Thought for food: impacts of urbanisation trends on soil resource availability in New Zealand

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Abstract

Sustainable food production requires maintaining land of suitable quantity and quality to meet the needs of current and future generations. We analysed urbanisation trends and their impact on soil resource availability in New Zealand, with a particular focus on highly versatile soils defined as Land Use Capability Class (LUC) 1 or 2 soils. LUC Class 1 and 2 soils occur predominantly in four regions (Canterbury, Manawatu-Wanganui, Taranaki, and Waikato). Urbanisation rates (% converted of original extent measured by the Land Resource Inventory) were highest for LUC Class 1 (5.6%) and Class 2 (3.96%) compared with <0.01 to 2.0% for LUC Classes 3-8. Dwelling densities outside of urban areas as measured by census data also gradually increased, although the full implication for soil resources requires further research. Overall currently available data sources for analysing land-use/land-cover change provide only broad assessments, are inconsistent, and have their own issues with data quality. Soils are non-replaceable national assets that require long-term protection. Appropriate policies and land-use management planning underpinned by robust land-use data and trend analyses are needed nationally, regionally, and locally to ensure future generations enjoy the same range of options for their food production as we do today.

Keywords: land use capability, land use change, sustainable production, versatile soils

Introduction

Sustainable food production requires maintaining land of suitable quantity and quality to feed current and future generations (Lal 2009), including 1–3 billion additional people expected by 2050 (UNDP 2008). Climate change will complicate the situation by affecting agricultural production and decreasing reliability of food production (Fischer *et al.* 2005; Parry *et al.* 2004; Tait *et al.* 2008). Production patterns are expected to shift among regions based on differential responses to changing climate (Ewert *et al.* 2005; Lhomme *et al.* 2009; Tan & Shibasaki 2003; Tubiello *et al.* 2007). Greater frequency and severity of extreme events such as droughts, floods, or high winds could decrease yields or increase risk of business failure (Stroombergen *et al.* 2008). Essential inputs (e.g., phosphorus, pesticides derived from fossil fuels) needed to maintain high levels of agricultural output will become scarcer and therefore more expensive (Cordell *et al.* 2009; Robert 2010). Taken together, the global food system may struggle to meet increasing demand (Schmidhuber & Tubiello 2007).

In New Zealand, agricultural production helps meet critical needs both globally and locally. In 2009, primary production exports contributed NZ $1 500 million to GDP, about 35% of our total exports. New Zealand is the world's largest dairy exporter, accounting for about 33% of the world dairy trade, and is also a major supplier of agricultural products such as kiwifruit, avocados, apples, and wine. Success in primary production is due partly to its versatile soils, which can support a wide variety of agricultural production. For many products, New Zealand country is self-sufficient. However, a preliminary analysis (Rutledge 2008) indicated that conversion rates of land to non-production (urban) uses were highest for highly versatile soils, defined as those rated as Land Use Capability (LUC) Class 1 or 2. Without proper land-use planning, urban expansion could gradually erode New Zealand's food production potential, and thereby affect our export production as well as our ability to feed ourselves.

We undertook an analysis to identify trends in land-use changes and their consequences for soil resources. Specifically, we were interested in the extent and rates of urbanisation of soils of different LUC classes. Given that New Zealand has a fixed land area and an even smaller area of versatile soils, any loss of versatile soils represents a permanent decrease in national production potential. In some cases, we lose the option to produce particular crops. In other cases production could be shifted to other soils, but at the risk of reduced yields or the need for increased management or inputs to maintain the same yields.

Methods

Land-use trends were analysed using a combinatorial

Table 1 Area of LUC class recorded by the LRI. Upper value in each cell is area in thousands of hectares. Lower value in each cell is % of national total. Top 5 regions by % area nationally in each column is shown in bold. Regions/unitary authorities listed from north to south and west to east.

