Maneb and Mancozeb….."

Their conclusion included that ETU degraded significantly at a lower rate in the subsurface soil as compared to the surface soil, hence

> "The slow degradation of ETU in subsurface soil compared with surface soil implies a greater risk of groundwater contamination once ETU has leached to the subsurface."[24]

The Danish Environmental Protection Agency, in a project, conducted empirical research[25] (2003) in Denmark which has shown that pesticides land beside plants on the soil surface, where it does more harm than good. The project has measured the proportion of pesticide involved. Surprisingly, the results show that the amount that ends up on the soil surface depends not only on how big the plants are and how much of the soil surface they cover, it also depends on such factors as how open the plants are. Spraying technique and additives in the pesticides also play a large role. The deposition of pesticides on soil not only affects the soil but it can subsequently run off into the

[22] http://extoxnet.orst.edu/pips/mancozeb.htm
[23] Helle Johannesen, Annette Beth Nielsen, Arne Helweg, Inge S. Fomsgaard, Degradation of [^{14}C]Ethylenethiourea in Surface and Subsurface Soil, The Science of the Total Environment, 191 (1996), 271-276
[24] Ibid
[25] Deposition of Pesticides on the Soil Surface, Pesticides Research No. 65, Danish EPA, 2003, ISBN: 87-7972-944-4, available at:
http://www.mst.dk/homepage/default.asp?Sub=http://www.mst.dk/udgiv/Publications/2003/87-7972-943-6/html/default_eng.htm

groundwater and surface water. Therefore it is useful to know the proportion of a pesticide that lands on the soil under the crops when assessing the risks of run-off.

This study was carried out in 1999-2001 for four agricultural crops: winter wheat, spring barley, beet, and potatoes. These four crops are very widespread in Denmark and require a large amount of pesticide protection. Together, this means that they represent a very large percentage of the total consumption of pesticides in Denmark. Assessments of the risk have hitherto been based on estimated figures for the amount of pesticide falling beside the plants. The assumption has been that the deposits on the soil are inversely proportional to the plant cover at the time of spraying. The objective of the project was therefore to obtain more accurate figures for the amount of pesticide landing on the soil from spraying at different times in the growth season.

The main conclusion was that plant cover does not necessarily screen the soil. The results of the project show the amount of spray liquid hitting the soil when it is applied at different times during the growth of the plants. The actual results of the project have demonstrated some slight deviations from the assumption that the amount of spray landing on the soil corresponds to the area of the soil surface not covered by the plants at the time of spraying. In the early stages of growth, where the crops are very open, less spray ends on the soil than would immediately be expected from the soil cover. In contrast, there are measurable amounts of pesticide on the soil after spraying at later stages in the plant growth, when the soil surface is entirely covered by the crop.

A4.2.2 Sorption of Pesticides to Soil:

Sorption is the ability of substances (soil in this case) to soak up or attract contaminants and hold them to its surface. After the application of pesticides to fields, they primarily bound to organic material or clay in soils. In a study[26] by the Danish Environmental Protection Agency (2004), the influence of sorption on the degradation of pesticides and other chemicals was conducted. The study reveals that if chemicals are bound to the soil, the degradation rate is relatively slower. This is due to the fact that the soil microbes cannot have complete accessibility to them while being bound to the soil particles.

[26] Danish Environmental Protection Agency, The Influence of Sorption on the Degradation of Pesticides and other Chemicals in Soil, Environmental Project No. 902, 2004

The Danish Environmental Protection Agency conducted another study[27] which was composed of a review on Polycyclic Aromatic Hydrocarbons (PAH) contamination that is often found in the soil environment. Non-volatility, general poor water solubility and a unique tendency to bind to organic substances in the soil, are the characteristics of this chemical. Due to these characteristics, only very few PAHs are dissolved in the soil environment. In other words, the bioavailability, which is the substances' (PAHs in this case) availability to biological degradation by microorganisms, is reduced due to sorption. The study states,

"This project describes the possibilities of natural PAH degradation in soil and groundwater. Some natural degradation does take place, but multi-ringed PAHs are slowly degradable, and because of their low water solubility and their strong binding to organic matter, they often fail to be readily available for biodegradation." "PAHs have been in the spotlight for a number of years so substantial data are available on their toxicity, biodegradability, mobility in soil, etc. The overall purposes of the project were to assess the potential for degrading PAHs in soil and groundwater and to describe the importance of PAHs' physical and chemical properties in relation to their behaviour and degradability."[28]

The main conclusion of the study is that

"Natural degradation of PAHs has been seen in both soil and groundwater. However, some factors decrease or prevent degradation. One factor is that a large amount of PAHs in soil often exists in free phase in solid particles (e.g. tar and soot particles). Another factor is that PAHs, as a result of the ageing process, are absorbed in the organic material in soil. Both explain why PAHs are not readily available for biological degradation."[29]

[27] Mette Broholm Rambøll, Søren Knudsen, Jens Nonboe Andersen, Natural Degradation of PAHs in Soil and Groundwater, Environmental Project No. 582, Danish EPA, 2001, available only in Danish at: http://www.mst.dk/udgiv/publikationer/2001/87-7944-367-2/html/

[28] Ibid

[29] Ibid

L. Clausen *et al.*[30] have studied, in their experiments, the adsorption of pesticides on four different minerals and their interaction. They reveal,

> "The fate of pesticides in aquifers is influenced by the small but not insignificant adsorption of pesticides to mineral surfaces. Batch experiments with five pesticides and four minerals were conducted to quantify the contributions to adsorption from different mineral surfaces and compare adsorption characteristics of selected pesticides. Investigated mineral phases included quartz, calcite, kaolinite, and α-alumina. Selected pesticides comprised atrazine (6-chloro-N^2-ethyl-N^4-isopropyl-1,3,5-triazine-2,4-diamine), isoproturon [3-(4-isopropylphenyl)-1,1-dimethylurea)], mecoprop [(*RS*)-2-(4-chloro-2-methylphenoxy)propionic acid], 2,4-D (2,4-dichlorophenoxyacetic acid), and bentazone [3-isopropyl-1*H*-2,1,3-benzothiadiazin-4-(3*H*)-one 2,2-dioxide]. Specific surface area and mineral surface charge proved to be important for the adsorption of these pesticides. Detectable adsorption of the anionic pesticides (mecoprop, 2,4-D, and bentazone) was only measured when positive sites were present on the mineral surface. However, when $CaCl_2$ was added as an electrolyte, a detectable adsorption of mecoprop and 2,4-D was also measured on kaolinite (which exhibits a negative surface charge), probably due to formation of Ca–pesticide–surface complexes. Adsorption of the uncharged pesticides (atrazine and isoproturon) was detected only on kaolinite. The lack of adsorption on α-alumina indicates that the uncharged pesticides have a greater affinity for the silanol surface sites (=SiOH) than for the aluminol surface sites (=AlOH) in kaolinite. No measurable effect of ionic strength was found for the uncharged pesticides. The results indicate that quartz and calcite play a smaller role than clay minerals."

Mineralization is a natural process where the humus and soil organic matter is converted into inorganic substances by microbial breakdown. Mineralization (of pesticides and herbicides) is an important bioremediation and biodegradation process that occurs naturally in agricultural lands. Mineralization takes place in the presence of naturally occurring bacteria in the soil. These bacteria are responsible for the degradation of chemical compounds that persist in the soil due to pesticide applications. Higher the

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[30] L. Clausen, I. Fabricius and L. Madsen, Adsorption of Pesticides onto Quartz, Calcite, Kaolinite, and α-Alumina, Journal of Environmental Quality, Volume 30, Issue 3, May-June 2001

rate of degradation, higher would be the mineralization process and vice versa, hence they are directly proportional to each other. Helle Johannesen *et al.*[31] (2003) studied the mineralization process in the soil,

> "The aim of the study was to determine the effect of aging of the herbicide isoproturon and its metabolites monodesmethyl-isoproturon and 4-isopropyl-aniline in agricultural soil on their availability to the degrading bacterium *Sphingomonas* sp. strain SRS2. The ^{14}C-ring-labeled isoproturon, monodesmethyl-isoproturon, and 4-isopropyl-aniline were added to sterilized soil and stored for 1, 49, 71, or 131 d before inoculation with strain SRS2. The availability of the compounds was estimated from the initial mineralization and the amount of $^{14}CO_2$ recovered after 120 d of incubation. Aging in soil for 131 d reduced the initial mineralization of isoproturon and monodesmethyl-isoproturon and, in the case of isoproturon, also reduced the recovery of $^{14}CO_2$. Initial mineralization and recovery of $^{14}CO_2$ from aged 4-isopropyl-aniline were slightly reduced, but less $^{14}CO_2$ was generally produced than with isoproturon or monodesmethyl-isoproturon. Thus, recovery of $^{14}CO_2$ from ^{14}C-isoproturon and ^{14}C-monodesmethyl-isoproturon was 50.7 to 64.4% of the initially added ^{14}C, while recovery from ^{14}C-4-isopropyl-aniline was only 11.7 to 17.0%. Sorption measurements revealed similar Freundlich constants (K_f) for isoproturon and monodesmethyl-isoproturon, whereas K_f for 4-isopropyl-aniline was more than fivefold greater. The findings imply that in soil, partial degradation of isoproturon to 4-isopropyl-aniline may lead to reduced mineralization of the herbicide due to sorption of the aniline moiety."

A4.2.3 Soil Contamination due to Chemicals:

Soil contamination is another major source of soil degradation. Soil is contaminated by potentially hazardous chemical compounds, resulting from several sources e.g. pesticides. In Denmark, dioxins are a potential source of soil contamination. Dioxin is a short word typically used for two groups of tri-cyclic, halogenated, organic

[31] Helle Johannesen, Sebastian R. Sørensen and Jens Aamand, Mineralization of Soil-Aged Isoproturon and Isoproturon Metabolites by Sphingomonas sp. Strain SRS2, Journal of Environmental Quality, July-August 2003, Volume 32, Issue 4

compounds, of which some chlorinated compounds have turned out to be extremely toxic to the environmental components. Dioxin is an organic chemical that degrades with great difficulty and is a member of the toxic chemicals known as ‘Persistent Organic Pollutants’ (POP). Many kinds of pesticides contain dioxins that may interact with the soil. In Denmark, dioxins are used in pesticide production and hence they end up in the soil with their anticipated detrimental impacts. Following is a table (from Danish Environmental Protection Agency, 2000) that shows the 1998 Danish consumption of pesticides that contain dioxins:

Table No. 3; Danish consumption of pesticides confirmed or suspected to contain dioxins[32].

Common name	**Consumption in Denmark 1998 kg active substance**
Bromoxynil	80,192
Chlorfenvinphos	89
Chlorothalonil	25,070
2,4-D	0
Dicamba	3,183
Dichlorprop	302
Dichlor-P	4,347
Diflubenzuron	392
Diuron	27,370
Imazalil	12,389
Linuron	8,019
MCPA	159,444
Mechlorprop	19,413
Mechlorprop-p	1,269
Paclobutrazol	23
Tetradifon	5
Total	**341,507**

[32] Erik Hansen, Substance Flow Analysis for Dioxins in Denmark, Environmental Project No. 570, 2000, Danish Environmental Protection Agency, available at: http://www.mst.dk/udgiv/Publications/2000/87-7944-295-1/pdf/87-7944-297-8.pdf

In Denmark, in 2000, the total direct emission of dioxins to the soil environment was estimated at 1.3-54 g I-TEQ/year[33]. In 2002, the estimation was 0.7-42 g I-TEQ/year[34]. Among others (non agricultural practices), manure from domestic animals applied to farmland is a dominant source. Manure from domestic animals is generally applied to farmland and will contain dioxins originating from the feedstuff. Moreover, other minor sources seem to be the use of pesticides and sewage sludge. The detailed investigations of the turnover of dioxins in the Danish agricultural sector are not available.

In 2001, The National Environmental Research Institute, Denmark, conducted an investigation of the dioxin content in the soil in Denmark. The concentration of dioxin has been measured at 33 different places all over the country in various types of soil from both near and far from expected sources to emission sites. Since dioxin is present in the topsoil, the measurements were carried out in a depth of 0 – 10 cm. It was found that the concentration of dioxin in soils in the urban areas was higher than in rural areas. In urban areas the concentration is approximately 3.6 – 19 ng I-TEQ/kg dry matter and in rural areas it is 0.5 – 0.66 ng I-TEQ/dry matter.

A4.2.4 Pesticide Leaching:

The process by which soluble materials of pesticide chemicals or contaminants in the soil are washed into the subsoil layer or carried away by water after being dissolved is called as *pesticide leaching.* The concept of pesticide leaching is similar to making tea, where the flavour leaches out of the tea leaves. Pesticide leaching not only poses a potential threat to the Danish aquatic underground environment but it has also been physically determined. The Geological Survey of Denmark and Greenland[35] (2000) detected pesticides and their metabolites in 29% of the water wells tested in 1999. These findings were of great concern due to the fact that in Denmark, 99% of the water used for

[33] Ibid

[34] Erik Hansen and Charlotte Libak Hansen, Substance Flow Analysis for Dioxins 2002, Environmental Project No. 811, 2003, Danish Environmental Protection Agency, available at: http://www.mst.dk/udgiv/publications/2003/87-7972-675-5/pdf/87-7972-676-3.pdf

[35] GEUS, 2000, Grundvandsovervågning, Geological Survey of Denmark and Greenland, (In Danish)

domestic supply and consumption is sourced from groundwater wells. Hence pesticide leaching has caused great problems to the ground water in Denmark.

Similarly, Stockmarr[36] (2000) reported that pesticides and their degradation products have been up till now detected in 30% of all screens monitored. These are the findings of Danish National Groundwater Monitoring Programme (GRUMO).

Jeanne Kjær *et al.*[37] (2005) evaluated the risk of leaching of pesticides, through soil, to groundwater.

> "Pesticide leaching is an important process with respect to contamination risk to the aquatic environment. The risk of leaching was thus evaluated for glyphosate (*N*-phosphonomethyl-glycine) and its degradation product AMPA (amino-methylphosphonic acid) under field conditions at one sandy and two loamy sites. Over a 2-yr period, tile-drainage water, ground water, and soil water were sampled and analyzed for pesticides. At a sandy site, the strong soil sorption capacity and lack of macropores seemed to prevent leaching of both glyphosate and AMPA. At one loamy site, which received low precipitation with little intensity, the residence time within the root zone seemed sufficient to prevent leaching of glyphosate, probably due to degradation and sorption. Minor leaching of AMPA was observed at this site, although the concentration was generally low, being on the order of 0.05 μg L^{-1} or less. At another loamy site, however, glyphosate and AMPA leached from the root zone into the tile drains (1 m below ground surface [BGS]) in average concentrations exceeding 0.1 μg L^{-1}, which is the EU threshold value for drinking water. The leaching of glyphosate was mainly governed by pronounced macropore flow occurring within the first months after application. AMPA was frequently detected more than 1.5 yr after application, thus indicating a minor release and limited degradation capacity within the soil. Leaching has so far been confined to the depth of the tile drains, and the pesticides have rarely been detected in monitoring screens located at lower depths. This study suggests that as both glyphosate and AMPA can leach through structured soils, they thereby pose a potential risk to the aquatic environment".

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[36] Stockmarr, J. (2000), Groundwater Monitoring 2000, Geological Survey of Denmark and Greenland, December 2000

[37] Jeanne Kjær, Preben Olsen, Marlene Ullum and Ruth Grant**,** Leaching of Glyphosate and Amino-Methylphosphonic Acid from Danish Agricultural Field Sites**,** Journal of Environmental Quality, March-April 2005, Volume 34, Issue 2

Trine Henriksen *et al.*[38] (2004), conducted a field experiment on the leaching of herbicide metabolites to ground water and showed that their degradation in subsoil took place very slowly.

> "Leaching to the ground water of metabolites from the herbicide metribuzin [4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-5-one] has been measured in a Danish field experiment in concentrations exceeding the European Union threshold limit for pesticides at 0.1 μg/L. In the present work, degradation and sorption of metribuzin and the metabolites desamino-metribuzin (DA), diketo-metribuzin (DK), and desamino-diketo-metribuzin (DADK) were studied in a Danish sandy loam topsoil and subsoil from the field in question, using accelerated solvent extraction and liquid chromatography–tandem mass spectrometry (LC–MS/MS) analysis. Fast dissipation of metribuzin and the metabolites was observed in the topsoil, with 50% disappearance within 30 to 40 d. A two-compartment model described degradation of metribuzin and DA, whereas that of DADK could be described using first-order kinetics. Part of the dissipation was probably due to incorporation into soil organic matter. Degradation in subsoil occurred very slowly, with extrapolated half-lives of more than one year. Sorption in the topsoil followed the order DA > metribuzin > DK > DADK. Subsoil sorption was considerably lower, and was hardly measurable for metribuzin and DK. Abiotic degradation was considerably higher in the topsoil than the subsoil, especially concerning the de-amination step, indicating that organic matter may be related to the degradation process. The present results confirm observations of metribuzin and transformation product leaching made in the field experiment and demonstrate the need for knowledge on primary metabolites when assessing the risk for pesticide leaching".

For the control of weeds in conventional farms in Denmark, Phenoxyalkanoic acid herbicides are mainly used. The phenoxyalkanoic acids are considered to be potential contaminants of water in Denmark. These pesticides are in extensive use and in

[38] Trine Henriksen, Bo Svensmark and René K. Juhler, Degradation and Sorption of Metribuzin and Primary Metabolites in a Sandy Soil, Journal of Environmental Quality, March-April 2004, Volume 33, Issue 2

an experiment G. Felding[39] (1990) monitored the leaching of these compounds. Residues of the phenoxyalkanoic acid herbicides were not found in water samples taken from the top of the groundwater zone (l-2 m below the soil surface), rather they were found deeper below because these pesticide molecules leach down to the water at a faster rate. This is due to the fact that they belong to the group of pesticides that have the highest water solubility and are present in soil mainly in the dissociated form. Moreover, their adsorption to soil humus and clay minerals is small because of the high polarity and negative charge of the compounds. Due to these characteristics, these chemicals are degraded relatively easily and at the same time are leached to ground water at a faster pace due to their mobility.

Gitte Felding[40] (1995) of the Danish Institute of Plant and Soil Science, Department of Weed Control and Pesticide Ecology, Slagelse, Denmark, measured the content of phenoxyalkanoic acid herbicides in water.

"The content of the phenoxyalkanoic acid herbicides 2,4-D, dichlorprop, MCPA, and mecoprop was measured over a 2-year period in drainage water from three clayey soils in Denmark. The herbicide content in 17 out of 65 water samples was above 0.1 pg 1-l which is the maximum residue limit for drinking water in Europe. Application of mecoprop in the autumn did not cause the expected leaching. The highest concentrations for 2,4-D, dichlorprop, MCPA and mecoprop were 0.24, 0.30, 0.29 and 0.34 /Ig l-l, respectively."

[39] G. Felding, Side Effect of Pesticides, Weeds (ISBN 87-88976-14-9), 1990, pp. 211-224 (in Danish), 7th Danish Plant Protection Conference

[40] Gitte Felding, Leaching of Phenoxyalkanoic Acid Herbicides from Farmland; The Science of the Total Environment 168 (1995) 11-18

A4.3 BIOLOGICAL DEGRADATION OF SOIL:

A4.3.1 Impact on Soil Biota:

The soil biota have been adversely affected in Denmark. The major reason for this biological degradation of the soil is the excessive use of pesticides. The application of pesticides on the arable land has unintended detrimental effects on non-target living soil organisms. The Danish Environmental Protection Agency carried out a research project[41] in Denmark and it was concluded that soil living organisms are killed due to pesticide application on crops. The mortality rate of soil biota depends on the bioavailability of pesticides in them. In this research, the effects of insecticides on ground and rove beetles were investigated in 1994, 1995 and 1996 in laboratory and field tests using Cyperp (cypermethrin) and Roxion 400 (dimethoate) as test insecticides. These two insecticides were chosen because these two together cover approximately 40 % of the total consumption of insecticides in Denmark. The impacts of these insecticides were observed according to a standard test on two beetles; the rove beetle, *Aleochara bilineata* (Staphylinidae) and ground beetle, *Bembidion lampros* (Carabidae).

These tests were carried out in a 'worst case' situation in order to seek the most obvious detrimental effects. The worst case conditions depend on the individual species and its biology. The tests were carried out under variable conditions. The results showed mortality for these species. In addition, the results suggest that pesticide application may cause effects on other insects as well.

Ironically, even recommended dosages of pesticides have shown to have detrimental effects on the soil fauna in Danish fields. Petersen & Gjelstrup[42] (1995) showed that with the application of recommended dosages of the insecticide dimethoate, the inhibition of the collembolan population growth occurred.

[41] Gyldenkærne, Steen; Ravn, Hans Peter, Effect of Dimethoate and Cypermethrin on Soil Dwelling Beetles, 1998, Pesticides Research 45, Danish Environmental Protection Agency, Denmark, available at: http://www.mst.dk/udgiv/Publications/1998/87-7909-048-6/pdf/87-7909-048-6.PDF

[42] Petersen, H., Gjelstrup, P. 1985, Development of a Semi-Field Method for Evaluation of Laboratory Tests as Compared to Field Conditions. IN: Løkke, H. (ed.) Effects of Pesticides on Meso- and Microfauna in Soil, Bekæmpelsesmiddelforskning fra Miljøstyrelsen 8, Danish Environmental Protection Agency, Copenhagen, pp. 67–142

A5 ANALYSIS OF THE COMPARATIVE EMPIRICAL STUDY FOR SOIL DEGRADATION:

A5.1 ACCEPTANCE/REJECTION OF NULL HYPOTHESIS FOR SOIL DEGRADATION:

A5.1.1 Proposition 1:

If the farming types do not qualitatively outweigh each other in terms of soil degradation (from the empirical literature in the comparative study), then the null hypothesis that "no association exists between organic and conventional farming types and *soil degradation* levels" is accepted and it will be concluded that "no association exists". Then there is no need for any further evaluation.

A5.1.2 Proposition 2:

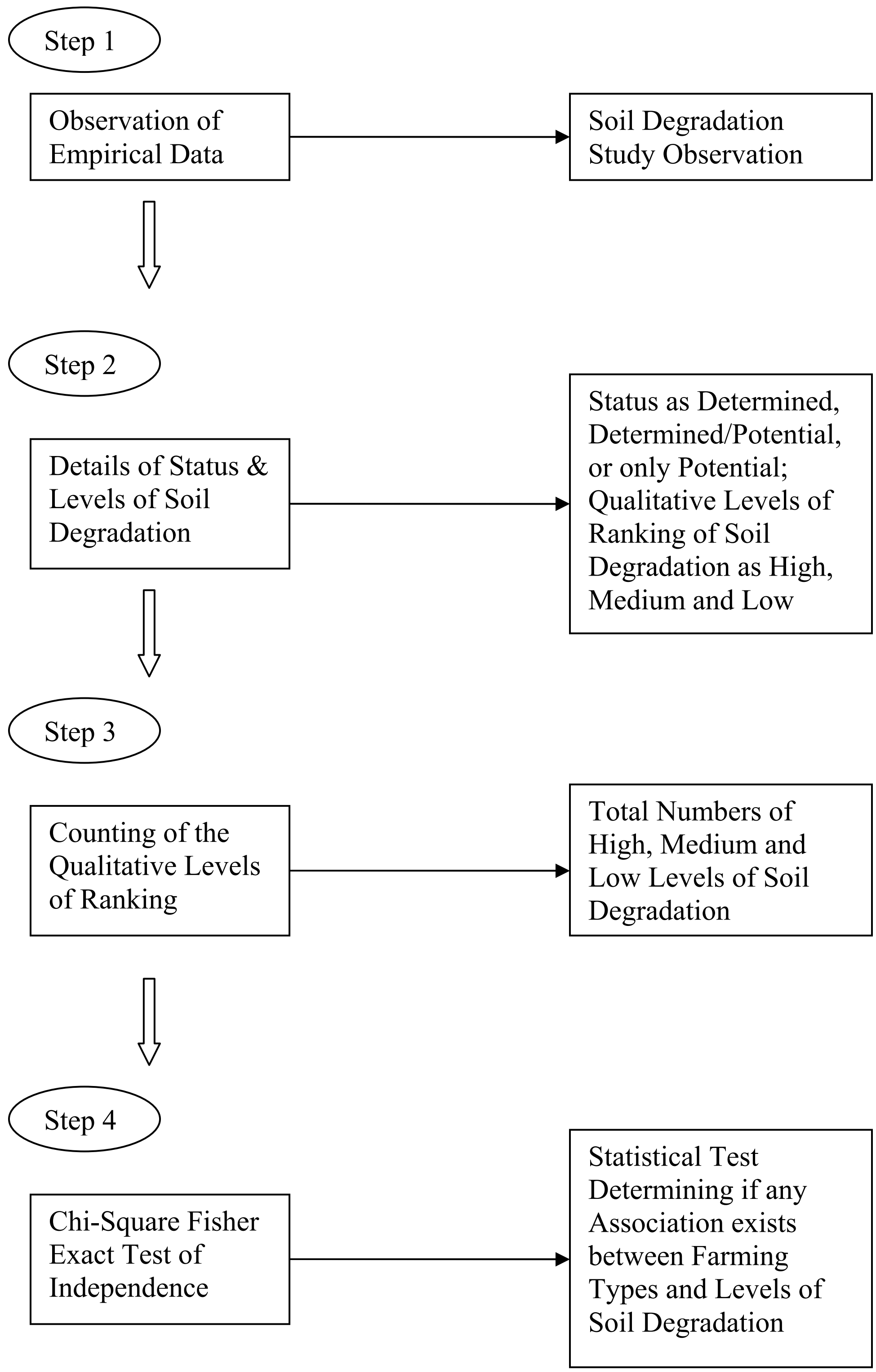
If any of the farming types qualitatively outweigh each other in terms of soil degradation (from the empirical literature in the comparative study), then the null hypothesis that "no association exists between organic and conventional farming types and *soil degradation* levels" is rejected and it will be concluded that the "association does exist".

