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Adoption of erosion management practices in New Zealand

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ABSTRACT

Soil erosion is a serious environmental threat to New Zealand's agricultural sector. Economic costs of soil erosion are significant and the costs of adopting mitigation and management practices, given the targets set by environmetal policy, do not spread uniformly across space, economic activities and types of erosion processes. Management practices have been widely employed by farmers and promoted by several policy programs. Practices are not mutually exclusive and could be jointly adopted by comparing productivity gains against costs of implementation. However, research on the identification of the drivers of adoption is scarce in New Zealand. To identify the determinants of adoption of management practices in New Zealand farms, we combine novel survey information with data on climate and erosion in a multivariate probit framework. This framework allows identification of potential complementarity or substitution between management practices. We find significant and heterogeneous effects from erosion levels, temperature, wind velocity and primary land uses on the adoption of any of the practices. In addition, we also find significant complementarities between management practices. The results of this study are important because the complementarities relate to external effects of erosion mitigation which can help to promote public acceptability of mitigation policies.

1. Introduction

New Zealand (NZ) loses 96 million tonnes of soil per year because of erosion processes (Basher, 2013). This rate is about 10 times faster than the rest of the world, and accounts for between 1.1% and 1.7% of the world's total soil loss to the oceans, despite a land area of only 0.1% of the global total (Hicks et al., 2011; Parliamentary Commissioner for the Environment, 2005). In addition, 10% of the national territory is categorised as suffering from severe and extreme erosion (Dymond et al., 2010), and only 8.4 million ha out of a total 26.5 million ha are capable of sustainable pastoral and cropping uses without soil conservation measures being applied (Eyles and Newsome, 1992).

Economic costs of soil erosion are significant. Farm infrastructure damage costs reach US$8.9 million per annum (in 2013 figures); agricultural production losses, because of productivity declines in pastoral agriculture and arable cropping, cost US$45.1 million per annum. Other direct damages (e.g. roads, rail infrastructure, utility network, recreation facility) amount to US$26.2 million per annum, and indirect costs amount to US$35.5 million per annum. In total, the economic cost of erosion in New Zealand reaches US$122.9 million per annum, which corresponds to 1.31% of the national agricultural production in 2013 (Eastwood et al., 2000). Concerns about the impacts of erosion have led farmers to seek management practices that make agriculture more sustainable (Wu and Babcock, 1998).

However, the costs of adopting mitigation practices, given the targets set by environmetal policy, do not spread uniformly across space, economic activities and types of erosion processes. For the case of agriculture in the Waikato District, mitigating surface erosion is more costly than mitigating mass-movement erosion. A district-wide reduction target of 50% for mass-movement erosion could be achieved at an annual cost of less than 3% ($15.7 m) of the baseline regional net revenue, whereas the same target for surface erosion would bring cost to 19% of the baseline regional net revenue ($109.1 m). The dramatic differences in costs are because of the distribution of the spatial distribution of economic enterprises, baseline erosion rates, and the differing effectiveness of mitigation alternatives. For example, lower earning Sheep and Beef (S&B) farms are primarily located in highly erodible land (HEL) areas with high levels of mass-movement erosion, whereas more profitable Dairy farms are situated on flat non-HEL areas, often where mitigation alternatives for surface erosion (e.g., shelter belts) are already adopted in the baseline. Hence, S&B farms mainly adopt stock reduction and spaced planting of trees as the cost-minimizing management practices, whereas Dairy farms show low adoption rates of any type of practices (Fernandez and Daigneault, 2016).

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The spatial pattern of erosion processes differs across the country. For example, erosion in the North Island occurs mainly in areas of hill country cleared of forest, often triggered by heavy rainfall. In the South Island, in turn, serious erosion is due mainly to natural processes, such as rain and natural erosion, especially along the Southern Alps. Much of this land is in the public conservation estate or is extensively farmed land of low productive value (Ministry for the Environment, 2015). In either case, high economic costs and the complexity of farmer's responses emphasise the desirability of conservation or management practices that reduce soil loss and consequently support the sustainability of New Zealand agriculture. Given that the benefits of mitigation activities are dependent on their direct and opportunity costs (Daigneault et al., 2017), the successful adoption of management practices requires the analysis of the drivers behind adoption decisions, and their economic and environmental implications (Wu and Babcock, 1998).

Although soil erosion is a serious environmental problem in New Zealand (Basher, 2013; Dymond et al., 2010), research on the adoption of management practices is scarce. Studies in other countries have found a wide range of determinants of adoption of practices for different cultural environments, agricultural and farming systems, soil types, climate features, farmers' attitudes, and local conditions (Knowler and Bradshaw, 2007; Rodríguez-Entrena and Arriaza, 2013; Rutgers et al., 2012). Those determinants of adoption shape the willingness of farmers to implement management practices, particularly when costs are non-negligible and the potential (and uncertain) benefits accrue only in the long run. Hence, the purpose of this paper is to identify the determinants that influence the adoption of erosion management practices in New Zealand farms. To identify the determinants we combine novel survey information with data on climate and erosion in a multivariate probit framework. This framework allows identification of potential relations of complementarity or substitution between management practices by allowing error terms to be freely correlated (Cappellari and Jenkins, 2003). We use data from the Survey of Rural Decision Makers (SRDM) (Brown, 2015) to analyse the joint adoption of five management practices, namely water management, soil fixation, sediment management, tree planting, and land retirement. The variables tested had heterogeneous effects on the likelihood of adopting any of the management practices.

