7 A Co-Production Perspective on Soil Development in the Friesian Woodlands

Martijn P.W. Sonneveld, Johan Bouma and Tom Veldkamp

1 Introduction

Soil science has mainly developed along two distinct lines, both of which have their origins in the 19th century. One followed the work of Carl Sprengel and Justus von Liebig on the mineral nutrients of plants and the theory of the Law of the Minimum[1]. The other one followed the work of Dokuchaev and Hans Jenny on the theory of soil forming factors. Soil classification and soil survey mainly originate from this second school of thought. Their products, soil taxonomic systems and soil maps respectively, have now been completed in many countries all over the world.

Humans have traditionally been regarded as being one of the soil forming factors. However, in general, soil taxonomic systems only include very major alterations to the soil profile caused by land use practices over a significant period. The effects of different types of management over shorter periods (of say, decades) are usually not considered[2]. Thus, the man-made plaggen soils are for example recognised as separate classes but the effects of more recent changes in land use are not reflected within distinct (sub)-classes[3].

The large amount of information that has been gathered about Dutch soils has provided the means to rationalise land use practices and increase agricultural productivity[4]. An influential textbook on theoretical soil science from 1970, written for employees of the Dutch Ministry of Agriculture, formulated productivity (P) as follows:

$$P = f[(S, C, L)\, M] \qquad (1)$$

The symbols in this equation refer to aspects related to soil, climate, landscape and the management influences of the farmer respectively. Reasoning from the viewpoint of potential productivity (calculated for example on the basis of photosynthesis), the actual productivity of the land was thought to be a function of the limitations caused by these production factors. This is expressed in the formula below, where the subscript *l* refers to limitations of these specific factors.

$$P_{act} = P_{pot} - [(S_l, C_l, L_l)\, M_l\,] \qquad (2)$$

Soil suitability systems were developed which included qualitative assessments of the suitability of, and limitations on, agricultural land use, mainly based on expert judgment and field trials[5]. For example, for the Dutch grasslands, the soil suitability classification system included, factors such as moisture supply capacity, drainage status and trafficability, yielding a total of 28 possible suitability classes. These have been included in many subsequent soil survey reports. In suitability systems such as these, or other land evaluation systems, the effects of different land use trajectories within a single soil series or land unit are usually not accounted for[6].

In recent years, concerns about the environmental impact of agricultural activities have stimulated the broadening of research aims. Such concerns can be seen as adding a further constraint on the potential production of a particular soil. Yet, they may also lead us to a different way of looking at soils. Recent publications have indicated that different agricultural practices carried out on, initially similar, soils can result in significantly different soil properties (Droogers and Bouma 1997; Pulleman *et al.* 2000). This insight provides a 'window of opportunity' (Bouma 1994) for re-balancing land-based agricultural systems, taking account the characteristics of specific soils within the context of the landscape and agricultural practices. In this approach, soils are seen as the result of co-production between natural processes with land use practices.

This chapter explores the potential of this co-production perspective for dairy farming systems in the Netherlands. It draws on empirical evidence from a case study, of the VEL and VANLA environmental co-operatives[7] in the Northern Friesian Woodlands. The following section of this chapter provides a brief introduction to the characteristics of the region, and particularly of its soils. The soils in this area are sandy and the loss of nutrients, especially nitrate, to groundwater is an important issue. We follow this by a discussion of important land use trajectories for dairy farming in the Netherlands. The problem of nitrate leaching is discussed, together with the approaches that have been proposed to address this problem. In the light of this we review the different land use trajectories that have been adopted on a single soil series and show how they have led to different soil characteristics (specifically with respect to nitrate leaching) and thus lend themselves to different management strategies. In conclusion we discuss the issue of re-balancing co-production from a spatial point of view.

2 The Friesian Woodlands

2.1 Soil surveys

The soils of the Friesian woodlands have been extensively surveyed and mapped. Veenenbos (1949) undertook one of the earliest soil surveys of the Friesian Woodlands, a detailed soil and landscape survey which aimed at producing a map to indicate which soils were suitable as arable land, grassland and rotational land[8]. This survey later led to the publication of a landscape description and a soil map (Veenenbos 1954; Veenenbos 1964). Further survey work was carried out by van der Schans and Vleeshouwer (1956), whose work aimed at improving the hydrology of the VANLA area (in the municipality of Achtkarspelen). They also provided information on the suitability for grassland of the units that they mapped. Cnossen and Heijink (1958) subsequently made a more detailed description of the northern part of the Friesian Woodlands which, to a large extent, overlaps with the VEL and VANLA area. The Dutch soil classification system (de Bakker and Schelling 1966) initiated the mapping of soils across the entire Netherlands. The Friesian Woodlands were surveyed between 1972 and 1978, leading to the publication of 1:50,000 scale soil maps and additional reports (StiBoKa 1981). More detailed surveys of the area were performed by (Kiestra and Rutten 1986) and (Makken 1991), yielding additional information on soil properties and the distribution of soils in the landscape.

2.2 Landscape development

It is evident from these surveys that the current landscape of the Friesian Woodlands is to a large extent a man-made one, which has dramatically changed over the past one thousand years. Prior to these human interventions the landscape was shaped by Pleistocene (peri-)glacial morphology and Holocene peat deposits. The most southern part of the area belonged to the large till-plateau of the north of the Netherlands, where glacial till is covered by wind-blown sands. Large drainage valley systems were able to erode most of the till and cover sand in the northern part of the area. This provided the opportunity for marine influence when the sea level rose during the warmer climate of the Holocene. These wetter conditions stimulated peat growth, especially on the transition between the higher till-plateau and the lower lying marine areas. Peat also developed in poorly drained depressions in the sandy area and came to form substantial peat deposits in the northern provinces.

The earliest embankments were created before 1100 A.D. to protect the area from the sea. After the second half of the 13[th] century, dykes were created to more effectively protect the area against large-scale sea intrusions. This stimulated human occupation and reclamation of large parts of the peat area. Peat reclamation activities took place in different phases but were mostly finished by the beginning of the 19th century. In time, large, mostly sandy, areas had become reclaimed for agriculture. Cultivation of arable crops was initially the most common land use on these sandy soils but in time most arable land was gradually transformed into grassland, and dairy farming has been the dominant land use for more than the past hundred years.

