The Waikato Horticultural Complex: An archaeological reconstruction of a Polynesian horticultural system

Warren John Gumbley

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Department of Archaeology and Natural History
College of Asian and the Pacific
The Australian National University
Canberra

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Cover image: Te Parapara Garden, Hamilton Gardens (New Zealand), March 2020. The garden contained several old varieties of *kūmara* (sweet potato), including Taputini, which are the upright variety in the middle fore-ground.

Except where otherwise acknowledged in the text, this thesis is based on original research by the author. The thesis also draws on information from cultural heritage management reports relating to horticultural sites in the Waikato region of New Zealand. The multi-disciplinary nature of this thesis has necessitated the use of reports from specialists in palaeoecological and sedimentological disciplines. All photographs are by the author unless otherwise credited.

66,000 words

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Dr Bruce McFadgen initially introduced me to the field examination of Māori horticulture and may to some extent assume a portion of the blame for me pursuing this research interest. Dr Neville Ritchie is equally culpable for introducing me to the archaeology of the Waikato region by giving me a job at the Department of Conservation in 1991 and introducing me to borrow pits.

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Abstract

This thesis considers the transfer and adaptation of Polynesian horticulture to New Zealand through examination of the archaeology of the Waikato Horticultural Complex, an inland horticultural system relying on intensive soil adaptation within a swidden process. The successful transfer and adaptation of Polynesian horticulture, a system developed in the tropics and based on tropical plants, to the temperate climate of Aotearoa/New Zealand has long been considered enigmatic with a number of attempts to understand how this was effected.

The Waikato Horticultural Complex is characterised by the quarrying and transport of coarse lithic material to garden sites often glossed as Māori-made soils that are recognised as distinct soil types by soil scientists. The Waikato Horticultural Complex presents archaeologically in two similar but distinct aspects indicating two parallel agronomic processes. A multi-disciplinary approach has been followed in examining the Waikato Horticultural Complex.

The examination of the Waikato Horticultural Complex occurs at two scales. The first places the horticultural system within the wider regional landscape through understanding its scale and its interaction with that landscape, primarily the soils, geology and vegetation. Secondly the Waikato Horticultural Complex is contextualised with a review of the archaeology of Polynesian horticulture as understood in Eastern Polynesia, along with an examination of the literature describing the ‘made soils’ phenomena in New Zealand, where it appears to be a strategy distinct within Polynesia.

Specifically, the nature of the Waikato Horticultural Complex is described and characterised. The data relating to the Waikato Horticultural Complex drawn on for this thesis has been derived from a mass of reporting generated through the Cultural Heritage Management process. Most of this reporting has been created by the author of this thesis. These data describe the collective attributes or features of the Waikato Horticultural Complex, which relate to forest clearance, garden development including the quarrying of coarse lithic material and the features and context in which it is found following transport to the gardens, crop storage structures along with elements reflecting domestic activities. Data relating to the palaeo-environment, along with plant microfossil data relating to cultigens is reviewed.

Questions of depositional processes and function of the transported material within the associated archaeological contexts are central to understanding potential motives for the application of the labour intensive process. As well as “standard” archaeological techniques two additional approaches have been applied. At the micro-scale, soil micromorphological techniques have been applied to the examination of both manifestations of the made soil phenomenon, which have resolved questions about depositional and post-depositional processes and the presence or absence of relict features from now-destroyed components of the gardens. To further test the role of actual and potential elements of the agronomy employed in relation to the transported material the results from experimental garden plots have also been considered.

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1 Introduction

The history of Polynesian migrations is a history of meeting challenges found on arrival in new island environments, but the exceptional adaptation pressures on migration to New Zealand have been remarked on numerous times and Kirch (1984: 92) provided a typical example with this assessment:

> "With the colonization of New Zealand, Polynesians from the tropical, central archipelagos of East Polynesia (probably the Society Islands) suddenly faced drastically different environmental conditions which truly challenged their ingenuity and ability to adapt. Even in the north where the climate is milder, only four of the crop species transferred from the tropical homeland would survive the temperate climate".

These four food crops were sweet potato/*kūmara* (*Ipomoea batatas*) (*kūmara* will be the preferred term used here), *taro* (*Colocasia esculenta*), yam/*uwhe* (*Dioscoria alata*) and gourd/*hue* (*Lagenaria siceraria*). Other tropical imports to New Zealand also utilised by Māori were, *ti pore* (*Cordyline fruticosa*) and paper mulberry/*aute* (*Broussonetia papyrifera*) (Best 1976).

The importance of horticulture for the successful settlement of New Zealand and the obstacles to overcome when it was transferred from the tropics, began to be articulated in the late 1950s and the 1960s as part of the debate on the nature of settlement of New Zealand. The debate centred around two opposing views. One supported a dichotomous model of early settlement by non-agriculturalists followed by a later migration of agriculturalists, particularly as articulated by Duff (1956). The rival view, which has since become orthodoxy, was driven by the growing awareness that accumulating data were indicating a simpler process of primary settlement followed by a continuum of adaptation (Golson 1959, 1960; Golson and Gathercole 1962; Green 1970, 1972; Groube 1967, 1971; Yen 1961). Many have assumed Māori horticultural activity in the various regions of New Zealand may have been a challenging activity with a less than ideal climate. Groube for example classed the inland Waikato with respect to horticulture as one of "the second priority climates" (1971:161).

Golson (1959), initially identified the need to accommodate an imposed seasonal horticulture with its associated requirement for crop storage and correctly identified the development of crop storage pits, particularly for *kūmara*, as central to the successful accommodation of a tropical horticultural system to the cooler climate of New Zealand. Indeed, as Yen (1971: 2) noted, "discussions have centred on the adaptation of the sweet potato" precisely because of its need for seasonal storage. Ideas about other forms of adaptation were less coherently expressed but equally strongly implied. Yen canvassed the underlying issues of horticultural transferal throughout Oceania:

> "The portable features of agriculture are the plant materials, the tools and ideas behind their use. They are the detachable parts of former environments which become the endowment. These, together with the elements of natural exploitation, have to undergo a reassortment or resegregation as a first step in the colonization of a new island as an Introductory-Developmental sequence whose progress is dictated by the ultimate constraints offered by the new environment and the genetic flexibility of the introduced species" (Yen 1973: 76).

