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Raising surface water levels in peat areas with dairy farming Upscaling hydrological, agronomical and economic effects from farm-scale to local scale

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ABSTRACT

Raising surface water levels in peat areas is a measure to reduce soil subsidence, to prevent decay of wooden foundations and to stimulate wet nature restoration and reduce greenhouse gas emissions. However, in these areas dairy farms are present and farming at wetter soils is difficult due to lower bearing capacity of the soil for cattle and machines. Water boards are responsible for the water management of peat areas and thus have to evaluate the effects of water management strategies for the different land use functions. Therefore the hydrological, agronomical and economic effects of different surface water levels are calculated for dairy farms. The 'Waterpas' model is used to simulate hydrological effects, dairy farm management and economic results for different meteorological years. The raised surface water level causes a decrease in gross grass yield and a reduction in grass quality. This leads to higher costs and less farmers' income relative to a reference situation with a freeboard of 60 cm. Raising the surface water increases the average costs for farmers with €89 ha^{-1} year^{-1} for a freeboard of 50 cm, €170 ha^{-1} year^{-1} for a freeboard of 40 cm and €239 ha^{-1} year^{-1} for a freeboard of 30 cm.

However, water boards are not only interested in the effects for individual farms, but also for an entire region. A new spatial method was developed for upscaling from farm to polder level. For grassland fields in a typical Dutch peat area classes can be distinguished using GIS data on soil type, soil surface elevation, surface water levels, locations of farms and farm characteristics. The classification is based on 4 classes of freeboards of the grassland fields and 7 typical distributions of grassland fields within a dairy farm. The farm economics were simulated for these typical classes. An increase in costs was simulated for the whole polder Zegveld (1400 ha grassland) of €119,000 year^{-1} at 10 cm surface water level rise; €133,000 year^{-1} at 20 cm surface water level rise and €185,000 year^{-1} at 30 cm surface water level rise.

For an integral environmental evaluation of changing hydrological conditions it is advised to incorporate effects on nutrient emission to groundwater and surface water and emission of ammonia and greenhouse gases to the atmosphere.

1. Introduction

1.1. Peat soils, dairy farming and water management

Peat soils are rich in organic matter and due to mineralization nutrients for plant growth become available. However, the oxidation processes of organic matter releases CO_2 to the atmosphere and leads to soil subsidence due to the disappearance of organic matter (Schipper and McLeod, 2001; Van den Akker, 2004). Water management of peat is decisive for the rate of oxidation, soil subsidence and soil consolidation (Renger et al., 2002; Hendriks et al., 2007). Under wetter conditions less oxygen can enter the soil, and the oxidation and soil subsidence is delayed compared to drier soil conditions. Peat soils are often used as grassland for dairy farming (Montanarella et al., 2006). In for example the United Kingdom (Kechavarzi et al., 2007), Poland (Sapek et al., 2009), Germany (Kluge et al., 2008) and New Zealand (Schipper and McLeod, 2001) large peat areas are used as grassland for dairy farming and active water management is used to achieve the desired soil conditions.

For dairy farmers it is important that the peat soils are dry enough and thus have enough bearing capacity to be able to use the grassland for grazing or cutting the grass. However, the grasslands are a part of the whole dairy farming management (Schils et al., 2007). Farmers have to make decisions on fertilisation, grazing, cutting grass and importing feed mainly based on farm economic considerations. So, for the farmer the consequences of changes in

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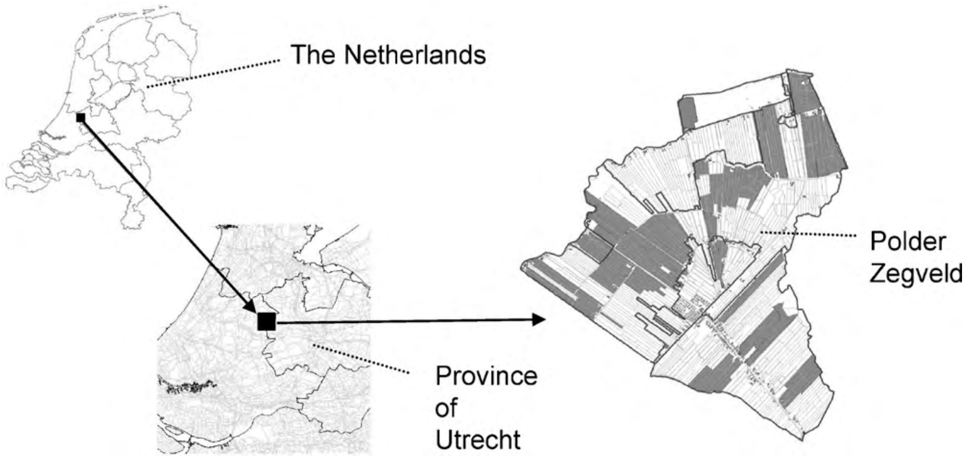