2.3 *A typical soil*

The typical sandy soils of the area closely resemble the renowned man-made plaggen soils[9]. The original sandy soils that developed in the Pleistocene covered sand deposits, had poor fertility and were also very wet. A mixed farming system was adopted where sheep manure was collected in pot-stables in which heather-sods were used as bedding material. The resulting plaggen manure, a combination of dung and heather-sods was applied to the arable fields. As well as increasing the fertility of the soil, this also gradually raised the soil, freeing it from frequent waterlogging[10]. These soils do not completely conform to the characteristics of typical plaggen soil and are sometimes referred to as plaggic intergrades (e.g. Pape 1970). In the former peat reclamation areas, the soil that appeared at the surface was also extremely low in fertility. As a consequence, it became common practice to mix peat remains with the underlying subsoil dredged from reclamation canals. These canals also provided the infrastructure to bring in large amount of city waste and materials from artificial hills, both of which improved fertility. Hence, a man-made surface layer was developed on these sandy soils, which, from a soil morphological point of view, makes them comparable to the plaggic intergrades. Many of these soils are classified as 'laarpodzol'[11] soils and belong to the cHn23 soil series. They cover large parts of the northern Friesian Woodlands and constitute more than 40 per cent of the land in the VEL and VANLA area. Most of the land in this soil series is currently used as grassland. These have been subject to different trajectories of land use, following recent developments and trends that have occurred in Dutch dairy farming.

3 Land Use Developments in Dutch Dairy Farming

3.1 *Cultivation of silage maize*

One of the most eye-catching developments in dairy farming in the Netherlands has been the increase in area used to cultivate silage maize (*Zea* mays L.). Before the 1970s the area used for maize was negligible, but by the 1990s it had grown to more than 200,000 ha (Table 1). In some exceptional years during the 1990s more than 230,000 ha of maize was grown.

Table 1 Area in The Netherlands used for growing silage maize (1000 ha, source: CBS 2000)

Year	1970	1975	1980	1990	2000
Netherlands	6.4	77.5	139.1	205.8	205.0

Recent years (2001 and 2002) have seen a stabilisation of this figure at just above 200,000 ha. Some 60-70% (more than 130,000 ha.) of this maize is used for dairy farming (van Dijk *et al.* 1995). Several reasons have contributed to the widespread adoption of maize. Firstly, this roughage crop is fairly easy to cultivate and gives a good yield, of consistent quality. Secondly, the control and removal of weeds is simple. Thirdly, cultivation demands little labour or attention and the crop can therefore be grown on fields distant from farm buildings and can be managed by a contract worker. Fourthly, subsidies are available for maize cultivation (Anonymous 1993; Maenhout 1984). Finally maize is tolerant of high applications of organic manure, which means that it fits well in intensive animal farming systems. The possibility of growing maize on remote fields has meant that is often continuously grown, without rotation. During the mid-eighties there were indications that this practice was leading to a decline in yields. At the same time, concerns were expressed about the effects that this would have on soil structure[12]. Research carried out in the mid-eighties Alblas (1990) estimated that about 50 per cent of the maize fields in the Netherlands had a slightly compacted subsoil and severe compaction of the subsoil had occurred on some 25 per cent. Although the Ministry of Agriculture later provided some guidelines for minimising negative impacts on the soil under a regime of continuous cultivation (van Dijk *et al.* 1995), considerable damage to soil structure still seems widespread.

3.2 *Grassland renovation*

Another important change that has occurred in land use within dairy farming systems is the ploughing and reseeding of grassland. This is done, mainly to improve the botanical composition of the sward. As grasslands mature they generally go through a less productive period, called the 'years of depression' or in Dutch the 'sukkelperiode.' One strategy to offset this problem is to adopt ley-arable systems. However, a more widely adopted strategy for grassland improvement is that of ploughing and reseeding. Scientific interpretations of the benefits and disadvantages of this practice differ[13]. This is illustrated by Hoogerkamp (1974), who describes how research and extension agencies in the UK and in Germany arrived at conflicting views over the issue of ploughing and reseeding grassland. Field trials on experimental plots in the UK in the first half of the 20th century showed that production levels were greatly improved when grassland was ploughed and reseeded. As a consequence, British researchers and extension workers advocated young (and especially temporary) grassland. Experimental work by German grassland scientists led them to different conclusions. They found that although production levels are higher shortly after reseeding, they quickly fall below the levels of old grassland. In consequence German farmers were advised to maintain their old grassland and ploughing and reseeding was not promoted.

In 1992/1993, it was estimated that reseeding was carried out on 4.6 per cent of the total grassland area in the Netherlands. This is lower than the figures for the 1980s (Verstraten 1996) but there are considerable regional variations. In the southern part of the Netherlands the figure is much higher, at 10 per cent. In 1999 the national figure had risen to 7.7 per cent of the total grassland area. In all some 70,000 ha, was being reseeded annually (CBS 2000). Eighty five per cent of this area was grassland that had been established for less than 15 years. This seems to indicate that the occurrence of the 'years of depression' acts as a major stimulus for grassland renovation.

3.3 Maintaining old grassland

Hoogerkamp (1984) drew on earlier work by 't Hart (1950) which suggested that the period of lower production can be overcome through proper grassland management and relatively good soil conditions which are the keys for creating high-quality old grassland[14]. The traditional farming phrase *'oude kracht'* (old force) is used to indicate this quality and is often used a justification for not ploughing up old grassland. The high value attributed to old grasslands may be related to their generally high organic matter content. Some regard this as *'locked-up capital, bearing no current interest'* which can only be used when a conversion to arable land takes place (Davies 1960; cited by Hoogerkamp 1984). Hoogerkamp (1974) takes issue with this and emphasises the importance of organic matter for grassland production because it provides a more abundant supply of nitrogen. He also stresses that reseeding is costly and carries a considerable risk of failure. Other reasons also underlie the maintenance of old pastures. Tradition and the preservation of biodiversity[15] are now frequently mentioned as reasons, but location, accessibility and the importance of the whole-farm strategy can also be important reasons for farmers (Janssens *et al.* 2002). In the VEL and VANLA area, farmers also mention that ploughing and reseeding brings less fertile subsoil to the surface in some parts of the fields (van der Ploeg 1999).