His ideas, although in this instance focused on Oceania as a whole, were honed on the New Zealand question (e.g. Yen 1961) and initially strongly influenced by Golson's important 1959 analysis of culture change in New Zealand. Yen's (1991) identification of the readiness of successful transfer among tropical high islands in comparison to the difficulties which must have been experienced in Polynesia's marginal climates underpins the research detailed in this thesis. The role of *kūmara* in the adaptive process has been widely acknowledged as central to the establishment of what Yen termed systematic agriculture in New Zealand (Yen 1961).

Leaving the importance of crop storage aside we are left with agronomic processes as the principal avenue for successful adaptation to New Zealand as a precursor to successful development of systematic horticulture. The range of archaeological features identified in New Zealand associated with horticulture have been extensively described (Barber 2004, Furey 2006) but understanding of the agronomy underlying these archaeological manifestations is weakly understood with considerable reliance placed on the historical sources and the early ethnographic record to explain the roles of archaeological evidence.

The presence of a particular process involving the addition of coarse material such as sand or gravel to gardens was first noted in the middle nineteenth century, primarily by missionaries, travellers and government agents (e.g. Colenso 1880; Shortland 1856; Taylor 1856; Wakefield 1845; Yate 1835). One missionary, Archdeacon Walsh specifically identified the practice in the Waikato region:

> "In Waikato the clay land was often treated in this manner with sand from the pumice plains where pits from which the supply was procured are still to be seen" (1902: 14).

It was not until the 1930s (Grange et al. 1939) when soil scientists began to systemically examine the soils of the Waikato that the phenomenon of anthropogenic soils specifically resulting from Māori activities were described in detail.

Archaeological research in the Waikato Region began in the late 1960s with interest focused on *pā*[1] or fortified settlements (Bellwood 1971a, 1978; Peters 1971; Shawcross 1968). This included an examination of the Taniwha Pā, in the northern Waikato (Law and Green 1972), which had a striking density of storage pits devoted to storing crops within a fortified site, evidently privileging this over accommodating inhabitants. In the early 1970s Cassels (1972a, 1972b, 1972c) attempted to synthesise the archaeological information available for inland Waikato, as understood at the time, with environmental and ecological data. His model is, therefore, strongly environmentally focussed and ultimately proposes "a number of 'types' of site-location" (Cassels 1972a, 227), which were essentially sub-sets of the local environment where sites of varying natures could be congregated. These site locations types were (Cassels 1972a):

- lakeside sites,
- forest-edge sites,
- river sites,
- fernland sites with varied environs,
- fernland site with undiversified environs,
- *kūmara* cultivation sites.

Not surprisingly, given that Cassels developed his hypotheses in the early 1970s, there was little data available and he relied heavily on Bellwood (1971a, 1978), Peters (1971), Shawcross (1968) and to some extent soil scientists (Grange et al. 1939; Taylor 1958), as well as the unpublished fieldwork Cassels undertook in the wider Waikato area.

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[1] *Pā* are a significant part of the cultural landscape of New Zealand with over 7000 recorded in the New Zealand Archaeological Association site recording scheme, with most recorded in the northern half of North Island. For simplicity's sake *pā* are best described as defended villages varying in size from a few hundred square metres to several hectares, with similarly varying degrees of internal complexity.

Cassels considered the role of soils as the significant environmental variable. He divided the soils in the Waikato into two broad groups on the basis of suitability for Māori horticulture. Those soils which had one or more qualities; situated on steep land, subject to high rainfall (over 1500 mm), low fertility, or "heavy, compact" (Cassels 1972a: 200) were not suitable for Māori horticulture. Of the remaining soils he noted a dichotomy between soils that were otherwise suitable but were not cultivated and the second set that "were altered in various ways, chiefly by the addition of sand, gravel, and charcoal" (Cassels 1972a: 200) for growing *kūmara.*

Cassels argued that lakes, and to some degree swamps, provided a form of optimal location for Māori occupation because of the range of resources available within a catchment exploited by the local inhabitants (1972a, 1972b, 1972c). Consequently, he argued, these locations were probably the earliest of the inland areas settled (Cassels 1972c: 21–23). However, the earlier emphasis on lake *pā* by Bellwood and Shawcross appears to have encouraged Cassels' prioritisation of these landforms because data from swamp pā represented the bulk of the reliable archaeological data for the region. Cassels also noted that the highest density of occupation sites, in all cases *pā*, were associated with soils modified for the gardening of *kūmara* (Cassels 1972a: 224–226). These are the "made" soils identified by soil scientists as created by Māori. Essentially, Cassels considered the *pā*/made-soils complex found along the rivers to be the second most favoured site-location category. As a generalisation, his observation that archaeological sites, particularly *pā*, congregate strongly around waterways and where Māori-made agricultural soils are found, remains valid, and in this sense it has provided a workable, if rather simple, predictive model. However, there is no reason to believe, as Cassels proposed, that lakes were the early focus of settlement. The weight of current evidence from site record data explicitly points to the Waikato River as the primary focus of Māori activity. This should be no surprise, it is one of New Zealand's major water-courses, which would have contained an array of fish, crustacean and shellfish resources, and is flanked by some of North Island's best soils. Given these available resources and its unparalleled value as a communications artery it seems probable it formed an early focus for permanent settlement rather than the more isolated lakes. In summary, Cassels understood the explicit relationship between *pā* and the horticultural landscape focused on the Waikato River and was correct to emphasise it.

Since Cassels' work, further archaeological research projects in the Waikato virtually ceased but in the 1990s Cultural Heritage Management (CHM) driven archaeology began to be increasingly practiced. Over time the data generated has highlighted the substance and significance of Māori-developed horticultural systems in the archaeological landscape.

Research into horticultural systems lend themselves to a multidisciplinary approach to capture the range of variables inherent in horticulture. A multidisciplinary approach is essential to understanding the nature of the archaeological remains, the taphonomic processes leading to their current state, their place in the historic environment and landscape, and the timing of horticultural development. As a consequence, this research has involved inputs from technical specialists in charcoal analysis (Dr Rod Wallace), plant microfossil analysis (Dr Mark Horrocks) and soil micromorphology (Dr Elle Grono). The archaeological research is augmented by the results of an experimental garden grown over three season and inspired by earlier experimental gardening (Burtenshaw et al. 2003, Horn 1993, Worrall 1993, Yen 1960). The experimental garden was designed to incorporate features identified archaeologically with the aim that data produced could be employed to contextualise the archaeology and permit inferences to be made about agronomic processes associated with the archaeologically visible horticultural system.

