CAPACITY OF SOILS TO SUSTAIN OR EXTEND CURRENT CROP AND ANIMAL PRODUCTION: NEW ZEALAND AND SOUTH PACIFIC ISLANDS PERSPECTIVE

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Summary

The maintenance of soil productivity is an important issue for New Zealand since primary products account for over 60% of export income. Continued inputs of nitrogen, phosphorus, sulfur and micronutrients in the form of mineral fertilizers are required to sustain soil fertility. There is also a need to assess the effects of changes in the type and intensity of landuse on nutrient dynamics, balances and associated potential adverse environmental impacts. Soil erosion is a major threat to the productive capacity of hill country and steepland areas of New Zealand, which will require the development and implementation of appropriate monitoring and management strategies. Most South Pacific Island nations are essentially agrarian and natural soil fertility is generally very

low. The maintenance and expansion of primary production from these soils is a major challenge that will require increased inputs of mineral fertilizers, together with recycling of organic residues and manure and increased use of legume cover crops. In addition to the threat posed by rising sea level as a consequence of global climate change, there is also a need for continued assessment and mitigation of the effects of deforestation and waste disposal on soil and environmental quality in many South Pacific Island countries.

1. Introduction

The aim of this article is to describe and discuss the principal factors that influence the capacity of soil to sustain or extend current crop and animal production in New Zealand and South Pacific Island countries. This includes a general description of key aspects of the geography, landforms, climate and soils, together with details of the most important factors that determine current and future soil productivity, and issues of future research requirements.

2. New Zealand

2.1. Geography and Landforms

New Zealand comprises three main islands (North, South and Stewart) situated between 165^o and 180^oE and 33^o and 47^oS, with a total land area of 270,000 km^2 (27 million ha). The original Maori settlers are believed to have arrived in New Zealand around 800 years ago, compared with human settlement of Australia that began 50-60,000 years ago. The total Maori population in 1800 was estimated to be 100,000. The first European to visit New Zealand was the Dutch explorer Abel Tasman in 1642, followed by James Cook from England in the 1770s. Organized European settlement of New Zealand (mainly from England, Scotland and Ireland) began in 1840, and by 1900 there were 750,000 European residents compared with only 40,000 Maori. European settlement continued throughout the twentieth century and the Maori population recovered. The current population of New Zealand is 3.6 million, of which 75% are of European descent compared to 15% Maori and 4% Pacific Islanders.

The landmass that is now New Zealand was thrust up from the ocean 120-140 million years ago as an island off the coast of the super-continent Gondwana. As a consequence of its location on the junction of the major Pacific and Indian-Australian tectonic plates, New Zealand is geologically very active. Between 50 and 25 million years ago New Zealand was gradually pushed down until only 20% of the current land area was above sea level. Thereafter the land was raised and twisted by plate movement, a process that is continuing with an uplift rate of up to 10 mm per annum. The impacts of this tectonic stress are evident in the nature of the New Zealand landscape. Only 15% of the land area is flat ($<3^o$), while rolling ($3-12^o$), hill ($12-28^o$) and steepland ($>28^o$) areas make up 14, 21 and 48%, respectively (lakes account for the remaining 2% of land area). Furthermore, 60% of the land is more than 300 m above sea level (20% above 900 m), with the highest point at 3754 m (Mt Cook). The extent of geological activity is also evident from the number and frequency of earthquakes experienced and the level of volcanic activity. The latter is particularly important in the North Island where major eruptions over the past 20,000 years have shaped the landscape (e.g. Lake Taupo). For example, pumice and ash from the last Taupo eruption in AD 115 is estimated to have destroyed 2 million ha of forest, while the 1886 Mt Tarawera eruption spread volcanic mud over 12,000 ha and ash over 1.4 million ha (as well as causing >100 deaths). Most (75%) of the rocks in New Zealand are sedimentary, having accumulated from erosion of other rocks and include sandstone, greywacke, argillites (siltstone, mudstone) and limestone. The remaining rocks are mostly igneous in origin formed from molten magma that either cooled or hardened beneath the surface (e.g. granite, gabbro) or was deposited on the surface following eruption (e.g. rhyolitic-andesitic tephra, basalt).

2.2. Climate

As a direct consequence of being 1500 km long, the New Zealand climate varies from sub-tropical in the north to sub-Antarctic in the far south. The overall climate can best be described as maritime, temperate, windy, with warm to hot summers and cool to cold winters. The mean annual temperature ranges from 16 ^{o}C in the north to 10 ^{o}C in the south. The climate is also greatly influenced by the topography and as a result of prevailing moist westerly winds and the presence of high mountain ranges (>2000 m) in both main islands, the west tends to be wetter than the east. This is particularly evident in the South Island where the average annual rainfall in the east is 400 to 1200 mm (<800 mm in most areas) compared with >2400 mm to the west of the main dividing ranges.

2.3. Soils and Landuse

New Zealand soils developed from sedimentary and igneous rocks mainly under evergreen podocarp (e.g. rimu (*Dacrydium cupressinum*), totara (*Podocarpus totara*), kahikatea (*Dacrycarpus dacrydiodes*)), beech (*Nothofagus* sp.) and kauri (*Agathis australis*) forests. More than 100 distinct soil types have been identified according to the New Zealand Soil Classification System, which can be divided in to 3 main categories:

- Pallic and Brown soils: derived from greywacke, sandstone, siltstone and mudstone as colluvium, alluvium and loess;
- Pumice soils: derived from rhyolytic tephra (central North Island);
- Allophanic and Oxidic soils: derived from andesitic tephra and basalt (mainly North Island).

