Appraising Soil Fertility in Early Colonial New Zealand: The ‘Biometric Fallacy’ and Beyond

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ABSTRACT

During the late eighteenth century explorers applied a biometric model, where soil fertility was correlated with tree height, throughout the world. This model was a natural extrapolation from the ‘humus theory’ of soil fertility. Accordingly, when dense forest cover was found over large areas of New Zealand this created an inaccurate perception that its soils were very rich. This was exploited to the full by the New Zealand Company, the main agency involved in promoting the organised settlement of New Zealand. During the 1840s, the biometric approach to soil fertility appraisal was found to be a false one, and was replaced by a developing ecological one, which relied on specific plant indicators of soil fertility.

KEYWORDS

Soil fertility, humus theory, biometric fallacy, New Zealand Company, ecological model

INTRODUCTION

It has long been recognised that during the early nineteenth century there was a ‘myth’ that New Zealand’s soils were exceptionally fertile, and that the New Zealand Company made full use of that myth in their cause of promoting emigration to New Zealand.[1] The New Zealand Company’s exploitation of this myth was entirely in keeping with their somewhat dubious record of commercial behaviour. However, when one looks further into the development of the ‘biometric fallacy’, which I have termed it, for reasons which will become clear,

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one finds amongst its instigators several individuals, most notably Captain James Cook, whose observations have generally been regarded as relatively objective and reliable. In short, the myth was more than just a creation of unscrupulous marketing and wishful thinking.

CONSTRUCTING THE 'BIOMETRIC FALLACY'

In order to see why the 'biometric fallacy' arose it is necessary to examine eighteenth-century European thinking about what made soils fertile. By this time, only the first steps towards the modern understanding of soil chemistry and plant nutrition had been made – the existence of carbon dioxide, for example, was not documented until 1755.[2] This was not a hindrance for agriculturists, as they could use their own past experience of growing crops on particular soils to predict the agricultural potential of the same soils, or soils on which the same natural vegetation grew, when they found them elsewhere. Eighteenth-century explorers, however, were heading off into completely foreign plant and soil environments, and thus only had theory to guide their soil fertility assessments.

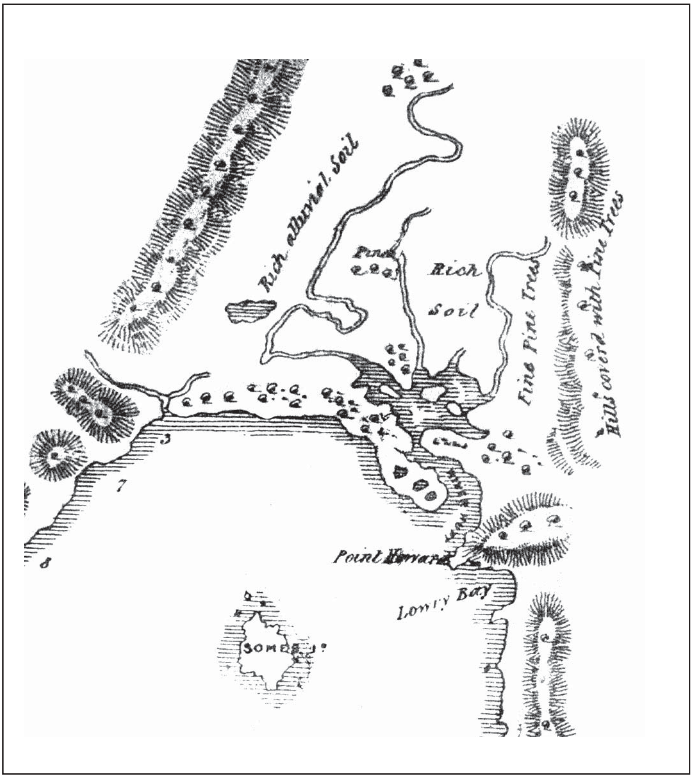
At the time, the dominant hypothesis for explaining levels of soil fertility was the 'humus theory'. This theory had its genesis in a work written by the Polish physician J.A. Külbel in 1740, and was more fully elucidated by the Swedish chemist J.G. Wallerius in *Agriculturae Fundamenta Chemica* (1761). To put it simply, the theory argued that decayed animal and plant matter in the form of mould constituted the 'principle of vegetation', that is, the singular source of plant food. The only purpose, Wallerius argued, of other soil constituents in the soil, such as soil minerals and water, were the conversion of the humus into a form usable by plants.[3] Its adoption by two giant figures in the natural history world, that is Count Buffon in France and Carl von Linné in Sweden, almost guaranteed its diffusion amongst the European scientific community.[4]