If there is any association present, this would imply that there is also difference present (from a statistical point of view). After reaching to this decision on the null hypothesis, then it is crucial for the conclusion to determine the difference and evaluate the type of farming system that degrades the soil more. But this would be possible if there is enough data in the comparative study to conduct a statistical analysis to determine any difference, if present.

A5.2 METHODOLOGY OF ANALYSIS:

In order to comprehend the results of the comparative study of organic and conventional agriculture for soil management, the analysis is conducted in a stepwise procedure. The 'Schematic Diagram No. 3' on the next page elaborates the methodology of the analysis of soil degradation for a clear understanding:

Schematic Diagram No. 3; Showing stepwise procedure of the methodology of analysis.

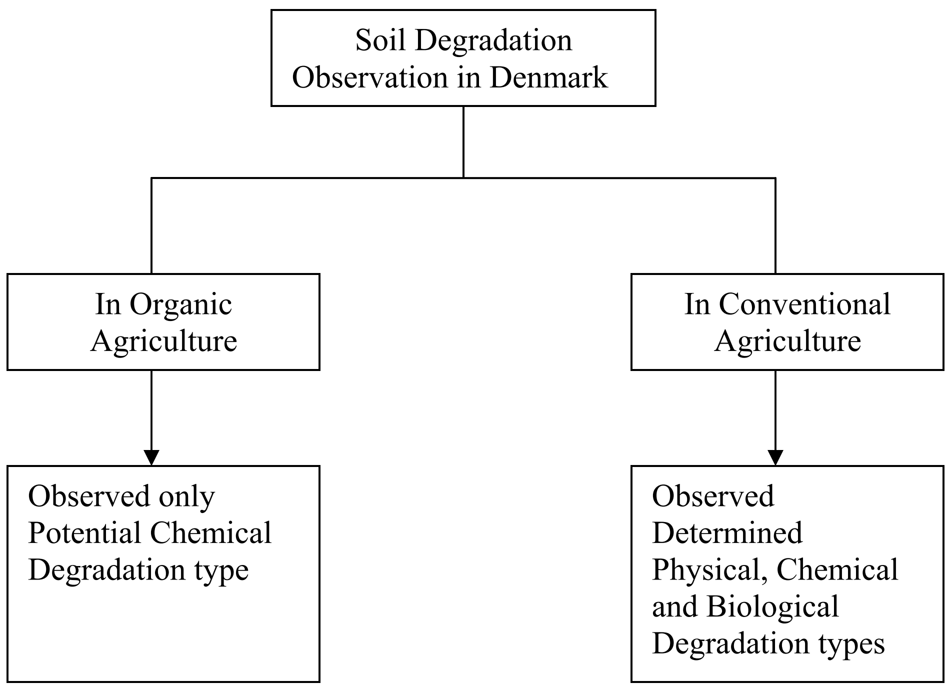


A5.2.1 Step No. 1: Observation of Empirical Data:

In the first step, the physical, chemical and biological soil degradation types for both organic and conventional agriculture are observed to classify their status as potential and/or determined. Hence the observations are:

Observation of *Soil Degradation* in Both Farming Types:

Schematic Diagram No. 4; Showing the observation for different *soil degradation* types in both organic and conventional agriculture separately.



A5.2.2 Step No. 2: Qualitative Ranking and Details of Soil Degradation Dimensions:

The qualitative ranking is given to the three dimensions of degradations for both the farming systems separately in the following 'Table No. 4, Table No. 5 and Table No. 6'.

The rankings are given according to the status of each of the references in the review in the following manner:

1. If degradation types are 'determined', then ranking = High
2. If degradation types are 'potential' and/or 'determined', then ranking = Medium
3. If degradation types are 'potential', then ranking = Low
4. If degradation types are 'unknown', then ranking = Unknown

Note that the High, Medium and Low are the "Levels of Soil Degradation" in the above formula.

In this step, using data from the comparative empirical study and inputs from Step No. 1, the details of physical, chemical and biological dimensions and status of soil degradation for both farming types are presented separately in the following 'No. 4, Table No. 5 and Table No. 6':

Table No. 4; Presenting details of *Physical Soil Degradation* dimension in organic and conventional agriculture from the comparative empirical study.

Farming Type	S No.	Types of Physical Soil Degradation	List of References	Observed Status	Qualitative Levels of Ranking
Organic Agriculture		Unknown	Unknown	Unknown	Unknown
Conventional Agriculture	1.	Soil Compaction	Ref. No. 13, Page No. 46	Potential	Low
	2.	Water Erosion			
	2a.	Sheet Erosion	Ref. No. 14, Page No. 47	Determined	High
	2b.	Rill Erosion	Ref. No. 14, Page No. 47	Determined	High
	2c.	Tillage Erosion	Ref. No. 14, Page No. 47	Determined	High
	2d.	Bank Erosion	Ref. No. 14, Page No. 47	Determined	High
	3.	Tillage Erosion	Ref. No. 15, Page No. 48	Potential/Determined	Medium
	4.	Tillage	Ref. No. 16, Page No. 49	Potential/Determined	Medium
			Ref. No. 17, Page No. 50	Potential/Determined	Medium
			Ref. No. 18, Page No. 51	Determined	High

Table No. 5; Presenting details of *Chemical Soil Degradation* dimension in organic and conventional agriculture from the comparative empirical study.

Farming Type	**S No.**	**Types of Chemical Soil Degradation**	**List of References**	**Observed Status**	**Qualitative Ranking**
Organic Agriculture	1.	Sewage Sludge	Ref. No. 6, Page No. 40	Potential	Low
	2.	Application of Ash	Ref. No. 7, Page No. 41	Potential	Low
	3.	Mineralization of Flora Parts	Ref. No. 8, Page No. 42	Potential	Low
	4.	Nitrogen Losses	Ref. No. 9, Page No. 43	Potential	Low
	5.	Sulphate Leaching	Ref. No. 10, Page No. 44	Potential	Low
	6.	Potassium Leaching	Ref. No. 11, Page No. 45	Potential	Low
			Ref. No. 12, Page No. 46	Potential	Low
Conventional Agriculture	1.	Pesticide Application	Ref. No. 19, Page No. 53	Determined	High
			Ref. No. 20, Page No. 53	Determined	High
			Ref. No. 23, Page No. 54	Determined	High
			Ref. No. 25, Page No. 54	Determined	High
	2.	Sorption of Pesticides	Ref. No. 26, Page No. 55	Determined	High
			Ref. No. 27, Page No. 56	Determined	High
			Ref. No. 30, Page No. 57	Determined	High
			Ref. No. 31, Page No. 58	Determined	High
	3.	Soil Contamination	Ref. No. 33, Page No. 60	Determined	High
			Ref. No. 34, Page No. 60	Determined	High
	4.	Pesticide Leaching	Ref. No. 35, Page No. 60	Determined	High
			Ref. No. 36, Page No. 61	Determined	High
			Ref. No. 37, Page No. 61	Potential	Low

			Ref. No. 38, Page No. 62	Determined	High
			Ref. No. 39, Page No. 63	Determined	High
			Ref. No. 40, Page No. 63	Determined	High

Table No. 6; Presenting details of *Biological Soil Degradation* dimension in organic and conventional agriculture from the comparative empirical study.

Farming Type	**S No.**	**Types of Biological Soil Degradation**	**List of References**	**Observed Status**	**Qualitative Ranking**
Organic Agriculture		Unknown	Unknown	Unknown	Unknown
Conventional Agriculture	1.	Soil Biota	Ref. No. 41, Page No. 64	Determined	High
			Ref. No. 42, Page No. 64	Determined	High

A5.2.3 Step No. 3: Counting of Qualitative Levels of Ranking for Soil Degradation:

Table No. 7; Contingency table providing the total counts in the three dimensions of soil degradation in both farming systems for the three qualitative levels (derived from Step No. 2).

Farming Type	**Degradation Dimension**	**Total Number of References ranked 'High'**	**Total Number of References ranked 'Medium'**	**Total Number of References ranked 'Low'**
Organic	Physical	0	0	0
	Chemical	0	0	7
	Biological	0	0	0
Totals		**0**	**0**	**7**
Conventional	Physical	5	3	1
	Chemical	15	0	1
	Biological	2	0	0
Totals		**22**	**3**	**2**

The totals in this table reflect the collective degradation (Physical+Chemical+Biological) for both farming systems in three levels and they are used in the following step.

A5.2.4 Step No. 4: Statistical Analysis, Fisher Exact Test of Independence:

In order to determine if any association exists between farming types and soil degradation, the following contingency **Table No. 8** is presented, (derived from Table No. 7):

Farming Type	**Levels of Soil Degradation**		
	High	Medium	Low
Organic Agriculture	0	0	7
Conventional Agriculture	22	3	2

Table No. 9; Showing the Expected Frequency in order to determine the statistical test to be applied:

Farming Type	**Levels of Soil Degradation**			
	High	Medium	Low	Totals
Organic Agriculture	0 (7x22/34)=4.5	0 (7x3/34)=0.6	7 (7x8/34)=1.64	7
Conventional Agriculture	22 (27x22/34)=17.4	3 (27x3/34)=2.38	2 (27x8/34)=6.3	27
Totals	22	3	8	34

Table No 9 shows the statistical calculation in which the Expected Frequency is less than 5. Normally, the Expected Frequency for each of the cells in the table should be greater than 5 in a normal Chi-Square test. But since in this table the Expected Frequency of some of the cells is less than 5, therefore, ‘Chi-Square Fisher Exact Test of Independence’ is used for the results to determine the association.

Rejection of the Null Hypothesis for Soil Degradation:

To determine the association between the farming types and levels of soil degradation, Fisher Exact test is applied in the analysis. The information in the rows and columns from Table No. 8 is used in the calculation of the P value. The P value is calculated and is compared with alpha = 0.05. If the P value > 0.05 then the null hypothesis is accepted. If the P value < 0.05 then the null hypothesis is rejected and it shows that there is some association between the farming types and levels of soil degradation.

Following are the results of the Fisher Exact Test of Independence:

Chi square (with 2 degrees of freedom):
(including empty -zero- cell)
Pearson's= 24.486 (p= 0.0000)

Chi squares (both with 2 degree of freedom):
(excluding empty -zero- cell)
Pearson's= 29.633 (p= 0.0000)
Likelihood Ratio= 25.04 (p= 0.0000)

In the above calculations, since the P value = 0.0000 < 0.05, therefore, the null hypothesis for soil degradation that "no association exists between organic and conventional farming types and levels of *soil degradation*" is rejected and it shows that the association is highly significant and it is concluded that there is some association between farming types and levels of soil degradation. Therefore, Proposition No. 1 (heading A5.1.1, page 65) is rejected and Proposition No. 2 (heading A5.1.2, page 65) is accepted.

This furthermore implies that difference also exists between farming types and levels of soil degradation. This difference is obvious from the evaluation of the review of the empirical data of soil degradation. The difference between farming types and soil degradation levels cannot be calculated quantitatively on a statistical basis. This is due to the fact that the comparison cannot be conducted statistically, because from Table No. 8, (page 71) the soil degradation ranked sampling values are available for all the three levels (high, medium, low) in conventional agriculture but in organic agriculture, the ranked sampling value is available for only one level (low) whereas for the other two levels (high and medium), the ranked sampling values are not available. Therefore, if the values for the two levels are unknown, then a statistical comparative analysis cannot be conducted.

SECTION B:

A THOROUGH COMPARATIVE STUDY AND ANALYSIS FOR SOIL CONSERVATION

B1 NULL HYPOTHESIS FOR SOIL CONSERVATION:

To determine if organic farming *conserves* the soil, the obvious system to compare it with, is its counterpart – conventional farming. So, it is deemed necessary to compare the *soil conservation* in organic farming with conventional farming in Denmark. The farming type that *conserves* the soil more will *degrade* the soil less; so the relation is inversely proportional. Hence statistically, the null hypothesis is that ‘no association exists between farming types and *soil conservation* levels’. The soil conservation levels taken into consideration in this thesis are; high soil conservation, medium soil conservation and low soil conservation. In the analysis of this comparative study, the various empirical findings, under the various ‘selected parameters’ mentioned in the following Table No. 10 (Page 74), are ranked according to these three levels of soil conservation in order to find if any association is present.

This null hypothesis is *accepted* if there is clear evidence from existing Danish empirical literature that ‘no association between farming types and soil conservation levels exists’. Conversely, if the evidence is available that the association is present, then the null hypothesis is *rejected* and it will be concluded that ‘association exists between organic and conventional farming types and *soil conservation* levels’.

The quantitative results obtained after the statistical analysis, to identify any association between the farming types and soil conservation levels, would determine if a comparative statistical analysis can be conducted to find any difference, if any, between the two different farming types for soil conservation.

B2 LIST OF SELECTED PARAMETERS OF SOIL CONSERVATION:

Following is the list of selected parameters of soil conservation for the comparative study. The parameters have been selected in light of the agro-climatic conditions and farming practices in Denmark. All the empirical data, in the comparative study for soil conservation, have been distributed according to the selected parameters of soil conservation. In other words, the empirical data have been gathered depending on these important parameters that determine the severity of soil conservation in Denmark.

Table No. 10; Showing the Selected Parameters in the Comparative Study of both Farming Systems for Soil Conservation.

Dimension of Conservation	**Serial No.**	**Selected Parameters**
Physical Conservation	1.	Conservation Tillage
	2.	Soil Physical Properties
Chemical Conservation	1.	Reduced Nitrogen Leaching
	2.	Increased Soil Organic Matter
	3.	Increased Soil Fertility
	4.	Sewage Sludge
	5.	Organic Manures
Biological Conservation	1.	Soil Biota (including various bio-indicators)
	2.	Entomological Benefits
	3.	Avian Benefits
	4.	Crop Rotations
	5.	Use of Catch Crops
	6.	Farm Hedgerow Diversity

The above selected parameters have been used in the following comparative study for each dimension of soil conservation. These various dimensions have been presented separately in each of the farming types so as to provide a clear and better understanding of the soil conservation in their respective selected parameters.

B3 SOIL CONSERVATION IN ORGANIC FARMING:

B3.1 PHYSICAL CONSERVATION OF SOIL:

B3.1.1 Conservation Tillage:

In Danish organic farming, conservation tillage techniques are used which are basically designed to reduce soil erosion and overland flow. Most conservation tillage techniques involve less manipulation of the soil than conventional techniques, leaving more plant matter on the soil surface. In Denmark, non-inversion and reduced tillage systems are primarily used as conservation tillage systems. The practice of conservation tillage has a great beneficial impact on soil structure, particularly the topsoil. Munkholm *et al.*[43] (2001) studied the effects of non-inversion tillage on the soil during the early stages of conversion to reduced tillage systems.

"Optimisation of soil tilth is of paramount importance in organic plant production in order to enhance crop growth. Non-inversion and reduced tillage systems are often claimed to be preferable for organic farming. The purpose of this study was to evaluate the early stage effects of converting a mouldboard-ploughed soil to a non-inversion tillage system. A multi-level experimental strategy including in situ, on-site and laboratory methods was followed in order to relate quantitative measures of soil physical properties directly to soil behaviour in the field. A non-inversion deep soil loosening (0–35 cm) tillage system (NINV) was compared to a conventional mouldboard ploughing and harrowing tillage system (CONV). The experimental site was located on an organically managed sandy loam soil. The tillage treatments were applied to plots in two fields (B_3 and B_4) at the experimental site. Limited numbers of measurements were performed in the B_3 field during the 1997–1999 growing seasons. A more comprehensive programme was carried out in the B_4 field in May and September 1998. A root-restricting plough pan was detected in the CONV treated soil. The NINV treatment effectively

[43] Lars J. Munkholm, Per Schjønning and Karl J. Rasmussen, Non-inversion Tillage Effects on Soil Mechanical Properties of a Humid Sandy Loam, Soil and Tillage Research, Volume 62, Issues 1-2, October 2001, Pages 1-14

loosened the plough pan resulting in a visibly improved soil structure and a decrease in soil strength. The penetration resistance in the plough pan was reduced from about 1800 kPa in CONV to less than 1000 kPa in NINV when measured at field capacity. The loosening of the plough pan was still evident after 2 years without tillage operations in a perennial grass/clover crop. The topsoil of the CONV treatment had a more desirable tilth than that of the NINV treatment, which had higher soil strength at the 7–14 cm depth. In accordance with this, the CONV treated topsoil fragmented more readily than the NINV soil in the field. The laboratory measurements on soil from the September sampling showed that the NINV treatment had lower friability index (i.e., friability index of 0.16 and 0.22 for NINV and CONV, respectively) and higher tensile strength of air-dry aggregates. The differences in topsoil tilth were not eliminated by natural soil meliorating processes during the growing season. This paper discusses the early stage effects of converting to non-inversion tillage. A number of years of continued treatment may be required before beneficial effects of non-inversion tillage are manifested in improved topsoil tilth."

The results show that, in general, soil aggregates from the non-inversion treated soil were stronger than soil aggregates from the conventional treatment. Hence, non-inversion tillage systems exhibit high soil strength.

T. Keller *et al.*[44] (2002) conducted an experiment and their comparative study demonstrated that on-land ploughing, a conservation tillage type, may reduce the risk for subsoil compaction compared to conventional ploughing. They reported,

"Ploughing is a field operation considered to be associated with severe soil compaction. Two experiments were carried out in Denmark on Eutric Cambisols with a Claas Challenger 2-65 E rubber-tracked tractor with a total weight of 185 kN. In Experiment A, the vertical stress under the track during ploughing was measured by stress sensors at 0.1m depth in order to study stress distribution. In Experiment B, the vertical soil displacement and vertical normal soil stress during ploughing were measured

[44] T. Keller, A. Trautner, J. Arvidsson, Stress Distribution and Soil Displacement Under a Rubber-tracked and a Wheeled Tractor During Ploughing, both On-land and Within Furrows, Soil & Tillage Research 68 (2002) 39–47

simultaneously at three different depths. The tracked tractor was compared to a wheeled tractor with a total weight of 97 kN. The rubber-tracked tractor and the wheeled tractor were pulling a plough with 12 and 7 bodies, respectively. The tracked tractor ploughed on-land, whereas the wheeled tractor ploughed both on-land and conventionally (two wheels running in the furrow). In Experiment A, vertical stress was found to be much higher under the rear than under the front part of the tracks. It was caused by unsuitable adjustment of the plough to the tractor for given field conditions. By lowering the point of application of the draught force induced by the plough, maximum vertical stress was reduced from 304 to 158 kPa. However, the vertical stress was concentrated under the supporting rollers and wheels as well as under the centre line of the track, so that maximum stress was 3.8 times higher than average stress. In Experiment B, the vertical stress was higher below the wheeled tractor than below the tracked tractor, which had been adjusted as in Experiment A. No significant difference in maximum vertical soil stress was found between the tracked tractor and the wheeled tractor ploughing on-land at any depth. The vertical stress at 0.3 and 0.5m depth was significantly higher during conventional ploughing (i.e. under the in-furrow wheels) than during on-land ploughing. The higher vertical stress also resulted in larger vertical soil displacement at 0.3m depth under the in-furrow wheels when ploughing conventionally than under the on-land ploughing tractor. At 0.5m depth, no residual vertical soil displacement occurred because the soil strength was very high. The results clearly demonstrated that on-land ploughing may reduce the risk for subsoil compaction compared to conventional ploughing. Using tracks instead of wheels may further reduce this risk. However, this is only the case if the tractor is well balanced. Thus, each particular tillage tool should be adjusted to the tractor, also with respect to the soil type and the field conditions."

They concluded their study as,

"On-land ploughing reduced the vertical stress and the vertical soil displacement in the subsoil compared to conventional ploughing with one side of the tractor running in the furrow……."[45]

[45] T. Keller, A. Trautner, J. Arvidsson, Stress Distribution and Soil Displacement Under a Rubber-tracked and a Wheeled Tractor During Ploughing, both On-land and Within Furrows, Soil & Tillage Research 68 (2002) 39–47

As a result of ploughless tillage the topsoil density is increased. This allows the soil to be more fertile for the crops. P. Schjønning *et al.*[46] (1989) studied the impact of long-term conservation tillage on soil strength and stability. The studies revealed the fact that the soil strength and stability of Danish coarse sandy soil and a fine loam soil increased with long-term reduced tillage practices. In the studies,

> "Topsoil wet aggregate stability was measured during the last 13 years of an 18-year-old field trial with reduced cultivation. Soil strength and soil compressibility were analyzed by a micropenetrometer and a confined, uniaxial compression test, respectively. The trials were situated on a coarse sandy soil and a fine loam in Jutland, Denmark.
>
> During the trial period, a considerable decrease in topsoil aggregate stability was observed if the soil was ploughed annually and all plant residues were removed from the field. Shallow tillage by tine cultivation to c. 10-cm depth and especially rotovating to only 5-cm depth diminished the structure deterioration induced by the continuous growing of cereals after ploughing. A crop of Italian ryegrass (*Lolium multiflorum*), grown after harvest of the small grain cereal crop, also stabilized the aggregates in ploughed as well as in shallow-tilled soil, but the differences induced were less than those induced by the tillage systems.
>
> In the top layers of the loamy soil, reduced compressibility was observed in the rotovated soil compared with ploughed and tine-cultivated soil.
>
> Soil strength increased in the non-tilled layers of shallow cultivated soil compared with ploughed soil. A compact soil layer beneath the rotovation depth in the loamy soil (called a "rotovator-pan") was found to have strength values which might depress root development."

B3.1.2 Soil Physical Properties:

Soil crumbs result due to soil aggregation. In organic farming, soil crumbs play a constructive role in the increase of soil fertility. Soil crumbs allow many macropores in the soil physical structure that increase the transport of water and oxygen to plant roots leading to better conditions of the soil biota and nutrient fertility. Crops growing in such

[46] P. Schjønning and K. J. Rasmussen, Long-Term Reduced Cultivation. I. Soil Strength and Stability, Soil and Tillage Research, Volume 15, Issues 1-2, December 1989, Pages 79-90

soils are not liable to stress and are resistant to pests and other diseases. Elmholt *et al.*[47] (2005) emphasized on soil aggregation to be a matter of proper management.

> "Soil crumbs are important to soil functions. These include plant growth, and the growth of fungi and bacteria forming agents for binding and bonding of new crumbs. We have studied how commercial organic and conventional farming affect this interaction. A diverse crop rotation, including grass, and animal manure resulted in stable crumbs with a high content of biological binding and bonding agents. A cash crop rotation with the addition of only synthetic fertilizers resulted in small, stable aggregates – more like clods - with clay as binding agent. Such a soil will provide poor conditions for preparing seedbeds, because prolonged rain makes it soft and muddy while drought makes it hard as brick."

They explained how soil aggregates in Danish agricultural soils are formed,

> "Soil has to be friable in order to provide a proper seedbed when tilled – it must be able to form 'crumbs' (aggregates). Aggregates are formed by primary particles - clay and sand, which are held together by binding and bonding agents. In Danish agricultural soils, biological agents are the most important. These can be divided into: (1) 'gluing' binding agents (extracellular polysaccharides) formed by plant roots, bacteria and fungi, and (2) 'enmeshing' agents. The latter consist primarily of fungal hyphae, bonding together small crumbs into larger ones. Several inorganic compounds - as well as clay - may also act as binding agents."[48]

They concluded by stating,

> "Both organically cultivated soils had more biomass and a higher content of biological binding and bonding agents than their conventional neighbour. The reason might be that grass was a part of the crop rotation at the organic farms but not the conventional……Formation of crumbs is primarily stimulated by a diverse crop rotation and organic fertilisers."[49]

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[47] Elmholt, S.; Schjønning, P. and Munkholm, L.J. (2005), Soil Aggregation – A Matter of Proper Management, DARCOFenews, Newsletter from Danish Research Centre for Organic Food and Farming, June 2005, No. 2, Available online at: http://www.darcof.dk/enews/jun05/crumb.html
[48] Ibid
[49] Ibid

Moreover, soil crumbs also improve associated physical characteristics of the soil to soil fertility, like soil porosity, aeration, infiltration of water, etc. Elmholt *et al.*[50] (2000) demonstrated that Danish organic farming systems offer better conditions for soil crumbs and soil physical properties.