Fig. 1. Location of the polder Zegveld in the peat area of the province of Utrecht in the western part of The Netherlands. The grey areas in polder Zegveld indicate the area of the grassland where farmers use local pumps to keep the surface water level at a lower level.

water management have to examined on the farm-scale and not at the scale of individual grassland fields. However, water management has often an influence at larger spatial scales, for example a whole polder or a watershed. Water boards are responsible for the water management at that larger scale and have to take into account also other functions than dairy farming, for example nature conservation and build-up areas.

The challenge is to connect the farm-scale with the next larger local spatial scale of a polder or a watershed. Effects of changes in water management cannot be inferred from a simple summing up of the effects of all grassland fields. Upscaling is more complex because we have to take into account the farm management. This paper describes a new approach for upscaling hydrological, agronomical and economic effects from farm-scale to local scale. We use a typical Dutch situation as an example to demonstrate the potential of the upscaling method. However, the method is widely applicable for all situations with dairy farming at peat soils with controlled water management.

1.2. Dairy farming at peat soils in The Netherlands

Climate change, soil subsidence and rising of the sea level will all have major impact on the water systems in The Netherlands. Large parts of the Dutch delta are below sea level and have to be artificially drained. Peat areas in The Netherlands suffer from severe soil subsidence, mainly due to oxidation of the organic peat material. The subsidence ranges from about 6–12 mm year^{-1}, depending on the local groundwater depths (Van den Akker et al., 2007). In peat areas several combinations of agriculture, nature reserves, built-up areas of villages and farms exist. Nature reserves and some of the buildings ask for relatively shallow groundwater levels of 30 cm below the soil surface or less. These shallow groundwater levels prevent water stress in nature reserves, reduces land subsidence, and prevent decay of wooden foundations of buildings. Agriculture, mostly dairy farming, demands deeper groundwater levels in the growing season, to have favorable working and grazing conditions.

Water boards are responsible for maintaining prescribed surface water levels in the peat areas, aiming at an optimal water level for all land use functions. There is a trend towards larger areas with a similar surface water level management, to reduce the costs of water management and to prevent the development of even larger differences in soil surface elevation due to subsidence. It is important for water boards and farmers to know the agronomical and economic effects of possible future surface water levels. Dairy farmers are interested in the consequences of higher surface water levels for farm management and income, and for water boards the total effect on the hydrological system, operational costs of water management and economic consequences on the local scale are important. Ultimately, the water boards have to decide which surface water levels will be maintained in future.

The Waterpas model (De Vos et al., 2006) was developed to simulate water flow, grass production and dairy farm management simultaneously. With Waterpas it is possible to simulate the effects of changing hydrological and meteorological conditions. Farm economics are calculated and relationships between changing hydrological conditions and farmers' income are inferred. 'Waterpas' results for a case study in the polder Zegveld, in the heart of the main Dutch peat district (Fig. 1), showed that raising the surface water level from 60 to 40 cm below the average soil surface results in a decrease in net grass yield and a reduction in farm income of €222 ha^{-1} year^{-1} (De Vos et al., 2006). Dairy farming on wet peat soils is considered as agriculture with a natural handicap in Less Favorable Areas (EU, 2005). The raising of surface water levels in the peat district is meant to maintain the countryside and support other functions like build-up areas. Dutch farmers who actively support nature conservation or development can get a financial compensation.

Waterpas results are obtained at the farm-scale. Water boards and policy makers also need information on economic effects of changing hydrological and meteorological conditions at the local or national scale. This paper describes a methodology for upscaling Waterpas results from the farm-scale to the local scale, using generally available Geographical Information System (GIS) data. This paper starts with a brief description of the Waterpas model and summarizes the results of calculations at the farm-scale for different surface water levels. The methodology of upscaling using GIS data is presented and applied for a case study of the polder Zegveld. The upscaling method is discussed and ideas for future developments are presented.

2. Waterpas model

The Waterpas model links sub-models for water flow in the saturated and unsaturated zone of the soil and for the interaction with surface water (SWAP) (Belmans et al., 1983; Kroes and Van Dam, 2003), grass production (GRAMIN) (Mandersloot et al., 1999), and grassland management (GGW) (GGP, 2000) (see Fig. 2). In Waterpas a dairy farm consists of several grassland fields (Fig. 3), which are considered for simulation purposes as one-dimensional columns. Inputs for farm management include the number and size of the