The term Waikato Horticultural Complex is chosen to reflect the realisation that this is not a unifocal system but a complex interplay of agronomies and environment. It is important to note the absence of traditional information on the horticulture of the Waikato. This leaves a substantial explanatory void, which the objectives of this thesis intend to fill to some degree. Inherent in the objectives of this thesis is the need for a landscape approach which reflects the distribution of the archaeological data and allows the project to capture the scope of the agronomy and its scale.

In order to achieve these aims multiple lines of evidence will be explored. Chapters 2 and 3 consider the archaeology of horticulture in Eastern Polynesia and New Zealand to provide a wider context of the "parent" horticultural system and its translation to New Zealand in broad terms. Chapter 4 provides a background to the particular geology and soils of the inland Waikato on which the Waikato Horticultural Complex relies. Chapter 5 presents a detailed description of the archaeology of the Waikato Horticultural Complex, synthesising the range of data that has accumulated. Geoarchaeological analyses described in Chapter 6 are employed to apprehend the nature and structures of the soil modifications carried out by

Māori. They also play an important role in interpreting taphonomic processes occurring at sites. This is followed by Chapter 7, which considers data from charcoal analyses to examine the interplay between the horticultural process and the local environment including implications for the nature of the swidden cycle. Identifying plants grown in any horticultural system is fundamental to understanding any agronomy and Chapter 8 summarises data from plant microfossil analyses. Chapter 9 establishes the chronology of the Waikato Horticultural Complex through examination of the available radiocarbon dates. The archaeological data is contextualised through the results of a three season experimental garden as detailed in Chapter 10. Chapter 11 summarises and discusses six objectives including:

1. Characterisation of field evidence from investigations of sites forming the Waikato Horticultural Complex to understand the contexts into which transported materials were placed and to determine how they were deployed in the light of taphonomic processes.
2. Establishing the extent of the Waikato Horticultural Complex within the inland Waikato and to understand any possible limiting or enhancing environmental influences.
3. To understand the relationship of the horticultural system with the local environment, particularly within the frame of the swidden process and evaluate evidence for cyclical use.
4. Identifying cultigens grown in the Waikato Horticultural Complex.
5. Determination of the chronology of the Waikato Horticultural Complex with particular concern for identifying when and where this system appeared in the inland Waikato and the timing of its propagation.
6. Understanding the agronomy of the Waikato Horticultural Complex and to contextualise potential motives for the intensified agricultural inputs through the lens of results from an experimental garden.

This multi-disciplinary examination of the Waikato Horticultural Complex offers insight into the complex path of horticultural adaptation in New Zealand through the characterisation of horticulture in an inland environment that has typically been considered to be distinctly marginal for Polynesian horticulture. The outcome of this thesis is an archaeological reconstruction of the agronomy of the Waikato Horticultural Complex as a sophisticated series of actions designed to maximise yield and to instil resilience.

2 The archaeology of Eastern Polynesian horticulture

Horticulture has been one of the foci in archaeological research into the settlement of Polynesian and is viewed as a key element of the colonisation strategy employed throughout Polynesia. Polynesians were undoubtedly a maritime people but their economy rested as much on their ability as horticulturalists as it did on their abilities as navigators and fishers. In this chapter I present an overview of Polynesia horticulture to contextualise the difficulties facing the settlers of Aotearoa/New Zealand for the transfer and adaptation of horticulture.

2.1 The nature of Polynesian horticulture

The wider Oceanic horticulture system, namely that practiced in Melanesia, Micronesia and Polynesia, is grounded in a complex array of domesticated plants grown in suitable environments within the tropics. It is fundamentally a tropically focused form of horticulture in the sense of both its location in the tropics and use of tropical plants. The origins of most plants employed in this horticultural system were from the Indo-Malayan region (Bevacqua 1994; Yen 1971, 1973, 1991). Whistler provides a figure of 68 % from Indo-Malaya, with another 15 % from the New Guinea/Melanesia region (Whistler 1991: 42, 2009: 8).

Horticulture in Oceania is fundamentally about the development and maintenance of systems that are effective on islands of varying size, geomorphology and climate. New Zealand, the largest archipelago in Polynesia, aside, the islands vary between small coral atolls with very limited resources, especially soils and water, to larger high islands where resources are less constrained but nonetheless limited. Polynesia also ranged over a vast area within the tropical Pacific including the tropical margins and, of course, temperate New Zealand. The very success of horticulture across Polynesia demonstrates that it is a resilient system. In part this can be attributed to the range of domesticated or semi-domesticated plants associated with this form of horticulture. Whistler gives two figures for the number of plant species the ancestors of the Polynesians carried across the Pacific; either the more specific 72 (1991: 42) or a slightly more modest range of 50-60 plants (2009: 8). At the core of this raft of plant migrants, Whistler identifies 15 plants that formed the staples (2009: 9–10). These were:

Aroids –
    (*taro* (*Colocasia esculenta*),
    swamp taro (*Cyrtosperma merkusii*),
    giant taro (*Alocasia macrorrhizos*,

Tropical yams –
    winged yam (*Dioscorea alata*),
    spiny yam (*Dioscorea nummularia*),
    lesser yam (*Dioscorea esculenta*)
Tree crops —
    Coconut (*Cocos nucifera*),
    Breadfruit (*Artocarpus altilis*),
    Bananas (*Musa* sp.; *Eumusa* and *Australimusa*),
    Screwpine (*Pandanus tectorius*),
    Tahitian chestnut (*Inocapus fagifer*),
    Otaheite apple (*Spondia dulcis*),
    Malay apple (*Syzygium malaccense*).

Yen (1973) would add sago (*Metroxylon* spp.) to the list.

Kirch and Green (2001: Table 5.1: 123) provide a list of 27 "proto Polynesian crops" along with a list of 16 terms associated with horticulture, grouped under three headings: Garden/land, Gardening activities, and Harvesting (Kirch and Green 2001: Table 5.2: 127). The range of horticultural terms show Ancestral Polynesians employed both swidden and arboricultural systems. The two lists demonstrate the antiquity of this suite of plants and the associated technologies, which together formed a fundamental elemental of the pre-European Polynesian economy. Kirch and Green (2001: 125) note the absence of sweet potato (*Ipomoea batatas*) from the list of plant species. They also note the prominence of fruit and nut trees, commenting that their presence places "Ancestral Polynesian horticulture squarely in line with a wide-spread Oceanic pattern of arboriculture" and speculating that it "was a component of early Lapita (and, in Near Oceania, probably pre-Lapita) subsistence systems" (Kirch and Green 2001: 125). However, they propose that irrigation systems were absent from Ancestral Polynesia, arguing on the basis of archaeological evidence that these were the result of "local elaboration of such systems during the later time periods of island sequences" (Kirch and Green 2001: 130). They also cite linguistic evidence with reference to Kirch and Lepofsky (1993), for two sets of geographically distinct terms for irrigation, one represented in the Fiji/Western Polynesia region and the other Eastern Polynesia. However, Bellwood (1985) proposes that, given the antiquity of water control systems in Near Oceania, it is difficult to believe that early settlers of Polynesia were not practicing it.