When Maoris first arrived in New Zealand c. 1200 most of the land was covered by dense forest, which they began to clear by burning to facilitate settlement and hunting. Most of the forest clearance occurred between 1350 and 1550 and the consequent long-term impacts were greatest in the drier east coast regions of both main islands. By 1840 (immediately prior to large scale European settlement) the forest cover had been reduced from 85% (23 million ha) to 53% (14.3 million ha). Deforestation continued under European settlement as land was cleared for pastoral agriculture. Accordingly, at present the remaining native forest cover is only 23% of the total land area (6.3 million ha); most of this forest is protected from further clearance.

Currently 15.5 million ha of land in New Zealand is utilized for agriculture, horticulture and plantation forestry. The latter is based on growing exotic trees (principally radiata pine (*Pinus radiata*) from North America) on a 20-40 year rotation. Most of this area (12 million ha) is under extensive pastoral farming (sheep and beef) on hill country and steepland, while 2 million ha of flat and rolling land is under intensive agriculture and horticulture (1.5 million ha under pasture (dairy, beef, deer), 0.4 million ha is under arable cropping (wheat, barley, maize), and 0.1 million ha is under horticulture (apples, kiwifruit, grapes)). It is important to note recent and ongoing dramatic changes in landuse which have occurred in New Zealand that can be attributed to a combination of factors including the removal of all product and input subsidies in 1985. Thus between 1985 and 1995 sheep numbers declined from 70 to 50 million (46 million in 2000), and while total cattle numbers remained static over this period at 9 million the number of dairy cows increased by 40% from 2.9 to 4.1 million. Over the same period there was a dramatic increase in the land area under plantation forestry from 0.9 million ha in 1985 to 1.5 million in 1995 (predicted to increase to 2.3 million ha by 2010). Most of the recently established forests have been planted on hill country and steepland developed under pastoral farming since European settlement, and occurred in response to continued declines in returns from meat and wool and expected higher returns from forest products in the future.

2.4. Constraints to Soil Productivity

Land based primary production is a vital component of the New Zealand economy and agricultural, horticultural and forest products together account for 60-65% of the country's total export income. Accordingly factors that affect the capacity of soils to sustain or extend plant and animal production will have a major influence on continued prosperity and economic development. The capacity of soils to sustain production in New Zealand is determined mainly by climatic factors (including the availability of water from rainfall and irrigation) and a combination of biological and chemical fertility (including acidity) and erosion. These in turn are influenced by many factors including soil type, topography, aspect and climate, together with past, present and future landuse and management practices.

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Biographical Sketches

Leo M. Condron was born in Glasgow, Scotland. He obtained a Bachelor of Science (Honours) degree in Agricultural Chemistry from the University of Glasgow in 1980, and his PhD in Soil Science from the University of Canterbury (Lincoln College), New Zealand in 1986. After finishing his PhD, Dr Condron worked as an agronomist for the Fertiliser Manufacturers' Research Association in Auckland, New Zealand for 2 years. He then worked as an environmental consultant in Auckland, New Zealand for 1 year, before taking up a 2 year Postdoctoral Research Fellowship in soil science at the University of Saskatchewan, Canada. Dr Condron returned to New Zealand in 1989 to take up a Postdoctoral Research Fellowship in soil science and agronomy at Lincoln University. He was appointed to his present position of Lecturer/Senior Lecturer in Soil Science at Lincoln University in 1992. Dr Condron has carried out fundamental and applied research designed to optimise the efficiency of nutrient cycling in the soil environment in relation to changes in the type and intensity of land use, with a particular emphasis on phosphorus dynamics and availability. In 2002 he was awarded an OECD Fellowship to work on phosphorus transfer at the Institute of Grassland and Environmental Research in the UK. Dr Condron has published over 50 refereed papers and book chapters, together with over 80 other publications and research reports.

Hong J. Di was Born in Hebei, the People's Republic of China. He obtained his Bachelors degree in Soil Science and Agricultural Chemistry in 1983 from Hebei Agricultural University; his Master of Applied Science Degree in Soil Science in 1988 from University of Canterbury (Lincoln College), New Zealand, and his PhD degree in Soil Science in 1991 from Lincoln University. After finishing his PhD, Dr Di worked as a Postdoctoral Research Fellow at the University of Western Australia in Perth, Australia, for 3 years. Since 1995, Dr Di has been working as a Senior Lecturer/ Senior Research Scientist at Lincoln University, New Zealand. Dr Di's research focus is mainly on the losses and transformations of nitrogen and phosphorus and water contamination; pesticide transformations, leaching and groundwater contamination; modeling of nitrate and pesticide leaching; and the use of isotopic techniques to study nutrient dynamics in the soil. Dr Di is the recipient of the Leamy Award by the New Zealand Society of Soil Science for the most meritorious contribution to Soil Science in the past 3 years (2000), and the best publication medal by the Australian Society of Soil Society. He was OECD Fellow in 2001 to England and a Trimble Agricultural Research Fellow in 2002 to the USA. Dr Di is Associate Editor for the Journal of Environmental Quality. Dr Di has produced more than 50 refereed publications and more than 120 other significant publications. He is the author, together with Professor Keith Cameron, of a simple computer model (NLE) for estimating nitrate leaching losses and critical nitrogen application rates for dairy pasture systems.