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Relationships between soil fertility, herbage quality and manure composition on grassland-based dairy farms

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ABSTRACT

It is reasonable to expect that compliance with grassland fertilization recommendations in the long run results in optimal soil fertility, and subsequent herbage quality. Here, we evaluate the development of soil, herbage and manure characteristics and their relation over the last decades. We hypothesized that herbage and manure quality are related with soil fertility. We used a large database with results of soil tests, spring forage quality characteristics, and manure analyses, which were made on demand of dairy farmers. We considered the Netherlands as a whole and three selected regions with contrasting soil types (sandy soil, riverine clay, and peaty marine clay). Effects of soil fertility on herbage quality were evident when comparing farms. Farms higher in soil P and K generally have correspondingly higher contents in forage. On average, soil fertility and herbage characteristics were within or just above the agronomical optimal range during the last decades. Herbage crude protein content decreased in all regions during last two decades, which is likely an effect of legislative measures on decreasing the application of N. Selenium (Se) and sulphur (S) contents increased sharply on sandy soils, likely because of increased use of Se and S containing fertilizers. Manure composition did not differ between soil types. In conclusion, at farm level, the element composition of herbage reflected the soil fertility status. The contents of S, P, K, Na, Mg, and Ca in the herbage were all significantly influenced by soil fertility characteristics. Our results emphasize the importance of maintaining soil fertility for high quality roughage production.

1. Introduction

Grasslands cover large acreages of the world. Managed grasslands are especially found in temperate regions in New Zealand, western Europe, and the southern part of Latin America. These managed grasslands offer high-quality forage to dairy and beef cattle and thereby contribute to our food supply. In favourable regions, forage dry matter (DM) yields of 15 Mg per ha (Drennan et al., 2005) can be achieved, with proper (nutrient) management. To optimize production, fertilization recommendations for grassland, based on soil tests, have been developed, mostly during the 1950s and 1960s (Voss, 1998; Anonymus, 1989). It is expected that compliance with these recommendations would have resulted in soil fertility characteristics within the optimal ranges. Recommendations for grasslands also consider the element composition of the herbage, as ruminants require the intake of sufficient amounts of essential elements for optimal production and performance. Hence, next to soil fertility, compliance to fertilization recommendations would be expected to result also in optimal levels of essential elements in harvested herbage. Moreover, the composition of the excrements of ruminants reflects the composition of the diet and hence indirectly also the way farmers comply with fertilization recommendations. However, whether this is the case in farmers' practice has not been evaluated in a systematic way so far. It is known that yearly fertilization practices affects the mineral composition of herbage directly (Stout et al., 1977; Edmeades, 2003; Van Soest et al., 1978), but again little work has linked the effects of soil fertility to herbage quality and manure composition under practical conditions.

Soil fertility characteristics change over time due to changes in fertilization practises, for example in response to for example, fertilization recommendations and governmental regulations (e.g. De Clercq et al., 2001; Schröder and Neeteson, 2008). Herbage and manure quality may also vary between years, due to differences in weather conditions and fertilization practices. This inherent variability suggests that linking soil fertility to herbage quality and

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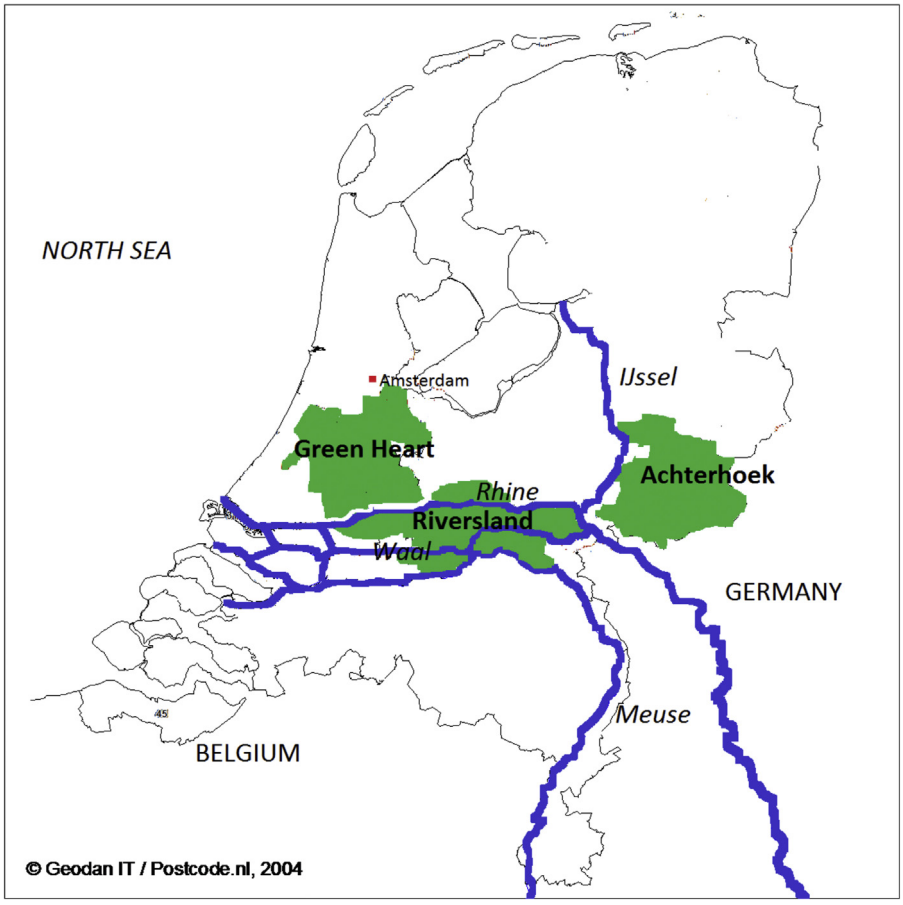