> "During the last decades Denmark has experienced a growing interest in low-input farming systems like organic farming. These systems rely on a high soil fertility to maintain nutrient availability and plant health. Soil aggregation contributes to this fertility, because it is crucial to soil porosity, aeration and infiltration of water. This paper reports a study of two pairs of differently managed, neighboring fields. The aim was to elucidate long-term effects of the different farming systems on physical and biological variables with influence on bonding and binding mechanisms of soil aggregation. Each pair consists of an organically grown dairy farm soil, based on a forage crop rotation system, including grass (Org-FCS(G)) and a conventionally managed soil. One of the conventional farms has a forage crop rotation with annual cash crops and no grass (Conv-FCS(NG)) and one has been grown continuously with small grain cereals and rape (Conv-CCS). Our results indicate that the Org-FCS(G) soils stimulate biotic soil aggregating agents as measured by extracellular polysaccharides (EPS) and hyphal length measurements, respectively. Generally, the Conv-CCS soil, which relies exclusively on synthetic fertilisers and cereal production, offered poor conditions for the biotic binding and bonding agents. Nevertheless this soil contained a large amount of stable macro-aggregates. This is explained by the physical results, which indicated that the strong macro-aggregation was due to clay dispersion and cementation processes rather than to biotic processes."

[50] Elmholt, Susanne; Munkholm, Lars J.; Debosz, Kasia and Schjønning, Per, (2000), Biotic and Abiotic Binding and Bonding Mechanisms in Soils with Long-term Differences in Management, Paper presented at Soil Stresses, Quality and Care, Aas, Norway, 10-12 April 2000; Published in Elmholt, Susanne; Stenberg, Bo; Grønlund, Arne and Nuutinen, V., Eds. DIAS report 38, page pp. 53-62. Danish Institute of Agricultural Sciences

B3.2 CHEMICAL CONSERVATION OF SOIL:

B3.2.1 Maintaining Soil Fertility:

One of the soil management principles of organic agriculture is to enhance the soil microbial biomass, its diversity and potential activity. Soil organic matter not only enhances the chemical but also the biological and physical properties of the soil, which further optimizes crop productivity. Therefore, organic agriculture relies on the management of soil organic matter.

Soil organic matter is the detritus, plant and animal residues or organic fraction of the soil, which is partially decomposed and partially resynthesized by the soil population. The soil organic matter, which holds large amounts of organically bound plant nutrients, become available for crop uptake due to mineralization.

Organic farming utilizes the naturally occurring ecological processes in the soil in the best possible manner, e.g. the decomposition of dead plant material and organic manure which provide natural nutrients to crop plants. This decomposition takes place due to the fungi, bacteria, microflora and soil fauna.

The content of soil organic matter is one of the leading factors determining soil fertility. N is the major element, essential for the growth of the crops, present in the SOM. For organic farms particularly, where the crop supply mostly depends on N mineralized from organic matter, the discharge and absorption of organic N is of special significance.

B3.2.1.1 Reduced Nitrate Leaching:

In order to maintain soil fertility, it is important that soil should have the required elements for the growth of the plant. The basic three elements are nitrogen, phosphorous and potassium. Organic farming tends to reduce the losses of these important elements resulting in the increase of soil fertility. One such example is from a research experiment which Dalgaard *et al.*[51] conducted.

[51] Dalgaard, Tommy; Heidmann, Tove; Mogensen, Lisbeth; Potential N-losses in Three Scenarios for Conversion to Organic Farming in a Local Area of Denmark, European Journal of Agronomy; April 2002, Vol. 16 Issue 3, p207, 11p

"Techniques are needed to investigate whether different strategies for conversion to organic farming might help to reduce N-losses. In this study, an N-balance technique was applied in a local area of Denmark; 25% of this area was designated as environmentally sensitive with special interests to protect groundwater quality. Three scenarios, where 25% of the local area was converted to organic farming, were compared to the present situation with conventional farming. The first two scenarios were conversion to organic dairy and pig production, respectively. The third scenario was conversion of the whole area with special interests in clean groundwater to organic farming, self-sufficient in fodder and fertiliser. Scenario 1 resulted in a lower N-surplus on the dairy farms, but the reduction was too small in order to significantly reduce the N-surplus in either the whole local area or within the area with special interests in clean groundwater. Scenario 2 resulted in an analogous result. In Scenario 3, the N-surplus was reduced significantly within the area with special interests in clean groundwater, but not within the whole local area. The N-surplus reduction from conversion to organic farming was divided into an extensification and a management effect. The extensification effect meant that the lower livestock density in the organic scenarios resulted in lower N-surpluses, due to an exponential relationship between livestock density and N-surplus. The management effect was primarily caused by lower net imports of fodder and fertilisers to the organic farms and the following higher self-sufficiency in fodder. In addition, the distribution of animal manure between the organic farms was more uniform than between the conventional farms and because of the exponential relationship between livestock density and N-surplus, this caused a lower average N-loss potential. We conclude that organic farming can help to reduce potential N-losses in environmentally sensitive areas, but only if the conversion is designed with respect to that aim and takes account of the spatial distribution of farm types present."

Other empirical examples also reveal similar reduced nitrate leaching. In organic farming, nitrogen leaching in Denmark is low from 27 to 40 kgNha−1 yr−1. This calculated range is derived from results of various experiments conducted at different locations and different soil types. Askegaard and Eriksen[52] (1997) experimented at Foulum in a dairy farm on a loamy sand soil and showed that 27 to 32 kgNha−1 yr−1 leached. Kristensen *et al.*[53] (1994) conducted experiments for Nitrogen leaching on various farm and soil types in Denmark and showed that 31 kgNha−1 yr−1 organic N leached whereas 29 kgNha−1 yr−1 conventional N leached. Magid and Kølster[54] (1995) conducted their experiment at Taastrup in a dairy farm on a clay loam soil and they recorded 40 kgNha−1 yr−1 of N leaching.

Hansen *et al.*[55] (2000) in another Danish investigation evaluated N leaching from both conventional and organic farming systems via a modelling approach. Their results clearly showed lesser leaching on sandy soil in an organic crop production system and an organic dairy farming system when compared to parallel conventional crop production and dairy farming systems. They described that

> "The level of nitrogen leaching from organic compared to conventional farming was evaluated by using a systems modelling approach. Two different methods were used for estimating and evaluating nitrate leaching. A simple function was used in which nitrate leaching is dependent on percolation, soil clay content, average nitrogen input and crop sequence. A nitrogen balance model was used to estimate the long-term potential for nitrate leaching. These methods were applied to models of both current conventional farming systems in Denmark in 1996 and of well-managed organic farming systems. On average, the total estimated nitrogen input to the organic systems was lower (104–216 kg N ha^{-1} $year^{-1}$) than to the conventional farming systems (146–311 kg N ha^{-1} $year^{-1}$). The N-balances in the organic fields showed a surplus of nitrogen (net input of nitrogen) in to

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[52] Askegaard, M. and Eriksen, J., 1997, Udbytter og kvælstofudvaskning i relation til gødningsniveau og type (yields and nitrogen leaching in relation to nitrogen application and type). In: *SP-report no. 15*, Danish Institute of Agricultural Science, pp. 37–46, in Danish

[53] Kristensen, S.P., Mathiasen, J., Lassen, J., Madsen, H.B. and Reenberg, A., 1994, A Comparison of the Leachable Inorganic Nitrogen Content in Organic and Conventional Farming Systems, Acta Agric. Scand. B. Soil Plant Sci. 44, pp. 19–27

[54] Magid, J. and Kølster, P., 1995, Modelling Nitrogen Cycling in an Ecological Crop Rotation-and Explorative Trial, *Biolog. Agric. Hortic.* 11, pp. 77–87

[55] Birgitte Hansen, Erik Steen Kristensen, Ruth Grant, Henning Høgh-Jensen, Svend Erik Simmelsgaard and Jørgen E. Olesen, Nitrogen Leaching from Conventional Versus Organic Farming Systems — A Systems Modelling Approach, European Journal of Agronomy, Volume 13, Issue 1, July 2000, Pages 65-82

the root zone of 60–143 kg N ha^{-1} $year^{-1}$. In the conventional systems the surplus varied from 25 to 155 kg N ha^{-1} $year^{-1}$. The modelled nitrogen leaching from the organic systems varied from 19 to 30 kg N ha^{-1} $year^{-1}$ on loamy soils to 36–65 kg N ha^{-1} $year^{-1}$ on sandy soils. The modelled nitrogen leaching from the organic systems was always lower than from the comparable conventional agricultural systems due to: (I) the lower total input of nitrogen to the organic systems; and (II) the composition of the organic crop rotations including extensive use of catch crops. However, the modelling of nitrogen leaching has many uncertainties, principally due to difficulties in predicting the nitrogen leaching from different types of grass fields. Comparison of the results from two methods: (i) modelling of nitrogen leaching; and (ii) N-balances for the root zones, showed that organic arable crop production and dairy/beef farming on sandy soils are farming systems with a clear potential for lower nitrogen leaching than from the selected conventional systems. It is still uncertain whether the nitrogen leaching is lower or higher from organic arable crop production systems on loamy soil and organic pig production on loamy and sandy soil than from the same conventional systems in Denmark. The results point to the need for future research in the following areas: (i) the ability to build up soil organic nitrogen in organic farming systems and the consequences for both the level of crop production and nitrogen leaching in the long term; (ii) the effects of catch crops in organic crop rotations; and (iii) a better operational understanding of nitrogen leaching from different types of organically managed grass and grass-clover fields."

B3.2.1.2 Increased Organic Matter:

In Denmark, the plant residues are left on the soil surface in annual ploughless tillage, resulting in increased organic matter in the topsoil.

"At the end of six years of direct drilling in Denmark, Rasmussen (1988) found that organic C increased significantly by 7.9 g kg^{-1} in the upper 0–2 cm soil layer after direct drilling, but in the 2–10 and 10–20 cm depths the increases were insignificant. No significant changes in the content of organic matter were found in depths below 10 cm."[56]

[56] Rasmussen, K.J., Ploughing, Direct Drilling and Reduced Cultivation for Cereals. Danish Journal of Plant Soil Science 92, 1988, pp. 233–248, In K. J. Rasmussen, Impact of Ploughless Soil Tillage on Yield

B3.2.1.3 Increased Soil Fertility:

Various organic farming practices e.g. manure application, diverse crop rotation, etc. have a positive effect on the soil fertility. This has been illustrated in an experiment by Schjønning *et al.*[57] (2004) illustrated this in their experiment.

> “The positive effects on soil tilth from cropping and fertilisation are prone to destructive forces from traffic and tillage. This presentation provides results from a project aiming to quantify the relative importance of crop rotation, fertilisation and traffic/tillage and their interactions.
>
> The investigation includes a field trial established 1986 on loamy sand and another initiated 1997 on a sandy loam. All 1986-trial plots are grown with annual cash crops. Annual incorporation of animal slurry and straw residues is compared to reference plots receiving no organic matter. In the 1997-trial, a diversified crop rotation including grass ley and catch crops is compared to a sequence of annual cash crops excluding catch crops. The latter treatment is performed with and without annual application of animal slurry. In both trials, half of all plots were mechanically compacted by tractor the year prior to investigation. The 1986-trial also included part-plots intensively tilled with a rotary cultivator.
>
> Results obtained so far in the 1997-trial indicate that soil organic carbon, microbial biomass, hyphal lengths and soil pore volume are significantly increased by manure application but especially by the diverse crop rotation. In contrast, clay dispersibility and wet aggregate stability were not significantly affected. Hence, biological soil attributes may serve as early indicators of soil quality changes. In the 1986-trial, significant effects of the organic matter treatment were apparent for some biological (microbial biomass), chemical (total and hot-water extractable organic C) and physical (bulk soil strength and friability) attributes. The mechanical disturbance by compaction as well as by intensive tillage caused a significant reduction in soil friability though partly alleviated by the organic matter-treatment.”

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and Soil Quality: A Scandinavian Review, Soil and Tillage Research, Volume 53, Issue 1, November 1999, Pages 3-14

[57] Schjønning, P.; Munkholm, L.J. and Elmholt, S. (2004) Soil Quality in Organic Farming - Effects of Crop Rotation, Animal Manure and Soil Compaction. Poster presented at EUROSOIL 2004, Freiburg, Germany, 6-10. September 2004

In another experiment, Schjønning *et al.*[58] (2002) have shown that various organic farming practices like application of organic manures and diversified crop rotations have positive effects on soil quality aspects in the long term. These practices contribute to the increased fertility of soil in Denmark.

"The development of low-input farming systems requires knowledge of the extent to which management characteristics influence the soil as a habitat for micro-organisms and a medium for plant growth. This paper presents a study of long-term effects of organically and conventionally cultivated systems on a range of soil physical, chemical and biological characteristics in Denmark. Seven soils were included, falling into three groups (I¯III). Each group consists of an organically managed soil (Org) referenced by one or two conventionally managed soils (Conv) with the same soil type (sandy loam) and pedological history. All organically managed soils were dairy farm soils (H), which had been organically managed for 46, 47 and 40 years, respectively. They had forage crop rotations and received animal manure. The conventional soils were either dairy farm soils or soils grown to annual cash crops (P). Undisturbed core samples were used for assessing dry bulk density and water retention. Undisturbed cubic samples were used for assessing wet stability of macro-aggregates, clay dispersibility, microbial biomass C, -glucosidase activity, ergosterol, and the abundance of different groups of fungi. Penetration resistance and ease of soil fragmentation were measured in the field. The quantifying methods were supplemented by a visual inspection of soil structure of the top 30 cm soil in the field. Irrespective of agricultural system, the use of tractors and heavy machinery had caused compaction of the subsoil in the form of a dense pan below ploughing depth. In group I, the H-soils were heavily trafficked and this overshadowed the long-term effects of the diversified crop rotations and animal manure applications on the physical parameters. Generally, the results highlight the paramount influence of soil tillage and traffic in agriculture. Further, the results confirm the positive effects of organic manures and diversified crop rotations on soil quality aspects. Microbial biomass

[58] Schjønning, Per; Elmholt, Susanne; Munkholm, Lars J. and Debosz, Kasia, Soil Quality Aspects of Humid Sandy Loams as Influenced by Organic and Conventional Long-term Management, (2002), Agriculture, Ecosystems & Environment 88(3):pp. 195-214

C was found to be higher in organically than in conventionally managed dairy farm soils, and appeared to correlate linearly to the volume of 0.2¯3.0 m pores (`protective' pore space). The simple model did, however, not explain a lower microbial biomass for two soils dressed only with synthetic fertilisers. The results further indicated that the contribution of the different biotic mechanisms responsible for macro-aggregation varied from soil to soil. The results revealed promising correlations between quantitative scientific laboratory methods and descriptive methods in the field."

B3.2.2 Application of Organic Fertilizers:

In the Danish organic farming, two major types of organic fertilizers are added to the fields for soil conservation. One is sewage sludge and the other is organic manure.

B3.2.2.1 Sewage Sludge:

Sewage sludge may be any solid, semi-solid or liquid residue that is extracted during the treatment of domestic/municipal waste/sewage water in water treatment plants.

Soil fertility is properly maintained if the degradation of various organic chemical substances in the sewage sludge takes place. G. K. Mortensen *et al.*[59] (2003) conducted pot experiments to determine if the chemical nonylphenol was properly degraded in the soil.

"Widespread application of sewage sludge to agricultural soils in Denmark has led to concern about the accumulation and effects of nonylphenol (NP) in the soil ecosystem. We have thus studied the degradation of NP and possible uptake in agricultural plants in greenhouse pot experiments. Different waste products including anaerobic and aerobic sludge, compost, and pig manure were incorporated into a sandy soil. In addition, NP was used to spike soil to known concentrations. Rape (Brassica napus L. cv Hyola 401) was sown in the pots and harvested after 30 d. In order to investigate the influence of plant growth on the degradation, plantfree pots were established. The concentrations in the soil were between 13 and 534 ppb dry weight. No

[59] Mortensen, Gerda Krog, Kure, Liv Kerstin, Degradation of Nonylphenol in Spiked Soils and in Soils Treated with Organic Waste Products, Environmental Toxicology & Chemistry; April 2003, Vol. 22 Issue 4, p718-721, 4p, 3 charts, 3 graphs

plant uptake was observed above the detection limit at 100 ppb dry weight. When NP was added as waste to the soil, plant growth significantly stimulated the degradation. In experiments with anaerobic and aerobic sludge, respectively, 13 and 8.3% of NP remained in the soil from pots planted with rape compared with 26 and 18% in soil without plant growth. When NP was added as a spike to soil, the degradation was more complete and plant growth did not influence the degradation. Percentages of 2.2 and 1.8 were still in the soil at harvest for planted and plant-free pots, respectively. The degradation of NP was more extensive in sludge-amended soil compared with compost."

In another experiment G.K. Mortensen *et al.* [60] studied the degradation of another chemical compound, linear alkylbenzene sulfonate, present in the sewage sludge. Their experiment revealed that

"Widespread application of sewage sludge to agricultural soils in Denmark has led to concern about the possible accumulation and effects of linear alkylbenzene sulfonate (LAS) in the soil ecosystem. Therefore, we have studied the uptake and degradation of LAS in greenhouse pot experiments. Sewage sludge was incorporated into a sandy soil to give a range from very low to very high applications (0.4 to 90 Mg dry wt. ha^{-1}). In addition, LAS was added as water solutions. The soil was transferred to pots and sown with barley (*Hordeum vulgare* L. cv. Apex), rape (*Brassica napus* L. cv. Hyola 401), or carrot (*Daucus carota* L.). Also, plant-free controls were established. For all additions there was no plant uptake above the detection limit at 0.5 mg LAS kg^{-1} d.w, but plant growth stimulated the degradation. With a growth period of 30 d, LAS concentrations in soil from pots with rape had dropped from 27 to 1.4 mg kg^{-1} dry wt., but in plant-free pots the concentration decreased only to 2.4 mg kg^{-1} dry wt. When LAS was added as a spike, the final concentration in soil from planted pots was 0.7 mg kg^{-1} dry wt., but in pots without plants the final concentration was much higher (2.5 mg kg^{-1} dry wt.). During degradation, the relative fraction of homologues C10, C11, and C12 decreased, while C13 increased."

[60] G.K. Mortensen, H. Egsgaard, P. Ambus, E.S. Jensen and C. Grøn, Influence of Plant Growth on Degradation of Linear Alkylbenzene Sulfonate in Sludge-Amended Soil, July-August 2001, Volume 30, Issue 4, Journal of Environmental Quality

Anne Marie Jacobsen *et al.*[61] also studied the natural degradation of organic compounds in an experiment. In particular, they studied the degradation and mobility of linear alkylbenzene sulfonate and nonylphenol in sludge-amended soil. They reported,

> "Degradation and mobility of the surfactants linear alkylbenzene sulfonate (LAS) and nonylphenol (NP) were investigated in a lysimeter study using a sandy loam soil and 45-cm soil columns. Anaerobically digested sewage sludge was incorporated in the top-15-cm soil layer to an initial content of 38 mg LAS and 0.56 mg NP kg^{-1} dry wt., respectively. Spring barley (*Hordeum vulgare* L.) was sown onto the columns. The lysimeters were placed outdoors and therefore received natural precipitation, but were also irrigated to a total amount of water equivalent to 700 mm of precipitation. Leachate and soil samples from three soil layers were collected continuously during a growth period of 110 d. Leachate samples and soil extracts were concentrated by solid-phase extraction (SPE) and analyzed using high performance liquid chromatography (HPLC) with fluorescence detection. The concentrations in the top-15-cm soil layer declined to 25 and 45% of the initial contents for LAS and NP, respectively, within the first 10 d of the study. At the end of the study, less than 1% LAS was left, while the NP content was below the detection limit. Assuming first-order degradation kinetics, half-lives of 20 and 37 d were estimated for LAS and NP, respectively. The surfactants were not measured in leachate samples in concentrations above the analytical detection limits of 4.0 and 0.5 μg L^{-1} for LAS and NP, respectively. In addition, neither LAS nor NP were measured in concentrations above the detection limits of 150 and 50 μg kg^{-1} dry wt., respectively, in soil layers below the 15 cm of sludge incorporation, indicating negligible downward transport of the surfactants in the lysimeters."

B3.2.2.2 Organic Manures:

Manure is organic matter of both animal and plant origin used as fertilizer in agriculture. In soil management, there are two kinds of manures; green manures and animal manures. Green manures are plant cover crops that are usually tilled into the soil a

[61] Anne Marie Jacobsen, Gerda Krog Mortensen and Hans Christian Bruun Hansen, Degradation and Mobility of Linear Alkylbenzene Sulfonate and Nonylphenol in Sludge-Amended Soil, Journal of Environmental Quality, January 1, 2004; 33(1): 232 - 240

few weeks before the new plantings. These crops are grown and then upon maturity are incorporated into the soil to increase the soil fertility or organic matter content and are not removed from the fields. Animal manures are organic materials that are excreted by animals especially cattle (herbivorous animals).

Green manures have a positive impact on the Danish soil meso-fauna, particularly the soil microarthropods. Axelsen *et al.*[62] (2000) demonstrated this in their experiments and reported,

> "The spring and summer abundance of soil living mites and Collembola was investigated in organically grown field plots which had been covered with either the nitrogen catch crops winter rye, hairy vetch, fodder radish and a control (stubble). The catch crops were incorporated in the soil shortly before sowing of spring barley with under sown clover grass. Microarthropods were extracted from 10 cm deep soil samples and were taken in May, June and August.
>
> The densities of both microarthropods were extremely high with up to 120,000 Collembola m^{-2} and 90,000 mites m^{-2}. The highest densities of Collembola were found in the plots with fodder radish as a catch crop, and the most abundant species were *Tullbergia* sp., *Isotoma notabilis* and *Folsomia fimetaria.* The mite fauna consisted mainly of Mesostigmatic and Prostigmatic mites and was more abundant in the catch crop plots than in the control plots in early June.
>
> The input of organic matter from the catch crops is supposed to be part of the reason for the high microarthropod densities, but the barley with undersown clover grass may also play a role."

Organic manures have positive effects on soil quality. Organic manures play an important role in the fertility of soil which in turn increases the yield. Olesen *et al.*[63] (2007) reported,

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[62] Jørgen Aagaard Axelsen and Kristian Thorup Kristensen, Collembola and Mites in Plots Fertilised with Different Types of Green Manure, Pedobiologia, Volume 44, Issue 5, 2000, Pages 556-566

[63] Jørgen E. Olesen, Elly M. Hansen, Margrethe Askegaard and Ilse A. Rasmussen, (at Danish Institute of Agricultural Sciences), The Value of Catch Crops and Organic Manures for Spring Barley in Organic Arable Farming, Field Crops Research, Volume 100, Issues 2-3, 1 February 2007, Pages 168-178

“The effect of nitrogen (N) supply and weeds on grain yield of spring barley was investigated from 1997 to 2004 in an organic farming crop rotation experiment in Denmark on three different soil types varying from coarse sand to sandy loam. Two experimental factors were included in the experiment in a factorial design: (1) catch crop (with and without), and (2) manure (with and without). The crop rotation included grass-clover as a green manure crop. Animal manure was applied as slurry in rates corresponding to 40% of the N demand of the cereal crops.

Application of 50 kg NH_4-N ha^{-1} in manure (slurry) increased average barley grain DM yield by 1.0–1.3 Mg DM ha^{-1}, whereas the use of catch crops (primarily perennial ryegrass) increased grain DM yield by 0.2–0.4 Mg DM ha^{-1} with the smallest effect on the loamy sand and sandy loam soils and the greatest effect on the coarse sandy soil. Model estimations showed that the average yield reduction from weeds varied from 0.2 to 0.4 Mg DM ha^{-1} depending on weed species and density. The yield effects of N supply were more predictable and less variable than the effects of weed infestation. The infestation level of leaf diseases was low and not a significant source of yield variation. The apparent recovery efficiency of N in grains (N use efficiency, NUE) from NH_4-N in applied manure varied from 29 to 38%. The NUE of above-ground N in catch crops sampled in November prior to the spring barley varied from 16 to 52% with the largest value on the coarse sandy soil and the smallest value on the sandy loam soil. A comparison of grain yield levels obtained at the different locations with changes in soil organic matter indicated a NUE of 21–26% for soil N mineralisation, which is smaller than that for the mineral N applied in manure. However, this estimate is uncertain and further studies are needed to quantify differences in NUE from various sources of N. The proportion of perennial weeds in total biomass increased during the experiment, particularly in treatments without manure application. The results show that manure application is a key factor in maintaining good crop yields in arable organic farming on sandy soils, and in securing crops that are sufficiently competitive against perennial weeds.”

Jesper Luxhøi *et al.*[64] (2004) have shown how animal slurries can help in maintaining the soil fertility particularly with the nitrogen mineralization in Danish soils. They reported,

> "At four sites across Denmark with varying medium- and long-term histories of annual slurry applications, N turnover rates and crop N use efficiencies were measured in 2000. No significant effect of medium-term (in this study, 3 years) annual slurry applications on gross N turnover was observed. However, a significant effect of long-term (in this study, >25 years) annual slurry applications was observed. At one site in Denmark with short-term (4 days before measurement) slurry application, N turnover was measured in 2001. Gross N turnover was 4–5 times higher in the slurry-amended soil compared to the unamended soil. In both years, net N turnover was unaffected by the slurry application. Generally, the crops had higher use efficiency of slurry NH_4^+-N than of mineral fertilizer-N, indicating that the crops were able to extract slurry organic-N, independently of the net mineralization. The measured net N mineralization rate was generally higher than the difference between gross rates. The application of $^{15}NH_4^+$ to soil (a prerequisite for the determination of N mineralization and N immobilization turnover), probably stimulated the gross N immobilization rate in soil with little native NH_4^+, since NH_4^+ is the substrate for immobilization. The results suggest that gross immobilization estimates should be interpreted with caution."