4 Soil as an Intermediary between Dairy Farming and the Environment

4.1 The problem of Nitrate leaching

After the 1970s it became clear that dairy farming was a significant contributor to the contamination of ground and surface waters by nitrate (Cameron and Wild 1984; Garwood and Ryden 1986; Ryden *et al.* 1984). Nitrate itself is not toxic but the process of reduction of nitrate to nitrite may lead to methaemoglobinaemia[16], posing health problems especially for young children. According to the European Drinking Water Directive, nitrate concentrations in water are not allowed to exceed the maximum admissible concentration of 50 mg nitrate l^{-1} (EC 1980). This same value was also used in the Nitrates Directive, adopted by the European Commission in 1991 (EC 1991). This Directive aimed to protect water against nitrate pollution from agriculture[17]. Its objectives were to control nitrate concentrations and to reduce the associated problems of eutrophication (Tunney 1992).

The leaching of nitrate from dairy farming systems may be the result of different processes[18]. In dairy farming, some studies indicate that grazed swards are particularly likely to lead to high nitrate concentrations (e.g. Scholefield *et al.* 1993; Whitehead 1995). Other studies have pointed to the leaching of nitrate following the ploughing of grassland (e.g. Lloyd 1992; Whitehead *et al.* 1990). This increase is mainly short term on reseeded pastures but may be substantial when a long-term arable period follows a grassland period. Losses of about 4 t N/ha have been reported from the upper 25 cm. Whitmore *et al.* (1992) found that in many areas in the UK, conversion of grassland to arable land may be held responsible for half of the nitrate concentrations observed in groundwater.

Recently established, ageing swards, there is generally a built-up of organic carbon and organic nitrogen. Initial rates of nitrogen storage or immobilisation are often high (in the range of 50-150 kg/ha) but these will decline over time as the build-up is asymptotic. Scholefield *et al.* (1993) compared nitrate leaching from a ploughed and reseeded pasture and a nearby 40-year old pasture. Using a constant input level of 400 kg fertiliser-N/ha they found that nitrate leaching on the old pasture was consistently higher, but noted that substantial N loss had probably occurred on the reseeded pasture in the first winter after ploughing. Cuttle and Scholefield (1995) attributed this to the higher potential of reseeded grassland to immobilise nitrogen. Because the net accumulation of nitrogen declines as the pasture ages, they concluded that a constant nitrogen input will result in increased nitrogen losses over time. In younger swards the efficiency of N fertiliser is relatively low (in terms of grassland production) as a higher proportion of the nitrogen that is applied contributes to the build-up of organic matter in the soil, rather than contributing to grass production. On this basis the accumulation of organic N in the soil will lead to increased mineralisation of soil-N and is an essential prerequisite to the greater efficiency of fertiliser use in longer established swards.

4.2 Addressing nitrate leaching at national level

Following the Nitrates Directive, the Dutch government implemented specific legislation to reduce nutrient losses from agriculture. In 1998, the Mineral Accounting System (MINAS) was adopted (van den Brandt and Smit 1998). This is a farm-level nutrient budgeting tool, aimed at achieving a reduction of nutrient losses, including nitrates, to the environment, and imposes levies on farmers who do not meet specified targets (Neeteson 2000).

This strategy involved developing thresholds that were both environmentally and agriculturally acceptable. Calculations of the agricultural acceptability were based on a series of (six) combinations of soil type and drainage status. These, it was assumed, would account for soil heterogeneity[19]. Other soil properties such as organic matter content, moisture and nitrogen supply capacities, were regarded as constants (van Eck 1995)[20]. As discussed in the first section, the approach adopted in this desk-top study took existing soil suitability systems and superimposed environmental quality, (in this case the maximum admissible nitrate concentration in groundwater) as an additional constraining factor. Influences of soil management were not taken into account. When implemented the thresholds were simplified to two different soil types, with one loss standard being applied to dry sandy soils and the other to all other soils.[21] Aside from imposing these thresholds, other regulations were adopted concerning grassland management and the use of animal manures and fertilisers (LNV 2001)[22].

4.3 Local land use trajectories in the Friesian Woodlands

Sonneveld *et al.* (2002) have recently investigated the effects of different land use trajectories on the properties of soils in the cHn23 soil series that are currently under grassland. Some of the findings of this study are given in Table 2.

Table 2 shows that the upper layer of land previously under continuous maize cultivation has considerable lower amounts of organic carbon in comparison to both reseeded and old grassland and considerably less organic nitrogen compared to old grassland. The subsoil (25-50 cm) of land previously under continuous maize cultivation also has considerably less organic carbon. In total there is a difference of up to 58 tons C ha^{-1} between (previous) arable land and old grassland. The differences in the subsoil are less pronounced which, to a large extent, is due to the higher densities of the subsoil. Differences between the bulk density of the sub soil and the topsoil were considerably lower for the old grassland (1.5 per cent) than on reseeded grassland and previous arable land, where these values were 5.9 per cent and 4.1 per cent respectively. The bulk density of the subsoil of the maize field was more than 16 per cent higher than that of old grassland, a difference that could be expected to limit rooting possibilities. .

Table 2 Variations in the properties of cHn23 soils according to differences in land use history

Land Use History	*0-25 cm*		*25-50 cm*	
	Organic Carbon	Organic Nitrogen	Organic Carbon	Organic Nitrogen
	tons ha^{-1}		tons ha^{-1}	
Grassland with previous cultivation of silage maize	89.2	9.3	90.5	9.6
Reseeded Grassland	119.3	9.5	102.2	8.6
Old Grassland	131.0	11.1	106.3	7.9

In general the survey showed that the ploughing of grassland to a depth of 25 cm leads to decreases of about 20 tons ha^{-1} of soil organic matter content and 1.5 tons ha^{-1} of organic nitrogen, in comparison with old grassland. This nitrogen will be partly taken up by the plant and partly lost to the environment. Averaging across the samples, we calculated that 67 per cent of the total variation in the percentage of soil organic carbon and 57 per cent of the variation in nitrogen content could be explained by land use history[23].

