Geoderma Regional 5 (2015) 44–53

Contents lists available at ScienceDirect

Geoderma Regional

journal homepage: www.elsevier.com/locate/geodrs

The economic value of detailed soil survey in a drinking water collection area in the Netherlands

M. Knotters *, H.R.J. Vroon

Alterra, Wageningen University and Research Centre, Team Soil, Water and Land Use, P.O. Box 47, 6700 AA Wageningen, The Netherlands

ARTICLE INFO

Article history:
Received 7 October 2014
Received in revised form 2 March 2015
Accepted 5 March 2015
Available online 11 March 2015

Keywords:
Podzols
Anthrosols
Gleysols
Arenosols
Water table depth
Crop yield reduction
Data-worth analysis
Map quality
Validation

ABSTRACT

In large parts of the Netherlands crop growth depends on the water table. If groundwater is withdrawn the water table is lowered and agricultural crop production may be reduced. Farmers in drinking water collection areas are legally compensated for these crop yield reductions. Soil maps are used to estimate crop yield reductions and hence legal compensations. We calculated the benefit of a detailed soil survey from the reduction of errors in legal compensations that can be achieved if a detailed soil map, 1:25,000, is used for estimation instead of the national soil map, 1:50,000. We compared this error reduction with the costs of the detailed soil survey. We selected 40 farms by stratified random sampling in the drinking water collection area 'Vierlingsbeek'. At each farm soil profile descriptions were made at a total of 137 randomly selected locations. Legal compensations estimated from the 1:50,000 soil map and information from the 1:25,000 soil map were compared with legal compensations calculated from the soil profile descriptions, and errors were calculated for each farm in € ha^{-1} year^{-1}. With an investment in detailed soil survey of €30 ha^{-1} the absolute error could be reduced on average by €13.16 ha^{-1} year^{-1}, the present value of which is €258 ha^{-1} assuming an interest of 3% and yearly compensations during a period of 30 years. We conclude therefore that for this study area detailed soil survey was worth the costs. Furthermore, we conclude that insight in the spatial dependence structure of classification errors at soil maps of various scales would be very helpful prior information in deciding on the detail of soil survey needed to support decisions at farm level.

1. Introduction

The soil map of the Netherlands, 1:50,000, has proved to be useful in numerous studies on land use planning, environmental policy et cetera at a national or regional level (Hartemink and Sonneveld, 2013). The national soil map is generally assumed to be too inaccurate to support decisions on farm level, however. To support these decisions detailed soil maps are made for areas of interest, commonly at a scale of 1:25,000 or 1:10,000, see Hartemink and Sonneveld (2013) for an overview of these large-scale soil maps. For example, detailed soil maps are made to estimate legal compensations to farmers in areas where the water table is lowered due to groundwater withdrawal. In large parts of the Netherlands crop growth depends on the water table, which is generally at 0 to 2 m depth. If groundwater is withdrawn the water table is lowered and agricultural crop production may be reduced. Farmers in drinking water collection areas are legally compensated for these crop yield reductions.

Legal compensations are estimated on the basis of tables giving percentages of crop yield reduction for combinations of soil types and water table depths. These tables are the so called HELP-tables (HELP, 1987; de Vos et al., 2006), developed for land evaluation, or the more detailed TCGB-tables (de Laat, 1980; Bouwmans, 1990). In the Netherlands, water table depths and soil types are mapped concurrently in soil surveys. The resulting soil maps and the tables with percentages of crop yield reductions for combinations of soil types and water table depths are used to estimate legal compensations for individual farmers in drinking water collection areas.

Until now it was assumed that the costs of a detailed soil survey are in good balance with the reduction of errors in estimated legal compensations to farmers in drinking water collection areas. This assumption was not verified by a quantitative analysis, however. If the costs of a detailed soil survey are much larger than the reduction of errors that can be achieved, it might be economically more attractive to pay farmers some extra compensation to eliminate possible underestimations instead of trying to reduce these errors by an expensive, detailed soil survey.

Analysis of the economic benefits of soil survey has a long history. Klingebiel (1966) compared the costs of soil survey with economic benefits estimated from case histories and records of soil survey users. In this analysis it was assumed that soil maps were used by most people or their builders or advisors in the surveyed area, and it was analysed how land use planning changed as compared to the situation in which

---

* Corresponding author.
E-mail addresses: martin.knotters@wur.nl (M. Knotters), henk.vroon@wur.nl (H.R.J. Vroon).

http://dx.doi.org/10.1016/j.geodrs.2015.03.002
2352-0094/

a soil map was not available. In many instances the benefits came through costs that could be avoided by using a soil map in land use plans. High benefit–cost ratios were found, and it was claimed that the investment of a soil survey is almost certain to pay for itself and return a profit within a year. Bie and Ulph (1972) demonstrated a method to evaluate the economic benefits to be expected before a soil survey is executed. This approach is based on prior information on proportions of soil types in comparable areas. The authors mentioned that at that time there was little available knowledge on the relationship between the purity achieved and the cost of a soil survey. They recommended an independent post-survey statistical sample to assess the purity achieved. Dent and Young (1981) elaborated upon the work of Bie and Ulph (1972) in a simplified example in which the profitability from different management systems on each of a number of mapping units is compared. Giasson et al. (2000) assessed the economic value of soil maps using Bayesian decision analysis techniques to find good balance between costs of soil survey and economic benefits for one hypothetical farm of 100 ha. This type of cost–benefit analysis is also referred to as data-worth analysis (Freeze et al., 1992). Manderson and Palmer (2006) estimated the costs of soil mapping at scales 1:10.000, 1:25.000 and 1:50.000, and emphasized the value of these maps in decision making at farm level in New-Zealand. Their cost estimates were based on Bie and Beckett (1971), but the benefits of soil maps were not quantified. The authors underlined the need of real examples using local farms to prove cost-effectiveness of soil maps. Our study presented here is such an example. We follow the recommendation by Bie and Ulph (1972) of an independent post-survey statistical sample to assess map purity. Rather than map purity we quantify the financial consequences of lack of map purity for individual farms, however.

