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Development of a New Zealand SedNet model for assessment of catchment-wide soil-conservation works

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ABSTRACT

Much hill country in New Zealand has been converted from indigenous forest to pastoral agriculture, resulting in increased soil erosion. Following a severe storm that hit the Manawatu–Wanaganui region in 2004 and caused 62,000 landslides, the Horizons Regional Council have implemented the Sustainable Land Use Initiative (SLUI), a programme of widespread soil conservation. We have developed a New Zealand version (SedNetNZ) of the Australian SedNet model to evaluate the impact of the SLUI programme in the 5850 km^2 Manawatu catchment. SedNetNZ spatially distributes budgets of fine sediment in the landscape. It incorporates landslide, gully, earthflow erosion, surficial erosion, bank erosion, and flood-plain deposition, the important forms of soil erosion in New Zealand. Modelled suspended sediment loads compared well with measured suspended sediment loads with an R^2 value of 0.85 after log transformation. A sensitivity analysis gave the uncertainty of estimated suspended sediment loads to be approximately plus or minus 50% (at the 95% confidence level). It is expected that by 2040, suspended sediment loads in targeted water management zones will decrease by about 40%. The expected decrease for the whole catchment is 34%. The expected reduction is due to maturity of tree planting on land at risk to soil erosion. The 34% reduction represents an annual rate of return of 20% on 20 million NZ$ of investment on soil conservation works through avoided damage to property and infrastructure and avoided clean-up costs.

1. Introduction

Much hill country in New Zealand has been converted from indigenous forest to pastoral agriculture. Consequently, soil erosion has accelerated, resulting in slope failures in many areas. On the 15/16th February, 2004, a severe rainstorm hit the Manawatu–Wanganui region, causing 62,000 landslides over an extensive area of 10,000 km^2 (Dymond et al., 2006) and flooding with recurrence interval of one in a hundred years. The cost of damage from landsliding, flooding, and siltation was 170 million NZ$ (Trafford, 2004). To mitigate damage from future events, the Horizons Regional Council has embarked on a major programme of soil conservation, the Sustainable Land Use Initiative (SLUI). SLUI is funded by a combination of central and local government, and farmers, to implement farm plans for sustainable land use. Through detailed land resource assessment, highly erodible land is identified for either retirement or soil conservation planting. The farm plans also endeavour to maintain farm productivity through increased efficiencies associated with better understanding of soil resources.

Some 325 farm plans have now been implemented in the Horizons region at a cost of approximately 30 million NZ$. It is now timely to evaluate the impact of these farm plans on reduced soil erosion to determine whether SLUI has been effective and whether modification to the scheme is required — a further 70 million NZ$ of work is planned. Earlier work showed that implementation of farm plans on 10% of the most erodible farms could reduce suspended sediment loads in rivers by as much as 50% (Dymond et al., 2010), and could reduce suspended sediment concentration by a similar amount (Ausseil and Dymond, 2008). However, as the implementation of SLUI has been through a voluntary rather than regulatory framework, some of the most erodible farms have not been included. Also, the earlier assessments by Dymond et al. (2010) used an erosion model, NZeem®, which models total erosion rather than individual erosion processes. The farm plans involve a range of soil conservation works, including afforestation, space-planted trees, gully-planted trees, riparian fencing and retirement, and engineering structures.

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As these mitigation measures are generally matched to particular types of erosion, a model that differentiates between different erosion processes is required to assess the impact of SLUI. Differentiation is necessary, but without the large number of parameters often needed for physically based models. What is needed is a model of intermediate complexity (Elliot and Basher, 2011), where the erosion processes are represented adequately but the number of parameters is small enough to be practical.

Wilkinson et al. (2009) developed a spatially distributed budget model of fine sediment (SedNet) for application in Australia. A large catchment is divided into many subcatchments, for which budgets of fine sediment are produced. Each budget quantifies fine sediment sources associated with the important erosion processes. In Australia, the driving processes in the hills are surficial erosion, and gully erosion which incise and extend drainage lines. In this paper, we describe the development of a similar model (SedNetNZ) adapted for New Zealand erosion processes and implemented for the Manawatu catchment (one of the three large catchments in SLUI). Likewise, we focus on fine sediment (which consists of clay, silt, and fine sand particles) as it dominates coarse sediment (coarse sand, gravel, and rock) in the total sediment loads by over 90% (Adams, 1979). However, in New Zealand, the driving processes in the hills are landslide, earthflow, and massive gully erosion. We develop new models of these processes for incorporation into SedNetNZ. We also show how a database of SLUI farm plans and soil conservation works is used to predict reduced suspended sediment loads in water management zones from 2004 through to 2040.