These findings challenge some of the assumptions that underpin soil suitability classifications, land evaluation systems and the recent classification systems that aim to achieve environmental goals. They show that agricultural practices have a significant effect on the characteristics of soils within this anthropogenic soil type. This influences the loss of nutrients to the environment and the risk of agrochemicals leaching into the groundwater (e.g. Droogers and Bouma 1997). In other words, locally different land use trajectories influence the relationships between agricultural systems and the (biophysical) environment. Dairy farms located on the same soil series, using similar fertilisation strategies may experience a wide range of economic and environmental outcomes because of spatially explicit variations in land use history. This observation provides an insight of potential value in the search for sustainable agricultural systems.

5 Spatially explicit paths towards sustainability

5.1 Local soil knowledge

For researchers, similar soils that have been subjected to different land use trajectories can also be regarded as 'field experiments'. In embarking on such ventures it is essential to remember that the perceptions of farmers about their soils and their behaviour may differ from those of the researcher (Bouma 1993; Garlynd *et al.* 1994; Harris and Bezdicek 1994). For example, soils often have local names, which, in many cases, are expressions of the more holistic approach of local farmers compared to scientists[24]. This approach has been described as 'art de la localité' (van der Ploeg 1991) or 'the art of the specific'. It involves a degree of craftsmanship; the ability to combine the specific elements of a farm such as animals, soils, crops and technology into a 'working whole' (Roep 2001). Local knowledge forms in essence the vehicle for integrating and co-ordinating the elements that exist within the farm system and farmer's labour acts as the linking agent, coordinating the various farm components and balancing them in relation to each other (van der Ploeg 1991). Agricultural enterprises are a unique integration of natural phenomena and human activities that are transformed into a working agro-ecosystem. In contrast with researchers, local people may think of a soil, not so much as 'something out there' but more as 'something inside' (Sillitoe 1998). Mendras (1970) reported from his research that

> *'the farmer felt as if he 'made' his field and knew it as the creator knows his creation, since the soil was the product of his constant care; ploughing, fertilising, rotating crops, maintenance of fallow ground and so on'.*

The assemblage of fields within a farm, become a unified working whole through the decisions and activities of the farmer. Through his selection of fields for different purposes and exerting his 'freedom' to apply different forms of management on different fields and at different times, the farm becomes a unique configuration of characteristic land units and land use. The specific combination of social, material and natural elements and the interrelationships between them, expresses a 'farming style' (van der Ploeg 1999). These appear as an expression of a coherent set of strategic notions about the way in which farming should be practised. This implies that, for local people, knowledge about the soil is part of a broader domain of knowledge. It is contextual, locally embedded within a cultural repertoire[25].

Changes in soil and landscape properties that have been brought about by past activities can affect both the awareness and the ability of the farmer to build new strategies. This is often expressed or perceived through characteristics that are not normally included within standard research enquiries although they do relate to recognisable land and soil quality parameters. For example, one farmer in the Friesian Woodlands said that he decided to minimise use of ploughing in grassland renovation because one of his fields felt like 'concrete', rather than resilient, after ploughing. This indicates how farming activities are often informed by a degree of reflection and looking back at past results. Tasks are continuously observed, interpreted, evaluated and adjusted (van der Ploeg 1987). Dairy farmers who did not follow the trend of frequently renovating their pastures (and were seen as 'old-fashioned') now find that they are considered to be 'modern' farmers, as their grassland management strategy meets requirements for lower emissions to groundwater.

5.2 Soils and co-production

The term co-production refers to the on-going interaction between farmers and living nature resulting in their mutual transformation (Gerritsen 2002; Renting and van der Ploeg 2001; Roep 2001; van der Ploeg 1999). Co-production influences the characteristics of farming, natural resource management and living nature (Roep 2001). Within this framework, the soil is both the result of an interaction between natural processes and land use practices, and influences future land use decisions and biophysical processes.

In contrast with other components of agriculture (such as technology, crops and animals) that can also be considered from a co-production perspective[26], the soil is non-transferable. It is at the roots of the locality and is specific to the field, the farm or the region. It influences farming in a number of ways, through e.g. the specificities of technology, crops and management practices. Yet at the same time it is influenced by these practices. Specific landscapes can, for example, be regarded as outcomes of co-production (Faber *et al.* 2000; van der Ploeg 1999), as results of continuing encounters and mutual transformation between man and nature. Land and landscape do not merely form the physical backdrop for human action but are the result of, and canvas for, a whole set of complex connections. People are generally connected to the landscape in which they grew up, which often contributes to an individual's sense of identity and feeling of belonging. Röling and Maarleveld (1999) refer to this as the 'soft side' of land, which reflects past interactions between people and land, in terms of organisation, religious beliefs and cultural practices[27]. In the future, these facets will influence individual and societal decisions that are taken about the development (or preservation) of these landscapes as well physical characteristics, such as nutrient flows, that occur.

In a narrower sense, co-production is also a part of agriculture. Land use practices influence land properties and these changing properties in turn influence the knowledge and behaviour of the land users. Land use is not simply a set of technical operations and artefacts, rather it is an emergent property of the interactions between the land and the society that lives from it. Natural limits on land use activities may exist because of, for example, geological and geomorphological conditions but can be reduced, removed and altered by human resourcefulness. The 'hard' way in which land and land use often been conceptualised is not so rigid at all. There is space to diversify or, more poetically, to *unfold*. It is possible to create specific expressions of the land and the soil. One farmer, again cited by Mendras (1970), expressed this idea this way: 'to know one's land, to improve it, takes a long time. The more you know it, the more you become attached to it'.

Izac and Swift (1994) regarded the unfolding material outcomes of the soil as *by-products* of agriculture, distinct from the general variety of agricultural *products*, such as animals, crops, fruits and medicines. Useful though this conceptualisation is, it does not sufficiently stress that such a by-product is also re-used within the farming system. Specific soils are an output of, and at the same time an input for, agriculture. In (semi) closed farming systems *all* products are inputs to the farming system through e.g. breeding with animals or producing seeds with plants. In other words, there is a continuous production and reproduction.

Droogers and Bouma (1997) have proposed a dual classification of soil systems; covering; *geno-phorms*, the taxonomically defined soil series, and *pheno-phorms*, the results of different types of management or land use. The later category would allow for specific expressions of a soil series that are related to land use history. Their work builds on the concept of the soil series as defined in Soil Taxonomy (Soil Survey Staff 1975). This later conceptualisation of soils serves as a vehicle to transfer information and research knowledge about soils from one area to another. In other words soil series are conceptual groups (Arnold 1983) that encompass a whole set of real soils (polypedons) which have evolved under different land use practices. Thus soil series can act as carriers of land use history.