	Land Use Capability (LUC) Class								
Region	1	2	3	4	5	6	7	8	Other*
Northland	0.43	36.15	90.92	300.84	8.24	**612.65**	153.71	28.44	23.41
	0.2	3.0	3.7	**10.8**	3.9	**8.2**	2.7	0.5	3.0
Auckland	4.34	53.60	64.29	79.64	0.00	175.19	57.41	12.26	51.03
	2.3	4.5	2.6	2.9	0.0	2.4	1.0	0.2	6.6
Waikato	**46.36**	**252.88**	**278.95**	**338.66**	10.30	**913.98**	390.14	119.59	**87.86**
	24.8	**21.1**	**11.4**	**12.2**	4.9	**12.3**	6.9	2.1	**11.3**
Bay of Plenty	2.82	52.84	74.29	182.76	0.66	283.19	392.62	202.47	30.16
	1.5	4.4	3.0	6.6	0.3	3.8	6.9	3.5	3.9
Gisborne	5.65	15.35	49.52	25.05	0.00	272.11	**393.02**	71.12	2.26
	3.0	1.3	2.0	0.9	0.0	3.6	**6.9**	1.2	0.3
Hawke's Bay	**17.51**	26.48	137.77	100.13	**23.79**	570.96	313.62	202.14	21.92
	9.4	2.2	5.6	3.6	**11.4**	7.7	5.5	3.5	2.8
Taranaki	**36.22**	**55.63**	93.34	69.42	**37.91**	146.19	229.21	49.99	5.44
	19.4	**4.6**	3.8	2.5	**18.1**	2.0	4.0	0.9	0.7
Manawatu-Wanganui	**33.94**	**171.40**	**185.19**	159.14	3.89	**821.27**	**608.53**	218.94	16.04
	18.2	**14.3**	**7.6**	5.7	1.9	**11.0**	**10.7**	3.8	2.1
Wellington	5.15	29.67	87.67	40.91	8.46	272.51	230.95	102.05	31.59
	2.8	2.5	3.6	1.5	4.0	3.7	4.1	1.8	4.1
Tasman	4.69	4.88	46.19	51.69	1.05	110.29	266.82	**470.42**	7.57
	2.5	0.4	1.9	1.9	0.5	1.5	4.7	**8.1**	1.0
Nelson	0.00	0.65	1.87	0.40	0.00	10.16	23.65	3.78	1.22
	0.0	<0.1	0.1	<0.1	0.0	0.1	0.4	0.1	0.1
Marlborough	2.45	11.40	48.20	29.84	0.61	289.02	360.86	282.73	16.20
	1.3	0.9	2.0	1.1	0.3	3.9	6.4	4.9	2.1
West Coast	0.00	0.00	14.69	151.33	11.56	292.23	**400.13**	**1409.04**	**55.51**
	0.0	0.0	0.6	5.5	5.5	3.9	**7.0**	**24.4**	**7.2**
Canterbury	23.18	270.26	545.32	516.49	24.28	**1165.30**	**712.54**	**1026.94**	**233.30**
	12.4	**22.5**	**22.4**	**18.6**	**11.6**	**15.6**	**12.6**	**17.8**	**30.1**
Otago	3.09	47.27	**342.90**	**431.02**	**44.55**	**1008.70**	**775.16**	**435.25**	**95.38**
	1.6	3.9	**14.1**	**15.6**	**21.3**	**13.5**	**13.7**	**7.5**	**12.3**
Southland	1.09	**171.31**	**377.85**	**294.61**	**33.79**	508.87	364.70	**1146.46**	**95.86**
	0.6	**14.3**	**15.5**	**10.6**	**16.2**	6.8	6.4	**19.8**	**12.4**
New Zealand	186.91	1199.77	2438.94	2771.92	209.07	7452.62	5673.07	5781.63	774.74
	0.7	4.5	9.2	10.5	0.8	28.1	21.4	21.8	2.9

*Other includes LRI classes estuaries, mines, lakes, rivers, and towns

analysis method described elsewhere (Rutledge *et al.* 2004; 2010; Walker *et al.* 2008). Briefly, the method overlays input spatial data layers and identifies all unique combinations based on the data layer attributes. The resulting combinatorial dataset can be queried to analyse a broad range of questions. For the current study, the following spatial data layers of land use/land cover were used as inputs:

1970s/1985	Land Resource Inventory LUC Classes (LRI) (Newsome 1992)
1990	Land Use and Carbon Analysis System (LUCAS) (Stephens *et al.* 2010)

Table 2 Urbanisation trends. Upper value in each cell is the area in hectares converted from the original area reported by the LRI. Lower value is the % of original LRI area.