The large number of species meant that a range of needs and environmental niches could be addressed on colonised islands regardless of the nature and usefulness of the indigenous species present on those islands. The diverse range of species formed an effective insurance policy founded on the likelihood that some, at least, of these species would survive the journey and be successfully adapted to the new environment. In this sense there was potential for the application of Polynesian horticultural practices to be tailored to an island's edaphic and hydrological regimes. Here we can identify a significant degree of resilience in its transfer and adaptation, something which Bulmer (1999) stressed as a motivating factor in the adaptation of Polynesian horticulture by Māori.

Even with such a range of species available to support settlement Yen points out several salient points. He acknowledges that:

> "Survival of crop plants after landfall would be comparatively easy on high tropical islands with water resources, varied soil media, and the ethnobotanical knowledge of the migrants.
>
> On more marginal soils, like the atolls and raised limestone platforms, with little water other than rainfall, it would be more difficult, but many of these conditions would have been known from the border regions of immediate provenience. It was on islands like Easter Island and New Zealand, outside of normal latitudinal adaptational ranges for the species, that horticultural skills would need to have been directed toward initial survival" (Yen 1991: 90).

He added the caveat that migration by canoe meant that only small stocks of this array of cultigens could be carried on any vessel. Yen took this as "strong evidence for this diffusion being a process rather than an event, involving many craft over time, different tracks, different destinations" (1991: 90). This observation is as significant for the transfer of Polynesian cultigens to New Zealand as it is for any other part of Polynesia. Despite the range of potential plants, successfully moving them to new islands was not a straight-forward matter. Barrau (1961), Whistler (2009) and Yen (1973) all observed a funnelling effect where the range of cultigens narrowed from west to east but Whistler (2009: 8) is more specific: "… there is a decrease in the number of canoe plants from Tonga in the west to Hawai'i in the east. (Hawai'i had only 26 of the original 50 to 60 canoe plants)."

Yen (1971) and Kirch (1994) reduced the range of Polynesian horticultural practices to three fundamental classes, water control systems for production of *taro*, dryland systems ranging from long fallow swidden to permanent short fallow systems, and perennial aboriculture. Barrau described a range of horticultural systems employed in the mid-twentieth century and provided a schematic characterisation of horticultural systems in Polynesia and Micronesia founded on types of landform and geology found in Oceania (Barrau 1961: Figures 11 and 12) (Figures 2.1 and 2.2). These identify integrated approaches to cultivation where root crops and tree crops are located in a range of environments specifically suited to each crop.

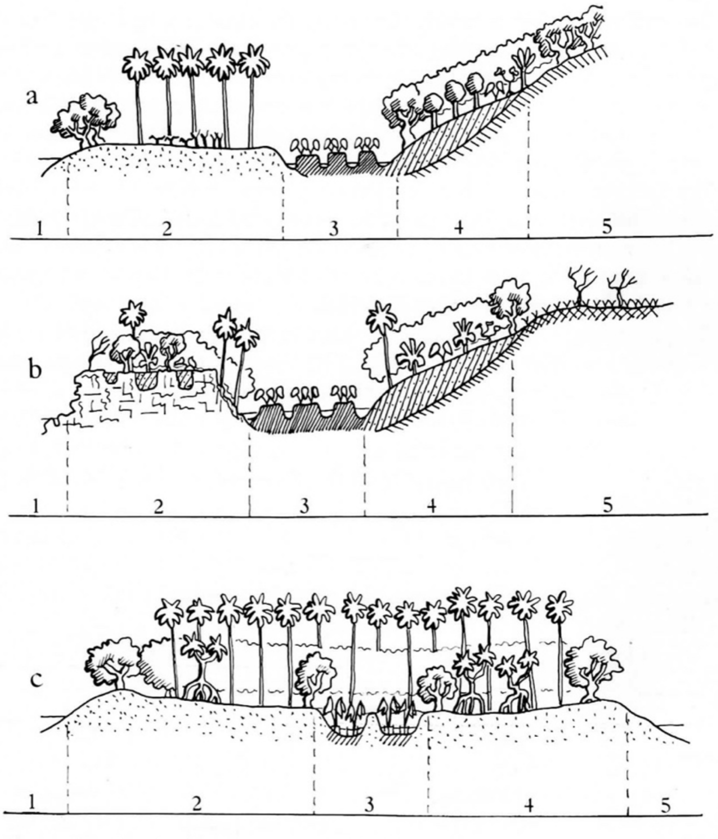

FIGURE 11.—Land utilization. **a,** high island, Rarotonga: 1, ocean; 2, coral calcimorphic soils, growing coconuts, sweet potatoes, tomatoes; 3, hydromorphic soils, taro gardens; 4, colluvium clay loam, citrus and gardens; 5, lateritic soils, scrub and secondary forest. **b,** high island, Atiu: 1, ocean; 2, *makatea*, uplifted coral plateau with clay loam in pockets, a few gardens and coconuts; 3, hydromorphic soils, taro gardens; 4, colluvium clay loam, gardens; 5, lateritic soils, ferns and *Casuarina*. **c,** atoll, Tarawa: 1, ocean; 2, coral calcimorphic soils, coconut and *Pandanus;* 3, *Cyrtosperma* pits; 4, coral calcimorphic soils, coconuts and *Pandanus;* 5, lagoon.

Figure 2.1: Three of the five horticultural system archetypes described by Barrau (1961: 26) for Polynesia and Micronesia.