5.3 Re-balancing co-production: a spatial perspective

The suitability of soils for grassland production cannot be unambiguously assessed solely on the basis of their biophysical properties[28]. The same is true when seeking to evaluate the potential for nitrate and other forms of leaching. Their *spatial* context also plays an important role in this. For example, a field containing mostly good soil types, may be valued differently if it contains a poor soil type within its boundaries. A farm where poor soils cover only a small percentage of the total surface will be viewed differently to one where poor soils cover a substantial area. On the other hand, the occurrence of only a small area of a high productive soil on a farm with mostly rather poor soils may influence the farming system dramatically in comparison with a similar farm that has only poor soils[29]. Land use can be spatially differentiated to fit the spatial heterogeneity within field or farm boundaries. This ability to exploit the spatial

heterogeneity of soils and arrive at a better 'working whole' gives the land its agricultural value. Farmers can follow different strategies in their enterprise and often will apply different types of management to specific fields. In consequence, soils may follow different land use trajectories due to the farmers' strategy or the location of the field with respect to the farm buildings. Thus, at the farm level, there is a dynamic interaction between the integrating and coordinating activities of the farmer (through his labour) and the processes in the soil. So not only do intersections occur between natural land units and the spatial units (fields) of the farm, but there is also an entanglement of land use with soil processes. Implicitly, the assessment of the suitability soil is not only dependent on local factors, but is also influenced by the characteristics of surrounding soils.
At a regional level, agriculture does not exist merely as a collection of inert and independent farms. They share (and form) a common landscape with similar natural resources and a cultural repertoire. In Europe, this has expressed itself in regionalised farming styles with specific farming techniques, regional products, local breeds and architecture (Renting and van der Ploeg 2001). At this, the regional level, the land also exhibits a degree of underlying dynamic interconnection, mostly by means of hydrological processes. Soils are contextual, even from a 'natural' point of view. They experience inputs (run-on) from upslope areas or undercutting from adjacent rivers. They act as intermediates between precipitation and the quantity and quality of surface waters. The effects of human influences on natural soil processes thus extend beyond the soil system itself. Landscape processes carry these influences across boundaries of basic agricultural units, such as fields and farms. The natural environment provides structure, containing natural agents and influences how fields or farms affect one another, nature conservation areas or surface waters[30]. Farmers share these common resources, which suggests that collective action needs to take place in order to maintain their sustainable use. Collective action can be pursued through geographic communal bodies, such as regional environmental cooperatives. Such organisations may well provide an attractive economic and agronomic alternative to rigid restrictions on land use to address problems such as nitrate leaching (e.g. Worrall and Burt 2001).

Soils that are the outcome of a specific land use trajectory may require the adoption of specific farm management strategies (or rejection of others). For example, it has been shown that long term organic farming leads to higher organic matter contents that can result in better soil structure, but only with specific management. Soils such as these are more at risk of being compacted by tillage, vehicular traffic or grazing under wet conditions. In other words the land use history of soils, channels management practices in specific directions, which may in turn require the use of specific technologies[31]. The development and existence of a particular expression of the soil (i.e. the *phenoform*), pre-supposes the co-development and existence of other practices or artefacts. This leads us back to the notion of working configurations, assemblages of different aspects of the farm that are mutually fine-tuned.

There is an increasing amount of empirical and theoretical evidence that soils and landscapes reflect agricultural activities and that these in turn influence future land use trajectories. These trajectories cannot be (re-) constructed on experimental fields or farms. It can often take decades to achieve equilibrium conditions, which would make it impractical and too costly to perform this type of research, especially on a range of soil types. Moreover, the technology or management practices that are needed to replicate these specific trajectories of land use, may not be easily found outside the context of the individual farm.

It is increasingly being realised that classical soil suitability approaches and land evaluation procedures do not account for the dynamic relationships between land users and their environment. The concept of *genoforms* and *phenoforms* helps enlarge the horizon of soil science and offers the opportunity of aligning research activities with local practices. It is to be hoped that researchers and local farmers can meet this challenge and work together in developing more sustainable agricultural systems.

References

Alblas, J. (1990), Bodemverdichting bij de teelt van maïs. rapport 117, PAGV, Lelystad.

Anon. (1993), Teelt van maïs. Teelthandleiding. PAGV, Lelystad, pp. 9-14.

Arnold, R.W. (1983), Concepts of soils and pedology. In: L.P. Wilding, N.E. Smeck and G.F. Hall (Editors), Pedogenesis and soil taxonomy. *Developments in Soil Science*. Elsevier, Amsterdam.

Beek, K.J. (1978), Land evaluation for agricultural development, 23. International Institute for Land Reclamation and Improvement, Wageningen, 336 pp.

Bouma, J. (1989),Using soil survey data for quantitative land evaluation. *Advances in Soil Science*, 9. Springer-Verlag, New York.

Bouma, J.(1993), Soil behavior under field conditions: differences in perception and their effects on research. *Geoderma*, 60: 1-14.

Bouma, J. (1994) Sustainable land use as a future focus for pedology. *Soil Science Society of America Journal*, 58(3): 645-646.

Bouma, J. (2001), The role of soil science in the land use negotiation process. *Soil Use and Management*, 17: 1-6.

Brandt, H.M.P. van den and H.P. Smit (1998), Mineral accounting: the way to combat eutrophication and to achieve the drinking water objective. *Environmental Pollution*, 102: 705-709.

Cameron, K.C. and A.Wild (1984), Potential Aquifer Pollution from Nitrate leaching following the plowing of temporary grassland. *Journal of Environmental Quality*, 13(2): 274-278.

Carton, O.T. and S.C. Jarvis (2001), Nitrogen and phosphorus cycles in agriculture. In: P. de Clerq *et al.* (Editors), *Nutrient management legislation in European countries*. Wageningen Pers, Wageningen, pp. 3-13.

CBS, 2000. Veel gras ingezaaid na maïs. Press release.

Cnossen, J. and W. Heijink (1958), Enkele opmerkingen omtrent de bodem–gesteldheid van de zandgronden in een deel van NoordOost-friesland. *Boor & Spade*, IX: 156-171.