		TO				
FROM	LRI Original Area 1985	LUCAS Settlements 1990	LCDB1 Urban[1] 1996/1997	LCDB2 Urban[1] 2001/2002	LUCAS Settlements 2008	Agribase Lifestyle Blocks[2] 2008
LUC 1	186914	4201 2.2	2953 1.6	4301 2.3	4201 2.2	6119 3.3
LUC 2	1199774	18504 1.5	10575 0.9	20051 1.7	19471 1.6	26892 2.2
LUC 3	2438938	21918 0.9	12207 0.5	23700 1.0	22378 0.9	34722 1.4
LUC 4	2771921	14766 0.5	8210 0.3	18956 0.7	15036 0.5	28078 1.0
LUC 5	209066	728 0.4	447 0.2	815 0.4	729 0.4	1950 0.9
LUC 6	7452618	13041 0.2	8238 0.1	17651 0.2	13411 0.2	36566 0.5
LUC 7	5673068	4386 0.1	2669 0.1	6444 0.1	4362 0.1	10724 0.2
LUC 8	5781631	753 0.0	461 0.0	1246 0.0	728 0.0	878 0.0
Estuary	27327	373 1.4	419 1.5	413 1.5	390 1.4	133 0.5
Lake	333647	528 0.2	398 0.1	1953 0.6	575 0.2	74 0.0
Quarry	1045	19 1.8	1 0.1	346 33.1	22 2.1	1 0.1
River	269506	627 0.2	508 0.2	794 0.3	669 0.2	454 0.2
Town	143219	119308 83.3	104988 73.3	118973 83.1	118830 83.0	1296 0.9
Total Urban	143219	198693	152074	215643	198683	147887

[1]Includes built-up areas, surface mines, transport infrastructure, urban parkland/open space

[2]Areas identified as lifestyle blocks but not urban as of LCDB 2001/2 or LUCAS 2008

1996/7 Land Cover Database Version 1c (LCDB1) (Thompson *et al.* 2003)
2001/2 Land Cover Database Version 2 (LCDB2) (Thompson *et al.* 2003)
2006 2006 Census Meshblocks (MB06) (Statistics NZ 2008)
2008 Agribase Land Use Classes (Agribase) (AssureQuality 2008)
2008 Land Use and Carbon Analysis System (LUCAS) (Stephens *et al.* 2010).

Results

Table 1 summarises the distribution of soil resources across New Zealand by region. LUC Class 1 and 2 soils account for 0.7% and 4.5% of total land area. Four regions (Canterbury, Manawatu-Wanganui, Taranaki, and Waikato) contain 75% and 63% of LUC Class 1 and 2 soils, respectively.

Table 2 summarises urbanisation trends by LUC classes nationally. Urban areas increased from 1985 (LRI) to 2008 (LUCAS). Inconsistencies appeared when comparing trends across data sets. LUCAS reported the same urban area (= Settlements) for 1990 and 2008 and more urban area in 1990 (198 693 ha) than LCDB1 in 1996/67 (152 074 ha). The spatial distribution of urban areas differed between the 2 LUCAS reporting years based on the different amounts converted from the LRI to 1990 or 1998, for example, 18 504 ha converted from LUC Class 2 by 1990 compared with 19 471 converted by 2008. The progression from LRI to LCDB1 to LCDB2 was more consistent for total area but also exhibited spatial differences. For example, of the 143 219 ha reported as town by the LRI, only 104 988 and 118 973 were considered urban as of LCDB1 and LCDB2, respectively. Agribase (AssureQuality 2008) reported a total of 147 887 ha of lifestyle blocks nationally.

Urbanisation rates decreased with increasing LUC

Table 3 Trends in census meshblock dwelling densities from 1996 to 2006 by LUC class. Numbers in cells represent the count of meshblocks in that density class as of 1996 (top), 2001 (middle), and 2006 (bottom). Only meshblocks without any urban area identified by LCDB or LUCAS or lifestyle blocks were included in the analysis. Arrows indicate the overall direction of the trend.

	Count of Meshblocks by Dwelling Density Class (Dwellings/ha)							
LUC Class	0	0.00001-0.001	0.00101-0.01	0.01001-0.1	0.10001-1.0	1.00001-5	5.00001-25	25.0001-387
1	↘ 40 27	- - -	→ 1 2 2	↘ 227 218 212	→ 529 530 531	↗ 104 119 124	↗ 43 40 49	↗ 4 5 9
2	↘ 339 315 205	- - -	→ 36 31 37	↘ 1497 1457 1379	↗ 1412 1442 1483	↗ 256 280 325	↗ 95 110 190	↗ 14 14 30
3	↘ 485 469 427	→ 1 - 1	→ 247 253 237	↘ 2314 2271 2197	↗ 1823 1856 1895	↗ 297 311 363	↗ 92 95 128	↗ 8 12 19
4	↘ 596 569 509	↘ 14 10 9	↘ 335 328 305	↘ 1944 1938 1866	↗ 1594 1602 1690	↗ 307 335 375	↗ 103 110 131	↗ 13 14 21
5	↘ 69 73 62	→ 1 1 -	→ 23 26 25	→ 214 212 211	→ 215 209 204	↗ 58 59 77	→ 25 26 25	→ 3 2 4
6	↘ 974 934 856	↘ 85 87 75	↘ 1088 1077 1052	↘ 1953 1950 1931	↗ 1012 1030 1113	↗ 258 291 319	↗ 99 99 117	↗ 13 14 19
7	↘ 639 624 606	↘ 113 108 94	→ 598 600 596	↘ 1037 1027 1013	↗ 706 717 746	↗ 173 179 189	↗ 65 76 82	↗ 7 7 10
8	↘ 417 394 388	→ 86 97 93	→ 163 159 163	↘ 375 370 371	↗ 382 400 395	↗ 85 90 96	↗ 47 43 46	↗ 6 8 9