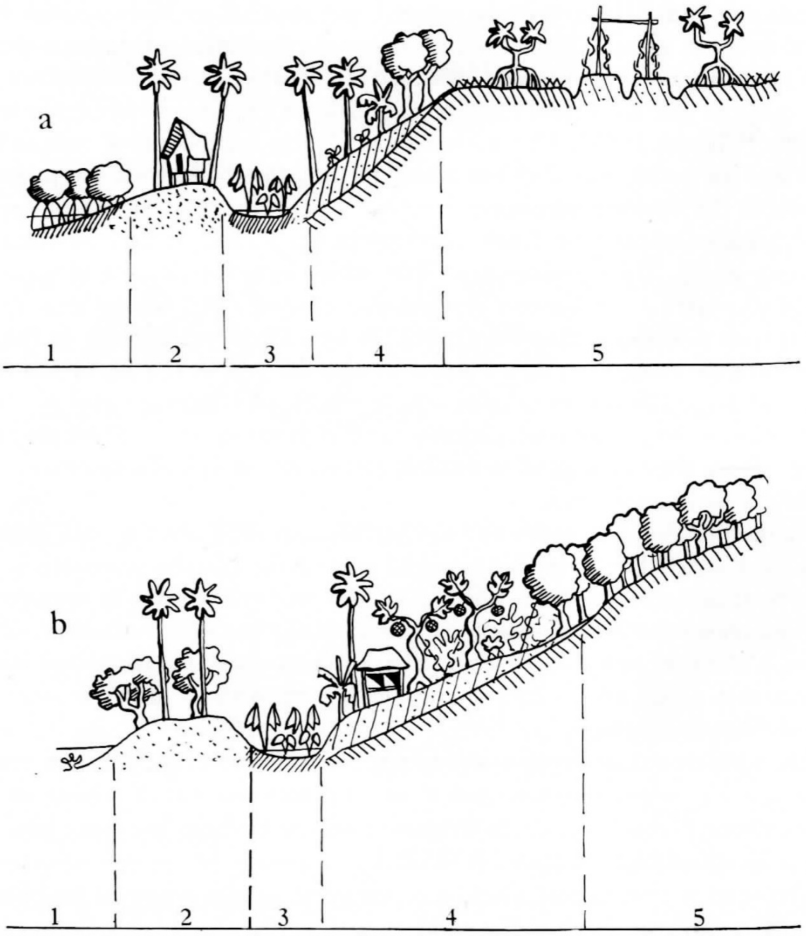

FIGURE 12.—Land utilization. **a**, Yap: 1, mangrove; 2, coconut palms, 3, aroids in swampy area; 4, coconut palms, *Inocarpus*, and bananas; 5, savannah dotted with *Pandanus* and yam garden. **b**, Fafin Island, Truk: 1, lagoon; 2, coconut palms and strand vegetation; 3, aroids in swampy area; 4, breadfruit, bananas, a few coconut palms, yams; 5, scrub and secondary forest.

Figure 2.2: Two of the five horticultural system archetypes described by Barrau (1961: 28) for Polynesia and Micronesia.

2.2 Mechanisms and processes for adaptation and change in Polynesian horticulture

Farrington (1985) described three dichotomous strands in the process of change in horticultural systems;

- expansion/contraction,
- intensification/dis-intensification,
- diversification/specialisation.

Brookfield (1984, 2001) added innovation to this package, with Kirch (1994) privileging this aspect to some degree. These elements are inevitably discussed in a diachronic context.

Expansion, although widely recognised as an important element of the development process, is an uncontroversial notion, generally considered to be an inevitable consequence of population increase from the founding population. Diversification and its opposite, specialisation, are more complex with both being identified in Polynesia. Tikopia, is referenced as an example of the historical adaptive process orienting to specialisation in arboriculture (Kirch & Yen 1982); while another specialised system, the Hawaiian dryland field systems, although focused on sweet potato, incorporated sugarcane, gourd, yam and banana, adding a diversified element to the system (Kirch 1985b: 443). In this fashion diversification/specialisation could be entwined synchronically and diachronically. Kirch (2017: 281) proposes that the general trajectory for Polynesian economies was toward specialisation and intensification.

Intensification, however, has received considerable attention in discussions of Polynesian horticulture with these appearing to crystallise following Leach's (1999) paper and the responses to it. Throughout the discussion on intensification of Polynesian horticulture there has been a wide acceptance of Brookfield's definition of intensification (1972, 1984, 2001). Brookfield proposed that "intensification must be measured by inputs only of capital, labour and skill against constant land" leading to "a greater concentration of production" (1972: 31). He admitted later (2001: 183) he would have added "and to give that production greater security" to the definition. In response to Leach, Athens (1999: 322) provided a broad and permissive definition of land use intensification, stating "the extraction of increasing amounts of horticultural resources within a defined region" and included expansion as a form of intensification. Morrison, however, is closer to Brookfield, emphasising that intensification can only occur in relation to a constant, stating that "intensification refers to an increase in the productive output per unit of land or labor (or to some other fixed quantity)" (1994:115) adding that what she terms "intensification proper" (1994: 142) requires the increases in labour and/or capital inputs into a fixed area of land. Intensification is only a reflection of the input, not output or yield, with Morrison noting that more labour may be applied in a degraded system with the same or less output (1999: 329). Kirch (1985a and b, 1994) reiterates the primacy of increased labour inputs for a constrained area of land, but later places the emphasis on increased output from a constant area of land (Kirch 2017: 281).

Change in horticulture occurred through increased capital or landesque inputs, which may take place over a considerable period but typically result in more or less permanent improvements in outputs. These take the form of structures such as terracing, walls, water control systems, crop storage structures or, as Brookfield proposes, modifications to the soil (Bayliss-Smith 1999; Brookfield 2001; Kirch 1985a, 1994, 2017; Leach 1999; Morrison 1994; Yen 1973). Non-permanent improvements result from the input of extra labour; shortening of fallow, plants with enhanced desirable characteristics that increase yield or allow their expansion into marginal zones, other improved technology and new agronomic methods. Kirch (1994: 2017) considered the last three innovations leading to increased outputs rather than intensified responses or activities.

It is clear there is consensus that the unilinear progression model, driven by population pressure, proposed by Boserup in 1965 does not reflect the complexity which is apparent (Boserup 1965). Changes in horticulture in Polynesia are multivariate, multilinear, following multiple strategies, with simultaneous synchronic and diachronic processes (Brookfield 2001; Kirch 1994, 2017; Leach 1999; Morrison 1994, 1999). Brookfield (1972: 37-38) draws attention to the important distinction between “production for use” in contrast to “social production”. Population pressure is recognised as one of the motivators for changing horticulture along with social and political drivers to produce social surpluses for exchange, enhancing status (*mana*), to improve or maintain quality of life, or to overcome adverse natural processes (Farrington 1985; Kirch 1985, 1994).

2.3 The archaeology of horticulture in Eastern Polynesia

Central Eastern Polynesia

The archaeological examination of horticulture in Central Eastern Polynesia has been focused in three areas, Rarotonga and Mangaia in the Southern Cook Islands, the Marquesas Islands and the Society Islands.