Conry, M. (1974), Plaggen soils, a review of man-made raised soils. *Soils & Fertilizers*, 37: 319-326.

Creutzberg, D. and H. de Bakker (1988), Soil management of Spodosols with a plaggen epipedon, ISRIC, Wageningen.

Bakker, H. de and J. Schelling (1966), A system of soil classification for the Netherlands, the higher levels. Pudoc, Wageningen, 217 pp.

Bruchem, J.van, H. Schiere and H. van Keulen (1999), Dairy farming in the Netherlands in transition towards more efficient nutrient use. *Livestock Production Science*, 61: 145-153.

Dekker, J.N.M. and T.E.M. van Leeuwen (1998), Voortschrijdende normstelling in het mestbeleid, de strategie bij de ontwikkeling van verliesnormen. Milieu, 13(3): 134-143.

Droogers, P. and J. Bouma (1997), Soil survey input in exploratory modeling of sustainable soil management practices. *Soil Science Society of America Journal*, 61(6): 1704-1710.

Dijk, W. van, J. Schroder, J.M.A. Nijssen and H. Everts (1995), Belang van vruchtwisseling bij maïs. In: W. van Dijk, D.A. van der Schans and B.A. Ten Hag (Editors), Themadag Maïs. Themaboekje. PAGV, Lelystad, pp. 61-75.

EC (1980), 80/778/EEC Directive relating to the quality of water intended for human consumption.

EC (1991), 91/676/EEC Directive concerning the protection of water against the pollution caused by nitrates from agricultural sources.

Eck, G. van (1995), Stikstofverliezen en stikstofoverschotten in de Nederlandse landbouw. Project Verliesnormen, Deelrapport 3, LNV.

Edelman, C.H. (1952), Some unusual aspects of soil science. *Boor & Spade*, V: 185-193.

Eshuis, J., M. Stuiver, F. Verhoeven, and J.D. van der Ploeg (2001), *Goede mest stinkt niet*. Studies voor landbouw en platteland. Ernsting, Wageningen, 138 pp.

Faber, G.H., J.P. Pronk, J.M. de Vries and E.L. Herfkens (2000), Natuur voor mensen, mensen voor natuur; nota natuur, bos en landschap in de 21e eeuw.

Frouws, J. (1994), *Mest en Macht: een politiek-sociologische studie naar belangen–behartiging en beleidsvorming inzake de mestproblematiek in Nederland vanaf 1970.* PhD Thesis, Agricultural University of Wageningen, Wageningen, 287 pp.

Garlynd, M.J., D.E. Romig, R.F. Harris and A.V. Kurakov (1994), Descriptive and analytical characterization for soil quality/health. In: J.W. Doran, D.C. Coleman and D.F. Bezdicek (Editors), *Defining soil quality for a sustainable environment*. SSSA Special Publication. Soil Science Society of America, Madison, pp. 159-168.

Garwood, E.A. and J.C. Ryden (1986), Nitrate loss through leaching and surface runoff from grassland: effects of water supply, soil type and management. In: H.G. Van der Meer (Editor), *Nitrogen fluxes in intensive grassland systems.* Martinus Nijhof Publishers, Dordrecht, pp. 99-113.

Gerritsen, P.R.W. (2002), *Diversity at stake; A farmers' perspective on biodiversity and conservation in Western Mexico.* PhD Thesis, Wageningen University, Wageningen, 286 pp.

Goss, M.J., E.G. Beauchamp and M.H. Miller (1995), Can a farming systems approach help minimize nitrogen losses to the environment? *Journal of Contaminant Hydrology*, 20: 285-297.

Harris, R.F. and D.F. Bezdicek (1994), Descriptive aspects of soil quality/health. In: J.W. Doran, D.C. Coleman and D.F. Bezdicek (Editors), *Defining soil quality for a sustainable environment.* SSSA Special Publication. Soil Science Society of America, Madison, pp. 23-35.

't Hart, M.L. (1950), Organische stof en grasland. *Landbouwkundig tijdschrift*, 62(7): 532-542.

Hillel, D. (1991), Out of the earth. University of California Press, Berkeley, 321 pp.

Hoogerkamp, M. (1974), De ophoping van organische stof onder grasland en de invloed hiervan op de opbrengst van grasland en akkerbouwgewassen: tijdelijk grasland, al dan niet periodiek heringezaaid blijvend grasland of oud grasland, Instituut voor biologische en scheikundig onderzoek van landbouwgewassen, Wageningen.

Hoogerkamp, M. (1984), *Changes in productivity of grassland with ageing.* PhD Thesis, Wageningen University, Wageningen, 78 pp.

Izac, A.M.N. and M.J. Swift (1994), On agricultural sustainability and its measurement in small-scale farming in sub-Saharan Africa. *Ecological Economics*, 11: 105.

Janssens, B., L. de Savornin Lohman, L van Soest and C. de Zwijger-de Brabander, (2002), Oude graslanden in Nederland – verkenning naar motieven, bedrijfsvoering en perspectieven voor in situ beheer. 3.02.04, LEI, Den Haag.

Jarvis, S.C. (2000), Progress in studies of nitrate leaching from grassland soils. *Soil Use and Management*, 16: 152-156.

Kellogg, C.E. (1941), The soils that support us. The Macmillan Company, New York etc., 370 pp.

Kiestra, E. and G. Rutten (1986), De bodemgesteldheid van het landinrichtings-gebied Twijzel-Buitenpost. Rapport 1801, Stiboka, Wageningen.

Lloyd, A. (1992), Nitrate leaching following the break-up of grassland for arable cropping. In: J.R. Archer *et al.* (Editors), *Nitrate and Farming Systems. Aspects of Applied Biology.* Churchill College, Cambridge, pp. 243-247.

LNV (2001), Besluit van 23 juli 2001, houdende wijziging van het Besluit gebruik dierlijke meststoffen 1998, het Besluit kwaliteit en gebruik overige organische meststoffen en het Lozingenbesluit open teelt en veehouderij. Staatsblad van het Koninkrijk der Nederlanden(479): 1-34.

Maenhout, C.A.A.A. (1984), Continuteelt of vruchtwisseling. 4, Proefstation voor de akkerbouw en de groenteteelt in de vollegrond, Lelystad.