In a previous study we made a cost–benefit analysis to support the decision on either investing in the quality of spatial data needed for estimating crop yield reduction or in paying extra compensations to farmers to account for errors in spatial data (Knotters et al., 2010). This analysis indicated that the use of soil maps of different scales gives rise to large differences in estimated legal compensations at farm level. Independent test data to validate the legal compensations estimated using soil maps at scale 1:50,000 or 1:25,000 were lacking at the moment of that study, however.

The aim of this study is to calculate the reduction of errors in legal compensations paid to farmers in a drinking water collection area that can be achieved if a detailed soil map, 1:25,000, is used for estimation instead of the national soil map, 1:50,000, and to compare this reduction in errors with the costs of the detailed soil survey. To this purpose we performed a validation study, in which we randomly selected 40 farms in a drinking water collection area. At these farms we made 137 soil profile descriptions at randomly selected locations. For these locations we could calculate 'true' compensations and compare them to the compensations estimated on the basis of the soil maps. Next, we compared the costs of detailed soil survey with the benefits in terms of reduced errors in estimated legal compensations.

2. Materials and methods

2.1. Study area

The study area of 1042 ha of farmland is situated around pumping-station 'Vierlingsbeek', where ground water is extracted to produce drinking water. The study area, in the south-eastern part of the Netherlands, is part of terrasses formed by the rivers Rhine and Meuse during the early and the middle Pleistocene. Fluviatile deposits, consisting of coarse sands and loam, were covered by eolic, fine sands during the late Pleistocene. The main soil types according to the World Reference Base (FAO, 2006) are Gleyic and Carbic Podzols, Plaggic Anthrosols, Umbric and Histic Gleysols, and Gleyic and Haplic Arenosols. Fig. 1 shows a detail of the national soil map 1:50,000 for the study area. Fig. 2 shows the soil map, 1:25,000, that was made to estimate crop yield reductions and legal compensations for farmers in the study area (Vroon and Brouwer, 2008). Both the 1:50,000 and the 1:25,000 soil maps provide information on water table depths, besides information on soil types. The seasonal fluctuation of water table depths is summarized in so called water-table classes (van Heesen, 1970), which are based on the average water table depth in the winter (mean highest water table, MHW) and the average water table depth in the summer (mean lowest water table, MLW) (van der Sluijs and de Gruijter, 1985). The soil surveys for the soil maps 1:50,000 and 1:25,000 took place after the groundwater withdrawal started, so the water table classes at both maps reflect water tables that have been lowered due to groundwater extraction.

The pumping-station is situated in a forest in the centre of the drinking water collection area. The outer border of the study area, i.e. the sphere of influence of the groundwater withdrawal, was estimated using a geohydrolical model of groundwater flow.

The agricultural land in the study area is in use by 171 farms. These are completely or partly situated in the study area, with areas varying from 0.1 to 63 ha distributed over one or more fields per farm. Although some farms are situated partly in the study area, we refer for convenience to these parts as to farms, using the areas within the study area in estimating legal compensations. Fig. 3 shows the distribution of areas of the 171 farms within the study area. A relatively large number of farms have less than 2 ha within the study area. These concern farms with the largest part outside the study area, for instance farms at the border of the drinking water collection area, small farms of part-time farmers, or small horticultural farms for cultivation of vegetables such as asparagus and leek, and ornamental plants such as roses and box trees.

2.2. Calculation of legal compensations

Lowering of water tables under farmland may have positive and negative effects on crop yield. In dry situations, with relatively deep water tables, lowering may increase drought stress and crop yield reduction. In wet situations, lowering of shallow water tables may improve aeration of the root zone, resulting in less crop yield reduction. If the negative effects on crop yield are larger than the positive effects farmers are legally compensated for the net crop yield reduction. The legal compensations are estimated on the basis of scientific and expert knowledge on the relationship between soil type, water table depth and crop yield. This knowledge is summarized in tables with percentages of crop yield reduction for combinations of soil types and water table depths: HELP-tables (HELP, 1987; de Vos et al., 2006), or TCGB-tables (de Laat, 1980; Bouwmans, 1990). As compared to the HELP-tables, the TCGB-tables take information into account about the subsoil at depths larger than 1.20 m. In this study we apply the HELP-tables, because we are interested in the effects of detailed information of spatial patterns, and not in the effect of incorporating information about the subsoil at depths larger than 1.20 m. It should be noted that the national soil map, 1:50,000, describes the soil up to a depth of 1.20 m.

For a brief description of the HELP-tables we refer to de Vos et al. (2006, Section 2). The percentages in the HELP-tables indicate average crop yield reductions for a meteorological period of 30 years at a field scale for various crops. Crop yield reductions due to both wet and dry soil conditions are given. Table 1 gives an example of the most recent version of the HELP-table for grassland at Gleyic Podzols. The total percentage of crop yield reduction is calculated from the reductions due to wet and dry soil conditions by

$$d_t = d_w + \left(\frac{100-d_w}{100}\right) \cdot d_d \tag{1}$$

with d_w and d_d the percentages of crop yield reduction due to wet and dry soil conditions, respectively.