Examination of the archaeology of horticulture in the Cook Islands has been sparse. Campbell (2001, 2003) focused on the identification and mapping of irrigated taro systems in the valleys of Rarotonga as part of his research on settlement patterns and landscape use. Compared to Rarotonga the Mangaian horticultural system is better understood archaeologically although this is unsophisticated and essentially based on the work of Allen (1971), who described the wet-field system as it operated in the late 1960s. Each of the seven principal stream networks contained a wet *taro* cultivation system, altogether totalling 310 acres (125 hectares). Allen described three forms of wet *taro* cultivation that appear to be functionally related to their location within the system. In the steep upper valleys, the *taro* gardens took the form of single flights of terraces fed by artificial channels. In the middle valleys large terraces were formed using earthen embankments that were further subdivided into multiple plots and irrigated by large channels fed from a dam. These plots included both typical wet *taro* fields (paddies) and raised bed plots similar to swamp *taro.* The lowest terraces, where the "gradients were negligible" and "excess water accumulates" (Allen 1971: 373), also had channels but here they acted as drains. The cultivation practice in these resembled raised bed swamp *taro* systems, albeit in artificial swamps. As part of his work Allen mapped the main Tamarua system and this along with Richard Walter's (personal communication) mapping of the Keia system form the two historical records. Supplementary root crops (dry *taro*, sweet potato and yams) were grown in pockets of suitable soils on the makatea as part of a swidden process. Sweet potatoes, if not the other crops, were harvested in spring; implying that they were a seasonal crop (Bellwood 1971). In addition Kirch et al. (2017) have identified both macro- and micro-botanical remains of cultigens from the Tangatatau site on Mangaia that represent seven tree species[2] along with sugarcane, *ti* and three root crops (*taro*, giant swamp *taro* and sweet potato) which testifies to a typically tropical Polynesian multi-storied horticultural system.

Addison's (2008a & b) work in the Marquesas has facilitated a more well-rounded understanding of the complexities of the horticultural systems practiced there. While the conventional understanding of Marquesan horticulture was of heavy reliance on breadfruit supplemented by *taro* and bananas, he also identified breadfruit as a drought prone species. Addison paints a picture of complex horticultural systems exploiting a range of environmental niches balanced to manage and minimise risk in the drought prone environments of the Marquesas archipelago. Addison proposes a model for the development of horticulture in the Marquesas (Addison 2008a) in which, initially, the focus was on wetland *taro* grown in optimal locations for both pondfield and swamp *taro* cultivation. However, the need to balance population increases in the unpredictably drought-prone climate, risk management strategies began to be emphasised. These took the form of preserved fermented breadfruit paste (along with expanded planting of breadfruit trees) and use of species (*Alocasia macrorrhizos*, yams and *ti*) that could provide a form of field storage of crops. Along with

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[2] Bananas, breadfruit, beach almond, candlenut, coconut, malay apple and tahitian chestnut.

this both wetland and mixed gardens would have expanded to their environmental limits with swidden horticulture becoming economically viable. Addison also proposes that reliance on preserved breadfruit paste would also have increased in scale. He argues that wetland *taro* would have provided fundamental resilience in the face of drought, noting a correlation between reliability of water flow and the size of the pondfield systems on various valleys on Nuku Hiva. The ability to store large quantities of breadfruit paste enabled the otherwise drought susceptible breadfruit to add to that resilience (Addison 2008b). Plant micro-fossil analysis of shell tools recovered from the Anaho Valley on Nuku Hiva has supplemented this picture by providing direct evidence of breadfruit, kava, *taro*, yam and sweet potato (*kūmar*a) with the latter associated with contexts of 1200-1400 AD along with evidence of mixed cropping being established by 1400-1600 AD (Allen and Ussher 2013).

Analysis of the ethnohistoric data for the Society Islands has enabled a reconstruction of the horticultural systems at or soon after contact with Europeans; these relied on 38 plant species, which Lepofsky has placed in six classes (Lepofsky 1994: 50-63, 1999):

1. house gardens,
2. nursery gardens,
3. ornamental gardens,
4. arboricultural plantations,
5. short-fallow swiddens,
6. wet-field horticulture.

Each of these classes contained particular arrays of plants located in specific landscape niches. The first three were predominantly coastal, with the nursery gardens devoted to kava and paper mulberry, plants valued by elites, while the house gardens were multi-species and labour and structurally intensive, which were also found in the inland valleys. Arboriculture was a functional part of the household gardens but also more expansively across the landscape. Swidden systems with a fallow of 1–15 years operated in the interior of the high islands and focused on yams, aroids and bananas. Wet-field systems were of both forms; the raised bed swamp *taro* gardens in the lowlands close to the coast, and the irrigated terrace gardens in the valley floors. Horticultural practice was, therefore, distributed widely across the landscape and seasonally available throughout the year (Lepofsky 1994, 1999).

Archaeological research of horticulture in the Society Islands has concentrated on Mo'orea (Kahn et al. 2014; Kahn et al. 2015a; Lepofsky 1994, 1995, 1999; Lepofsky et al. 1992; Lepofsky et al. 1996; Stevenson et al. 2017) but with attention to the islands of Raiatea (Lepofsky 1994, 1995) and Maupiti (Cauchois 2002; Kahn et al. 2015b). The evidence from Mo'orea and Raiatea is for early and substantial sedimentation of the valleys accompanied by raised levels of charcoal in sediments along with evidence from sediment cores for rapid forest clearance. Later, inland slopes are terraced, probably in the same areas of the early swidden, indicating a formalisation of the landscape with a short fallow cycle. Along with this, irrigated pondfield *taro* cultivation expanded to take advantage of the sedimentation in valleys. The apparent intensification of horticulture and its expansion into marginal areas in the landscape were accompanied by the development of elite associated structures (*marae*). Analysis of macro- and micro-botanical remains provides direct evidence for a range of tree crops (bananas, breadfruit, paper mulberry, guava, pandanus), root crops (*taro*, three varieties of swamp *taro*[3], sweet potato, yam, and arrowroot) and bottle gourd (Kahn et al. 2014; Kahn et al. 2015a; Lepofsky et al. 1992; Lepofsky et al. 1996; Stevenson et al. 2017). The depositional processes on Maupiti after Polynesian colonisation are much the same as Mo'orea and Raiatea with erosion of the hills and sedimentation of the valleys. A survey of the Haranui Valley identified "small agricultural and residential sites that dot the valley's interior" (Kahn et al. 2014: 9), including dryland horticultural complexes with associated flats probably related to habitation, some evidence for dams to develop small wet planting areas, and residential sites on the ridge crests. Cauchois' (2002) ethnographic study found that only dryland systems are employed today. The main crops grown in these gardens are *taro*, yam, banana and sweet potato for local or household consumption. She noted that many of the structures in the gardens, were made from timber, such as logs used to control soil movement down-slope, which would leave no evidence in the archaeological record.

