Abstract

The demand for increased food production has led to enhanced use of “external inputs” like chemicals, fertilizers, irrigation and effluent to boost yields. This has often been accompanied by unintended negative impacts on soil health and the ecosystem services provided by soil biota like earthworms and soil microbes. Intensive pastoralism has also been implicated in global warming because of greenhouse gas (GHG) emissions. This thesis evaluated the usefulness of earthworms and soil microbes as indicators of soil quality and how their occurrence, abundance, biomass and activity changed under different pastoral farming practices i.e. irrigation; effluent dispersal; conversion from sheep and cattle to dairy farming; and conversion from conventional to organic dairy farming. Effluent dispersal and irrigation led to significant increases in earthworm density and biomass that peaked in paddocks receiving both effluent and irrigation water. The epigeic earthworm Lumbricus rubellus increased by 32% where effluent had been spread, 123% if irrigated and by 180% where both effluent and irrigation water was added together. On the other hand, the anecic earthworm Aporrectodea longa was rare (5.9% of individuals and 5.2% of biomass) and appeared to be driven locally extinct in many irrigated sites while the most abundant and widespread earthworm, Aporrectodea caliginosa, varied comparatively little between treatments. . Earthworm density was 15.4% to 36.6% and biomass was -3.3% to 55.8% higher on sheep/beef farms than dairy farms when equivalent treatments were compared. Because of their sensitivity to soil management, L. rubellus and A. longa earthworms qualify as good soil quality indicator species. The strong experimental effects observed for all species between treatments were evident in the top 10 cm of soil only. Greenhouse gas emissions were strongly dependent on soil management, for example re-wetting soils receiving effluent increased CO2 emissions by 160.6% while it reduced N2O emissions by 16.5% but enhanced CH4 uptake capacity by 286.0%. . In addition, effluent only treated sites had the lowest CO2 emissions (50% less than untreated sites) yet highest N2O emissions were measured from the same sites (72.8% more than untreated sites). Temporal variation in the wetting and drying cycles was particularly high for N2O, with peak fluxes measured on the 6th day after soil wetting that signalled a hot spot for this gas. Irrigation and effluent dispersal increased nutrient levels and reduced soil bulk density on dairy farms. Irrigation also reduced soil bulk density and increased clover (Triloforium repens L.) cover, especially on sheep/beef pastures. There were reduced nutrient levels and more compact soils in land converted to dairy production, especially in unirrigated pastures. This demonstrates that relying heavily on chemical fertilization is not always sufficient to maintain higher nutrient levels and soil

organic carbon in intensified dairy production following conversion. Soil organic carbon and nitrogen were higher where abundance of Lumbricus rubellus, an epigeic earthworm, was lower and a greater water holding capacity where earthworm biomass was higher. However the study failed to find evidence for linear and directly proportional relationships between earthworm abundance and many important soil quality measures. Smart irrigation and nutrient management clearly provide potential solutions to maintain sustainability of the farming systems. This study found no evidence that conversion to organic dairying benefited earthworms or soil microbes, nor that the main soil macro-nutrient levels increased in the initial seven years following conversion. However conversion to organic increased soil structure and water holding capacity of the soil. A preliminary survey of farmers' knowledge and attitudes indicated broad scale awareness of the importance of soil health for sustainability and beneficial roles of earthworms, as well as willingness to monitor them. Farmers were less conscious of the contributions of soil microbes to farming sustainability. No farmer formally monitored earthworms or microbes, or actively and directly managed their abundance. Farmers had a very limited understanding of Overseer, the main nutrient budgeting tool used in New Zealand but some were sceptical of its accuracy. A change of strategy to better harness the ecosystem services of soil biota is required, including incorporation of the effects of soil biota into nutrient models for improving farming efficacy and reducing leaching to the atmosphere and waterways. Scientists should work with farmers to develop practical soil management options and a national stratified random monitoring scheme is needed to ensure that soil biota remain diverse and abundant to keep New Zealand's increasingly intensive pastoral farms resilient and sustainable.