Makken, H. (1991), De bodemgesteldheid van de landinrichtingsgebieden Achtkarspelen, Drachten en Eestrum. Report 146, Staring Centrum, Wageningen.

Mendras, H. (1970), The vanishing peasant; innovation and change in French Agriculture. MIT Press, Cambridge, 246 pp.

Neeteson, J.J. (2000), Nitrogen and phosphorus management on Dutch dairy farms: legislation and strategies employed to meet the regulations. *Biology and fertility of soils*, 30: 566-572.

Pape, J.C. (1970), Plaggen soils in The Netherlands. *Geoderma*, 4: 229-255.
Ploeg J.D. van der (1987), *De verwetenschappelijking van de landbouw–beoefening*. Landbouwuniversiteit Wageningen, Wageningen.
Ploeg, J.D.van der (1991), *Landbouw als mensenwerk*. Coutinho, Muiderberg, 328 pp.
Ploeg, J.D.van der (1999), *De virtuele boer*. Van Gorcum & Comp BV, Assen, 482 pp.
Ploeg, R.R. van der, W. Bohm and M.B. Kirkham (1999), On the origin of the theory of mineral nutrition of plants and the law of the minimum. *Soil Science Society of America Journal*, 63(5): 1055-1062.
Pulleman, M.M., J. Bouma, E.A. van Essen and E.W. Meijles (2000), Soil organic matter content as a function of different land use history. *Soil Science Society of America Journal*, 64: 689-693.
Renting, H. and J.D. van der Ploeg (2001), Reconnecting Nature, Farming and Society: Environmental Cooperatives in the Netherlands as Institutional Arrangements for Creating Coherence. *Journal of Environmental Policy and Planning*, 3: 85-101.
RIVM (2002), Minas en Milieu, balans en verkenning, RIVM, Alphen aan de Rijn.
Roep, D. (2001), *Vernieuwend werken; sporen van vermogen en onvermogen*. PhD Thesis, Wageningen University, Wageningen, 201 pp.
Röling, N. and M. Maarleveld (1999), Facing strategic narratives: An argument for interactive effectiveness. *Agriculture and Human Values*, 16: 295-308.
Ryden, J.C. (1984), The flow of nitrogen in grassland, The Fertilizer Society, London, pp. 43.
Ryden, J.C., P.R. Ball and E.A. Garwood (1984), Nitrate leaching from grassland. Nature, 311: 50-53.
Schans, R.P.H.P. van der and J.J. Vleeshouwer (1956), De bodemgesteldheid van het object Achtkarspelen. Report 416, Stiboka, Wageningen.
Scholefield, D. *et al.* (1993), Nitrate leaching from grazed grassland lysimeters: effects of fertilizer input, field drainage, age of sward and patterns of weather. *Journal of Soil Science*, 44: 601-613.
Schönfeld, M. (1950), Veldnamen in Nederland. Mededelingen/Koninklijke Nederlandse akademie van wetenschappen, afd. Letterkunde, Vol 12, Amsterdam, 200 pp.
Schoumans, O.F., O. Oenema and T.E.M. van Leeuwen (1998), Normstelling in het mestbeleid; wetenschappelijk inhoudelijke achtergronden. *Milieu*, 13(4): 174-184.
Sillitoe, P. (1998), Knowing the land: soil and land resource evaluation and indigenous knowledge. *Soil Use and Management*, 14(4): 188-193.
Soil Survey Staff (1975), Keys to soil taxonomy. U.S. Gov. Print. Office, Washington, D.C., 754 pp.
Sonneveld, M.P.W., J. Bouma and A. Veldkamp (2002), Refining soil survey information for a Dutch soil series using land use history. *Soil Use and Management*, 18: 157-163.
StiBoKa (1981), Bodemkaart van Nederland 1:50.000: toelichting bij de kaartbladen 6 West Leeuwarden 6 Oost Leeuwarden en het vaste land van de kaartbladen 2 West Schiermonnikoog en 2 Oost Schiermonnikoog, Stiboka, Wageningen.
Tunney, H. (1992), The EC Nitrate Directive. In: J.R. Archer *et al.* (Editors), *Nitrate and Farming Systems. Aspects of Applied Biology*. Churchill College, Cambridge, pp. 450.

Veenenbos, J.S. (1949), Bodemkartering in de Friese Wouden. *Boor & Spade*, III: 86-93.

Veenenbos, J.S. (1954), Het landschap van zuidoostelijk friesland en zijn ontstaan. *Boor & Spade*, VII: 111-136.

Veenenbos, J.S. (1964), Bodemgesteldheid van de 'Friese Wouden'. Rapport 584, Stiboka, Wageningen.

Veldkamp, A. *et al.* (2000), Multi-scale system approaches in agronomic research at the landscape level. *Soil & Tillage Research*, 1544: 1-12.

Verstraten, F. (1996), De teelt van gras en voedergewassen in Nederland. Rapport G35, Informatie- en Kenniscentrum Landbouw, Ede.

Vink, A.P.A. (1959), Beoordeling van landbouwgronden. *Landbouwkundig tijdschrift*, 71(6): 162-166.

Vink, A.P.A. (1963), Some investigations on the soil suitability classification for arable and grassland farming. Report 6, Soil Survey Institute, Wageningen.

Vink, A.P.A. and E.J. van Zuilen (1974), The suitability of the soils of the Netherlands for arable land and grassland. Report 8, Soil Survey Institute, Wageningen.

Whitehead, D.C. (1995), Grassland nitrogen. CAB International, Wallingford, 416 pp.

Whitehead, D.C., A.W. Bristow and D.R. Lockyer (1990), Organic matter and nitrogen in the unharvested fractions of grass swards in relation to the potential for nitrate leaching after ploughing. *Plant and Soil*, 123: 39-49.

Whitmore, A.P., N.J. Bradbury and P.A. Johnson (1992), Potential contribution of ploughed grassland to nitrate leaching. Agriculture, *Ecosystems and Environment*, 39: 221-233.

WinklerPrins, A.M.G.A. (1999), Local soil knowledge: A tool for sustainable land management. *Society and Natural Resources*, 12: 151-161.

Worrall, F. and T.P. Burt (2001), Inter-annual controls on nitrate export from an agricultural catchment – how much land-use change is safe? *Journal of Hydrology*, 243(3-4): 228-241.