2.3.1 Marginal Eastern Polynesia

2.3.1.1 Hawai'i

Three forms of horticulture have been identified in Hawai'i through archaeological and ethnographic research; irrigated pondfields, colluvial slope gardens and intensive dryland systems. Pondfield systems, which were structured around the "paddy" cultivation of *taro*, were the highest yielding of the three systems. The highly diverse colluvial slope systems and

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[3] Alocasia macrorrhizos, Amorphophallus paeoniifolius, Cyrtosperma merkusii.

the dryland systems, both rain-fed, provided similar levels of yield, although at approximately 40 % of the productivity by area of the pondfield systems. Kurashima and Kirch (2011) identify 12 cultigens commonly grown in Hawai'i, although breadfruit is not included in this tally. Allen (2004) notes that only a single variety of breadfruit was planted on Hawai'i and was grown at low density primarily for pig fodder, but Allen identifies it as locally important at Kona on Hawai'i. However, Kirch (1985a: 216) identifies breadfruit as one of the important crops secondary to the dominant stapes of *taro* and sweet potato. *Taro* was the principal crop in pondfield systems, supported by four secondary species grown on the periphery of the fields. All 12 species of cultigen were grown in the colluvial slope gardens with bananas forming the dominant crop. The dryland systems were dominated by sweet potato and another five plants crops were grown in association (Kurashima and Kirch 2011: Tables 1 and 2).

Each of the three horticultural systems occupied distinct spaces in the landscape. Pondfields were the principal horticultural system in the older more dissected islands in the western part of the archipelago, with dryland systems becoming common in the younger eastern islands of Molokai, Maui and particularly Hawai'i. Pondfields, as intensive landesque investments relying on water management, were located in valleys where permanent streams are found. Colluvial slope systems were "practiced on the lower to mid elevations on colluvial slopes of valleys, especially on the mid-to-older aged islands" (Kurashima and Kirch 2011: 3664). Allen (2004) makes a case for a similar practice in the Kalu'ulu ecological zone in the Kona system on Hawai'i, where it occupied the elevation zone between the dryland fields and the coastal zone.

Dryland systems are also classed as intensive on the basis of ethnographic evidence for short fallow practice and the presence of extensive stone wall field boundaries that have been sub-divided into progressively smaller enclosures over time (Dye 2014; Ladefoged et al. 2008a; McCoy and Graves 2010). While much of the recent research has concentrated on the leeward Kohala field system (DiNapoli and Morrison 2017a; Dye 2014; Kirch et al. 2012; Ladefoged et al. 2003; Ladefoged and Graves 2000, 2008; Ladefoged et al. 2011; Ladefoged et al. 2008 a & b; Lee et al. 2006; Vitousek et al. 2010; Vitousek et al. 2014), the Kona system (Allen 2004; McCoy et al. 2016), also on Hawai'i, has also been examined as have the dryland systems of Maui (Baer 2015; Baer et al. 2015; Coil and Kirch 2005; Dixon et al. 1999; Kirch et al. 2004, Kirch et al. 2005) and Molokai (Kurashima and Kirch 2011; McCoy 2005; McCoy and Hartshorn 2007; Vitousek et al. 2010). In each case these systems have been found to occupy a zone in the landscape, which, while broadly marginal for Polynesian horticulture, had favourable attributes in the form of geology (soil fertility), rainfall and temperature that could take advantage of the tolerances of sweet potato, and also to some extent *taro* and yam as a minor component (Kurashima and Kirch 2011). It appears that this system was, at least in some places, seasonal (Handy 1940: 143 quoted in Coil and Kirch 2005: 73). It has been proposed that the walls were built to form a permanent network of windbreaks to further ameliorate the environment and also to slow surface erosion of the soil. At the Kona system, Allen identifies another constructed element, low linear mounds with a regular form called *kuaiwi*, which she argues were used to assist with the cultivation of several species of secondary cultigens marginal to the main crop (which was grown between the *kuaiwi*) through the protection of soil moisture (Allen 2004).

The Hawai'i Biocomplexity Project sought to understand the development of horticulture by examining the physical environments associated with the horticultural systems (Kirch 2007; Kirch et al. 2007) and has led to an appreciation of the way critical variables such a soil nutrient levels, temperature and rainfall gradients were identified and targeted within what have been called environmental "sweet spots" (Kirch 2004, 2007; Ladefoged et al. 2009; McCoy and Graves 2010). This is allied to a concept called "farming the rock", where through the identification of suitable geological regimes and their careful and deliberate management, horticultural expansion into marginal environments could be achieved (Vitousek et al. 2014). This concept has been expanded to an understanding that nutrients eroding from the basalt geology were being trapped in the colluvial slope horticultural systems and the valley floor irrigated pondfields (Kurashima and Kirch 2011).

DiNapoli and Morrison (2017a) have highlighted how marginal the dryland garden environments were by stressing their historical vulnerability to drought stress and that increasing intensification would have further increased the risk of crop failure in parts or all of each dryland system. They proposed that on the basis of modelling for the Leeward Kohala system the risk would have been highest between 1450 and 1600 A.D.

Much of the earlier work in horticulture in Hawai'i focused on irrigated *taro* systems and although that emphasis has remained and been extended to the role of dryland systems in the eastern islands, the Hawai'i Biocomplexity Project has promoted a shift to understanding the horticultural process within the frame of the environment. This has led to the recognition of the strategy of "bet-hedging", risk management or variance minimisation as it is variously styled (Allen 2004; Bayliss-Smith 2008; Dixon et al. 1999; Lee et al. 2006). Simply framed, this is the identification of potentially suitable environments at both macro and micro levels and the expansion of horticulture into those zones. This is accompanied by the development of infrastructure to further mitigate adverse environmental constraints. These structures included terracing, boundary walls and *kuaiwi*, already mentioned, and mounds of basalt and soil at Kohala and Kona field systems. These last have been interpreted as planting mounds for sweet potato designed to preserve soil moisture (Allen 2004), although this begs the paradox of a planting mound being preserved after harvest of the tubers. Diversity of planting in all three systems was an allied risk minimisation strategy, which probably had some antiquity within Polynesian horticultural systems. These actions not only facilitated the beneficial effects of bringing another crop into the garden ecology but could also be employed to enhance the effects of the built infrastructure, such as the planting of sugarcane along garden walls to augment the wind abatement role of the walls (Lincoln et al. 2017). This emphasis on the horticultural environment and ecology has thrown attention on to the role of farmers, as opposed to chiefly land managers, in the process of horticultural expansion and adaptation to marginal environments (Quintus and Lincoln 2018).