class value (Table 2). LUC Classes 1 and 2 experienced the highest urbanisation rates, 2.3% and 1.7% of original extent converted, respectively. Lifestyle block conversions based on Agribase showed a similar trend. Based on available data, up to 5.6% of LUC Class 1 and 3.9% of LUC Class 2 soils underwent urbanisation if urban and lifestyle blocks are considered together.

Table 3 shows housing density trends in census meshblocks that did not contain either urban areas as identified by LCDB or LUCAS or lifestyle blocks as identified by Agribase. All LUC classes showed declines in the number of meshblocks with no dwellings (dwelling per hectares = 0). Counts of meshblocks with <0.1 dwellings per hectare (>10 hectares per dwelling) showed slightly declining (↘) or stable trends (→), whereas counts of meshblocks with >0.1 dwelling per hectare showed increasing trends (↗) except in 4 cases.

Discussion

While only a small portion of New Zealand's total area, development of urban areas and rural residential land such as lifestyle blocks differentially affected soil resources. LUC Class 1 and 2 soils experienced the highest rates of conversion as a percentage of original area. LUC Class 1 and 2 soils are typically considered the most versatile and productive soils. Further losses will either reduce options for growing different crops into the future and/or require shifting production to other soils that require more intensive and more expensive management to maintain or increase future production.

Dwelling density trends based on census meshblock data provided an indicator of urbanisation trends outside urban or rural residential areas. Overall those trends suggested an on-going subdivision of land outside of primary urban areas. However, the full implication of those trends for soil resources remains uncertain. Further study is needed to ascertain the actual density of new urban development and determine which soils have been affected.

The analysis was based on currently available, nationally consistent datasets: LUCAS, LCDB, Agribase and the census. Each dataset was designed for particular purposes and has advantages and disadvantages. The LCDB provided the best and most consistent information on land-cover and indirectly land-use change. However it is 8 years old and no firm commitments currently exist to update it. LUCAS provided recent land use data (2008). However, it was designed to fulfil Kyoto Protocol reporting obligations related to changes in agriculture and forestry, thus making it less reliable for analysing urbanisation trends. Agribase provided useful data on rural residential development trends but is voluntary, not comprehensive, and inaccurate in places. Census data offered some quantitative data on dwellings that can serve as an indicator of trends outside core urban areas (for example, built-up area in LCDB). However, census meshblocks were delineated for statistical purposes. As a result they vary considerably in area, making them less suitable for land-use change analysis. Comparison across datasets proved problematic given the differences in land classification and delineation. For example, a study in Marlborough (Rutledge *et al*. 2010) found inconsistencies in the delineation of LRI Town boundaries and LCDB Built-up areas.

Other potential sources of land-use/land-cover information exist that were not used in the current analysis. Cadastral information can indicate subdivision more definitively, but not necessarily land use. Valuation data include an assessment of current land use, although no official guidelines currently exist to assist in land use classification.

In summary, recent trends based on available data showed that urbanisation differentially affected our most versatile soils. If those trends continue, a large percentage of LUC Class 1 and 2 lands could be lost to agricultural production over the next 50-100 years. During that same period, impacts from climate change, population growth, and resource limitations will make agricultural access to versatile soils even more important. However currently available land-use data is inconsistent and incomplete, leading to difficulties in analysis and interpretation. New Zealand needs to commit to collecting consistent and accurate land use/ cover data to underpin robust analysis, monitoring, and reporting of land-use change and, more importantly, facilitate future forecasting needed to estimate and maintain agricultural production potential. Soils are non-replaceable national assets that require long-term protection. Appropriate policies and land-use management planning underpinned by robust land-use data and trend analyses are needed nationally, regionally, and locally to ensure future generations enjoy the same range of options for their food production as we do today.

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