Munkholm *et al.*[65] (2002) in a long term experiment showed that adding organic matter, in the form of animal manure, to a sandy loam soil improves the conditions for reduced tillage. Their experiment explains that

> "Current concern for soil quality has stimulated research on soil biological and chemical properties. In contrast, the mechanical behaviour of soil is somewhat neglected. We have examined the effects on soil mechanical properties of more than 100years of

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[64] Jesper Luxhøi, Kasia Debosz, Lars Elsgard and Lars S. Jensen, Mineralization of Nitrogen in Danish Soils, as Affected by Short-, Medium- and Long-term Annual Inputs of Animal Slurries, Biology and Fertility of Soils, Volume 39, Number 5 / April, 2004, 352-359

[65] Munkholm, Lars J.; Schjønning, Per; Debosz, Kasia; Jensen, Henry E. and Christensen, Bent T. Aggregate Strength and Mechanical Behaviour of a Sandy Loam Soil under Long-term Fertilization Treatments, (2002), European Journal of Soil Science 53(1):pp. 129-137

contrasting fertilization employing three treatments from the Askov long-term experiment: UNF (unfertilized), NPK (mineral fertilized) and AM (animal manured). We have measured tensile strength of aggregates when air-dry and when adjusted to 10, 30 and 100kPa pressure potential. Four aggregate size classes were investigated (1-2, 2-4, 4-8 and 8-16mm diameter). Soil fragmentation was characterized in the field using a drop-shatter test. Bulk soil strength was determined in the field using a shear vane and a torsional shear box. Soil texture, pH, cation exchange capacity and microbial biomass were measured. The unfertilized soil has little soil organic matter and microbial biomass and is dense. Its aggregates were strong when dry and weak when wet. In contrast, the manured soil had strong aggregates when wet and rather weak ones when dry. The NPK soil generally had intermediate properties. The differences between the soils when dry seem to be related to differences in dispersible clay content, whereas the differences when wet are related to differences in the amount of organic binding and bonding material. The optimal water content for tillage as well as the tolerable range in water content was largest in the manured soil and smallest in the unfertilized soil. Our results indicate that soil mechanical properties should be measured over a range of water regimes to determine the effects of various long-term fertilization treatments." They concluded by stating; "Evidently, adding organic matter to such a sandy loam improved the conditions for tillage".[66]

Application of organic manures in Danish organic agriculture has a profound impact on the earthworms' population. Christensen and Mather[67] (1997) have documented that the population of earthworms in the soil is directly influenced with the supply of organic manure. Their studies show that as a result of the conversion of a location from conventional arable production to organic farming at the Research Centre Foulum, Denmark, the earthworms increased by a factor of twenty (20) within a time

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[66] Munkholm, Lars J.; Schjønning, Per; Debosz, Kasia; Jensen, Henry E. and Christensen, Bent T. Aggregate Strength and Mechanical Behaviour of a Sandy Loam Soil under Long-term Fertilization Treatments, (2002), European Journal of Soil Science 53(1):pp. 129-137

[67] Christensen, O.M., Mather, J.G., 1997, Regnorme som Økoingeniører i Jordbruget: fra Konventionelt til Økologisk Jordbrug, IN: Kristensen, E.S. (Ed.), Økologisk Planteproduktion, SP Rapport No. 15, Forskningscenter for Økologisk Jordbrug

period of 11 years (between 1986-1997) even though there were great variations amongst the organic farms in the soil types and overall time since the conversion.

In another similar study, Christensen *et al.*[68] (1987) have shown that organic manure inputs to the soil affects the soil earthworms' population.

[68] Christensen O, Daugbjerg P, Hinge J, Jensen JP, & Sigurdardottir H, (1987), The Effects of Cultivation Practices on Earthworms and their Possible Role as Bioindicators, Tidsskrift for Planteavl 19, 15-32. [In Danish with English Summary]

B3.3 BIOLOGICAL CONSERVATION OF SOIL:

Organic farming conserves the biological activity of the soil environment. In Denmark, the soil biota mainly comprises of bacteria (*Monera*), fungi (*Mycota*), springtails (*Collembola*), mites (*Arachnida*), earthworms (*Lumbricus terrestris*). All practices of Danish organic agriculture ensure that the soil is rich with living organisms that are beneficial to it.

B3.3.1 Abundance of Soil Biota:

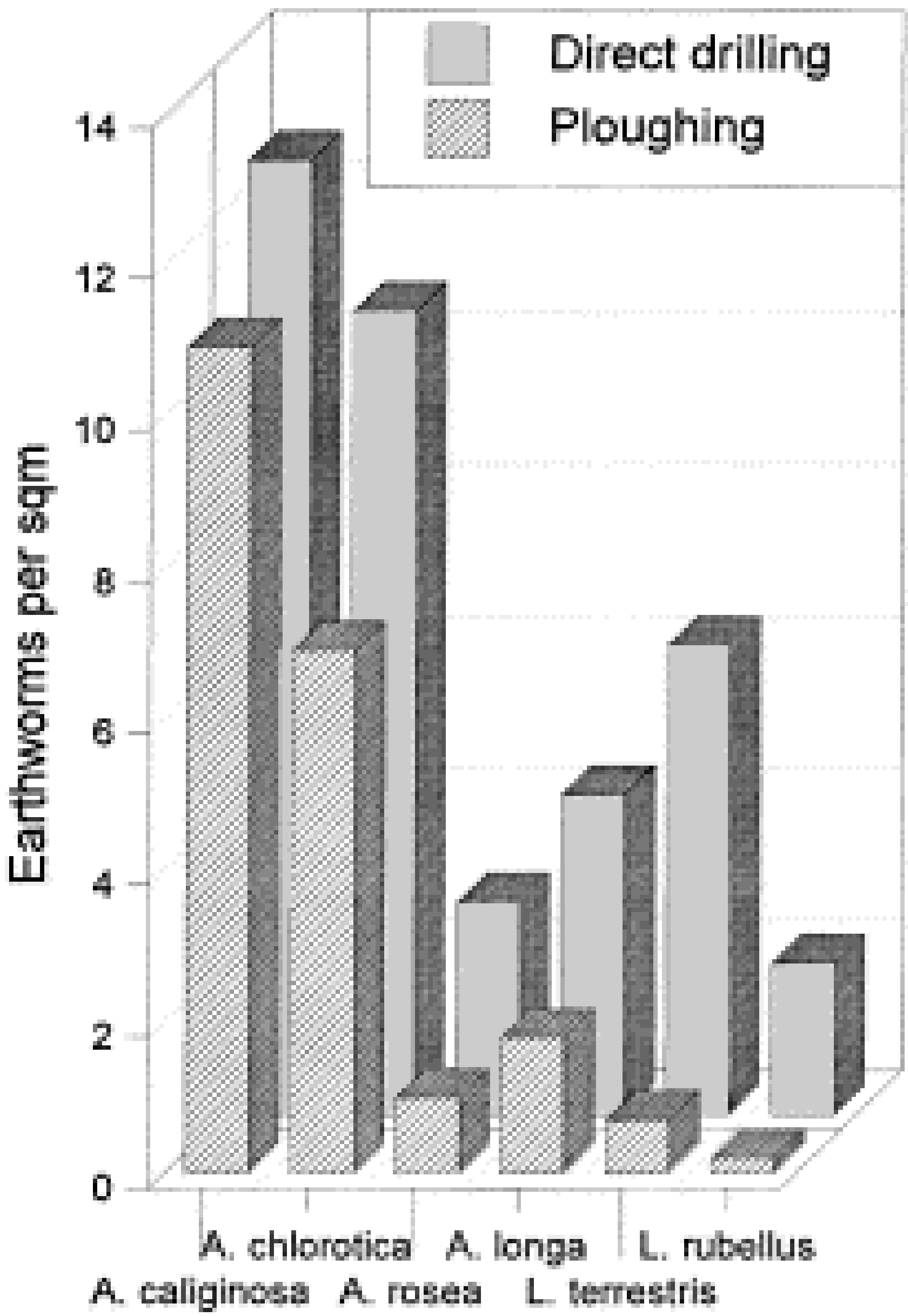
Soil biota are an essential element in organic farming. It comprises of both the soil flora and soil fauna. Soil biota are both micro and macro organisms which play an effective role in different settings and combinations in soil fertility. In Danish organic arable soils, earthworms constitute the major component of the soil fauna.

> "In two tillage systems in Denmark earthworms were analysed by Andersen (1987) six years after the start of an experiment located at five sites. Some of the results are shown in Fig. 8. Investigated species were: *Allolobophora chlorotica, Aporrectodea caliginosa, Aporrectodea rosea, Aporrectodea longa, Lumbricus terrestris* and *Lumbricus rubellus*. For all species counted, more earthworms were found after direct drilling than after ploughing — especially for the Lumbricus-species. The number of earthworms was significantly higher after direct drilling than after ploughing in three of five sites."[69]

Following is Figure 8, in the above reference, showing the population of earthworms:

[69] Andersen, A., 1987, Effects of Direct Drilling and Ploughing on Populations of Earthworms, Danish Journal of Plant Soil Science 91, pp. 3–14, In: K. J. Rasmussen, Impact of Ploughless Soil Tillage on Yield and Soil Quality: A Scandinavian Review, Soil and Tillage Research, Volume 53, Issue 1, November 1999, Pages 3-14

"Fig. 8. Number of earthworms per m^2 after ploughing and direct drilling in Denmark. Average of four locations (Andersen, 1987)"[70]



[70] Andersen, A., 1987, Effects of Direct Drilling and Ploughing on Populations of Earthworms, Danish Journal of Plant Soil Science 91, pp. 3–14, In: K. J. Rasmussen, Impact of Ploughless Soil Tillage on Yield and Soil Quality: A Scandinavian Review, Soil and Tillage Research, Volume 53, Issue 1, November 1999, Pages 3-14

Elmholt *et al.*[71] (2005) studied the variability of fungal species in agricultural systems.

> "A multi-soil study was conducted in Denmark including 29 sites, 8 classified as 'Organic', 11 as 'Conventional with manure and synthetic fertilisers' and 10 as 'Conventional with synthetic fertilisers'. The variability of fungal abundance within the three farming systems and the long-term effects of different farming systems on fungal propagules in soil were evaluated.
>
> Fungal abundance showed large variations within all three farming systems and this variability reduced the possibility to obtain general conclusions on fungal composition in soils under different farming systems. This was illustrated by the results on total propagule numbers of filamentous fungi and yeasts. *Penicillium spp.* and *Gliocladium roseum* were more abundant under organic than conventional farming, while *Trichoderma spp.* were most abundant in conventionally farmed soils with synthetic fertilisers. These results were not altered after adjusting for possible differences in basic soil properties like total-C and N, extractable P, CEC, base saturation and soil density. The paper discusses whether the differences in fungal abundance are characteristics of a farming system itself or associated with certain management factors being more prevalent in one farming system than the other."

Krogh[72] (1994) reported that in organic farming the presence of springtails and mites (micro-arthropods) was higher as compared to conventional farming. The research was conducted at Research Centre Foulum, Denmark. The difference is vivid from the following 'Table No. 11':

[71] Elmholt, S. and Labouriau, R. (2005), Fungi in Danish Soils under Organic and Conventional Farming, Agriculture, Ecosystems and Environment (107):pp. 65-73

[72] Krogh, P.H. (1994), Chapter 5, Monitoring the Soil Microarthropod Community in Organic, Integrated, and Conventional Farming Systems, In: Krogh, P.H. Microarthropods as Bioindicators, A Study of Disturbed Populations, PhD Thesis, Ministry of the Environment and Energy, National Environmental Research Institute, Silkeborg, pp. 81-94

Table No. 11; Modified from Krogh[73] (1994), which shows the mean numbers of micro-arthropods in four different farming systems at the Research Centre Foulum, Denmark, where data refer to total numbers per m^2.

Organisms	**Farming Systems**			
	Organic	Integrated Forage	Integrated Grain	Conventional
Springtails	16.9 x 1000 = 16900	8.1 x 1000 = 8100	14.0 x 1000 = 14000[74]	6.8 x 1000 = 6800
Mites	15.7 x 1000 = 15700	14.0 x 1000 = 14000	14.2 x 1000 = 14200	9.7 x 1000 = 9700
Total Micro-arthropods	32.6 x 1000 = 32600	22.1 x 1000 = 22100	28.2 x 1000 = 28200	16.5 x 1000 = 16500

The abundance of soil biota in Danish organic farming especially mould fungi affect the soil mineralization process. Hansen *et al.*[75] 2001 has reviewed,

> "The number of organisms in the soil is influenced by many factors, including soil type, type of fertiliser, crop rotation, cultivation, climate, time of the year, etc. It is therefore difficult to separate the effects of organic farming from other factors. In the case of moulds the evidence suggests greater numbers of these fungi in organic farming systems (Table 4). Furthermore, propagules of the genus *Penicillium* tends to occur in larger numbers at organic locations, although not in numbers that are significantly greater than for conventional arable farming. Yeast (*Ascomycetes*) numbers are significantly higher in organic and conventional dairy farm systems than in conventional arable systems (Axelsen and Elmholt, 1998 and Axelsen and Elmholt, 1998)".

[73] Krogh, P.H. (1994), Chapter 5, Monitoring the Soil Microarthropod Community in Organic, Integrated, and Conventional Farming Systems, In: Krogh, P.H. Microarthropods as Bioindicators, A Study of Disturbed Populations, PhD Thesis, Ministry of the Environment and Energy, National Environmental Research Institute, Silkeborg, pp. 81-94

[74] **"The figure '13.0 x 1000 collembolans' is an error of Table 3 in Krogh (1994) which I (Asif Khan Khattak) have corrected. By contacting the author, I have received confirmation of the error, and I have consequently used the corrected figure of 14.0 x 1000 collembolans"**

[75] Hansen B.; Alroe H.F.; Kristensen E.S., Approaches to Assess the Environmental Impact of Organic Farming with Particular Regard to Denmark, Agriculture, Ecosystems & Environment, Volume 83, Number 1, January 2001 , pp. 11-26(16),: The references of 'Axelsen and Elmholt, 1998 and Axelsen and Elmholt, 1998' in the review are respectively, 1. Axelsen, J.A., Elmholt, S., 1998, Jordbundens biologi, The Bichel Committee, Report from the Interdisciplinary Working Group on Organic Farming, Sub-report A3.4, (In Danish), Available on request from the DEPA, *and* 2. Axelsen, J.A., Elmholt, S., 1998, Scenarium om 100% økologisk jordbrug i Danmark, A3.4, Jordbundens biologi, Rapport for Bichel-Udvalget (in Danish)

In the above review, Table 4 is presented as follows:

"Table 4. Statistical estimates (mixed model) of the occurrence of moulds (total occurrence), the genus *Penicillium*, and yeasts (total occurrence) at 24 organic, 20 conventional (with manure) and 21 conventional (with artificial fertiliser) locations (modified from Axelsen and Elmholt, 1998 and Axelsen and Elmholt, 1998)

	Mould fungi		*Penicillium*		Yeast fungi	
Organic	85570 a	*3600*	39650 a	*2700*	28090 a	*2000*
Conventional (animal manure)	56930 b	*5300*	25160 b	*3700*	28800 a	*3200*
Conventional (artificial fertiliser)	60370 b	*5300*	37960 a	*4000*	15070 b	*2700*

„[76]

Mortensen *et al.*[77] demonstrated that the soil biota can play an effective role in eliminating naturally occurring toxins in the soil.

"Degradation of two mycotoxins: zearalenone (ZON) produced by species of *Fusarium* and ochratoxin A (OTA) produced by species of *Penicillium* were followed in pot experiments using agricultural topsoils from Danish experimental farms: a sandy soil, a sandy clay soil and a gyttja soil with a high content of silt. Experiments with unplanted soil and pots planted with barley were included. Soil samples were withdrawn during a period of 225 days and analysed for the content of OTA and ZON. The degradation of both toxins consisted of an initial fast degradation followed by a slower transformation step and was described well by a sum of two first-order kinetic equations. The decay first-order rate constants for the first step (k_1) were in the range 0.73–2.91 d^{-1} for OTA and 0.0612–0.108 d^{-1} for ZON, respectively. Half-lives ($t_{0.5}$) for ZON using data from the first phase were between 6.4 and 11 days, whereas the half-lives for OTA were about 0.2–1 day. The slowest degradation was measured in soil rich in clay. After 225 days, neither OTA nor ZON was detected in any of the soil types. Generally, the degradation of ZON and OTA was faster in planted soil than in unplanted soil, probably due to higher microbial activity. Due to the fast degradation of ZON and OTA in surface soil leaching as soluble substances appears to be limited."

[76] Ibid

[77] Gerda K. Mortensen, Bjarne W. Strobel and Hans C.B., Degradation of Zearalenone and Ochratoxin A in Three Danish Agricultural Soils, Chemosphere 2006 March, 62(10):1673-80

B3.3.2 Entomological and Avian Benefits:

Aphids are soft bodied insect pests that suck plant juices and are also transmitters of plant virus diseases. Reddersen[78] (1997) has established that in Denmark a lower density of aphids prevail in organic farming as compared to conventional farming. This is highly beneficial to organic farming where pesticides are not used for aphid control.

Similarly Reddersen[79] (1999) also showed that entomologically beneficial insects such as ground beetles (*Carabidae*) and spiders (*Araneae*) are abundantly available in organic farming systems.

In Danish agricultural fields, only a few bird species are found, including the lapwing (*Vanellus vanellus*) and skylark (*Alauda arvensis*). In a comparative study in conventionally and organically farmed areas, Braae *et al.*[80] (1988) and Christensen *et al.*[81] (1996) both exhibited that in organic farms more birds and greater bird diversity was present than in conventional farms. Moreover, Christensen *et al.*[82] (1996) associated the presence of skylarks with organic farms due to the fact that with the application of pesticides in conventional farms, the supply of insect food for these birds is reduced and hence these birds tend to feed on insects abundantly available on organic farms.

B3.3.3 Organic Cropping Systems:

Different organic cropping systems improve the biological conservation of the soil in several possible manners. Each cropping system has its unique interaction with the soil environment and hence contributes in its fertility. In organic cropping systems, the rotational grass is typically used for both cut silage and for grazing.

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[78] Reddersen, J., 1997, The Arthropod Fauna of Organic versus Conventional Cereal Fields in Denmark, IN: Proceedings of the Entomological Research in Organic Agriculture, March 1995, Vienna, Biological Agriculture and Horticulture, Volume 15, pp 61–71

[79] Reddersen, J., 1999, Naturindhold i Økologisk Jordbrug, Natur, Miljø og Ressourcer i Økologisk Jordbrug, FØJO Rapport 3, Forskningscenter for Økologisk Jordbrug, pp 69–84

[80] Braae, L., Nøhr, H., Petersen, B.S., 1988, Fuglefaunaen på Konventionelle of Økologiske Landbrug, Miljøprojekt 102, Danish Environmental Projection Agency, Copenhagen, 116 pp

[81] Christensen, K.D., Jacobsen, E.M., Nøhr, H., 1996, A Comparative Study of Bird Faunas in Conventionally and Organically Farmed Areas, Dansk Ornithologisk Forenings Tidsskrift 90, 21–28

[82] Ibid

B3.3.3.1 Crop Rotation:

Crop rotation is a soil conservation technique/practice in crop farming where several different crops are cultivated on the same land in successive seasons or years. It is opposite to growing the same crop every season or year, known as monoculture. Crop rotation is practised to replenish soil fertility and it also keeps down pest populations. Crop rotations in Danish organic farming are characterized by 23% rotational grass/grass–clover, 12% permanent grass and 46% arable crops.[83]

Crop rotation in organic farming has several advantages to the soil. For example, it reduces the leaching of sulphate in the case of catch crops and these catch crops may be used to synchronise sulpher availability with plant demand in a crop rotation. J. Eriksen *et al.*[84] (2002) investigated three catch crops, viz. Italian ryegrass, winter rape and fodder radish on sandy loam soil that have a high potential for reducing Sulphate leaching.

"Sulphate leaching losses may reduce the long-term possibility of maintaining the S supply of crops in low input farming systems. The ability of catch crops (Italian ryegrass (*Lolium multiflorum* Lam), winter rape (*Brassica napus* L.) and fodder radish (*Raphanus sativus* L.)) to reduce soil sulphate concentrations in autumn and make it available to a succeeding crop was investigated in 1996–1998 on sandy loam soil in Denmark. All catch crops reduced soil sulphate concentrations in the autumn compared to bare soil. Especially, the cruciferous catch crops had the ability to deplete efficiently soil sulphate levels and thus, reduce the sulphate leaching potential. The S uptake in aboveground catch crop was 8, 22 and 36 kg S per ha for ryegrass, winter rape and fodder radish, respectively. In the following spring, sulphate levels of the autumn bare soil were low in the top 0.5 m and a peak of sulphate was found at 0.75–1 m depth. In contrast, where a fodder radish catch crop had been grown, high sulphate levels were present in the top 0.5 m, but only small amounts of sulphate were found at 0.5–1.5 m depth. In spring

[83] Anonymous, 2003, Organic Farm Units, 2002, The Danish Plant Directorate, Ministry of Food, Agriculture and Fisheries, Lyngby, Denmark, http://www.pdir.dk/Default.asp?ID=2134 Accessed on 01-12-2005 (in Danish)

[84] J. Eriksen and K. Thorup-Kristensen, The Effect of Catch Crops on Sulphate Leaching and Availability of S in the Succeeding Crop on Sandy Loam Soil in Denmark, Agriculture, Ecosystems & Environment, Volume 90, Issue 3, August 2002, Pages 247-254

barley (*Hordeum vulgare* L.), that followed catch crops, S concentrations at heading and maturity revealed that the availability of soil S increased following winter rape and fodder radish, whereas there were indications that following ryegrass, the S availability was reduced compared to bare soil. This initial study showed that catch crops have a high potential for reducing sulphate leaching and may be used to synchronise S availability with plant demand in a crop rotation."

In cropping systems with alternating grass and arable crops, special attention is required to prevent nitrate leaching. In Denmark, crop rotations also reduce nitrate leaching. Askegaard *et al.*[85] (2005) demonstrated that the crop rotation with green manure reduced nitrate leaching to the soil.

"Nitrate leaching from crop rotations supporting organic grain production was investigated from 1997 to 2000 in a field experiment at three locations in Denmark on different soil types. Three experimental factors were included in the experiment in a factorial design: (1) proportion of N_2-fixing crops in the rotation (crop rotation), (2) catch crop (with and without), and (3) manure (with and without). Three, four-course rotations were compared, two at each location. The nitrate leaching was measured using ceramic suction cells. Leaching losses from the crop rotation with grass–clover green manure and without catch crops were 104, 54 and 35 kg N ha^{-1} yr^{-1} on the coarse sand, the loamy sand, and the sandy loam, respectively. There was no effect of manure application or time of ploughing-in the grass–clover green manure crop on the accumulated nitrate leaching from the entire rotation. Catch crops reduced nitrate leaching significantly, by 30–38%, on the sandy soils. At all locations catch crops reduced the annual averaged nitrate concentration to meet drinking water quality standards in the crop rotation with green manure. On the coarse sand there was a time lag between the onset of drainage and the start of N-uptake by the catch crop."

[85] M. Askegaard, J.E. Olesen & K. Kristensen, Nitrate Leaching from Organic Arable Crop Rotations: Effects of Location, Manure and Catch Crop, Soil Use and Management, Volume 21, Issue 2, Page 181 - June 2005

Søren O. Petersen *et al.*[86] conducted a study to determine the nitrous oxide emissions from organic and conventional crop rotations in five European countries. These countries are: Austria, Denmark, Finland, Italy and UK. In Denmark, the location selected was situated in Western Denmark (55°52′N, 9°34′E). The soil type was loamy sand. The nitrous oxide data were compiled together with information about nitrogen inputs, crop rotations and soil properties. In the experiments, organic rotations received only manure as nitrogen fertilizer, while manure accounted for 0–100% of fertilizer nitrogen in conventional rotations. Their results for Denmark found that nitrous oxide emissions were higher from conventional than from organic crop rotations. Furthermore, according to the statistical analysis that they conducted, the differences between locations and crop categories were significant.

B3.3.3.2 Use of Catch Crops:

A catch crop is a fast growing crop that is planted either between two regular crops in successive seasons or simultaneously between two rows of crops in the same season. These crops grow rapidly within 4 to 5 weeks. Catch crops benefit agriculture in several ways, such as provision of soil essential nutrients that is why they are extensively used in Danish organic agriculture.

In Denmark the perennial ryegrass (*Lolium perenne* L.) and white clover (*Trifolium repens* L.) are the two major catch crops that are used in crop rotations. These plants stimulate accumulation of organic matter in arable soils. In Denmark, approximately more than 30% of the farm area managed under organic farming uses the grass-clover rotation in order to increase the fertility of the soil. Some other catch crops that are cultivated in Denmark are Italian ryegrass (*Lolium multiflorum* Lam), winter rape (*Brassica napus* L.) and fodder radish (*Raphanus sativus* L.).