The paper is structured as follows. Section 2 describes the management practices for possible adoption. Section 3 describes the data and variables used for the SRDM. Section 4 explains the multivariate probit model used to analyse the adoption decisions. Section 5 describes the results. Section 6 concludes.

2. Erosion and management practices in New Zealand

Agriculture is central to New Zealand's economy, and along with other production from the land, it makes a major contribution to earnings. The ongoing productivity of land is therefore important as it underpins economic and social well-being (Ministry for the Environment, 2015). Then it is critical to understand farmer's responses to policies orientated toward conservation and adoption of management practices, as well as the spatial pattern of erosion across the country.

Fig. 1 shows the distribution of land use in New Zealand. Nearly 40% of New Zealand is exotic grassland (primarily pasture used to graze stock), agricultural and horticultural land occupies about 42% of the country, while plantation forestry covers a further 7.5%; crop lands, orchards, and vineyards account for 1.8%. Mature indigenous forest and regenerating forest cover 26% of the country. Most of this forest and regenerating forest is concentrated in hill and mountain areas, with little lowland forest remaining. Urban settlements cover 0.8% of total land area (Ministry for the Environment, 2015). Land uses overlap with different types of erosion processes (Fig. 2)

Based on Basher (2013), all the main types of erosion occur in New Zealand, namely: (i) Mass-movement erosion (shallow and deep landslides, slumps, earthflows); (ii) Gully erosion, which occurs as linear features cut by channellised runoff and as large, complex mass-movement–fluvial-erosion features that are typically amphitheatre-shaped (Marden et al., 2012), (iii) Surface erosion (sheet, rill and wind); and, (iv) Streambank erosion which is common along waterways, rivers and streams.

Because of the dominance of hilly and mountainous terrain, the most widespread type of erosion is mass-movement. Mass-movement erosion characterizes by a variety of landslide types ranging from small, shallow rapid failures to large, deep, creeping rock failures (Fig. 2a). Gully erosion in turn is most common in the soft rock hill country of the East Coast North Island, and in the North and South Island mountain lands (Fig. 2b). Earthflow (deep mass movement) erosion occurs mostly in the North Island, and is extensive on crushed mudstone and argillite in the Gisborne–East Coast area, Wairarapa and in southern Hawke's Bay (Fig. 2c). It also occurs in Northland, the soft rock hill country of inland Taranaki and the southern Waikato. Small areas occur on mudstone in North Canterbury, South Canterbury and coastal Otago (Basher, 2013).

For surface erosion processes, sheet erosion is the detachment of soil particles by raindrop impact and their removal downslope by water flowing overland as a sheet instead of undefined channels or rills. It is widely distributed particularly in the South Island, in the dry hill country and mountain lands of inland Marlborough, Canterbury and Central Otago, while in the North Island the most affected areas are slopes of the Volcanic Plateau (Fig. 2d). Streambank erosion in turn is one of the least understood erosion processes in New Zealand but still one of the most common processes mitigated by biological and structural erosion control (Fig. 2e). Wind erosion has long been a concern with dust clouds commonly observed blowing off cultivated paddocks. Wind erosion affects 13% of the country, where the most affected areas locate around coastal sand dunes of both islands and the Volcanic Plateau in the central North Island (Fig. 2f) (Basher, 2013).

The first major survey of the extent and severity of erosion in New Zealand was carried out in the South Island high country. The survey found that 25% of the land was extremely eroded, with less than half the topsoil remaining (Gibbs and Raeside 1945). Concerns then arose about the long-term consequences of erosion which resulted in the passing of the Soil Conservation and Rivers Control Act. In addition, catchment boards were created and made responsible for undertaking experimental, preventative and remedial soil conservation works (Basher, 2013). Since then a substantial effort has gone into establishing practices suitable for erosion control in New Zealand.

Erosion effects from wind have been mainly controlled by restoring the vegetative cover because of deforestation or intensification of agriculture (Basher and Painter, 1997). Poplars and willows have been planted for erosion control on pastoral hill country, riverbank protection, shade, and also in the form windbreaks. During the 1960s and 1970s, over two million poplars were planted through government-subsidised erosion management schemes (Wilkinson, 1999). Furthermore, of 136 gullies planted with poplars or willows, erosion was successfully controlled in over 42% (Thompson and Luckman, 1993). Many runoff control practices (drains, headlands) have been used since the 1950s; they were first tried on soil conservation reserves and trial sites in Central Otago, South Canterbury, North Canterbury, and the Earnscleugh Reserve. However, since the 1970s, these practices have lost favour as farm development and grant monies were directed into pasture improvement (Hicks et al., 2001). Field shelter by planting windbreaks is widely practised on both agricultural