Fig. 1. The locations of the studied regions Groene Hart, Rivierenland and Achterhoek, in the Netherlands.

manure composition can only be tested rigorously when using long-term data sets.

Here, we test (i) whether soil fertility and herbage quality have developed towards the optimal ranges according current fertilization recommendations, and (ii) how the herbage and manure quality are affected by differences in soil fertility on grassland-based dairy farms in the Netherlands. Thereby, we hypothesized that soils higher in soil fertility will have higher nutrient contents in herbage and manure. We tested our hypotheses on grassland-based dairy farms for the whole of the Netherlands and for three contrasting regions as regards soil type (peaty marine clay, riverine clay, and sandy soil).

2. Materials and methods

2.1. Site description

Agriculture in the Netherlands is one of the most productive in the world, which is due in part to its fertile soils. Part of this soil fertility is natural, i.e. inherited from the sea (peaty marine clay soils) or from the rivers Rhine and Meuse (riverine clay soils). The fluvial-glacial sandy soils in the east and south of the country had low fertility originally, but have been made fertile by farmers during the last few centuries. Approximately 62% of the agricultural area in the Netherlands is used for dairy farming (50% grassland and 12% fodder crops; CBS, 2012).

Dairy farming is the main agricultural sector in the Netherlands. We considered the Netherlands as a whole, and three contrasting dairy farming regions: (i) Groene Hart (peaty marine clay), (ii) Rivierenland (riverine clay) and (iii) Achterhoek (sand) (Fig. 1 and Table 1). Groene Hart with 90% permanent grassland and 6% fodder crops (CBS, 2012) is situated in the west between the main cities Amsterdam, Rotterdam, The Hague and Utrecht. Main soil types are peaty marine clay and peat on marine clay. Rivierenland is situated in the centre of the country between the rivers Rhine, Meuse, and Waal. Seventy five per cent of the agricultural area is grassland, 11% is for fodder crops. Achterhoek is situated in the east. Sandy soils are dominating here, with on average 5.5% soil organic matter (SOM) in the top soil. Of the agricultural area, 66% is grassland and 21% are fodder crops; ley farming (grassland – maize) is rather common.

2.2. Database of soil, herbage, and manure analyses

For this paper we could explore a data base of >5 million results of soil, herbage and manure analyses from farmers' fields in the Netherlands collected and by one laboratory. BLGG AgroXpertus (www.BLGG.AgroXpertus.nl) is the main soil and crop analysis laboratory in the Netherlands. Soil, herbage, and manure samples are taken at farmers' request from 1928 onwards (by more than 50% of the dairy farms). Results of the analyses have been stored in Microsoft Access from 1984 onwards. Before 1984, overviews of soil fertility characteristics were made occasionally (see also Reijneveld et al., 2009, 2010).

To gain insight in the relationships between soil fertility characteristics and the nutrient element contents of herbage and manure, we choose to analyze the maximum possible period of a certain characteristic.

In herbage, dry matter (DM), crude protein (CP), crude fibre, and crude ash contents are determined from 1960 onwards (based on NEN-ISO 12099, 2010). From 1996, phosphorus (P), potassium