If the 'humus theory' was held to be true, then the best measure of the fertility of an unfamiliar soil was likely to be the quantity of vegetable mould it contained. Unfortunately, determining this required time-consuming *in situ* field observation, so in practice it proved easier to make an assessment on the basis of the amount of biomass or, at a more basic approximation still, from the height of the local vegetation, which could be readily gauged from on board ship with the aid of a telescope. At the same time, finding lush vegetation also ruled out the possibility of an arid climate.

During the voyages to New Zealand by James Cook, J.F.M. de Surville and Marion du Fresne, observers repeatedly used the resulting 'biometrical' model when referring to soil fertility.[5] The European visitors to New Zealand's shores were particularly impressed by its dense forests, which covered two-thirds of the North Island and one-quarter of the South Island,[6] and which seemed to be ample proof that highly fertile soils could be found there. For instance, after seeing the Thames Valley the young Joseph Banks wrote in his journal that he had observed 'Swamps, which ... sufficiently evincd [sic] the richness of their soil by the great size of all the plants that grew upon them, and more particularly of the timber trees which were the streightest [sic], cleanest, and … largest I have ever seen …'[7]. Conversely, land which had neither forest cover nor deposits of alluvium from areas under forest, was regarded as having infertile soils. Thus, when it came to describing the south-eastern side of the Whitianga River, Cook stated that it was 'very barren produceing [sic] little but Fern and such other Plants as delight in a poor soil'.[8] On the basis of such observations, together with the evidence provided by Maori cultivations, it was concluded that the valleys and plains of the North Island, many of which were 'not overgrown with wood', possessed soils that were 'light and fertile'.[9]

In the numerous descriptive accounts of New Zealand published in the early nineteenth century, the notion that the North Island contained vast areas of rich soils remained largely unaltered. The South Island, in contrast, had initially been described as mountainous and barren, but after it was revisited during Cook's second voyage, its soils began to be viewed in a favourable light as well. John Nicholas in his *Narrative of a voyage to New Zealand* (1817), for example, remarked that 'from the astonishing height of the trees growing upon it, as well as from their great abundance, it would seem the soil must be rather fertile than otherwise'.[10] Once *Pakeha* (non-Maori) settlers began to establish themselves in New Zealand during the 1820s and 1830s, the reputation in regard to soil fertility of 'fern land', that is, land infested by bracken (*Pteridium esculentum*), also began to improve. As Charles Darwin wrote when the HMS *Beagle* visited New Zealand, 'the sight of so much fern impresses the mind with the idea of sterility. This, however, is not the case; for wherever the fern grows thick and breast-high, the land by tillage becomes productive'.[11] The initial disdain shown by Cook for 'fern land' owed much to the fact that the British species of bracken (*P. aquilinum*), which closely resembles its New Zealand counterpart, is generally associated with acid, nutrient-deficient soils. The latter, however, grows on a wide range of soils, in part because of its deliberate spread by Maori gardeners who tried to foster its growth with regular burnoffs on account of its root forming part of the Maori diet.[12]

By the late 1830s, therefore, the perception which had been built up in Europe was that fertile soils in New Zealand were ubiquitous. This perception proved ideal for the colonising machinations of the New Zealand Association, and its successor body, the New Zealand Company, who maintained in their promotional material that the 'average nature of the soil is a rich alluvial', and that both islands were 'extremely fertile and capable of the highest degree of cultivation'.[13] As well as hopefully attracting land buyers, these claims had an important secondary role in providing a moral justification for New Zealand's colonisation. By arguing that New Zealand's soils were incredibly productive, or at least that they would be once British agricultural practices were brought to bear on them, the Company was also able to make a case that New Zealand could accommodate far more people than the current Maori population. It was only fair, therefore, that some of Great Britain's teeming millions be allowed to make their home there. Moreover, if these assumptions were true, then the Maori population would not be losers by giving up some of their lands, because after colonisation one-tenth of their land would be more valuable than the whole was before.[14]



MAP 1. When a simplified rendition, detail from which is shown here, of Edward Chaffers's 'Chart of Port Nicholson, New Zealand' (1841), appeared in the *Westminster Review* ([H. S. Chapman], 'Emigration : Comparative prospects of our new colonies', *Westminster Review* 35, no. 69 (1841), facing page 178), Chaffers's annotations referring to tree size and soil fertility in the Hutt Valley were given much greater emphasis. Image enhancement by Marney Brosnan, University of Canterbury Geography Department.