It is of primary importance to prevent nitrate leaching in organic cropping systems with alternating grass and arable crops. For this, careful management is required which

[86] Søren O. Petersen, Kristiina Regina, Alfred Pöllinger, Elisabeth Rigler, Laura Valli, Sirwan Yamulki, Martti Esala, Claudio Fabbri, Eija Syväsalo and Finn P. Vinther, Nitrous Oxide Emissions from Organic and Conventional Crop Rotations in Five European Countries, Agriculture, Ecosystems & Environment, Volume 112, Issues 2-3, February 2006, Pages 200-206

includes, e.g., the use of N_2 fixing crops such as grass-clover. Catch crops, particularly ryegrass and grass clover, are used as high-input rotations. Grass-clover are N_2 fixing catch crops of vital importance in most Danish organic cropping systems. These types of catch crops reduce the loss of nutrients from the soil and thus maintain the soil nutritional status at a higher level. The use of long term grass-clover has shown reduced nitrate leaching from the fields. Jørgen Eriksen *et al.*[87] (2004) of the Danish Institute of Agricultural Sciences reported that these crops reduce nitrate leaching.

> "In the future there is expected to be a higher proportion of grass in the dairy crop rotation than today. Changes in the EU Common Agricultural Policy stipulate that subsidies should be decoupled from production. Pastures are thus better able to compete economically with other roughage/feedstuff sources. Also, the development in farm size is dramatic and as dairy farms grow bigger, an increasing number of farms cannot use the entire crop rotation for grazing. The management of dairy cattle grazing becomes increasingly difficult with distance to the milking parlour, and on these farms we already experience grass-intensive rotations located close to the farm buildings. Because of these conditions grass leys are expected to become older than the 2-3 years, which is currently most common. And this may affect both the production and the environment."

They concluded by saying,

> "The very low level of nitrate leaching from grazed 4-8-year-old grass-clover leys indicates that dairy crop rotations with a high proportion of grassland and with correct management are a suitable agricultural production in nitrate vulnerable zones."[88]

Andreas de Neergaard *et al.*[89] (2004) conducted a comparative study of perennial rye grass and white clover to determine which of these catch crops contributes more to the soil carbon pool.

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[87] Jørgen Eriksen, Finn P. Vinther and Karen Søegaard, Danish Institute of Agricultural Sciences, Low Nitrate Leaching from Long-term Grass-Clover, Available at: http://www.darcof.dk/enews/sep04/lowleach.html, and also at http://orgprints.org/5479/

[88] Ibid

[89] Andreas de Neergaard and Antonie Gorissen, Carbon Allocation to Roots, Rhizodeposits and Soil after Pulse Labelling: A Comparison of White Clover (*Trifolium repens* L.) and Perennial Ryegrass (*Lolium perenne* L.), Biology and Fertility of Soils, Volume 39, Number 4 / March, 2004, 228-234

"Organically managed farm areas in Denmark are expanding and typically contain clover-grass leys that are known to stimulate accumulation of organic matter in arable soils. We compared the C allocation to roots and soil from clover and grass, and determined for how long assimilated C remained mobile in these plant-soil systems. Pots with perennial ryegrass, white clover or a mixture of both were pulse-labelled with $^{14}CO_2$, and harvested for analyses after 4, 11, 20, and 30 days. ^{14}C losses by shoot respiration stopped within 4 days and after this incubation time the input of assimilated ^{14}C to below-ground compartments was greater in grass (52%) than in clover (36%). During the next 4 weeks, ^{14}C allocation below ground increased in grass (up to 75% at day 30), but remained constant in clover (37% at day 30). In the grass/clover mixture, the below-ground fraction increased to 50% at day 30. In clover, ^{14}C was incorporated sooner into stable plant and soil pools and less was released in rhizodeposition than in grass. This was confirmed by the ^{14}C in the soil microbial biomass that decreased fastest in the clover treatment. Root-derived C compounds of clover probably decomposed faster than those from grass. The larger size and specific activity of the soil microbial biomass in the mixed treatment suggested a stimulating effect of the two plant species on substrate utilisation by the microbial community. This study showed that a 2- to 3-week distribution period is needed before sampling for quantitative estimates of C allocation."

They concluded by stating,

"Overall our results indicate that the ryegrass contributes substantially more to below-ground carbon pools than the clover".[90]

Catch crops help organic farming systems in a number of ways. One such mechanism is that these crops reduce the loss of nutrients from the soil. Thorup-Kristensen *et al.*[91] (1998) in Denmark have demonstrated that a catch crop, succeeding the main crop, can absorb nitrate from the root region during autumn and winter and in so doing, reduce nitrate leaching.

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[90] Andreas de Neergaard and Antonie Gorissen, Carbon Allocation to Roots, Rhizodeposits and Soil after Pulse Labelling: A Comparison of White Clover (*Trifolium repens* L.) and Perennial Ryegrass (*Lolium perenne* L.), Biology and Fertility of Soils, Volume 39, Number 4 / March, 2004, 228-234

[91] Thorup-Kristensen, K. and Nielsen, N.E., 1998, Modelling and Measuring the Effect of Nitrogen Catch Crops on Nitrogen Supply for Succeeding Crops, Plant Soil 203, pp. 79–89

Askegaard *et al.*[92] (2007) investigated whether the catch crop clover was more beneficial to the cereal production or ryegrass. Their results showed,

> "In low input farming systems without inorganic N-fertilizer input, cereal cropping is a challenge because of the need for an adequate N supply. The objective of this investigation was to explore the feasibility of using clover (red/white) catch crops instead of ryegrass in crop production on coarse sand. Two field experiments tested the effects of clover and ryegrass catch crops on N and K leaching and on grain yield of a succeeding spring barley. Treatments included animal manure regimes, main crops (spring barley = low soil N status or lupin = high soil N status) and levels of K fertilizer (no K or 80 kg K ha^{-1}). The residual effect of the clover catch crop on grain yield of the succeeding spring barley was significantly higher than that of the ryegrass, especially under the low N conditions. When animal manure (70 kg total-N ha^{-1}) was added to the spring barley succeeding a ryegrass catch crop, the difference in residual effect between clover and ryegrass catch crops disappeared. Thus, clover appeared to have the potential to substitute animal manure. Leaching of NO_3-N and K was estimated by means of porous ceramic suction cups installed at 1 m depth. Both the clover and ryegrass catch crops reduced the annual flow-weighted mean NO_3-N concentrations from 13–16 to 5–8 mg L^{-1}, which is below the WHO maximum for drinking water. The annual NO_3-N leaching from a spring barley treatment without catch crops was approximately 100 kg ha^{-1}. Clover and ryegrass catch crops reduced the losses significantly by approximately 40–80% depending on year and treatment, with ryegrass being more effective than clover. Catch crops reduced K leaching significantly but the relative effect was lower than for N. The clover catch crops appeared suitable for low-N cropping systems on coarse sand with respect to both production and environment."

[92] Margrethe Askegaard and Jørgen Eriksen, Residual Effect and Leaching of N and K in Cropping Systems with Clover and Ryegrass Catch Crops on a Coarse Sand, Agriculture, Ecosystems & Environment, Article in Press (2007)

B3.3.3.3 Farm Hedgerow Diversity:

In the Danish agricultural landscapes, various types of vegetation are found in farm hedgerows. A farm hedgerow is a row of bushes or trees forming a hedge that demarcate the boundary between farms. It is well documented in Danish literature that organic farming is slightly superior in the conservation of herbaceous diversity of hedgerows as compared to conventional agriculture. For example, in one comparative study, Aude *et al.*[93] (2004) reported,

> "The aim was to compare and test differences in the conservation value of hedge bottom vegetation on organic and conventional farms. The studied hedgerows (28 organic and 28 conventional) were on average 14 years old and established in the same way, except that organic hedgerows were established and managed without use of pesticides. We investigated three sample plots of 10 m2 in all hedgerows together with a set of 13 explanatory variables. There were no differences in soil texture between hedgerow types but organic farms had higher pH and lower conductivity. Organic farms had higher total N values, which are explained by a slightly higher content of organic matter. There was highly significant interaction between farming type and neighbouring crop type according to soil phosphate concentration. Significantly more plant species were found in the organic hedgerows. The species compositions in organic hedgerows appeared significantly more similar to semi-natural communities when compared with other plant communities. We conclude that organic farming is slightly superior with regard to conservation of herbaceous diversity of hedgerows in intensively cultivated agricultural landscapes."

In another comparative study of organic and conventional farming and their impacts on hedgerow vegetation diversity, Aude *et al.*[94] (2003) explained the effect of pesticides on such vegetation,

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[93] Aude, Erik; Tybirk, Knud; Michelsen, Anders; Ejrnæs, Rasmus; Hald, Anna Bodil and Mark, Susanne, Conservation Value of the Herbaceous Vegetation in Hedgerows - Does Organic Farming make a Difference? Biological Conservation, Volume 118, Issue 4, August 2004, Pages 467-478

[94] E. Aude, K. Tybirk and M. Bruus Pedersen, Vegetation Diversity of Conventional and Organic Hedgerows in Denmark, Agriculture, Ecosystems & Environment, Volume 99, Issues 1-3, October 2003, Pages 135-147

"Many attempts have been made to reduce the impact of modern conventional farming on the environment and semi-natural ecosystems. One of them is organic farming, known primarily for the absence of pesticides and artificial fertilisers. The objective of this study was to study and test the differences in the spontaneous vegetation of comparable hedgerows in the same area situated within organic and conventional farming systems. The hedge bottom vegetation was surveyed during August 2001 in 13 hedgerows of each farming system. Farming type had not changed on either side of the hedgerows for the lifetime of the hedges (10–14 years). Sampling was associated with a set of 16 measured environmental variables. In the two farming systems hedgerows were comparable in terms of landscape, age, soil type, nutrient status and width. A mixed analysis of variance (ANOVA) found no significant difference in measured soil and radiation variables between farming types. Farming types only differed in the use of pesticides. Significant differences between farming types in plant species diversity at alpha, beta and gamma levels were found. More species that are normal in semi-natural habitats were found on organic farms. There was an overlap in species composition between farming type, but a slightly higher species turnover on conventional farms. The ordination axes were highly correlated with calibrated Ellenberg values of fertility, light and soil moisture. Soil fertility and farming type were important factors to explain variation in species composition. Organic farming had a significantly reduced impact on hedge bottom vegetation compared to conventional farming. Higher extinction due to pesticide drift and immigration rates may be responsible for the significantly higher species diversity and different species composition in hedges on organic farms."

In a particular Danish hedgerow biodiversity project, Bruus *et al.*[95] (2004) revealed that,

"The aim of the project was to compare flora and insect fauna of organic and conventional hedgerows and to study whether the drift of herbicides into hedgerows alone or in combination with differences in fertiliser application may explain any

[95] Marianne Bruus, Erik Aude & Knud Tybirk, Hedgerow Flora and Insect Fauna on Organic and Conventional Farms, IN: Proceedings of Crop Protection 2, First Danish Plant Congress, The Danish Ministry of Food, Agriculture and Fisheries, DJF Rapport January 2004, pp 59, Available at: DARCOF http://orgprints.org/3599/

differences. The project consequently consisted of two parts, viz. collection of flora and insect data in existing hedgerows (multi-row hedgerows, age 10-15 years) on two soil types and an experiment in which a sown grassland vegetation was treated with combinations of glyphosate (0-25% label rate) and nitrogen (0-100 kg N/ha/year) as a simulation of the most important agricultural conditions having an effect on flora and insect fauna in different agricultural systems. In the experiment flora and insect fauna were studied for three years. In the hedgerows clear differences in the floral composition were found, with more plant species in hedgerows at organically grown fields than at conventionally grown fields, on both sandy and loamy soils."

Similarly, a comparative study was conducted in Denmark on the impact of organic and conventional dairy farms on hedgerow vegetation. Petersen *et al.*[96] (2006) documented,

"The aim of this study was to assess, whether organic dairy farming has increased the biological diversity of field boundary vegetation when compared to conventional dairy farming, and if increasing organic farming duration affected diversity.

The diversity of plant species in field boundaries was found to be higher under organic than under conventional farming. Analysis of community patterns revealed that ruderal species and species with affinity to nutrient rich conditions were most common in conventional field borders, whereas stress-tolerant species were more abundant around organic farming. These differences occurred only 3–4 years after conversion to organic farming."

[96] S. Petersen, J.A. Axelsen K. Tybirk, E. Aude and P. Vestergaard, Effects of Organic Farming on Field Boundary Vegetation in Denmark, Agriculture, Ecosystems & Environment, Volume 113, Issues 1-4, April 2006, Pages 302-306

B4 SOIL CONSERVATION IN CONVENTIONAL FARMING:

No Danish specialist data was found for soil conservation in conventional agriculture. This is not unusual because the essence of conventional agricultural practices, i.e. mainly the use of heavy machinery and application of pesticides, does not take into consideration soil conservation. In other words, the *Soil Loss* and *Soil Harm* take place in conventional agriculture. It would be a paradox if conventional agriculture also conserves the soil through its practices at the same levels of organic agriculture, because then there would be no major difference, in terms of soil degradation, between organic and conventional agriculture.

The soil conservation in conventional farming remains unknown and this area is open for further research.

B5 ANALYSIS OF THE COMPARATIVE EMPIRICAL STUDY FOR SOIL CONSERVATION:

B5.1 ACCEPTANCE/REJECTION OF NULL HYPOTHESIS FOR SOIL CONSERVATION:

B5.1.1 Proposition 1:

If the farming types do not qualitatively outweigh each other in terms of soil conservation (from the empirical literature in the comparative study), then the null hypothesis that "no association exists between organic and conventional farming types and *soil conservation* levels" is accepted and it will be concluded that "no association exists". Then there is no need for any further evaluation.

B5.1.2 Proposition 2:

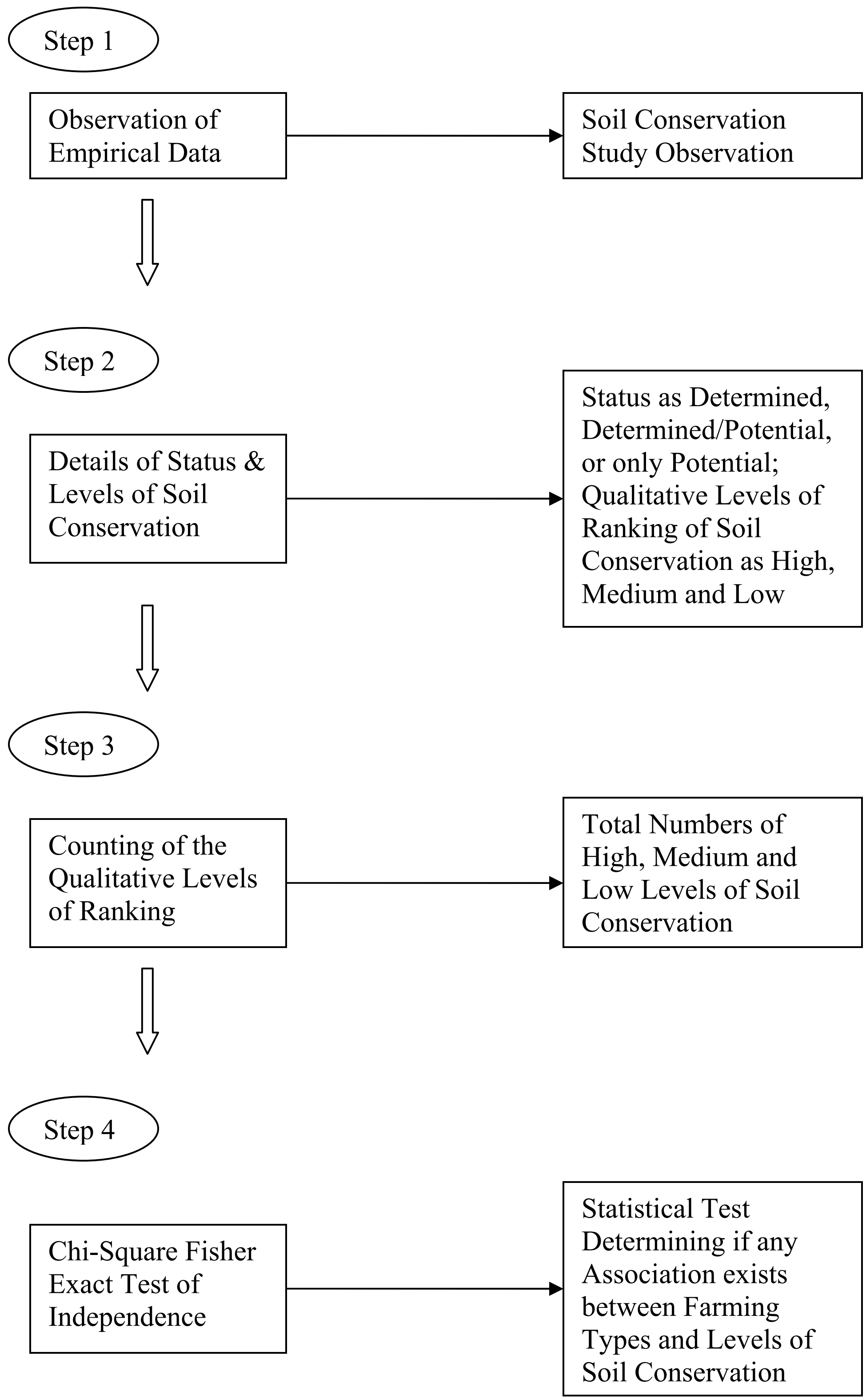
If any of the farming types qualitatively outweigh each other in terms of soil conservation (from the empirical literature in the comparative study), then the null hypothesis that "no association exists between organic and conventional farming types and *soil conservation* levels" is rejected and it will be concluded that the "association does exist".

If there is any association present, this would imply that there is also difference present (from a statistical point of view). After reaching to this decision on the null hypothesis, then it is crucial for the conclusion to determine the difference and evaluate the type of farming system that conserves the soil more. But this would be possible if there is enough data in the comparative study to conduct a statistical analysis to determine any difference, if present.

B5.2 METHODOLOGY OF ANALYSIS:

In order to comprehend the results of the comparative study of organic and conventional agriculture for soil management, the analysis is conducted in a stepwise procedure. The 'Schematic Diagram No. 5' on the next page elaborates the methodology of the analysis of soil conservation for a clear understanding:

Schematic Diagram No. 5; Showing stepwise procedure of methodology of analysis.

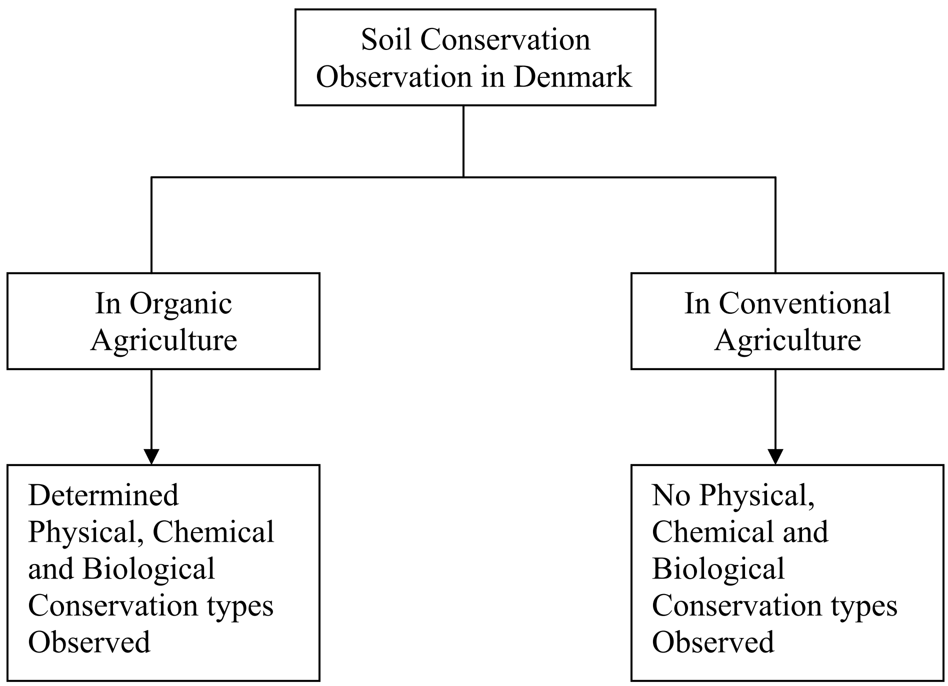


B5.2.1 Step No. 1: Observation of Empirical Data:

In the first step, the physical, chemical and biological soil conservation types for both organic and conventional agriculture are observed to classify their status as potential and/or determined. Hence the observations are:

Observation of *Soil Conservation* of Both Farming Types:

Schematic Diagram No. 6; Showing the observation for different *soil conservation* types in both organic and conventional agriculture separately.



B5.2.2 Step No. 2: Qualitative Ranking and Details of Soil Conservation Dimensions:

The qualitative ranking is given to the three dimensions of conservations for both the farming systems separately in the following 'Table No. 12, Table No. 13 and Table No. 14'.

The rankings are given according to the status of each of the references in the review in the following manner:

1. If conservation types are ‘determined’, then ranking = High
2. If conservation types are ‘potential’ and/or ‘determined’, then ranking = Medium
3. If conservation types are ‘potential’, then ranking = Low
4. If conservation types are ‘unknown or not observed’, then ranking = Nil

Note that the High, Medium and Low are the “Levels of Soil Degradation” in the above formula.

In this step, using data from the comparative empirical study and inputs from Step No. 1, the details of physical, chemical and biological dimensions and status of soil conservation for both farming types are presented separately in the following ‘Table No. 12, Table No. 13 and Table No. 14’:

Table No. 12; Presenting details of *Physical Soil Conservation* dimension in organic and conventional agriculture from the comparative empirical study.

Farming Type	S No.	Types of Physical Soil Conservation	List of References	Observed Status	Qualitative Ranking
Organic Agriculture	1.	Conservation Tillage	Ref. No. 43, Page No. 75	Determined	High
			Ref. No. 44, Page No. 76	Determined/Potential	Medium
			Ref. No. 46, Page No. 78	Determined	High
	2.	Soil Physical Properties	Ref. No. 47, Page No. 79	Determined	High
			Ref. No. 50, Page No. 80	Determined	High
Conventional Agriculture		Unknown	Unknown	Unknown	Unknown

Table No. 13; Presenting details of *Chemical Soil Conservation* dimension in organic and conventional agriculture from the comparative empirical study.

Farming Type	S No.	Types of Chemical Soil Conservation	List of References	Observed Status	Qualitative Ranking
Organic Agriculture	1.	Maintaining Soil Fertility	Ref. No. 51, Page No. 81	Potential	Low
			Ref. No. 52, Page No. 83	Determined	High
			Ref. No. 53, Page No. 83	Determined	High
			Ref. No. 54, Page No. 83	Determined	High
			Ref. No. 55, Page No. 83	Determined	High
			Ref. No. 56, Page No. 84	Determined	High
			Ref. No. 57, Page No. 85	Determined/Potential	Medium
			Ref. No. 58, Page No. 86	Determined	High
	2.	Application of Organic Fertilizers	Ref. No. 59, Page No. 87	Determined	High
			Ref. No. 60, Page No. 88	Determined	High
			Ref. No. 61, Page No. 89	Determined	High
			Ref. No. 62, Page No. 90	Determined	High
			Ref. No. 63, Page No. 90	Determined	High
			Ref. No. 64, Page No. 92	Potential	Low
			Ref. No. 65, Page No. 92	Determined	High
			Ref. No. 67, Page No. 93	Determined	High
			Ref. No. 68, Page No. 94	Determined	High
Conventional Agriculture		Unknown	Unknown	Unknown	Unknown

Table No. 14; Presenting details of *Biological Soil Conservation* dimension in organic and conventional agriculture from the comparative empirical study.

Farming Type	S No.	Types of Biological Soil Conservation	List of References	Observed Status	Qualitative Ranking
Organic Agriculture	1.	Abundance of Soil Biota	Ref. No. 69, Page No. 95	Determined	High
			Ref. No. 71, Page No. 97	Determined/Potential	Medium
			Ref. No. 72, Page No. 97	Determined	High
			Ref. No. 75, Page No. 98	Determined	High
			Ref. No. 77, Page No. 99	Potential	Low
	2.	Entomological and Avian Benefits	Ref. No. 78, Page No. 100	Determined	High
			Ref. No. 79, Page No. 100	Determined	High
			Ref. No. 80, Page No. 100	Determined	High
			Ref. No. 81, Page No. 100	Determined	High
	3.	Organic Cropping Systems	Ref. No. 84, Page No. 101	Determined/Potential	Medium
			Ref. No. 85, Page No. 102	Determined	High
			Ref. No. 86, Page No. 103	Determined	High
			Ref. No. 87, Page No. 104	Determined/Potential	High
			Ref. No. 89, Page No. 104	Determined	High
			Ref. No. 91, Page No. 105	Determined	High
			Ref. No. 92, Page No. 106	Determined	High
			Ref. No. 93, Page No. 107	Determined	High
			Ref. No. 94, Page No. 107	Determined/Potential	High
			Ref. No. 95, Page No. 108	Determined	High
			Ref. No. 96, Page No. 109	Determined	High
Conventional Agriculture		Unknown	Unknown	Unknown	Unknown

B5.2.3 Step No. 3: Counting of Qualitative Levels of Ranking for Soil Conservation:

Table No. 15; Contingency table providing the total counts in the three dimensions of soil conservation in both farming systems for the three qualitative levels (derived from Step No. 2).

