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Incorporating treading damage on wet soils in APSIM

Mike Dodd [a], **Val Snow** [a], **Dimetre Triadis** [a]

[a] *Bioeconomy Science Institute - AgResearch Group, New Zealand*

Email: mike.dodd@agresearch.co.nz

Abstract: APSIM was used to simulate the impacts of water table rise and treading damage on wet soils of lowland cattle-grazed pasture systems in New Zealand. A manager script was developed to capture the damage effects on pasture herbage accumulation rates and soil physical properties, as well as the recovery of soil properties over several months. Long-term simulations across six regions and six soil types showed substantial reductions in annual grazeable herbage where water tables were between 0.33 – 1.0 m of the soil surface, from a combination of waterlogging and treading damage suppression of pasture yield. New functionality in AgPasture enables broader exploration of the productivity impacts of future environmental change and management interactions.

Keywords: *AgPasture, cattle, waterlogging*

1. INTRODUCTION

Intensive dairy systems in New Zealand include year-round grazing of heavy cattle with relatively high instantaneous stocking rates during the late autumn to early spring period when soils are often near or above field capacity. This creates the potential for soil and pasture sward damage, which has both short and medium-term consequences for pasture production (Drewry et al. 2008). Global change models project increasing precipitation intensity and rising water tables in coastal lowlands, where intensive dairy systems are common.

The research reported here notes the development of treading damage and impact functions that have been incorporated into an APSIM manager that interacts with both the "SimpleGrazing" module, currently used to control pasture harvesting in the AgPasture module of APSIM, and with the physical properties of the APSIM soil module. These functions were used in a set of simulations across soil orders within a range of future water table scenarios for important dairying regions in New Zealand, to quantify the potential impact of water table rise on pasture productivity.

2. APPROACH

The scope of this study considers the effects of waterlogging and of livestock treading damage when soils are above field capacity (DUL in APSIM). The major considerations are the direct effects of treading on the physical damage to soils (macroporosity and infiltration rate), the direct effect of low soil aeration on plant roots under waterlogged conditions, and the indirect effects of soil damage on subsequent pasture productivity. Natural recovery of soil properties over time are included in the temporal dynamics. A generalised structure for the new treading damage component is shown in Fig. 1.

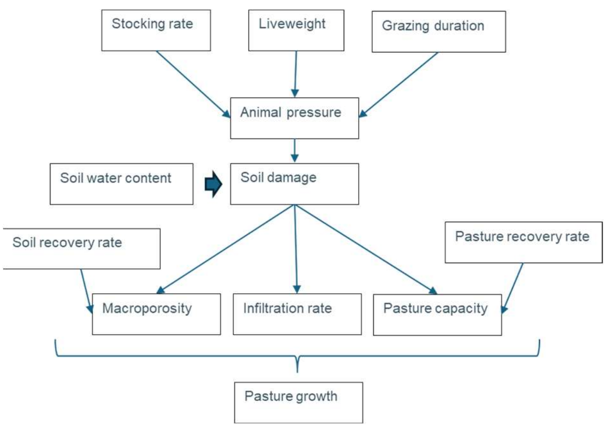

Figure 1. Conceptual structure of the treading model showing the effects of animal treading pressure and soil water content on soil and pasture properties.

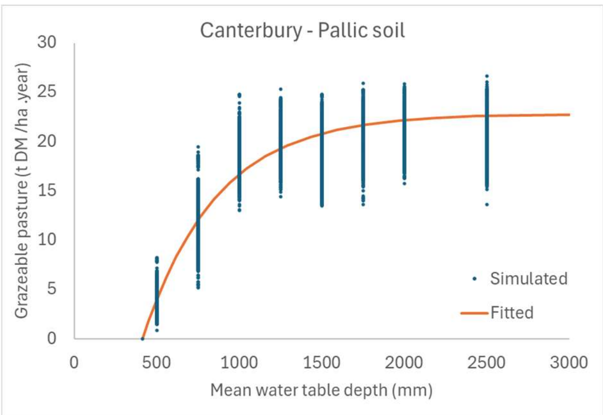

Figure 2 Effect of increasing water table depth on annual grazeable pasture yield on a Canterbury Pallic soil. The points show the year-to-year variation.

Animal pressure on soils and pastures can be quantified with a combination of three variables: livestock density (instantaneous animal numbers per hectare), mean livestock liveweight (kg /head) and duration of the damaging event (hours). These three variables can be multiplied to derive a single measure of livestock pressure. Soil damage is quantified in terms of a scaler as a proportion of soil surface area, commonly measured as the proportion of the grazed area affected by hoof impact. The pressure-damage relationship is a growth function sourced from empirical data (e.g., Zegwaard et al. 2000) and the exponent parameter is influenced by site conditions such as soil type and wetness. In the module, the damage variable has a daily value that can be updated with additional damage events. The effects of soil damage on two soil properties are expressed as linear functions of soil damage, also sourced from empirical data (e.g., Zegwaard et al. 2000; Pande 2002), representing a loss in macroporosity and infiltration rate from undamaged conditions up to a limit which is dependent on soil type.

The effects of animal damage on pasture production are expressed as function of animal pressure, based on the "Ready Reckoner" of Betteridge et al. (2003) which summarises the results of numerous pasture growth impact studies. This reflects a diminishing marginal impact of additional treading and the incomplete destruction of growing points. Waterlogging effects on plant growth (with or without treading) are already incorporated in AgPasture using soil water content relative to a species-specific minimum water-free porosity. Recovery of soil properties and pasture growing points over time has been measured at anywhere from one to nine months. This is implemented as a first-order decay function to decrease the daily value of damage.

To generate simulations of waterlogging and treading damage impacts on annual pasture production, six regional locations were chosen to represent coastal lowland areas that are susceptible to waterlogging as a result of future water table rise, where intensive pastoral systems are common. Within the regional locations, soil orders comprising over 12.5% of the area within any region were represented by specific profile descriptions. Across all regions and soil types, simulations were run for 10 mean water table depths over 52 years. The simulated production *vs* water table depth data were fitted with a nonlinear 3-parameter curve of the form:

$$P_{WT} = P_m \left(1 - \exp\left[\frac{wt_0 - WT}{\alpha}\right]\right) \quad \text{for} \quad WT > wt_0$$

where P_{WT} is the mean annual pasture production under a given mean water table depth (WT), P_m is the undamaged expected pasture production, wt_0 is the mean water table depth when P_{WT} declines to zero, and α is a curvature parameter.

3. RESULTS AND DISCUSSION

Considering pasture production at the deepest water table depths (i.e., non-wetness limiting and minimal damage), simulated mean annual grazable pasture production was lowest in Northland and highest in (irrigated) Canterbury, lowest on an Organic soil and highest on a Pumice soil. Pasture production for a Pallic soil in Canterbury across water table depths is shown in Figure 2, with the other region/soil combinations following a broadly similar pattern. The effect of reducing the water table depth was minimal until the water table depth reached ~1 m below the soil surface, at which point pasture production began to decline, until it was functionally zero once water tables reduced to 330-500 mm (depending on region/soil combination). This effect was from a combination of reduced aeration from the greater frequency of wetter root-zone soil layers at higher water tables, and the greater likelihood of treading damage on the wetter soils. The new functionality in the APSIM AgPasture and soil models enables broader exploration of the productivity impacts of future environmental change and management interactions.

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