The assessment of soil fertility using the biometrical model was even more to the fore once the New Zealand Company started purchasing land in New Zealand during 1839–40. The first two sites chosen for settlement were Wellington and New Plymouth. Both the Hutt Valley, which was at the hub of Wellington's agricultural operations, and New Plymouth were, as one might expect, surrounded by dense forest, a point that was made not only in written accounts but also through visual media such as prints and maps.[15] In case prospective emigrants were intimidated by this fact, the Company went to great lengths to remind them they were better off buying a wooded country section than one that was free from wood:

> North America enjoys immense tracts of the most fertile land, thickly wooded with ancient timber trees. The manner in which a country is wooded is the American's test of soil, and it is for the most part an accurate test. Recent alluvial tracts are of course excepted, but in other respects well-grown trees are understood to indicate richness ...If it be true that the richness of the soil is in exact proportion to the density of the forest, it follows that the clearness of the land, which is so often spoken of as an advantage enjoyed by the Australian Colonies, should be deemed a beacon to warn the prudent agriculturist from the spot …[16]

When those individuals who had chosen to cultivate 'fern land' at Wellington started out getting only stunted crops, many settlers took heed of the above advice, and selected land under forest. Before long, settlers there came to regard the rate of forest clearance as an important mark of their progress.[17]

THE 'BIOMETRIC FALLACY' EXPOSED

At this point, the use of the biometrical model for assessing soil fertility must have seemed perfectly sound to most observers. After all, the much smaller crops obtained to date from 'fern land' as opposed to forested land appeared an ample demonstration of the approach's validity. However, within the space of a year or two, a combination of factors undermined it so badly that alternative means for determining soil fertility had to be sought.

The first crushing blow for the biometrical approach to soil fertility appraisal came when its theoretical foundation, the 'humus theory', was discredited by the German chemist Liebig in his *Chemistry in its Application to Agriculture and Physiology* (1840). After pointing out several deficiencies in the humus theory, Liebig concluded that plants drew all their carbon from the atmosphere. Later, he also argued, this time erroneously, that they drew their nitrogen from the atmosphere too, and thus only took mineral nutrients from the soil.[18] This new hypothesis, which has become known as the 'mineral theory', made the amount of vegetable matter in the soil all but irrelevant. The second, and perhaps, more telling defeat for the biometrical model, was the discovery that kauri (*Agathis* *australis*), New Zealand's largest timber tree, generally grew on infertile soils.[19] This plant–soil association was exactly the opposite of what the model predicted. The New Zealand Company learnt this by early 1840, but they largely kept it quiet until 1842, when it served their purpose to decry the quality of kauri-covered land on the North Auckland peninsula.[20] The reason for this action, which most definitely quashed the idea that fertile soils could be found throughout New Zealand, was the deterioration in the Company's relationship with the Colonial administration. In signing the Treaty of Waitangi with Maori, the Colonial administration had curtailed the Company's ability to purchase land from Maori directly, and thereafter it further snubbed the Company by choosing to site the capital at Auckland. As a result, a bitter war of words broke out, with the Colonial administration describing Wellington as hillbound and windswept, while the Company, for its part, declared the land around Auckland to be sterile.[21]

The final knockback for the biometrical model came with the discovery that in many cases the infertility which the New Zealand Company settlers had been led to associate with 'fern land' was only temporary. Its cause was the low nitrogen content in the residual bracken material left once cultivation commenced. When it decays, microbes are unable to extract sufficient nitrogen from the bracken, and thus they draw it from the soil instead (a process known as nitrogen immobilisation).[22] Until the decay process was well advanced, which, under the cultivation regime employed by the new settlers, took about a year, any crops grown in the soil were nitrogen-starved. However, by the second or third year crop yields rose to levels not unlike those being obtained from forested land. As a result, by the end of the 1840s, many settlers had came to prefer 'fern land' over forested land, since fallowing the former required much less expense than clearing the latter.[23]

THE SEARCH FOR A REPLACEMENT METHODOLOGY

The unravelling of the biometrical approach for determining soil fertility was not all bad for the New Zealand Company. By the end of 1841, its two anticipated agricultural centres, Wellington and New Plymouth, had been established, and as a result it was looking to find a home for settlements where there would be more of a focus on pastoral farming. Grassy plains, an environment which the biometrical approach was not exactly conducive to promoting, were, for the time being, more desirable than new areas of dense forest. Having said this, the New Zealand Company needed to find a replacement methodology for making soil fertility appraisals, not only for the purpose of new promotional literature, but also for its own land surveying operations.