Farming Type	Conservation Dimension	Total Number of References ranked 'High'	Total Number of References ranked 'Medium'	Total Number of References ranked 'Low'
Organic	Physical	4	1	0
	Chemical	14	1	2
	Biological	16	4	1
Totals		**34**	**6**	**3**
Conventional	Physical	0	0	0
	Chemical	0	0	0
	Biological	0	0	0
Totals		**0**	**0**	**0**

The totals in this table reflect the collective degradation (Physical+Chemical+Biological) for both farming systems in three levels and they are used in the following step.

B5.2.4 Step No. 4: Statistical Analysis, Fisher Exact Test of Independence:

In order to determine if any association exists between farming types and soil degradation, the following contingency **Table No. 16** is presented, (derived from Table No. 15):

Farming Type	**Levels of Soil Conservation**		
	High	Medium	Low
Organic Agriculture	34	6	3
Conventional Agriculture	0	0	0

Table No. 17; Showing the Expected Frequency in order to determine the statistical test to be applied:

Farming Type	**Levels of Soil Conservation**			
	High	Medium	Low	Totals
Organic Agriculture	34 (43x34/43)=34	6 (43x6/43)=6	3 (43x3/43)=3	43
Conventional Agriculture	0 (0x34/43)=0	0 (0x6/43)=0	0 (0x3/43)=0	0
Totals	34	6	3	43

Table No. 17 shows the statistical calculation in which the Expected Frequency is less than 5. Normally, the Expected Frequency for each of the cells in the table should be greater than 5 in the normal Chi-Square test. But since in this table the Expected Frequency of some of the cells is less than 5, therefore, 'Chi-Square Fisher Exact Test of Independence' is used for the results to determine the association.

Rejection of the Null Hypothesis for Soil Conservation:

To determine the association between the farming types and levels of soil conservation, Fisher Exact test is applied in the analysis. The information in the rows and columns from Table No. 16 is used in the calculation of the P value. The P value is calculated and is compared with alpha = 0.05. If the P value > 0.05 then the null hypothesis is accepted. If the P value < 0.05 then the null hypothesis is rejected and it shows that there is some association between the farming types and levels of soil degradation.

Following are the results of the Fisher Exact Test of Independence:

Chi squares (both with 0.5 degree of freedom):
Pearson's= 0 (p= NaN000)
Likelihood Ratio= 0 (p= NaN000)

In the above calculations, since the P value = NaN000 < 0.05, therefore, the null hypothesis for soil conservation that "no association exists between organic and conventional farming types and levels of *soil conservation*" is rejected and it shows that the association is highly significant and it is concluded that there is some association between farming types and levels of soil conservation. Therefore, Proposition No. 1 (heading B5.1.1, page 111) is rejected and Proposition No. 2 (heading B5.1.2, page 111) is accepted.

This furthermore implies that difference also exists between farming types and levels of soil conservation. This difference is obvious from the evaluation of the review of the empirical data of soil conservation. The difference between farming types and soil conservation levels cannot be calculated quantitatively on a statistical basis. This is due to the fact that the comparison cannot be conducted statistically, because from Table No. 16 (page 117), the soil conservation ranked sampling values are available for all the three levels (high, medium, low) in organic agriculture but in conventional agriculture, the ranked sampling values are not available for all three levels, i.e. high, medium and low. Therefore, if the values for the three levels of conventional agriculture are unknown, then a statistical comparative analysis cannot be conducted.

CHAPTER 4

CASE STUDY – PART 2

ORGANIC AGRICULTURE AND ITS REGULATION IN DENMARK

Upon having a vivid distinction of soil conservation in organic farming from conventional farming (from case study part 1), the case study part 2 provides a detailed account of organic farming and its regulation in Denmark.

4.1 INTRODUCTION:

Denmark is situated in a temperate climatic region within coordinates 54° 33´- 57° 45´ N and 08° 04´-15° 11´ E. Denmark has a total area of 4,308,000 hectares and a population of 5.4 million inhabitants. The landscape of Denmark is flat with rich agricultural land. Approximately 60% (2.5 million hectares) of the total area is cultivated farmland. Various crops that are cultivated in Denmark are, small grains: wheat and barley (covering more than half of the total agricultural area); fodder crops: grass and maize for silage; sales crops: rape seed, sugar beets and grass seeds of various types; and vegetables.

4.2 TYPES OF SOIL IN DENMARK:

The Danish landscape is primarily divided into two regions. The central and eastern parts of the country have soils different from the western part. The central and eastern soils are clayey, calcareous and relatively fertile whereas, the western soils are sandy and less fertile. This geographical demarcation of two distinctive types of soils has its roots in the history of geological time scales. In order to understand the geographical distribution of soil types in Denmark, it is important to observe the following map of the landscape of Denmark from L. Krogh and M.H. Greve[97] (1999):

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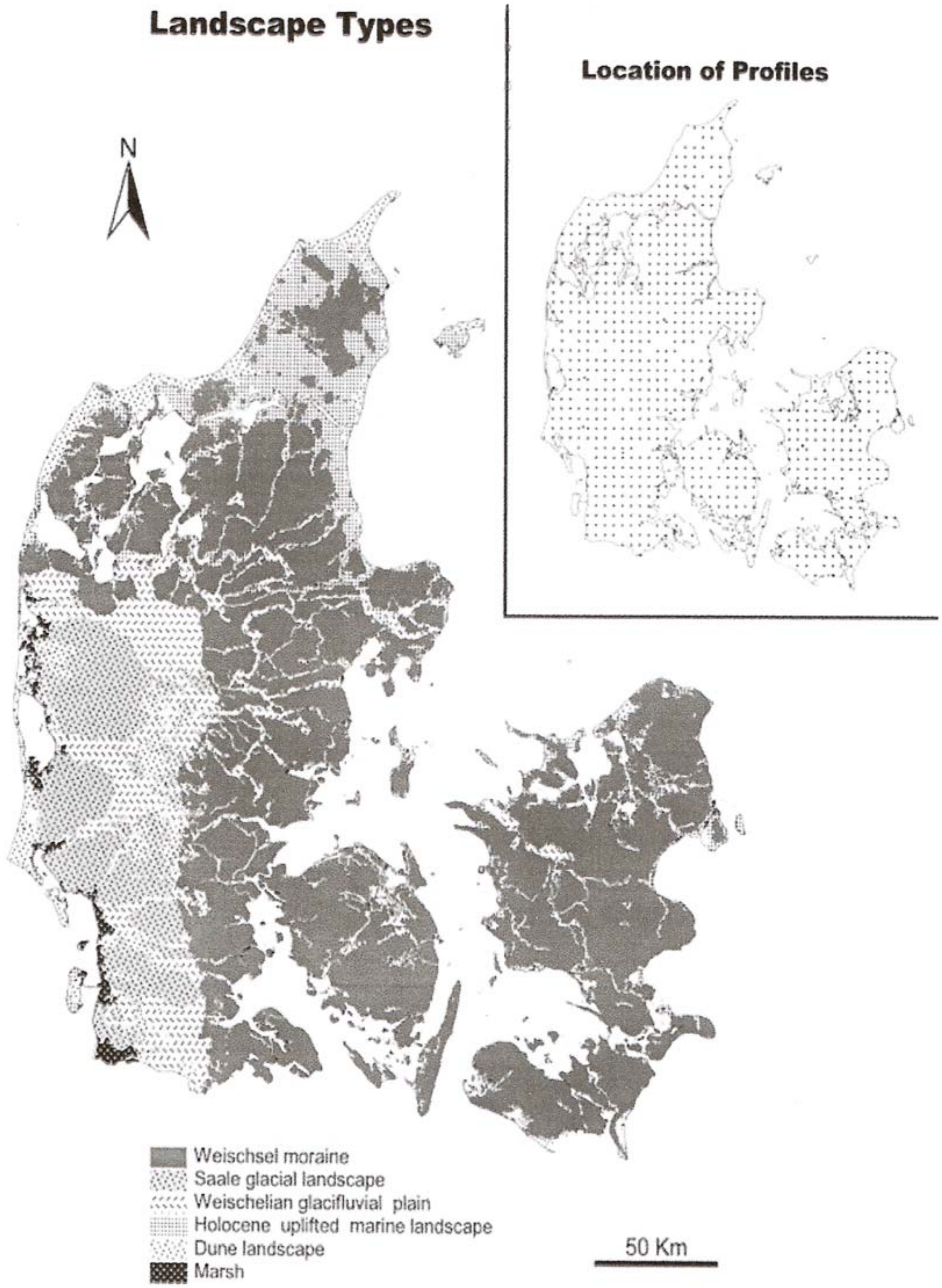
[97] L. Krogh and M.H. Greve, Evaluation of World Reference Base for Soil Resources and FAO Soil Map of the World Using Nationwide Grid Soil Data from Denmark, Soil Use and Management (1999) 15, 157-166

Figure No. 1; Geographical and geological presentation of the landscape of Denmark[98]:



98 L. Krogh and M.H. Greve, Evaluation of World Reference Base for Soil Resources and FAO Soil Map of the World Using Nationwide Grid Soil Data from Denmark, Soil Use and Management (1999) 15, 157-166

The map vividly shows the two separate types of regions with regards to the land. In geological terms, the morphology of the Danish landscape was shaped at the end of the Pleistocene Epoch by the last glaciation of the Ice Age. This glaciation is known as the Weichsel glaciation. The last glaciation took place around 10,000 BC[99]. The Weichsel glaciation covered the central and eastern parts of Denmark, while the western parts of Jutland (western region of Denmark) were ice-free. That is why the central and eastern region acquired a covering of fertile soil that formed the Weichselian low moraines. Hence, it can be said that the Weichsel glaciation has divided Denmark into two regions and each soil type is a specific formation by the interaction of geological history, parent material, climate, topography and time.

According to the FAO soil classification, the major Danish soil types can be classified as *Eutriv* and *Fluviso*[100].

4.3 ORGANIC FARMING IN DENMARK:

4.3.1 Definition of Organic Farming:

The Danish Research Centre for Organic Food and Farming (DARCOF) has defined organic farming as, “Organic farming describes a self-sustaining and persistent agro-ecosystem in good balance. As far as possible, the system is based on local and renewable resources. It builds on a holistic view that incorporates the ecological, economical and social aspects of agricultural production in both the local and global perspectives.

In organic farming nature is considered as a whole with its own innate value, and man has a moral obligation to farm in such a way that cultivated landscape constitutes a positive aspect of nature.”[101]

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[99] http://en.wikipedia.org/wiki/Wisconsin_glaciation#Weichsel_glaciation.2C_in_Scandinavia

[100] FAO, 1988, FAO/UNESCO Soil Map of the World, Revised Legend with Corrections, World Resources Report 60 FAO Rome, Reprinted as Technical Paper 20, ISRIC, Wageningen, 1994

[101] DARCOF, http://www.darcof.dk/organic/index.html

4.3.2 Principles of Organic Farming:

In Denmark there are a defined set[102] of production standards/principles for organic farming that include:

1. The banning of synthetic chemicals (biocides)
2. The banning of synthetic mineral fertilizers
3. No-tillage or reduced tillage cultivation practices, where the ground contact stress should be minimum
4. The banning of the use of genetically modified organisms (GMOs)

4.3.3 Aims of Organic Farming:

1. Reduce the use of non-renewable resources (e.g. fossil fuels) to a minimum
2. "To use, as far as possible, renewable resources in production and processing systems to avoid pollution and waste" as outlined in the IFOAM norms[103]
3. To reduce soil degradation and preserve the natural fertility of soil
4. To avoid all forms of pollution and contamination that results from agricultural activities
5. To reduce the use of non-renewable resources, including fossil fuels, in agriculture to a minimum possible extent
6. To produce foods of optimal nutritional quality in sufficient amounts
7. To promote farming practices that pay great regard to the environmental components

4.3.4 Characteristics of Organic Farming:

The distinctiveness/characteristics of organic farming are based on its practices. These practices are carried out for nature management on the farm level in Denmark.

1. In order to increase the transparency and cooperation with local interests, organic farming favours decentralized production systems[104]

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[102] Jespersen LM, International and National Organic Standards in the EU, The Danish Agricultural Advisory Centre, Section for Ecology, Aarhus Denmark, 1998, 75pp

[103] International Federation of Organic Agriculture Movements, IFOAM Norms 2002, 139pp

[104] DARCOF Users Committee, Principles of Organic Farming, The Danish Research Centre for Organic Farming, Tjele, Denmark, 2000. 32pp

2. To reduce the loss of nitrogen from farms, organic farming is considered as an effective means
3. Nature friendly farming practices

4.3.5 Organic Farming Practices for Soil Conservation:

The details of various organic farming practices for soil conservation are provided in Chapter 3. They are only listed here:

1. Increased Soil Organic Matter (SOM)
2. Reduced Soil Compaction
3. Organic Cropping Systems
    a) Use of N2 fixing crops
    b) Catch crops
    c) Crop Rotations
    d) Soil Aggregation
4. Conservation Tillage

4.3.6 Innovative Technologies in Organic Farming:

Due to its practices, organic farming is considered to be labour intensive than conventional farming where much of the work is done by heavy machinery. However, this is being substituted by the introduction of novel technologies. The reason for introducing such innovative technologies is to help reduce the anticipated labour demand by 80-85%. The technologies introduced in organic farming include GPS controlled allocation of manure, band-steaming and robotic weeding for intra-row weed control. These selected technologies are either available or have been tested as a prototype technology.

4.4 SITUATION OF ORGANIC FARMING IN DENMARK:

The history and the development of organic farming are presented as follows:

4.4.1 History of Organic Agriculture in Denmark:

Cultivation started in Denmark around 3500 years BC and there is a probability that some areas might have been under cultivation ever since[105].

Although modern organic farming has been going on in Denmark since the 1930s, it was not until the 1980s that serious growth occurred. Since then organic agriculture has flourished and a great wave of conversion to organic farming started.

The organic farms in Denmark consist mainly of two types of farms, full time dairy farms and part time arable farms. Denmark currently has one of Europe's most developed organic agriculture sector, as measured by both farm area and market share. In 1988 the total area cultivated under organic farming was only 6000 ha. In the proceeding years till 2002 there has been a steady and gradual increase in acreage under organic farming. Table No. 18 (modified from the Danish Plant Directorate) shows the tremendous growth in terms of farms and arable land:

[105] Hedeager, L. & Kristiansen, K. 1988. Oldtid. o.4000 f.kr.-1000 e.kr. In: Det Danske Landbrugs Historie I. Oldtid og Middelalder (eds C. BjÖrn, T. Dahlerup, S.P. Jensen & E.H. Pedersen), AiO as, Odense, pp.11-202

Table No. 18; Total Number of Organic Farms and Farmland from 1989 to 2006 (Source: Danish Plant Directorate)[106].

Year	Farms	% of all Farms	Hectares	% of all Agricultural Land
1989	401		9554	
1990	523		11,581	
1991	672		17,963	
1992	675		18,653	
1993	640		20,090	
1994	677		21,145	
1995	1050	1.5	40,884	1.5
1996	1166	1.7	46,171	1.7
1997	1617	2.5	64,329	2.4
1998	2228	3.5	99,163	3.7
1999	3099	5.2	146,685	5.5
2000	3466	6.4	165,258	6.2
2001	3525	6.5	173,497	6.5
2002	3714	7.3	178,360	6.7
2003	3510	7.2	168,154	6.3
2004	3166	6.6	160,209	5.9
2005	3036	6.4	150,815	5.5
2006	2794	5.8	144,303	5.3

Regarding the regional distribution within Denmark, the biggest share of organic farms is found in Jutland, followed by Zealand (20.9 percent) and Funen (5.9 percent). In the southern part of Jutland approx. 12 per cent of the area is organic, in total Jutland accounted for 73 per cent of the organic production area. The eastern part of Denmark is dominated with crop producers in comparison to dairy farms while it is vice versa in the western part of Denmark.

In this regard, Pia Frederiksen[107] (2004) has documented, "The majority of Danish organic farms are specialised, and regional specialisation also characterises the organic farming. Livestock is dominantly confined to Jutland and crop cultivation to

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106 Statistics on Organic Farms 2006, Authorizations and Production, Danish Plant Directorate, Ministry of Food, Agriculture and Fisheries, Available at: http://www.pdir.dk/Files/Filer/Oekologi/Statistik/06/Statistik_2006.doc

107 Frederiksen, Pia (2004), Lokalisering af Økologiske Bedrifter - Regional Specialisering og Koncentration? [Localisation of Organic Farms - Regional Specialisation and Concentration?], [Oral] Presentation at *Facetter af landskabsforskningen, Danish Landscape Ecological Association*, National Environmental Research Institute, 16. September 2004, IN: DARCOF, http://orgprints.org/3359/

eastern Denmark, but Jutland has a more mixed composition of farm types than eastern Denmark in general. A certian concentration of organic farms are found - especially in Southern Jutland, and local processes seem to influence conversion to organic farming."

Table No. 19; (Modified from the Danish Dairy Board) Total Number of Organic Dairy Farms and Milk Deliveries from 1994 to 2006 (Source: Danish Dairy Board)[108]

Year	Number of Dairy Farms	Deliveries 1,000 tonnes
1994	146	47
1995	147	50
1996	344	129
1997	430	137
1998	672	175
1999	751	294
2000	827	415
2001	749	451
2002	695	443
2003	636	434
2004	513	399
2005	490	404
2006	480	417

4.4.2 Development of Organic Farming:

Organic agriculture in Denmark has been derived from alternative agricultural systems to conventional agriculture from a few other European countries. These systems include:

a) Bio-Dynamic System from Germany (started in the 1920s)
b) Howard Balfour System from England (started in the 1940s)
c) Organic-Biological System from Switzerland (started in the 1960s)

Although these systems have their own backgrounds, yet all are antagonistic to the practices of conventional agriculture. Amongst these, the *Bio-Dynamic System* from Germany was highly influential and had a great impact on the early development of organic agriculture in Denmark in the 1930s. Later on, Denmark experience a shift to the

[108] Danish Dairy Board, Available at: http://www.mejeri.dk/smcms/danishdairyboard_dk/Facts_figures/Danish_dairy/8__Organic_products/9_a__Number_of/Index.htm?ID=5235

other farming systems. In the 1980s, the concept of organic agriculture was based on the principles of the *Howard Balfour* and the *Organic-Biological* agricultural systems. Conclusively, the major emphasis, in organic crop production, was laid on the evasion of all chemical pollution that included use of chemical sprays and artificial fertilizers.

As a result, more organic farms were established during this period in particular. In 1981, the Danish Organization for Organic Farming (LØJ) was founded and hence the Danish organic movement was organized.

Later, the dead lobsters in Danish coastal waters (mentioned earlier in this chapter) triggered the Danish government to implement the world’s first comprehensive regulation on organic farming in 1987. In the same year, the establishment of the Council on Organic Food and Agriculture was an important step. One of the major functions of the council is to serve as a platform for consensus building on organic policies.

In the 1990, the Danish government introduced an organic state label, the red Ø-label. In the 1990s organic agriculture bloomed and the country witnessed a massive increase in the production and sales of organic products, particularly dairy products.

For the coordination of extensive research on organic farming, the Danish Research Centre for Organic Farming was established in 1996 under the Ministry of Food, Agriculture and Fisheries. From 2003 onwards Denmark has experienced stagnation in the organic farming and its industry.

In short, the development of organic agriculture in Denmark can be categorized into *six* stages. *Firstly*, the early introduction of nature or/and organic farming in 1930s; *secondly*, the development of modern organic farming in 1960s where the modern pioneers emerge; *thirdly*, the organization of stakeholders and limited consumption of organic produce in the early 1980s; *fourthly*, political and governmental support and coverage by mass media of organic agriculture in the late 1980s; *fifthly*, tremendous bloom of organic agriculture and consumption in the 1990s; *sixthly*, the stagnation of organic agriculture in the early 2000s.

The highlights of the development of organic farming are presented in the following table:

Table No. 20; Organic Production Highlights in Denmark; Source: The Danish Agricultural Advisory Service (DAAS)[109]

1936	The Biodynamic Association and Demeter Association were established.
1972	An umbrella organisation, the International Federation of Organic Agriculture Movements (IFOAM), was set up for societies working towards alternative agriculture.
1981	The Danish Association of Organic Farming is founded and a number of specific rules are formulated. The association sets up its own inspectorate.
1982	The first Danish organic agricultural college is set up in Jutland.
1985	The first organic agricultural advisory service was set up.
1987	The Danish parliament adopts the world's first comprehensive legislation on organic farming. State inspection and certification scheme are introduced.
1988	The first litre of organic milk is bottled at a small dairy.
1990	Launch of a national campaign for organic agriculture.
1993	The largest Danish supermarket chain, Coop Denmark, reduced prices by 15 to 20 percent on a large number of organic products. Boom in consumption.
1993	General economical support for organic farming is introduced.
1995	The Danish Ministry of Food, Agriculture and Fisheries presents a comprehensive Action plan I designed to propel organic farming towards the year 2000.
1996	The 7th IFOAM World Conference is held in Denmark. The Danish Ministry of Food, Agriculture and Fisheries introduce an increased support to plant producers. The Danish Research Centre for Organic Farming is established, and the Organic research station Rugballegaard is established.
1998	The number of organic farms more than triples over a five-year period.
1999	Organic organisations establish co-operation in the Centre for Organic Agriculture. Action plan II is introduced.
2000	Organic e-commerce is launched by the company "Aarstiderne" – www.arstiderne.com.
2001	Denmark hosts the European Organic Food and Farming Conference.
2003	General economical support scheme for organic farming is changed.
2004	Launch of a national campaign for the European logo for organic agriculture. The first year since 1989 with a decrease in the number of organic farms. National regulation opened up for organic fish in Denmark.

[109] The Danish Agricultural Advisory Service (DAAS), Available at: http://www.lr.dk/oekologi/diverse/org_agri.htm#Organic%20Agriculture%20in%20Denmark#Organic%20Agriculture%20in%20Denmark

Due to the excessive use of pesticides and chemicals frequently used in conventional farming, there has been a growing public concern about the contamination of food and the environment. As a result, in the last few decades, organic farming has gained increasing popularity and the trend to consume organic farming products has increased. The gradual increase in the total organic cultivation area of Denmark has depended on the consumers to pay a relatively higher price for organic products, e.g. a general observation shows that dairy organic products consumption has increased in the recent years.

4.4.3 Success Factors for Promotion of Organic Agriculture:

Various success factors for promoting organic agriculture in Denmark have been carried out extensively. Following are several of these success factors, though this list cannot be considered exhaustive:

a) State Funding
b) Level of State Involvement
c) Education and Research
d) Labelling
e) Degree of Farmer/Stakeholder Organization
f) Marketing
g) Domestic Demand

Table No. 21; Lists the success factors for promoting organic agriculture in Denmark and qualitative ranking of how well they are implemented in the country. In the ranking column, A = Very High and B = High

S.No.	Success Factors	Description	Ranking
1.	State Funding	Subsidies, green taxes, etc.	A
2.	Level of State Involvement	Action plans, cooperation with stakeholders	A
3.	Education and Research	Schools/training programs, advisory services, etc.	A
4.	Labelling	How well recognized, trusted, clear are they?	A
5.	Organization of Farmer/Stakeholder	Networks, knowledge exchange, cooperation to set policy, etc.	B
6.	Marketing	Public, private awareness, campaigns, sales initiatives, etc.	B
7.	Domestic Demand	Domestic market share	B

4.4.3.1 Description/Qualitative Analysis of Success Factors:

A brief analysis is given here in order to comprehend how Denmark has been a success story in organic agriculture.

In Denmark, the *level of state involvement* in the promotion of organic agriculture, especially *state funding*, has been a cardinal factor for growth. Historically, the level of state involvement has been very high. This has been possible through the implementation of the first comprehensive legislation on organic farming – well before the EU legislation. In addition to financial support to organic farmers, the Danish government also discouraged conventional farming by levying high taxes on products such as insecticides and pesticides.

The state controlled label, ‘red Ø-label’, was introduced in 1990 which strengthened the consumption of organic products even more. The sole label for organic products is supported by government certification and has offered a high level of certainty to consumers with regard to the genuineness of products.

The Danish government has also been deeply involved in the promotion of organic farming through education and research, direct subsidies, series of action plans and coordination of the whole sector.

The involvement of private stakeholders in organic farming has been higher in Denmark. Positive elements in this area include the involvement of supermarket chains in the promotion and selling of organic products, a high degree of cooperation amongst stakeholders themselves and good cooperation between stakeholders and public authorities.

One of the reasons for the high degree of consumption, within the domestic market in Denmark, is also a dependable supply of the organic products.

Marketing of organic products has been high in Denmark. The cooperation in marketing between the private stakeholders and the government has been very successful in Denmark. The large food chains have also been very instrumental in the marketing of organic products.

Through out the years, domestic demand has been a direct incentive for a high level of organic farming in Denmark. This is due to the awareness of the existence and the advantages of organic products over conventional products. Domestic demand has been growing in Denmark in the consecutive years. An important factor that appears to improve local demand is the credibility of the labels for organic products. The governmental support of a single label certainly helped make the label trustworthy and well known; and most likely helped create the high degree of local consumption. A single label emanating from the public stakeholder seems to be the best solution to the labeling problem.