Notes

1 See also Chapter 1 for a more detailed description on the Law of the Minimum or for example van der Ploeg *et al.* (1999).

2 This actually follows from one of the assumptions behind the development of Soil Taxonomy in the United States.

3 Although at the time of the publication of the Dutch system of soil classification (De Bakker & Schelling 1966), the need was felt to include such considerations.

4 This was part of the modernisation process of Dutch agriculture (van der Ploeg 1987).

5 Soil suitability is traditionally defined as '*the degree of success with which a crop or range of crops can be regularly grown on a certain soil, within the existing type of farming, under good management, and under good conditions of parcellation and accessibility*'. See also Vink and van Zuilen (1974).

6 Interactions between the land use and the soil are then excluded for the purpose of simplification. For a more detailed discussion see e.g. Beek (1978).

7 See Stuiver *et al.* (this book) and Reijs *et al.* (this book).

8 This study was performed at the request of the Dutch Ministry of Agriculture, with the specific aim of addressing the *'problem of intensification of small farms'*. At the time, the area was predominately grassland, but it was recommended that large-scale conversions of grassland into arable land, especially in the higher parts of the landscape, would be necessary to secure a *'healthy foundation of the small farm'*.

9 For detailed information on their origin, properties and distribution, the reader is referred to Conry (1974), Creutzberg and de Bakker (1988),.Edelman (1952) and Pape (1970).

10 According to Veenenbos (1954), this may well have been the main purpose of this intervention.

11 The Dutch soil classification system made extensive use of local names. The soil names that were introduced at the lowest level of the classification system were a combination of scientific names and the name of the locality where a specific soil was prevalent. Soil conditions, land use and reclamation history all influenced these local fieldnames (Schönfeld 1950). In this case, 'Laar' refers to an open place in the woods and was as a name for reclaimed areas in the Middle Ages.

12 Of particular concern was the effect that soil compaction would have on the rooting potential of the crop, which could lead to a potential yield drop of more than 15 per cent.

13 For the Netherlands, see Minderhoud (1959) on the desirability of grassland renovation to overcome the years of depression.

14 The difficulties of creating (and maintaining) highly productive pastures are traditionally widely recognised. Hoogerkamp (1984) quotes the saying *'to break a pasture makes a man, to make a pasture breaks a man'*.

15 The issue of biodiversity has recently received special attention as the ploughing of old pastures may lead to a significant loss in genetic diversity. See also Janssens *et al.* (2002).

16 Also known as *blue-baby syndrome*

17 It was recently reported that for the upper groundwater in the sandy areas in the Netherlands, the average nitrate concentration for the period 1996-2000 was twice the standard in the Nitrates Directive (RIVM 2002).

18 The loss of nitrogen from agricultural systems through nitrate leaching can however not be viewed in isolation from the whole nutrient cycle at dairy farms (Carton and Jarvis 2001, Jarvis 2000 and Ryden 1984). Other related environmental concerns are Ammonia (NH_3), Nitrous oxide (N_2O), Phosphorus (P) and Methane (CH_4). Most recent studies have therefore adopted a farming systems approach (e.g. Van Bruchem *et al.* 1999). See also Goss *et al.* (1995) who argue that restrictions on farm management addressing single issues may not always be suitable in a local context when the whole farming system is considered.

19 The major soil types came from the then available guidelines on nitrogen fertilisation where soil types were differentiated on the basis of their nitrogen supply capacity. These are not the same as the soil types that are distinguished in the Dutch soil classification system.

20 For more background information on the development of the final loss standards, the reader is referred to Dekker and van Leeuwen (1998) and Schoumans *et al.* (1998). These publications provide more insight into the issue of a rational development of loss standards. See also Frouws (1994) for a long-term overview on manure policy. For specific information on the whole Dutch legislation on manure and fertilisers in relation to the Nitrates Directive, the reader is referred to Henkens and van Keulen (2001).

21 Dry sandy soils being defined as soils where the groundwater table is on average between 40cm and 120cm below the surface. This corresponds with groundwater classes VI and higher.

22 These included limits on: the periods for using animal manure and artificial fertiliser; the use of animal manure on sloping fields and; the periods where grassland ploughing is

allowed. Specifically, grassland ploughing is prohibited in the period from September 16th until January 31st.

23 Soil organic matter content is also greatly influenced by the local hydrological conditions (past and present). If groundwater class data is taken into account, around 75 per cent of the total variation in soil organic carbon content and 59 per cent of the variation in nitrogen in the topsoil can be explained by land use history.

24 In the field of ethnopedology, special attention is given to the documentation and understanding of local approaches to soil perception, classification, appraisal, use and management. For further reading see WinklerPrins (1999).

25 See Stuiver *et al.* (this book) for a more elaborate discussion of the differences between local knowledge in general and scientific knowledge.

26 See van der Ploeg *et al.* (this book,).

27 Many ancient cultures did not see the land as solely a capital or a means of production. In many cases, spiritual values were attached to the land and a deep sense of connection was felt and expressed (see e.g. Kellog 1941 and Hillel 1991). The same holds true in many parts of the 'under-developed world'

28 For more detailed information soil suitability classification and land evaluation, the reader is referred to Vink (1959 & 1963), Beek (1978), Bouma (1989 & 2001). See also Veldkamp *et al.* (2000) for a background on multi-scale approaches.

29 The example originally comes from an observation of Kellog (1941) and refers to the notion of *soil pattern*. In the Netherlands, this aspect has been referred to as 'kaartbeeld'. The mixed farming system, characteristic of large parts of Western Europe, provides an example of how soil heterogeneity was exploited in a way that led to a type of agriculture that was sustained for centuries. Although the concept of soil patterns has long been recognised it has, surprisingly, hardly been systematically studied.

30 These 'off-site' effects are often major issues in debates on environmental quality, especially in the tropics.

31The small-scale landscape of the Friesian woodlands, with its small fields did not match with the heavy and large machinery that was needed for injecting manure into the soil. The technology was not adapted to the land and there was a perceived threat of damage to the structure of the soil. As a consequence, local farmers developed their own machine (called the 'area friendly machine'), which fitted better in small fields. See Eshuis *et al.* (2001) for a more detailed report on the development of this machine.