There were two contenders to fill this gap. The first of these was the geological or, strictly speaking, pedological model, where soils were classified, and their fertility judged, on the basis of their geological origins. Since the start of the nineteenth century, the role of the physical make-up of the soil in determining fertility had begun to be explored by soil scientists such as Humphry Davy, and now that Liebig was preaching the message that a soil's mineral chemistry determined its fertility, there seemed even more reason to focus study on the geological parent material of the soil. Accordingly, during the 1850s and 1860s the sub-discipline of agrogeology, which later became pedology, became well established in Europe.[24] In the New Zealand context, the greatest exponent of the geological approach was the German geologist and naturalist Ernst Dieffenbach, who, incidentally, was one of Liebig's first students. Dieffenbach's views on its application are best summed up by his comment, in a report on the Chatham Islands, that he intended to 'make some remarks about the geology of the [Chatham] island, this being the most natural foundation for a description of the land, as far as it interests the agriculturist'.[25] In keeping with this policy, Dieffenbach's *Travels in New Zealand* (1843), which described his explorations in New Zealand at the behest of the New Zealand Company, contained numerous references to soil fertility in relation to geology.[26] Yet apart from Dieffenbach, the Company surveyor Frederick Tuckett was the only individual to employ the geological approach to any extent. The probable reason for its neglect by others is that few surveyors or explorers had sufficient geological training to apply it, and it was ill-suited to information exchange between Maori and Pakeha because of the differences in geological terminologies. Still another disincentive to its use was the need to make subsurface observations, which meant that the surveyor or explorer had to take time out to either find a geological exposure or, as Tuckett occasionally did, dig a soil pit.[27]

The second contender was the ecological or, strictly speaking, edaphic, model. As early as 1835 the missionary William Yate had written an account denoting the type of soil preferred by each major species of native tree, but its significance had been lost because of the pervasive influence of the biometrical approach.[28] When the latter become untenable, however, surveyors began to adopt the ecological model. In contrast to the geological model, it required no field work other than visual inspection, and because of this greater visibility settlers became familiar with the native flora far more readily than they did with local rock types. Moreover, as the following quote from a report by the surveyor Robert Stokes on the Wairarapa Valley shows, the fact that trees were identified by their Maori names also enabled the harnessing of Maori environmental knowledge:

> on the banks of the rivers, and in different parts of the valley, are large groves and belts of trees, which the natives informed us were chiefly totara, kaikatea [kahikatea], rimu, mataihi [matai], and toa toha [toatoa], trees which are never found but in the best soil.[29]

Collectively, these advantages meant that the ecological model prevailed. By 1848, its acceptance was such that it formed the basis for the section on judging the quality of land in the New Zealand Company-sponsored volume *Hand-book for New Zealand*. After telling settlers that ‘the *quality* of wild land may be judged of, if timbered, by the kinds and size of trees’, this section went on to state that a combination of tall rimu (*Dacrydium cupressinum*), totara (*Podocarpus totara*), matai (*Podocarpus spicatus*, currently *Prumnopitys taxifolia*) and kahikitea (*Podocarpus dacrydioides*, currently *Dacrycarpus dacrydioides*) trees grew on the best soil, the same trees if scraggy were a sign of cold clayey soil, manuka (*Leptospermum scoparium*) and tawa (*Beilschmiedia tawa*) were indicative of inferior clayey or stony land, and abundant pukatea (*Laurelia novae-zelandiae*) growth was a sign of wet and swampy land.[30] Having said this, the model was still in its developmental stage when it came to the appraisal of soil fertility on land without forest. The best general advice which the *Hand-book for New Zealand* could give, for example, was to gauge fertility from the height of the fern and luxuriance of grass.[31] As time went on, distinctions between types of non-arboreal vegetation nevertheless began to be made. Indeed, when a map of the Canterbury settlement – the last act of colonisation in which the New Zealand Company took part – appeared in 1851, some eight types of vegetation,