In summary, the Danish government is highly involved in the promotion process. This includes a state-supported certification-labeling scheme, research and education initiatives, coordination and planning efforts, direct subsidization, and a series of five-year action plans.

4.5 SOIL DEGRADATION AND ITS KINDS IN DENMARK:

Soil degradation is the decline or loss of soil functions. Soil degradation takes place in all the three dimensions in Denmark. This has been described in detail in Case Study Part 1 and here they are only listed as follows:

1. Physical Degradation of Soil
2. Chemical Degradation of Soil
3. Biological Degradation of Soil

4.6 FACTORS AFFECTING SOIL DEGRADATION IN DENMARK:

A few of the all the factors that affect soil degradation are briefly presented as follows:

4.6.1 Soil Erosion:

Wind, water, sheet, rill, tillage and bank erosion are the dominant soil erosion processes in Denmark. There are two major causes of soil erosion pertaining to agriculture in Denmark, firstly, unsustainable conventional agricultural practices and secondly, overgrazing. Soil erosion reduces the overall soil fertility and productivity of the soil. This happens when the essential plant nutrients and soil organic matter are physically eroded off the topsoil and are lost.

4.6.2 Wind Erosion:

The history of wind erosion shows that this has been a problem the farmers have faced in Denmark since along time back. It has been prevalent from the Viking Ages and the Iron Age till date. The wind drift, during the Iron Age, resulted in several agricultural fields to be covered by sand.

Denmark has dealt with soil erosion problems due to wind since the last 125 years. Wind erosion is predominant on sandy soils with low soil fertility. Wind erosion is aggravated in dry and windy climatic periods and by large-scale agricultural practices.

As mentioned earlier in this chapter (4.2), the western part of Denmark is covered with sandy soils due to the Weichsel glaciation. High risk areas for wind erosion are located in western Denmark on soils developed on material from the last Weichsel glaciation. Riksen and De Graaff[110] (2001) have reported that the hazard of wind erosion is greatest (about 1 million ha) in the lowlands of western Denmark where the soils are very vulnerable.

At the Danish farm level, damage to crops, loss of fertile topsoil, loss of soil structure and the long term soil degradation occur due to wind erosion.

4.6.3 Water Erosion:

In 1984, the Danish Environmental Protection Agency published 'NPo – Report' (nitrogen, phosphorous and organic matter), in which soil erosion was indicated as an important process for transporting phosphorous from the fields to the aquatic environment.

In 1986, eutrophication appeared in the coastal waters of Denmark as a result of phosphorous (sourced from pesticides) transport to the aquatic environment. This environmental issue was broadcast on 8th October 1986 on Danish television, where dead lobsters were shown as a result of eutrophication problems in Danish coastal waters.

A report, edited by Rekolainen and Leek (1996), assesses the erosion risk over the whole territory of Denmark. According to the report, in Denmark, water erosion is considered to be the major problem. This is due to the fact that water erosion does not only have detrimental impact on soils and agriculture but also due to its noteworthy

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[110] M. J. P. M. Riksen, J. de Graaff, On-site and Off-site Effects of Wind Erosion on European Light Soils, Land Degradation & Development, Volume 12, Issue 1, Pages 1 - 11

contribution on the phosphorous loading of freshwater bodies. It further highlights areas having a higher risk of erosion which are, Eastern Jutland, Zealand and Funen in Denmark.

4.6.4 Soil Contamination:

The European Environment Agency (EEA)[111] (1998) reported the available data on the number of potentially and definitely contaminated sites in Denmark. These sites were classified as abandoned or operating industrial, waste and military sites.

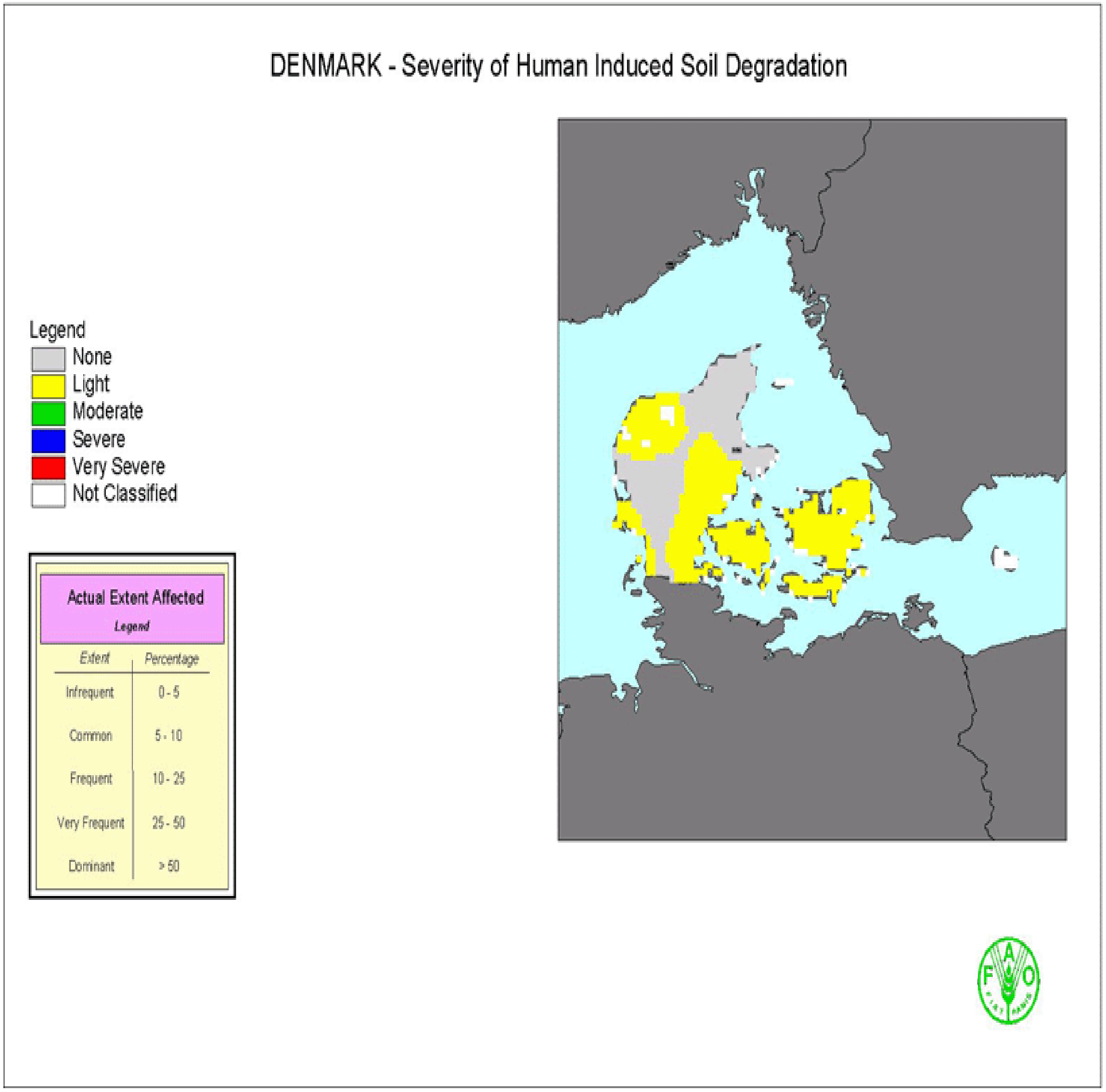
Table No. 22; Modified from the EEA report showing types of sites and number of potentially contaminated and contaminated sites in Denmark. Note: AB = abandoned, OP = operational, ID = identified, ED = estimated.

Country	**Industrial Sites**		**Waste Sites**		**Military Sites**	**Potentially Contaminated Sites**		**Contaminated Sites**	
	AB	OP	AB	OP		ID	ED	ID	ED
Denmark	X	X	X		X	37,000	40,000	3673	14,000

The data shows that in total, an estimated ~ 40,000 sites are potentially contaminated. Out of these, 37,000 sites are identified with a potential for contamination. The data further shows that a total of estimated ~ 14,000 sites are contaminated. Out of these, 3673 sites have been identified as contaminated sites and where verification of the contamination and assessment of risks has been completed.

[111] Prokop. G., Edelgaard I., Schamann M., EEA-ETC/S, 1998, Contaminated Sites in the EU and EFTA Countries, IN: Environmental Issues, 3.6 Soil Degradation, EEA

Figure No. 2; Showing the estimation of the severity of human-induced soil degradation in Denmark. Source: Food and Agriculture Organization of the United Nations[112]



[112] Food and Agriculture Organization of the United Nations, Available at: http://www.fao.org/landandwater/agll/glasod/glasodmaps.jsp?country=DNK&search=Display+map+%21

4.7 ORGANIC AGRICULTURE POLICY IN DENMARK:

The regulation of organic farming has influenced soil management practices. It enables organic farming practices to reduce soil degradation and hence manage soil in a better manner. Organic farming production standards are implemented, in Denmark, in the form of nationally adapted organic farming regulations.

In this portion of the chapter, the regulatory process of organic farming in Denmark is discussed but a brief introduction is also given to the regulation of soil activities at the Danish level. This will help one to understand how such policies affect soil degradation in Denmark. These policies affect soil degradation directly whereas the organic farming policies affect it indirectly. This is due to the fact that organic farming policies have a holistic approach in their implementation where due consideration is given to nature and the environment. Hence, soil being an essential component of the environment is included in this approach.

4.7.1 Regulation of Soil in Denmark:

Denmark has addressed the soil degradation problem at the national level and it has comprehensive regulations targeting this problem. The major laws affecting soil degradation are aimed at solving soil erosion problems. As mentioned earlier in this chapter, there are various types of soil erosion problems in Denmark such as wind erosion and water erosion. The following table elaborates several major policies implemented at the national level in Denmark:

Table No. 23; Major laws affecting soil erosion in Denmark, Veihe *et al.*[113] (2003)

Type of Erosion	Law	Title	Aim
Wind Erosion	Law No. 812 of 21 December 1988	Law on windbreaks	Establishment of windbreaks
	Notification No. 17 of 18 January 1996	Notification on windbreaks and subsidies for planting windbreaks	To reduce wind speed over areas which are being or are going to be used for agricultural purposes
	Notification No. 812 of 21 September 2001	Notification on subsidies for planting schemes to improve biotopes and to reduce wind speed	To reduce wind speed on agricultural areas and/or to act as connecting lines in the landscape and to increase the percentage of small biotopes on farms as well as to facilitate public access
Water Erosion	Law No. 302 of 9 June 1982	Law on water courses	To protect the environment in water courses
	Law No. 392 of 10 June 1987	Water Environment Protection Plan 1	Protection of the water environment
	Notification No. 655 of 9 October 1987	Notification on crop rotation and fertilizer/manure plans as well as green fields within agriculture	To reduce nitrate leaching associated with agricultural activities and to ensure optimum use of fertilizers/manure
	Law No. 9 of 3 January 1992	Law on environmental protection	Protection of the environment including a section on water courses (Law No. 302)
	Law No. 472 of 1 July 1998	Law on agriculture's use of fertilizers/manure and on plant cover	To regulate the agricultural sector's use of fertilizers/manure and to establish a demand for establishment of plant cover with the aim to reduce nitrate leaching
	Notification No. 632 of 23 June 2001	Notification on water courses (selection on buffer zones)	To maintain and secure the buffer zone and in that way to protect the water course from bank erosion associated with the use of heavy machinery in the agricultural production

[113] A. Veihe, B. Hasholt and I. G. Schiøtz, Soil Erosion in Denmark: Processes and Politics, Environmental Science & Policy, Volume 6, Issue 1, February 2003, Pages 37-50

4.7.2 Regulation of Organic Agriculture in Denmark:

The development of organic farming has been part of the Danish governmental policy for many years. One of the driving factors for this is that in many ways organic farming can directly address the problems of conventional agriculture. Prior to the implementation of the governmental regulation in 1987, particular steps were taken at the non-governmental level for policy development. In 1981, the Danish Organisation for Organic Farming (LØJ) was founded. This organisation was comprised of farmers, consumers and processors. It made its own farming and breeding regulations and had an independent inspection. These were non-governmental regulations which were mainly inspired by the IFOAM basic standards.

At the governmental level, the Danish organic agriculture is regulated by a European Union (EU) Directive and by numerous national regulations. These policies are presented in separate sections as follows:

4.7.2.1 The EU Directive on Organic Agriculture:

The legislation EU 2092/91 regulates organic agriculture in the EU. For the control of physical loss of soil, i.e. wind erosion, there is no direct policy at the European level. It is worth mentioning that organic agriculture is the only sustainable system which is defined from a legal perspective. The EU Regulation 2092/91 and 1804/99 ensure that all organic products of crop production and animal husbandry must be certified. Moreover, in the EU Regulation 1804/99, several general principles are provided for the management and rearing of farm animals.

4.7.2.2 National Regulations:

In Denmark there is a general governmental trend to draft ‘Action Plans’ for environmental regulation. These ‘Action Plans’ typically combine several tools or measures for restricting the consumption of any dangerous substance e.g. pesticides. For example, in the field of pesticides, Denmark has pursued ‘Action Plans’ since 1986. Similarly, this phenomenon has also been included in organic farming. As mentioned earlier, the Danish government in 1987 founded the Council on Organic Food and Agriculture, which has one of the key functions to draft ‘Action Plans’ for the promotion and implementation of organic agriculture[114]. Hence, in 1987, the Danish government adopted the world's first comprehensive legislation on organic farming.

For organic farming, in 1995, the Council on Organic Food and Agriculture introduced 'Action Plan 1' (Action Plan to Promote Organic Food Production in Denmark). This plan had 65 recommendations to the Minister of Agriculture, Food and Fishery in order to promote organic farming and it served as a catalyst for the political developments, pertaining to organic farming, in the consecutive years.

The Council on Organic Food and Agriculture developed the 'Action Plan II' (Action Plan for Ecology in Development) for organic farming in 1999, published by the Danish Ministry of Food, Agriculture and Fisheries. In the 'Action Plan II' there are various expectations that are described such as organic agriculture solving environmental problems. Hence those actions are mentioned which should be taken to promote the development of organic farming in Denmark.

In 2004, the national regulation opened up for organic fish in Denmark. According to the regulation, organic fish from both salt water and fresh water aquaculture can be labelled with the Danish inspection label. Certain criteria have to be implemented in order to label the fish as organic, e.g. fish are allowed to be treated with antibiotics only once, adding colour to the feed is prohibited, etc.

The organic farming 'Action Plans' have contributed to the development of the organic food and farming. For example, the implementation of organic farming in Denmark required the consensus of all the stakeholders. To reach this consensus, tackling of barriers to further development was essential. Here, 'Action Plans' have been utilized as an important instrument for the continuous dialogue amongst the stakeholders.

According to the organic farming legislation in 1987, state inspection and certification schemes were introduced in the country. The Danish Plant Directorate has a Department of Organic Farming which carries out inspection at all stages of the production and processing of organic foods. Especially, in order to verify that all is up to the required standards, the Directorate inspects the organic farms prior to the harvesting of the crops.

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[114] Anonymous (1999), Action plan II, Developments in Organic Farming, The Danish Directorate for Development, The Danish Ministry of Food, Agriculture and Fisheries (English Summary)

Shortly after the introduction of the 1987 organic farming legislation, the state inspection logo, known as the red Ø label, was also introduced. All organic farms are registered with the Directorate. The Directorate has several offices across the country.

In addition to the administrative functions, the Danish Plant Directorate prepares policies and lays down regulations for organic farming.

CHAPTER 5

DISCUSSION AND CRITICAL ANALYSIS

5.1 GENERAL DISCUSSION:

As far as the author knows, this kind of research work has not been conducted before as a case study of Denmark.

Agriculture is a locally studied subject of a particular area or region depending on agro-climatic conditions. Hence due to this dynamism, every area or region has its own unique agricultural properties and characteristics. Various farming entities are also studied locally, one being soil. Since the soil, all around the world, has various types, therefore, it becomes difficult to study soil and its interaction with agriculture globally. Whereas a site specific study of the interaction of soil and local agricultural farming practices is more useful and a better knowledge can be gained.

An important aspect of the critical analysis is to look into the soil degradation reduction, if any, that has occurred due to organic agriculture and its practices in Denmark and compare this reduction with the soil degradation status prior to the introduction and development of organic farming. This reduction in degradation can be observed in the approximately 7% of the total cultivated land which accounts for organic farming. Since the author has not witnessed and observed this information, therefore, it is not included in the analysis and this interesting area is open for further research.

This case study of Denmark gives a detailed insight to the soil management practices of Danish soils encompassing both degradation and conservation aspects. Moreover, it also sheds light on the general soil-plant interaction that takes place in the Danish landscape. A general and particular understanding can be grasped of the importance of parameters selected in this case study. The understanding is developed by looking at the empirical studies under each selected parameter which also put light on the soil degradation or soil conservation phenomena.

The case study part 1 is divided into two major divisions depending on the approach of the comparative study as shown in the methodology. The approach has been to conduct two comparative studies in light of the review of the available and accessible empirical literature for both soil degradation and soil conservation separately.

The first part, which comprises of a comparative study for soil degradation in Denmark, demonstrates from the analysis that there is some association between the two farming types (organic farming and conventional farming) and the levels of soil degradation. This further implies that there is also some statistical difference existing which cannot be established in this study due to the fact that a comparison cannot be made in light of the empirical literature used. In this part of the chapter, all three dimensions of conservation i.e. physical, chemical and biological dimensions are included. For each dimension, empirical data has been included to fully support the conservation aspect.

The second part of the chapter, which presents a comparative study for soil conservation in Denmark, shows vividly that some association exists between the two farming types and the levels of soil conservation. Similarly, this also implies that there is some statistical difference existing and this also cannot be established due to the lack of information or empirical studies.

In this study, an attempt has been made to study the soil management in both organic agriculture and conventional agriculture in light of the selected parameters, which gives us an overall qualitative picture if soil management in organic agriculture can help in reducing the soil degradation. The quantitative analysis gives us a picture of the association between the two farming types on the three levels of both soil degradation and soil conservation in separate analyses. The quantitative analysis reveals that there is some association between farming types and soil degradation/soil conservation, which implies that difference also exists. However, a comparative study followed by a statistical quantitative analysis cannot be conducted between the two farming systems, in this study, in order to find if any (statistical) difference exists in terms of soil degradation and/or soil conservation. This is due to the fact that if a statistical test needs to be applied, for this purpose, then there should be data available for both farming systems. This study, on one hand, could not include any data for the two dimensions (physical and biological) of soil degradation in organic farming (Table No. 8, Page 71) and, on the other, for the three dimensions (physical, chemical and biological) of soil conservation in conventional farming (Table No. 16, Page 117). This area of study is open for further research and if the missing values are available in the future, then it can be calculated statistically if the difference exists.

The overall findings of this thesis reveal that soil can be properly managed in organic agriculture so as to reduce its degradation in Denmark. These findings have been drawn from a unique methodology that is adopted in this thesis. The methodology stresses upon the need for a comparative study of soil management (including soil degradation and soil conservation) in both farming systems based on review and analysis pertaining to the empirical studies conducted in Denmark. The comparative study, according to the methodology adopted, has been possible due to the fact that a lot of Danish research has been conducted and published in the broad area of ‘soil management’. Moreover, other research areas which have had impact on soil management have also been utilized in the case study in an optimal manner so as to draw conclusions in order to answer the problem formulation question rightly.

Another aspect of this study shows from Denmark’s point of view, how organic agriculture and its practices preserve the soil fertility for sustainable agriculture. In this regard, the environmental benefits of organic farming are manifold. Organic agriculture and soil conservation are highly inter-linked. The essence of practicing organic agriculture is to protect the environment and its components, primarily soil. Soil can be properly managed in organic farming, in order to reduce its degradation. The environmental benefits of organic farming occur due to its management practices. These are traditional conservation farming methods, inclusion of novel technologies, exclusion of unnatural inputs like synthetic pesticides and fertilizers, etc. The management practices in organic farming emphasize on soil fertility, natural pest control, diverse crop rotations, habitat diversity, etc.

The importance of soil, as a natural resource, has been emphasized prior to the case study in order to provide a background for the comprehension of soil management practices in the comparative study from an ecological point of view. The background of soil resource management helps in understanding the significance of various environment friendly practices that are being used in Danish organic agriculture.

In the analysis, the lack of research is identified in two areas. The first one is the unavailability of data on the approximately 7% agricultural land cultivated on organic farming practices. The author has not witnessed any such data where there has been a comparative study in Denmark to look into soil conservation and degradation before and after the application of organic farming practices in all the three dimensions (physical, chemical, biological). Therefore, it might make it difficult for the policy makers to enact regulation against conventional farming, though it is a universal truth that organic farming is environment friendly and ecologically safe whereas, conventional farming is not.

The second area identified in the lack of research is that empirical studies are completely missing for some of the parameters that have been selected for both of the comparative studies. Due to lack of this data, statistical tests to determine any ‘difference’ between the two farming types cannot be determined. And hence, the lack of knowledge has affected the regulatory process in this particular area. The data is essentially required for all the three dimensions of both soil conservation and degradation in order to have a sound judgment for the policy making in this area.

In the future, if this missing data is available then it would be possible to conduct a statistical analysis in order to figure out the ‘difference’ between the two farming types for soil conservation and degradation. This would lead to the proper decision making and regulation in this important field of agriculture. But at the moment, in the presence of the available data, it has only been possible to establish statistically the ‘association’ that exists between;

a) organic farming / conventional farming and soil degradation
b) organic farming / conventional farming and soil conservation

For policy making, this information is very critical because the regulation of science is based on the results of experiments/data so that it should benefit mankind. Hence in this case, the science refers to both the organic and conventional farming, and so the regulation of science is the regulation of these farming types. Since this study shows great loopholes in the empirical data for the proper establishment of the science, therefore, it becomes difficult for policy makers to provide a solid ground for the regulation of this science. However, the results of the statistical test showing association gives some picture in evaluating the soil conservation and degradation that takes place in both farming systems. The background knowledge of both farming systems provides an insight to the environmental consequences of them.

It is beyond the scope of this thesis to theorize the reasons/factors due to which there are missing areas of empirical research, as has been presented in the comparative study and analyzed in this chapter (in Table No. 24, Page No. 148, and Table No. 25, Page No. 157). But it is important to point out the consequences which the lack of research has for regulation and societal planning in this area.

This study shows that there are certain identified areas/parameters where there is complete lack of research, as a result of which proper comparison/analysis cannot be made. If the missing areas of research which have been highlighted in this thesis (in Tables No. 24, Page No. 148, and Table No. 25, Page No. 157) are filled up by consecutive follow-up empirical research, then the consequences for environmental regulation and societal planning can be understood very clearly. In this case, the background knowledge required for policy makers would be sufficient to decide about the regulation of ‘environmental hazards of conventional farming’.

The question might arise, ‘What is needed before a scientifically sound comparison between the two farming types can be done, and proper planning be executed?’ Obviously, thanks to lack of research primarily within the area of ‘environmental hazards of conventional farming’, that such a comparison cannot be done properly at the present time, as a result of which conventional farming continues to be the dominant system in Denmark. This is in the interest of those stakeholders who promote conventional farming. They benefit from this type of farming at the expense of our environment (though more research is required in this field, but this thesis has established the positive association between organic agriculture and soil management in Denmark).

Most of the times, we hear that ‘more research is needed’. This is a tactic used to just delay the decisions that could or should be done, even if there is evidence available to some extent. Although more research is required in this area, yet the results of the statistical analysis for the association in this thesis reveal that there is a negative association between conventional agriculture and soil management in Denmark. This gives a direction to any future planning on the regulation of conventional farming in Denmark.

In the analysis, it is important to mention the meeting point between science and social science. The science is the availability of empirical data that has been included for the parameters, whereas, the social science aspect is the regulation and planning of farming practices. This interaction between science and social science proves to be highly beneficial in making future better strategies for planning and regulation. Undoubtedly, the lack of this interaction cannot guarantee an informed and appropriate decision for societal planning. This would lead to regulation which is not in the best interest of the public. Therefore, the need for this interaction has been focused in this analysis so that positive results are yielded from this particular interaction between science and social science.

The author suggests that there is a need to carry out more empirical studies in the areas/parameters which have been identified in this thesis where there is complete lack of research. There might be ongoing research and such studies should be encouraged by the government so that at the end of the day, there is ample amount of empirical data which would ultimately help in the execution of proper planning and regulation that is not biased, not based on speculations and not a result of limited research. In the future, if the problem of lack of knowledge is overcome, then in this case, it would be possible to make an informed decision regarding the soil degradation/conservation upon regulation and planning.

5.2 DISCUSSION AND CRITICAL ANALYSIS OF THE COMPARATIVE STUDIES:

The discussion and critical analysis of both the comparative studies is given separately in two portions. The *first* critical analysis is of the comparative study of organic and conventional agriculture for soil degradation, whereas, the *second* one is of the comparative study of organic and conventional agriculture for soil conservation.

5.2.1 DISCUSSION AND CRITICAL ANALYSIS OF THE COMPARATIVE STUDY FOR SOIL DEGRADATION:

The soil degradation in organic farming and in conventional farming has been analyzed separately in two portions. The *first* portion analyzes soil degradation in organic farming, whereas the *second* portion analyzes soil degradation in conventional farming.

