Quantifying and Valuing the Ecosystem Services of Pastoral Soils under a Dairy Use

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Abstract

The full range of ecosystem services provided by soils are rarely recognised or understood, nor is the link between soil natural capital and these services. Understanding these concepts is more important than ever to meet the food and fibre demands of a growing global population, while ensuring the sustainability of the finite resource that is soil. The objective of the thesis was to develop a framework to describe the natural capital and ecosystem services of pastoral soils, and to apply it to quantify and value soil ecosystem services under a dairy use in New Zealand.

A new conceptual framework was developed from current scientific understanding of land classification, soil formation, soil processes and ecosystem services concepts. The framework links soil formation, maintenance and degradation processes to soil natural capital stocks, and provides a basis for exploring the influence of drivers like climate and land use on soil natural capital stocks and the flow of ecosystem services. The soil services identified included provision of food, support to human infrastructure and animals, flood mitigation, filtering of nutrients and contaminants, detoxification and recycling of wastes, carbon storage and greenhouse gases regulation, and pest and disease populations regulation. Based on the conceptual framework, new methodology was developed to quantify and model each provisioning and regulating service from soils. Proxies based on soil properties and a process-based model were used to explore the impacts of soil type (Horotiu silt loam and Te Kowhai silt loam) and dairy management practices on soil properties and processes behind each service at the farm scale. Neoclassical economic valuation techniques were then used to value soil ecosystem services for the case study examples.

Under a dairy operation, the total value of soil ecosystem services was $15,777/ha/yr for a Horotiu silt loam. Regulating services ($11,445/ha/yr) had a greater value than provisioning services ($4,322/ha/yr). The ecosystem services from a Te Kowhai silt loam were less valuable, $11,687/ha/yr. The difference in value between soils reflects differences in their physical structure and associated hydraulic properties, the natural capital stocks behind many services. Valuing some services (e.g. filtering of P) was challenging since some services cannot be substituted by artificial inputs or manufactured capital.

This new approach provides for the first time land managers and policy makers with the ability to compare the total utility of soils, not just their productivity and versatility for different land uses. It also provides a powerful practical tool for evaluating the environmental impact of farm management practices, resource management options and policy alternatives at the regional and national levels, by enabling direct linkages between the economy and the environment. This study allows the value of soil to be benchmarked against commonly used indicators of economic performance such as GDP at the national level and net profits at the farm scale. The case study examples showed that the value of ‘un-priced’ soil ecosystem services to be significantly higher than net profit of dairy farms.

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Acronyms and Symbols

Acronyms:

ASC: Anion storage capacity

AWC: Available water capacity

BCA: Benefit cost analysis

BD: Bulk density

CEC: Cation exchange capacity

DFE: Dairy farm effluents

DM: Dry matter

DOC: Dissolved organic carbon

DOM: Dissolved organic matter

DON: Dissolved organic nitrogen

DOP: Dissolved organic phosphorus

EDCs: Endocrine-disrupting chemicals

ES: Ecosystem services

FC: Field capacity

GHG: Greenhouse gas

GHGs: Greenhouse gases

GT: Grazing time

HM: Heavy metals

HR: Horotiu silt loam

IPCC: Intergovernmental Panel on Climate Change

K sat: Hydraulic conductivity

MAF: Ministry for agriculture and forestry in New Zealand

MEA: Millennium ecosystem assessment

MfE: Ministry for the environment in New Zealand

Mp: Macroporosity

MS: Milk solids

NC: Natural capital

NZ: New Zealand

OM: Organic matter

PL: Plastic limit

RF: Rainfall

RO: Runoff

Sat: Saturation

SP: Stress point

SPASMO: Soil plant atmosphere model

SR: Stocking rate

SWC: Soil water content

TDF: Typical dairy farm

TEV: Total economic value

TK : Te Kowhai silt loam

WFPS: Water-filled pore space

WP: Wilting point

WTA: Willingness to accept compensation

WTP: Willingness to pay

Symbols:

Ammonia: NH_3

Ammonium: NH_4^+

Boron: B

Calcium: Ca

Carbon dioxide: CO_2

Carbon: C

Chloride: Cl

Cobalt: Co

Copper: Cu

Hydrogen: H

Iron: Fe

Magnesium: Mg

Manganese: Mn

Methane: CH_4

Molybdenum: Mo

Nitrate: NO_3^-

Nitrogen: N

Nitrous oxide: N_2O

Oxygen: O_2

Phosphorus: P

Potassium: K

Silicon: Si

Sodium: Na

Sulphur: S

Zinc: Zn