MAP 2. During the ‘topographic’ survey of the Canterbury Settlement, surveyors classified land quality on the basis of its natural vegetation cover, which was in keeping with their application of an ecological approach to soil fertility appraisal. Detail from ‘Part of the Canterbury Settlement’ (1851), in *Historic Charts and Maps of New Zealand* 2nd edn, ed. Peter B. Maling (Auckland: Reed Books, 1999), 241, Plate 107. Reproduced with permission of the author

other than forest, were named upon it. For the record, the soils under flax (*Phormium tenax*) and within the reclaimable swampland, on which raupo (*Typha muelleri*) grew, were thought the most fertile of the non-forested areas, but at the same time they were seen as the most inaccessible to cultivation.[32]

CONCLUSION

As it turned out, the ecological model, which modern research has shown to have a sound scientific basis, continued to play a central role in indicating the quality of land which was still in its natural state throughout the remainder of the nineteenth century.[33] Yet while its precedessor, the biometrical model, had passed out of favour almost as soon as organised settlement began, the impact of the 'biometric fallacy' was a long lasting one. Firstly, the perceived link between forest and soil fertility helped impede settlement in areas where forest was lacking. As Judith Johnston observed the Canterbury settlers found it necessary in the early 1850s to assert that just because the Canterbury Plains were nearly treeless this did not mean they were sterile.[34] Secondly, the perception of extraordinarily rich forest soils, which the New Zealand Company did its best to promote, created the notion that no action, such as manuring or fallowing, was needed to maintain fertility once land had been cleared. As in the case of the first impact, it took a good decade or so, and a good deal of soil deterioration, before this idea could be expunged from settlers' minds. By far the most significant impact, however, is one that is still with us today. Because the 'biometric fallacy' erroneously suggested that large areas of fertile land could be found everywhere, both the New Zealand Company and the Colonial government tended to set aside ridiculously small reserves for the indigenous Maori population, when buying large tracts of Maori land. The New Zealand Company had set the trend, by setting aside one-tenth of its Wellington purchase. Given the heroic stories of 'agricultural improvement' which abounded at this time, the Company's promises that the productivity of this apparently fertile land would be increased ten fold at least[35] may not have seemed unreasonable. Once the 'biometric fallacy' was exposed, however, the faulty nature of this policy should have been obvious. If it was, there was never sufficient political will to rectify it.

NOTES

[1] See Ray Hargreaves, '"Speed the Plough": An Historical Geography of New Zealand Farming Before the Introduction of Refrigeration' (Ph.D. diss., University of Otago, 1966), vol. 1, 112–15; Judith A. Johnston, 'Image and Reality: Initial Assessments of Soil Fertility in New Zealand', *Australian Geographer* 14, no.3 (1979), 160–6; Brad Patterson, 'Reading between the lines: people, politics, and the conduct of surveys in the southern

North Island, New Zealand, 1840–1876' (Ph.D. diss., Victoria University of Wellington, 1984), vol. 1, 167–9.

[2] Black's 'discovery' of carbon dioxide ('fixed air') is described in Sir E. John Russell, *A History of Agricultural Science in Great Britain 1620–1954* (London: George Allen & Unwin, 1966), 48. Perhaps the most inspired eighteenth century investigator of plant nutrition was Henry Home, Lord Kames, who correctly predicted that plants take up nitrates. See G. E. Fussell, *Science and Crop Nutrition before Liebig* (Lawrence, Kansas: Coronado Press 1971), 119–20.

[3] I. A. Krupenikov, *History of Soil Science: From its Inception to the Present*, translated by A. K. Dhote (Rotterdam: A. A. Balkema, 1993), 90–1; E. Walter Russell, *Soil Conditions and Plant Growth* 10th edn, 1st to 7th editions by Sir E. John Russell (London: Longman, 1973), 6.

[4] See Comte George Louis Leclerc de Buffon, 'Histoire Naturelle'. In *Ouvres Complètes de Buffon: avec des extracts de Daubenton et la classification de Cuvier* (Paris: Chez Furne, 1861), I, 121; and, for Linnaeus's views on soil, Clarence J. Glacken, *Traces on the Rhodian Shore: Nature and Culture in Western Thought from Ancient Times to the End of the Eighteenth Century* (Berkeley: University of California Press, 1967), 511.