The review of the comparative study of organic and conventional agriculture for soil degradation is summarized and presented in the following table which provides a comprehensive understanding:

Table No. 24; Review of the Parameters Selected in the Comparative Study of both Farming Systems for Soil Degradation.

Dimension of Degradation	Serial No.	Selected Parameters	Empirical Studies found in Organic Agriculture	Empirical Studies found in Conventional Agriculture	Parameters used in Soil Conservation Comparative Study
Physical Degradation	1.	Soil Compaction	No	Yes	No
	2.	Water Erosion	No	Yes	No
	3.	Tillage Erosion	No	Yes	No
	4.	Tillage	No	Yes	No
Chemical Degradation	1.	Sewage Sludge	Yes	No	Yes
	2.	Ash from Biomass Combustion	Yes	No	No
	3.	Flora Parts Mineralization	Yes	No	No
	4.	Nitrogen Losses	Yes	No	No
	5.	Sulphate Leaching	Yes	No	No
	6.	Potassium Leaching	Yes	No	No
	7.	Pesticide Application	No	Yes	No
	8.	Sorption of Pesticides	No	Yes	No
	9.	Soil Contamination due to Chemicals	No	Yes	No
	10.	Pesticide Leaching	No	Yes	No
Biological Degradation	1.	Soil Biota (including various bio-indicators)	No	Yes	Yes

5.2.1.1 Critical Analysis of Soil Degradation in Organic Farming:

The fourth column in Table No. 24 is explained in this section.

In order to comprehend this discussion and critical analysis, it is necessary to provide an account of the various parameters used in all the three dimensions of degradation separately. Therefore, the discussion on all the parameters used in all three physical, chemical and biological degradation dimensions are presented as follows:

a) Physical Degradation Parameters:

Empirical Studies were not observed in all the selected parameters of Physical Degradation (***Soil Compaction, Water Erosion, Tillage Erosion and Tillage***). Degradation due to ***Soil Compaction***, ***Tillage*** and ***Tillage Erosion*** are generally expected to be less due to the limited use of machinery on farms and the use of non-inversion tillage techniques. ***Water Erosion*** can take place in both farming systems.

b) Chemical Degradation Parameters:

As mentioned earlier in section A3 (page 40), only risks associated with the chemical degradation dimension of soil are listed, whereas empirical data showing the determined status of the chemical degradation were not observed.

In the chemical degradation dimension, ***Sewage Sludge*** is taken as a parameter because even though sewage sludge is used in Danish organic farms to increase the soil fertility, yet there are concerns that it contains organic contaminants such as Di(2-ethylhexyl)phthalate (DEHP) that may leach to the ground water through soil. Upon reaching to the ground water, they are either deposited at the water bed or there is a possibility to be dissolved in the water molecules depending on the chemical properties and solubility of the organic contaminants. In Denmark, groundwater contributes to around 99% of the total drinking water and water for domestic use. If the risk of these organic contaminants in the sewage sludge is a potential one, then in the long run, the drinking water can be hazardous to humans. But since only around 5% of the total agricultural land is organically cultivated, the quantity of sewage sludge applied can be anticipated to be very less in order for it to be a potential risk.

The parameter of ***Ash*** derived from the combustion of biomass in Denmark contains macronutrients that increase the soil fertility. But ash also contains toxic cadmium (Cd) which has detrimental impacts on the soil. If high concentration of trace elements such as mercury (Hg), lead (Pd), cadmium (Cd) and arsenic (As) are prevalent in the soil, then instead of accelerating plant growth, impaired and retarded growth of plants takes place. Though ash contains toxic heavy metal Cd, yet this amount can be reduced as shown in the case study in section A3.1.2 (page 41). Hence, if processed and remediated ash is applied to agricultural fields that contain reduced amounts of Cd, then the risk associated with its use can be reduced.

Another parameter taken into consideration is the ***Mineralization of Flora Parts***. There is a general understanding that all flora parts play an essential role in the enhancement of soil fertility. This happens due to the mineralization process that takes place in the organic flora parts. Though according to this background, it is anticipated that this particular parameter should be included in the soil conservation comparative study only, yet it has also been selected as a parameter in the soil degradation case study. This is due to the fact that there are instances where certain flora parts can be toxic in nature due to particular substances they contain. For example, ptaquiloside is suspected to be a carcinogenic compound present in the common fern (Bracken) which can be included in the food chain via soil. There might be other plants which might have certain toxic compounds that may be injurious to human health hence this area of research needs to be further explored. But so far this issue is only dealt with as a risk and it has not been determined that certain plant parts are toxic and carcinogenic in nature.

One of the important parameters selected is ***Nitrogen Losses***. Nitrogen losses/leaching is a parameter used in both the soil degradation and soil conservation case studies. Nitrogen loss has an inverse relationship to the soil, i.e. if the reduction of nitrogen losses takes place then it helps in soil conservation, whereas if nitrogen losses are high then the soil is degraded. Therefore, this parameter has been included in the thesis in both the comparative studies. Organic agriculture is a low input farming system hence it mostly relies on the elements available within it. Therefore conservation of these elements is very important in order to have fertile soils and increase in the yield. Nitrogen, being one of the essential elements, plays an essential role in the soil fertility and general plant growth. If the nitrogen losses are high the N-cycle is affected and gradually the supply is reduced. If losses are very high, then in this case, the impact on plant growth is visible. Consequently from a productivity point of view, the yield is also reduced. Generally, organic farming reduces nitrogen losses in the fields because less import of nitrogen to the soil reduces the potential for nitrogen losses which is not the case in conventional agriculture where high amounts of artificial fertilizers are incorporated into the soil environment, hence the potential of nitrogen loss being high.

Similarly, ***Sulphate Leaching and Potassium Leaching*** both are also identified as two separate parameters. These two elements also play an important role in plant development. The losses of sulpher and potassium mean that the soil cannot provide these essential plant nutrients which have adverse effects consequently. As mentioned in the case study, strict regulations have been implemented in Denmark which has had impact on the availability of sulpher in organic farming. The reduction in emissions of SO_X gases, over the years, has led to reduced deposition of sulpher on the topsoil. On one hand organic farming is a low input farming system and on the other reduced amounts of the supply of sulpher from the atmosphere to the topsoil can affect plant growth in the long run. This condition can be aggravated if sulphate leaching is high in organic farming systems. Therefore there is a great need, particularly in this area, to conduct more research and figure out the implications of reduced supply of atmospheric sulpher and its impact on crops, in the long run, in organic farms in Denmark.

For the parameters of ***Pesticide Application, Sorption of Pesticides, Soil Contamination due to Chemicals*** **and** ***Pesticide Leaching***, empirical data was not found and in principle cannot be available due to the fact that organic farming is based on the concept of being free from the use of pesticides and other chemical contaminations.

c) Biological Degradation Parameter:

Empirical Studies were not found in the selected parameter of Biological Degradation. However, this does not imply that there is no kind of biological degradation in organic farming. There is a possibility that there maybe but it might have not been reported. The author has not come across empirical literature in the selected parameter of the biological degradation dimension.

5.2.1.2 Critical Analysis of Soil Degradation in Conventional Farming:

This section explains the fifth column in Table No. 24.

To understand this discussion and critical analysis, it is necessary to provide an account of the various parameters used in all the three dimensions of degradation separately. Therefore, the discussion on all the parameters used in all three physical, chemical and biological degradation dimensions are presented as follows:

a) Physical Degradation Parameters:

Soil Compaction is a critical parameter with regards to determining the topsoil and subsoil degradation resulting in compaction from the use of heavy machinery in the fields for cultivation purposes. As a result of compaction, soil is physically degraded and this degradation can be observed in the soil physical properties. Soil compaction in Danish agriculture happens due to the extensive use of tractors and other mechanical vehicles for various purposes that include, seedbed preparation, tillage and ploughing, seed cultivation, water application, pesticide application, crop harvesting, etc. it is worth mentioning here that due to all these practices, the severity of subsoil compaction is higher in comparison to the topsoil compaction. So, due to soil compaction, both soil properties and processes are affected that lead to the gradual and rapid soil degradation. The impact of subsoil compactions can be observed in the root zone of plants. The development of roots and root hairs is hampered and uptake of nutrients is retarded as a result of which plant growth and development is slow and consequently the crop yield can be significantly reduced.

In comparison to the topsoil, the subsoil compaction has longer damaging effects on the soil biota. For example, the burrowing animals find it harder to penetrate in the denser soils. Once compacted, the loosing is also difficult and mostly it can be loosened mechanically which can cause even more damage to the topsoil. The pore space is retarded and it leads to reduced supplies of oxygen and water, which not only affects the soil biota but also the crops cultivated on the fields. Affected soils cannot absorb rainfall properly and thus are prone to erosion and runoff. Due to these and many other reasons, soil compaction is a concern to scientists. However, this topic is complicated and requires detailed information regarding the local climatic field conditions of any particular area.

Water Erosion and Tillage Erosion are also important parameters for the estimation and determination of soil degradation in Danish agriculture. Water erosion, which is *Soil Loss*, is taken as a parameter that can be included in both the farming systems, e.g. the natural losses of soil resulting from rains is present in both organic and conventional agriculture. Tillage Erosion, which is *Soil Harm*, has been observed in the empirical studies of conventional agriculture where tillage practices have a greater impact on the soil as compared to organic farming systems. This is due to the fact that limited tillage, such as non-inversion tillage, takes place in organic farming keeping in view the phenomenon of soil conservation. The best key to stop tillage erosion is to eliminate tillage. In other words, tillage erosion can be completely eliminated with the continuous use of no-till systems.

A related parameter selected is ***Tillage*** itself. Not only erosion takes place due to tillage, which has been discussed above under the ***Tillage Erosion*** parameter, but also a number of soil properties are altered. One such example, in the soil biological properties, is the reduction in soil biota that are essential for soil formation and conservation. In Denmark, rains also influence the soil post-tillage conditions. Since the average annual precipitation rate is around 30 inches and during the rainy season the soil degradation conditions resulting from tillage are aggravated because wet soil is more vulnerable to damage as compared to dry soil. The structural stability is low in such soil conditions. Another example which demonstrates the impact of soil compaction as soil chemical properties is the impact on nitrogen mineralization. The synchrony between nitrogen mineralization rate and the nitrogen uptake by plants is an important factor for the required plant growth. Conventional tillage practices do not improve this synchronization.

Tillage disturbs the living conditions of soil biota and the decomposition rates of organic matter can be delayed due to these disturbances. It also disturbs the availability of essentials elements, such as nitrogen, carbon, etc, in the soil. It has impact on physical, chemical and biological properties of the soil.

b) Chemical Degradation Parameters:

Since artificial fertilizers are mainly used in conventional farms in Denmark, therefore it is obvious that the natural fertilizers (***Sewage Sludge, Ash***), which are also parameters, are normally not used. Moreover, empirical studies were not found for these parameters and also for the parameter of ***Flora Parts Mineralization*** showing any chemical degradation in conventional farming. This degradation is normally not found in conventional farming due to the fact that the stubble and other vegetation, if any, are removed during the ploughing process which is not the case in organic farming. In organic farming, the rich organic layers, formed from the debris, stubble and other flora parts are transformed through the mineralization process.

From a general understanding, it is expected that the ***Nitrogen Leaching, Sulphate Leaching and Potassium Leaching*** (which are also parameters) can take place in Danish conventional farms due to the fact that this farming type allows high external inputs of artificial fertilizers and hence increasing the potential for leaching of all the essential elements. However, ironically, no empirical data has been found for these parameters showing chemical degradation in conventional agriculture.

Pesticide Application parameter is essential in knowing and identifying the damages caused to the soil with direct application. Pesticides affect the soil in several ways. Pesticides have detrimental impacts on both the lithosphere and hydrosphere. The soils are affected with the application. Moreover, one of the universally acknowledged aspects is the impact on non-target species. The ground water is contaminated with the leaching of pesticides and its metabolites.

In certain pesticides, depending on their chemical composition, the degradation rate can be slow, in which case, the pesticide molecules stay attached to the soil resulting in other detrimental effects in addition to the disturbance of the soil chemical environment. Hence, the slow degradation rate has been a concern to soil scientists. Pesticides and their metabolites also reach groundwater which can be hazardous to human health once this groundwater is consumed. The non-target species which are beneficial to agricultural farms are adversely affected due to pesticide application. There are various insect species that are highly beneficial in the control of various diseases caused due to pests and vectors. The concept of Integrated Pest Management (IPM) is affected if various species, which are predators of pests, are destroyed due to these pesticides. These predators do not harm the crops but in fact they kill the pests and eat them up for their own survival. This area of IPM is of relevant importance in the control of pathogenic organisms in agricultural fields. But the impact is reduced when these predators are killed, as non-target organisms, during pesticide application. Upon pesticide application, there is a great probability for the pesticides to run off to surface water during the rainy seasons. The rain water, upon reaching the soil surface, picks up the molecules of the pesticides and washes it away to the streams. This water is contaminated with the various chemicals of pesticides and if consumed by humans, can prove to be highly toxic.

In addition to pesticide application, one of the subsequent impacts on the soil is ***Pesticide Sorption***. This has been selected as a separate parameter because of its importance in the determination of chemical degradation of soil due to hazardous chemicals. The sorption of pesticides to the soil reduces its rate of bio-degradation because the soil microbes cannot have complete accessibility. This alters the chemical environment of the soil medium.

Sorption is a process which takes place in the presence of water. Rain water when precipitates also take along with it the toxic chemical molecules of pesticides. When pesticides enter the soil along with water molecules, some of it sticks with soil particles, particularly organic matter, through a process called sorption.

Pesticide Leaching is taken as a separate parameter in order to seek the chemical degradation of soil caused due to the use of pesticides from a leaching point of view. Upon application, the soluble chemicals present in the pesticides are seeped to the subsoil layer from where it reaches the water table. Upon reaching the water table, these chemicals are mixed with the groundwater and if it is consumed by humans, then the after-effects can be hazardous to human health. Pesticide leaching has caused great problems to the groundwater in Denmark, as obvious from the research findings that have been reviewed in the case study. Therefore, there is a great need to remedy the processes involved in the contamination of ground water in Denmark.

c) Biological Degradation Parameter:

There are various indicators within the parameter of ***Soil Biota***. These indicators are mostly living organisms such as insects, earthworms, collembolans, etc. Their presence is an indication that the soils are rich in fauna and flora which help in maintaining the fertility of soils. However, the soil population can be degraded with the biological degradation of the soil resulting from several factors. The soil fauna and flora are the important elements of soil formation.

There are several parameters of biological degradation such as, community diversity (soil biota), nutrient cycling, accumulation of pollutants, redox status, etc. But only one, i.e. soil biota has been selected in this study. However, there are several further indicators of this single parameter as mentioned earlier. One of the important indicators is the effects of toxic compounds on soil microorganisms. These toxic compounds found in Denmark are pesticides, toxic organic and inorganic pollutants.

5.2.2 DISCUSSION AND CRITICAL ANALYSIS OF THE COMPARATIVE STUDY FOR SOIL CONSERVATION:

The soil conservation in organic farming and in conventional farming has been analyzed separately in two portions. The *first* portion analyzes soil conservation in organic farming, whereas the *second* portion analyzes soil conservation in conventional farming.

The review of the comparative study of organic and conventional agriculture for soil conservation is summarized and presented in the following table which provides a comprehensive understanding:

Table No. 25; Review of the Parameters Selected in the Comparative Study of both Farming Systems for Soil Conservation.

Dimension of Conservation	Serial No.	Selected Parameters	Empirical Studies found in Organic Agriculture	Empirical Studies found in Conventional Agriculture	Parameters used in Soil Degradation Comparative Study
Physical Conservation	1.	Conservation Tillage	Yes	No	No
	2.	Soil Physical Properties	Yes	No	No
Chemical Conservation	1.	Reduced Nitrogen Leaching	Yes	No	No
	2.	Increased Soil Organic Matter	Yes	No	No
	3.	Increased Soil Fertility	Yes	No	No
	4.	Sewage Sludge	Yes	No	Yes
	5.	Organic Manures	Yes	No	No
Biological Conservation	1.	Soil Biota (including various bio-indicators)	Yes	No	Yes
	2.	Entomological Benefits	Yes	No	No
	3.	Avian Benefits	Yes	No	No
	4.	Crop Rotations	Yes	No	No
	5.	Use of Catch Crops	Yes	No	No
	6.	Farm Hedgerow Diversity	Yes	No	No

5.2.2.1 Critical Analysis of Soil Conservation in Organic Farming:

The fourth column in Table No. 25 is explained in this section.

In order to comprehend this discussion and critical analysis, it is necessary to provide an account of the various parameters used in all the three dimensions of conservation separately. Therefore, the discussion on all the parameters used in all three physical, chemical and biological conservation dimensions are presented as follows:

a) Physical Conservation Parameters:

In Denmark, ***Conservation Tillage*** in organic farming can be considered as one of the most important parameters in determining the physical conservation dimension of soil. The essence of soil conservation lies in the practice of conservation tillage. Conservation tillage means ploughing the soil in an optimal manner where the natural state of the soil environment is disturbed to a minimum possible extent. There are various techniques applied in conservation tillage in Denmark. All techniques have the same objectives, i.e. a) to reduce *soil loss* in the form of erosion and overland flow, b) to reduce *soil harm* in the form of various anthropogenic activities. With the help of these techniques, the soil loss and soil harm is minimized to a greater extent. Most of the conservation tillage techniques leave more plant matter on the soil surface which is converted into inorganic form. The benefits of conservation tillage are manifold.

The basic principle of conservation tillage is to disturb the soil condition to a minimum possible extent. This parameter has its importance in soil conservation because it involves less manipulation of the soil environment. Conservation tillage has a direct impact on the physical state of the soil, especially its structure. Of the various techniques of conservation tillage applied in organic farming, non-inversion tillage and reduced tillage are widely used. These techniques ensure high conservation in the tillage process. They not only increase the topsoil density but also improve the subsoil by non-compaction.

Another parameter, normally studied independently of conservation tillage in the physical conservation dimension is ***Soil Physical Properties***. Though there are several properties associated to this parameter, yet it is considered as one parameter in this study. One of the physical properties considered under this common parameter is the formation of soil crumbs in the farms. Soil crumb formation is a physical characteristic that is highly beneficial to the soil environment. Soil crumbs form when soil molecules are bound to each other. Infact, soil crumb formation takes place when the humus is mixed with clay. This aggregation results due to several key players such as chemical bonding, living organisms, water molecules, soil parent material, etc. These are known as 'Soil Binding Agents'. Soil crumbs are rich in mineral content and they significantly improve the drainage of the soil. The macropore formation during the soil crumbs formation plays an important role due to the fact that these macropores allow more oxygen, water and nutrients to circulate through the soil. Additionally, an important factor of plant growth related to soil crumbs formation is that plants are not liable to nutrient and water stress.

b) Chemical Conservation Parameters:

In the parameter of ***Maintaining Soil Fertility***, there are a few indicators that collectively contribute to maintaining the fertility of the soil. These indicators are; a) reduced nitrate leaching, b) increased organic matter and c) increased soil fertility.

Reduced nitrate leaching assures to maintain soil fertility. This indicator demonstrates the availability of nitrogen in the soil environment. The higher the rate of nitrogen leaching, greater would be the loss of nitrogen from the soil and the plants would get reduced amounts of this important growth mineral. Therefore, organic farming practices try to ensure the reduction of nitrate leaching so that the required amounts of nitrogen is supplied to the crops for their optimal growth. An important aspect in organic farming is that it greatly relies on the internal sources of nitrogen as no external inputs are allowed. Therefore, all the internal available nitrogen has to be properly utilized. This can be managed to a greater extent with the help of various management practices.

The indicator of *increased organic matter* presents the condition of the topsoil fertility. The high organic matter content of the soils is responsible for the release of mineral elements. These nutrients reflect the high state of soil fertility. The organic matter is composed of animal and plant remains, the plant remains being more dominant. Various plant parts such as the roots, stubbles and leaves contribute to this organic matter. After crop harvesting, the root system remains in the soil contributing to enhanced soil fertility.

Though reduced nitrate leaching and increased organic matter in the soils contribute to soil fertility, yet ***increased soil fertility*** itself can also be considered as an indicator for the parameter of 'maintaining soil fertility'. The management practices that are applied in organic agriculture not only enhance the soil fertility but also maintain it. This gives support to the notion of sustainable soil fertility which ensures that the soil will remain fertile for a longer period and thus the next generations that will come, will not face many problems that are associated with soil degradation.

Application of Organic Fertilizers is a parameter taken into consideration under the chemical conservation dimension due to its high importance in organic farming in Denmark. Since artificial fertilizers are not used in organic farming, the demand for organic fertilizers is always high. An important aspect that is observed in Denmark associated to the use of these fertilizers is the transportation element from urban to rural areas. The re-circulation of nutrients and organic matter from urban to rural areas is important in organic agriculture. Therefore, re-circulation is a basic principle within organic farming and these nutrients entering into urban areas should be returned to it. During this process the public in Denmark has raised certain concerns pertaining to this re-circulation. One such concern is contamination with organic pollutants, heavy metals or even GMOs. But processing of organic wastes, such as composting, minimizes the risks of such contamination.

The various sources of fertilizers that are frequently used in Denmark are human wastes, municipal sorted waste compost, sewage sludge and purely organic fertilizers used are cattle slurry, deep litter and green manure. However, empirical literature could only be found for sewage sludge and organic manures. The importance of the application of organic fertilizers has already been highlighted in the comparative study. Much research work has been conducted on sewage sludge in Denmark due to the fact that with the application of sewage sludge in the correct amount, the fertility goes up, due to the presence of high content of nutrients and organic matter in it.

c) Biological Conservation Parameters:

As mentioned earlier, though there are several parameters to determine the level of biological soil degradation dimension, yet only one (Soil Biota) has been selected due to its importance. But in the case of the dimension of biological soil conservation, there are several parameters that are selected due to the importance of these in organic farming. Still there is a common parameter used in both cases, this is the parameter of 'soil biota'. This is an important parameter which can be used to determine both the biological degradation and conservation dimensions.

Abundance of Soil Biota is a parameter which cannot be ignored when determining the soil biological conservation dimension. This parameter is of paramount significance due to the fact that living organisms are an essential element in the soil medium amongst others. The higher the presence of living organisms in a soil represents higher biological conservation which subsequently has a highly beneficial impact on the fertility of the soil. Within this parameter, there are various indicators which are primarily living organisms and they reflect or indicate the level of biological conservation in soils. The populations of various indicators have been presented in detail in the comparative study in light of the empirical studies conducted in Denmark.

In organic farming systems, insects and birds can also be essential parameters for the detection of biological conservation. Hence, the parameter of ***Entomological and Avian Benefits*** has been selected. Beneficial insects are actively observed in organic farming systems due to the fact that there are no traces of pesticides which normally hinders the rapid growth of their populations. The second component of this parameter is birds which are widely observed in organic fields due to the presence of insects which they feed on. As mentioned in the comparative study for soil conservation, organic fields in Denmark possess only a few bird species but still there presence is a positive indication in terms of conservation. Biological conservation of all life forms, both flora and fauna, is eminent in organic farming.

Organic Cropping Systems itself is a parameter which has various indicators. These indicators are basically the various farming practices within cropping systems that determine the level of biological conservation in organic farming. These management practices have been used since a long time and their impacts have been widely acknowledged. One important indicator of this parameter is the *crop rotation practice*. This is the practice of cultivating different crops on alternative basis on the same land in the successive years or seasons. The benefits of crop rotation are manifold but it is usually practised to replenish soil and curb pests and the diseases that they spread. Crop rotation helps in maintaining the sustainability and the efficiency of cropland in the long run. Crop rotation systems promote an increase in organic matter. The cited literature in the comparative study for soil conservation has highlighted the importance of crop rotations in organic farms in Denmark.

Another indicator is *catch crops* which are extensively used in organic farms. These crops provide soil with the essential nutrients in order to increase their fertility. A combination of management practices that include the use of catch crops in crop rotations practices has shown to have highly beneficial impacts on the biological conservation of the soil. An important aspect of catch crops that has been observed in the cited literature reveals that fact that these crops can reduce the loss of nutrients from the soil and make them available for the next crop. Catch crops are good tools in organic farming systems for the detection of biological conservation of soil. Most of the catch crops that are grown in Denmark are used to catch the element nitrogen from the soil and prevent it from leaching.

The parameter of ***Farm Hedgerow Diversity*** also provides information regarding the biological conservation dimension. The presence of various types of vegetation in the hedgerow soils is an indication of high biological conservation. Therefore this parameter plays an important role in understanding the biological conservation that takes place in organic farms in Denmark. Empirical literature in the comparative study has already shown that the diversity of vegetation in the farm hedgerows is greater in organic farms as compared to conventional farms. Most of these studies are comparative studies and in such studies, it is relatively easier to determine the farming system where farm hedgerow biodiversity is greater.

5.2.2.2 Critical Analysis of Soil Conservation in Conventional Farming:

This section explains the fifth column in Table No. 25.

It has already been explained in the comparative study that no empirical data was found in conventional farming. Though this is anticipated but still this does not mean that no sort of conservation takes place in conventional farming in Denmark. There might be some kind of conservation taking place but at the same time there is a possibility that this might have not been reported. The author has not come across any kind of empirical data pertaining to all the selected parameters for the soil conservation in the three dimensions, i.e. physical, chemical and biological in conventional farming in Denmark.

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