2. Manawatu catchment

The 5850-km^2 Manawatu catchment is situated in the lower North Island of New Zealand (Fig. 1). It drains the southern Ruahine and northern Tararua mountain ranges and hill country on the eastern boundary. The Manawatu River has the unusual distinction of flowing from the east back through the mountain ranges it drains before crossing the Manawatu plains and sand country to the sea on the west coast. Apart from the mountain ranges, which are covered in natural forest and shrubland, the land cover is predominantly pasture, with 17% of land under dairy farming and 57% under sheep and beef farming. Mean annual rainfall in the catchment ranges from 900 mm on the west coast sand country to 3000 mm on the top of the Tararua mountain ranges. The mountains consist of greywacke/argillite, and hill country is either Tertiary-aged mudstone, or Tertiary-aged sandstone, either cohesive or non-cohesive.

Brown soils are dominant in mountains and hill country. These have brown or yellow-brown subsoil below a dark grey-brown topsoil and have moderate to low fertility. Pallic soils are also common in hill country. Due to low content of iron oxide, these have pale-coloured subsoils. They are wet in winter and dry in summer. High subsoil density often

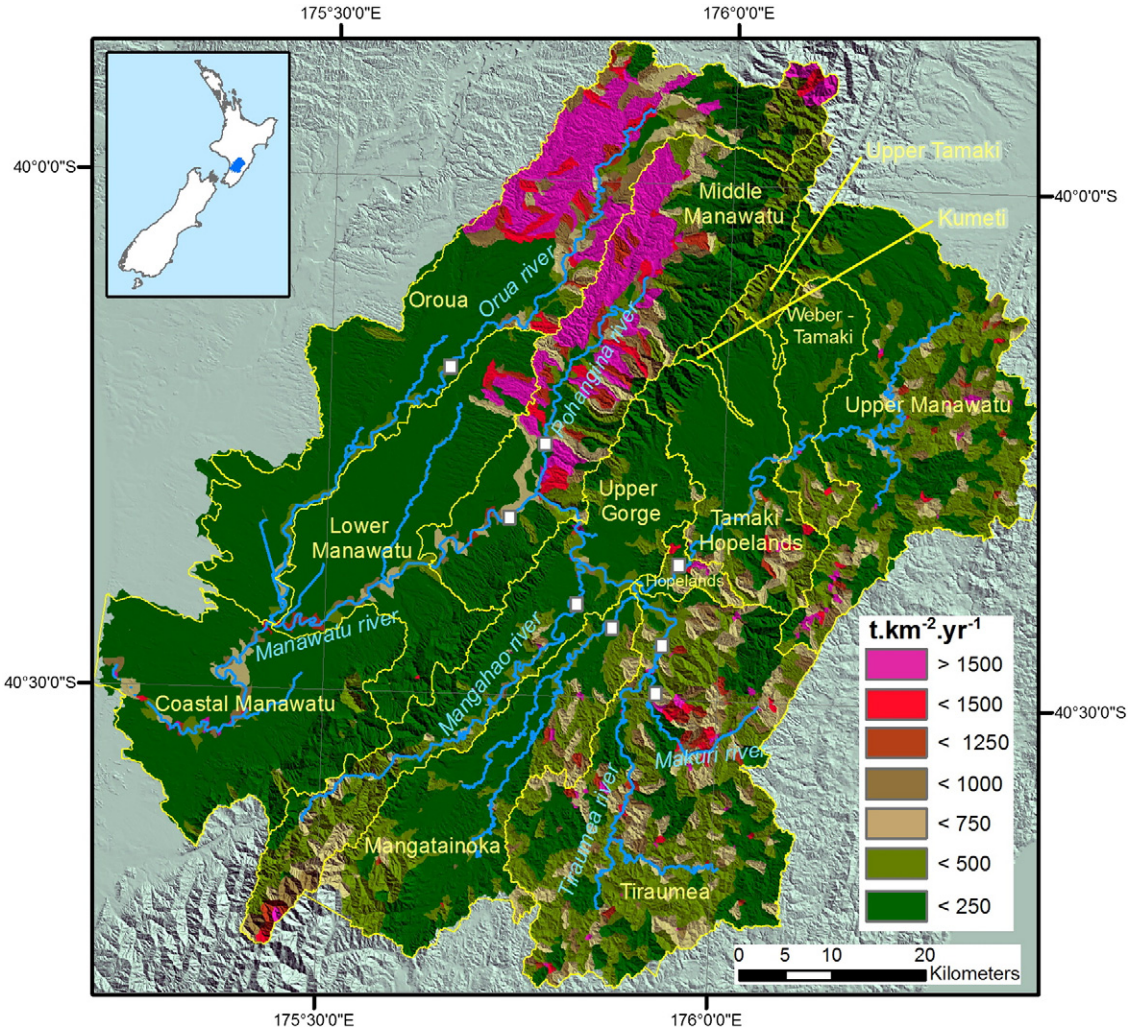

Fig. 1. Location of the Manawatu catchment and net sediment yield (t km^{-2} yr^{-1}) in the subcatchments for the year 2004. Water management zones are shown in yellow. White squares show location of water-level recorders.