[5] See, as well as the examples to be given subsequently in the text, Sydney Parkinson, *A Journal of a Voyage to the South Seas* (1784; reprint, Dover, New Hampshire: Caliban Books, 1984), 100; Johann Reinhold Forster, *Observations Made During a Voyage Round the World*, ed. Nicholas Thomas, Harriet Guest and Michael Dettelbach (1778; reprint, Honolulu: University of Hawaii, 1996), 43; Jean Francois Marie de Surville, January 1770, *Extracts from Journals Relating to the Visit of the French Ship* St. Jean Baptiste *in December 1769 Under the Command of J. F. M. de Surville*, trans. Isabel Ollivier and Cheryl Hingley (Wellington: Alexander Turnbull Library Endowment Trust with Indosuez New Zealand, 1982), 38; Ambrose-Bernard-Marie le Jar de Clesmeur, July 1772? *Extracts from Journals relating to the visit to New Zealand in May–July 1772 of the French ships* Mascarin *and* Marquis de Castries *under the command of M.-J. du Fresne*, trans. Isabel Ollivier (Wellington: Alexander Turnbull Library Endowment Trust with Indosuez New Zealand, 1985), 31. It is worth noting that Parkinson, Daniel Solander, and Joseph Banks were all 'apostles' of Linnaeus. Michael Dettelbach, '"A Kind of Linnean Being": Forster and Eighteenth-Century Natural History', in Forster, *Observations*, lix–lx.

[6] These are estimates of forest cover in 1840. Michael Roche, 'Destruction Under the Guise of Improvement? The Forest, 1840–1920', in *Enviromental Histories of New Zealand*, ed. Eric Pawson and Tom Brooking (South Melbourne: Oxford University Press, 2002), 105.

[7] Joseph Banks, March 1770, *The* Endeavour *Journal of Joseph Banks, 1768–1771*, ed. J. C. Beaglehole (Sydney: Trustees of the Public Library of New South Wales in association with Angus and Robertson, 1962), vol. 2, 3.

[8] James Cook, 15 November 1769, *The Journals of Captain James Cook on his Voyages of Discovery*, ed. J. C. Beaglehole (Cambridge: Cambridge University Press for the Hakluyt Society, 1955), vol. 1, 203.

[9] John Hawkesworth, *An Account of the Voyages undertaken by the order of his present Majesty for making Discoveries in the Southern Hemisphere, And successively performed by Commodore Byron, Captain Wallis, Captain Carteret, and Captain Cook, in the* Dolphin, *in the* Swallow, *and in the* Endeavour (London: W. Strahan & T. Cadell, 1773), vol. 3, 437–8.

[10] John Liddiard Nicholas, *Narrative of a voyage to New Zealand performed in the years 1814 and 1815, in company with the Rev. Samuel Marsden, Principal Chaplain of New South Wales* (1817; reprint, Auckland, Wilson & Horton, 1971), vol. 2, 230. The words 'mountainous' and 'barren' were used to describe the South Island in Hawkesworth, *An Account of the Voyages*, vol. 3, 437.
[11] Charles Darwin, 'Journals and Remarks: 1832–1836', 23 December 1835, in *Narrative of the Surveying Voyages of His Majesty's Ships* Adventure *and* Beagle, *between the years 1826 and 1836*, ed. Robert Fitzroy (London: Henry Colburn, 1839), vol. 3, 506. See also, for example, the comment of Nicholas, *Narrative of a voyage to New Zealand*, vol. 1, 260.
[12] Colenso referred to the past conflation of the two bracken species in William Colenso, 'The Vegetable Food of the ancient New Zealanders before Cook's Visit', *Transactions and Proceedings of the New Zealand Institute* 13(1880), 24–5. The association of *P. aquilinum* with poor soils is described in W. W. Fletcher and R. C. Kirkwood, 'The Bracken Fern (*Pteridium aquilinum* L. (Kuhn); its Biology and Control', in *The Experimental Biology of Ferns*, ed. A. F. Dyer (London: Academic Press, 1979), 601. Comparatively, the New Zealand species grows so widely as to be a weed (R. J. Chinnock, *Common Ferns and Fern Allies in New Zealand*, illustrated by Eric Heath (Auckland: Reed Methuen, 1987), 41. For a discussion of Maori 'management' of New Zealand bracken, see Janet Davidson, *The Prehistory of New Zealand* 2nd edn (Auckland: Longman Paul, 1988), 39, 128.
[13] *The New Zealand Colonisation Company (1838) to be Incorporated by Charter, or Act of Parliament*, cited in Geoff Park, 'Edward Gibbon Wakefield's dream, Thomas Shepherd's eye and New Zealand's Spatial Constitution', in *Edward Gibbon Wakefield and the Colonial Dream: a Reconsideration*, ed. Andrew Mason (Wellington: Friends of the Turnbull Library in association with GP Books, 1997), 135. For other similar comments in New Zealand Company-sponsored literature, see John Ward, *Information relative to New Zealand, compiled for the use of Colonists* 2nd edn (1840; reprint, Christchurch: Capper Press, 1975), 1–2; Charles Heaphy, *Narrative of a Residence in various parts of New Zealand. Together with a description of the present state of the Company's settlements* (1842; reprint, Christchurch: Capper Press, 1972), 26–9.
[14] [Edward Gibbon Wakefield], *The British Colonization of New Zealand; being an account of the Principles, Objects, and Plans of the New Zealand Association* (London, 1837), 271, 274; Instructions to Colonel Wakefield, cited in Ward, *Information relative to New Zealand* 2nd edn, 119–20.
[15] Advertising material appended to Charles Heaphy's *Narrative of a Residence in various parts of New Zealand* shows no less than four 'views' of Wellington and New Plymouth being published and sold as individual prints. Several maps were also sold individually. (Heaphy, *Narrative of a Residence in various parts of New Zealand*, [second and third unnumbered pages after 142]).
[16] *New Zealand Journal*, 30 January 1841, 27.
[17] William Wakefield to the New Zealand Company, [3 December 1840], *New Zealand Journal*, 22 May 1841, 126; *New Zealand Journal*, 25 June 1842, 149.
[18] Margaret W. Rossiter, *The Emergence of Agricultural Science: Justus Liebig and the Americans, 1840–1880* (New Haven: Yale University Press, 1975), 20–3, 42–3, 146.
[19] Audrey Eagle, *Eagle's Trees and Shrubs of New Zealand*, rev. edn (Auckland: William Collins, 1986), vol. 1, p. 245; Les Molloy, *Soils in the New Zealand Landscape: The*

Living Mantle 2nd edn, with photographs by Quentin Christie (Lincoln: New Zealand Society of Soil Science, 1993), 92–3.

[20] Charles Heaphy noted that 'in all places where the Kauri fir grows' the soil was 'a hard red clay, which yields but little on being cleared and cultivated' (Heaphy, *Narrative of a Residence in various parts of New Zealand*, 108), while Petre's *Account of the Settlements of the New Zealand Company*, which was ghost-written by Henry Chapman (see Patricia Burns, *Fatal Success: a history of the New Zealand Company*, ed. Henry Richardson (Auckland: Heinemann Reed, 1989), 158) stated that 'a great part of the northern extremity is known to be barren' (Henry William Petre, *An Account of the Settlements of the New Zealand Company, from personal observation during a residence there* 5th edn (1842; reprint, Christchurch: Capper Press, 1971), 88. Previously, in January 1840, Edward Jerningham Wakefield had recorded in his journal that 'wherever the *kauri* forest has been cut down or burnt, nothing grew but stunted fern'. E. J. Wakefield, *Adventure in New Zealand from 1839 to 1844, with some account of the British Colonization of the island*, ed. Sir Robert Stout (1845; reprint, Christchurch: Whitcombe and Tombs, 1908), 137.

[21] See Burns, *Fatal Success*, 154–7, 175–6, and *New Zealand Journal*, 31 July 1841, 188–9. Auckland's settlers also took literary aim at the Company with pamphlets such as Theophilus Heale, *New Zealand and the New Zealand Company: being a consideration of how far their interests are similar* (London: Sherwood, Gilbert and Piper, London, 1842).

[22] A recent study of New Zealand bracken found nitrogen concentrations of around 0.8% for fronds, 0.4% for live rhizomes, and 0.3% for frond stalks during winter (G. R. Evans, A. H. Nordmeyer, and C. M. Kelland, 'Biomass and nutrient pools of bracken growing under radiata pine, Nelson, New Zealand', in *Bracken Biology and Management: Papers from an International Conference BRACKEN 89, University of Sydney, 18–21 July 1989*, ed. J. A. Thomson and R. T. Smith (Sydney: University of Sydney, 1989), 191). A similar figure for frond stalks, of 0.24%, has been recorded in a British study by Frankland. This also recorded a carbon content in the stalks of 48%, giving a carbon:nitrogen ratio of 200:1 (Juliet C. Frankland, 'Decomposition of bracken litter', *Botanical Journal of the Linnean Society* 76, nos. 1–3 (1976), 134–7). Generally, nitrogen is immobilised by microbes when the substance has a carbon:nitrogen ratio of over 25:1 (R. G. McClaren and K. C. Cameron, *Soil Science: An Introduction to the Properties and Management of New Zealand Soils* (Auckland: Oxford University Press, 1990), 153–4). In British conditions, it took five years for this point in the decay process to be reached.

[23] This switch from forest to 'fern land' was most noticeable at New Plymouth, and at the Franco-German settlement at Akaroa. Anon. to Thomas Woolcombe, 23 January 1843. *Letters from Settlers and Labouring Emigrants, in the New Zealand Company's Settlements of Wellington, Nelson, and New Plymouth. From February, 1842, to January, 1843* (London: Smith, Elder & Co., 1843), 204–5; William Mein Smith [to William Wakefield], 12 December 1842. *New Zealand Journal*, 2 September 1843, 233–4. For a comparison of the cost of breaking-in forest and 'fern land' at New Plymouth, see R. P. Hargreaves, 'Pioneer Farming in Taranaki 1841–1850', *New Zealand Geographer* 19, no. 1 (1963), 48.

[24] Krupenikov, *History of Soil Science*, 123–4, 131–41.

[25] E. Dieffenbach, 'Description of the Chatham Islands', *New Zealand Journal* 2(38) (3 July 1841), 158. Previously published in the *New Zealand Gazette and Wellington Spectator*. In Liebig's *Familiar Letters on Chemistry*, Dieffenbach is referred to as one

of his ‘first pupils’ (Justus Liebig, *Familiar Letters on Chemistry, and its relation to commerce, physiology, and agriculture* 3rd edn, ed. John Gardner (London: Taylor and Walton, 1845), iv–v.

[26] Dieffenbach, Ern[e]st, *Travels in New Zealand; with contributions to the Geography, Geology, Botany, and Natural History of that Country* (1843; reprint, Christchurch: Capper Press, 1974), vol. 1, 186, 205, 239, 244, 248, 333, 366–7, 403.

[27] F. Tuckett, 19 April, 10 May, 20 May, 24 May 1844, Journal of Frederick Tuckett, in Thomas Morland Hocken, *Contributions to the Early History of New Zealand [Settlement of Otago]* (London: Sampson Low and Marston, 1898), 208, 219, 222, 223.

[28] William Yate, *An Account of New Zealand, and of the formation and progress of the Church Missionary Society’s Mission in the Northern Island* (London: Seeley and Burnside, 1835), 33–51.

[29] R. Stokes, ‘Report on the Expedition to the Wairarapa’, *New Zealand Journal*, 6 Aug. 1842, 184.

[30] [E. J. Wakefield], *The Hand-book for New Zealand; consisting of the most recent information compiled for the use of intending colonists* (London: John W. Parker, 1848), 461. Similar advice, directed at surveyors, was contained in Arthur Whitehead, *A Treatise on Practical Surveying, as applicable to New Zealand and other colonies* (London: Longman & Co., 1848), 48.

[31] It did note, however, that if patches of stunted manuka were found, this was a sign of poor land, and conversely, an abundance of cabbage trees (*Cordyline* spp.) was a sign of good land. [Wakefield], *The Hand-book for New Zealand*, 461–2.

[32] Charles O. Torlesse, [‘Report upon the Canterbury Block’], Part One. *Lyttelton Times*, 14 Jun. 1851, 6.

[33] See, for example, H. S. Gibbs, ‘Development and Plant Relationships of Lowland Forest Soils’, in *Lowland Forests in New Zealand. Proceedings of a Symposium held at the University of Waikato, Hamilton, 27–28 May 1980*, ed. K. Thompson, A. P. H. Hodder and A. S. Edmonds (Hamilton: University of Waikato, 1983), 35–44.

[34] Judith A. Johnston, ‘Image and Reality: Initial Assessments of Soil Fertility in New Zealand’, *Australian Geographer* 14, no.3 (1979), 162.

[35] [Wakefield], *The British Colonization of New Zealand*, 312.