2.3.1.2 Rapa-iti

Rapa-iti, at 27.59° S is south of the Tropic of Capricorn and slightly more southerly than Rapa Nui, is within marginal Eastern Polynesia for the purposes of consideration of horticulture. Rapa-iti is a small, high and steep island with a markedly dissected landscape with a relatively cool climate, where plants and seeds transferred from Tahiti in the 1820s with missionaries “did not thrive, the climate being much colder than that of Tahiti” (Anderson 2012: 36). Horticulture appears to have relied substantially on wetland *taro* cultivation in the river valleys as well as secondary planting of *taro* in slope gardens. It is uncertain whether this was common *taro* or Alocasia macrorrhizos. *Taro* was also preserved as a fermented paste in pits, in a similar manner to breadfruit, which did not grow on the island, along with yams, coconut, kava and most forms of banana. *Ti*, gourd, paper mulberry, a banana variety and sweet potato were all grown on the island in the nineteenth century and the last may have been a nineteenth century introduction (Anderson 2012).

Dated radiocarbon samples recovered from a series of rockshelters, fortifications and sediment cores indicates settlement in period the 1150 to 1250 AD with pondfield *taro* production peaking after the mid-sixteenth century followed soon after by the development of fortifications (Kennett et al 2006). A series of sediment cores at Tukou swamp have identified both *taro* and pandanus pollen with both appearing in the late thirteenth century soon after Polynesian settlement with an associated rise on microcharcoal in the sediments (Prebble et al. 2013). Coconut polymorphs along with candlenut polymorphs and macrobotanical remains have also been identified at similarly early dates (Prebble et al. 2019).

Remote sensing analyses indicate there were a total of 83.75 hectares of *taro* pondfields spread among the various catchments (Bartruff et al. 2012). Analysis of the variables, slope, hydrology, geology, and elevation/temperature indicate catchment size was a strong predictor of the scale of each pondfield system. Sediment cores indicate a rise in charcoal densities and the advent of *taro* pollen soon after human arrival with a concomitant decrease in forest (DiNapoli et al. 2017b; Prebble and Anderson 2012). However, no archaeological investigations targeting the horticultural systems themselves have been undertaken.

2.3.1.3 Rapa Nui/Easter Island.

Rapa Nui is 27.11ºS and forms the south-eastern corner of the Polynesian Triangle. The island's climate is relatively cool, compared to tropical Polynesia. The island is windy with relatively low rainfall, 600-2000 mm/annum with an average of c. 1100 mm, albeit unpredictable and a tendency to drought. Today it is largely deforested but at the time of settlement by Polynesians the island was clad in forest composing principally of *Sophora toromiro*, *Triumfetta semitriloba* and an extinct Arecaceae species palm (Horrocks et al. 2016). Analyses of plant microfossils from archaeological deposits as well as wetland sediments have identified sweet potato, *taro*, banana, bottle gourd, yam, *ti* and paper mulberry remains (Horrocks and Wozniak 2008; Horrocks et al. 2012, Sherwood et al. 2019). As well as identification of plant species, a charcoal-rich sediment layer has been identified at Te Niu, which had been interpreted as chronicling the anthropogenic clearance of forest with fire, thought to be associated with swidden cultivation practices (Horrocks and Wozniak 2008). As well as a constrained and unpredictable climate it is widely identified that Rapa Nui's volcanic soils are nutrient poor and generally excessively drained. It is proposed that the two are related with the island's andic soils, which are structurally and chemically prone to nutrient leaching and that this was exacerbated as rainfall increased with elevation (Di Napoli et al. 2017b; Stevenson et al. 2006). Together, these are commonly viewed as significant constraints on horticultural production. However, Louwagie et al. assessed the climate as "close to optimal for sweet potato, rather moderate for banana and almost marginal for *taro*, yam and sugar cane" (2006: 290).

Consequently, Rapa-Nui has a distinctive array of archaeological remains relating to horticulture, which have been arranged into six classes all of which are characterised by the use of lithic material (Stevenson et al. 2002):

- *Manavai* are small rock enclosures, 2-6 m long with 0.7-1.5 m high walls.
- Planting circles are rings of stacked rocks, 1-1.5 m diameter enclosing a planting pit where vegetable mulch was concentrated.
- *Pu* are a form of deep growing depression approximately 0.5-0.6 m diameter located in rocky areas.
- True mulch is referred to as "veneer surfaces", which consist of a 20-30 cm layers of rocks spread across the ground surface at varying densities.
- "Mulched soils" is a class which, paradoxically given the definition of mulch, refers to rock clasts of 2-20 cm that were mixed into the upper soil profile up to 0.3 or 0.5 m deep. "Mulched soils" can be associated with "veneer surfaces"
- Stacked boulder concentrations are associated with "veneer surfaces".

Altogether these innovations have been identified as agronomic intensification and substantial effort has been expended in understanding the motives for this process and their actual or potential benefits.

Examination of a 122 m soil profile exposed at the toe of the western slope of Maunga Orito provides a useful insight into the process of landscape and agronomic change. The profile was located in an area of horticultural activity and close to an obsidian source. Stevenson et al. (2006) reported the presence of palm root casts in the clayish B horizon. They also noted evidence that the original A horizon and the upper part of the B horizon were absent, which they interpreted as evidence of sheet erosion. Overlying the truncated B horizon was a mixed soil with an irregular but abrupt boundary that included evidence of planting pits, and which they interpreted as a relict gardening soil. After the garden was abandoned they proposed there was another period of colluvium accumulation that was interrupted by a domestic occupation, with fireplaces apparent in the profile. Following this, colluvium continued to accumulate until a second episode of gardening was indicated by a mixed soil and more planting pits. This, in turn, was capped by a veneer surface formed from 10-20 cm diameter rocks and boulders (30-40 cm diameter). Stevenson et al. (2006) noted that lithic mulch, in the form of rocks in the upper soil profile, was absent as were rocks generally through the profile. This, along with the presence of veneer surfaces and rock gardens across the local ground surface, was taken as support for the cultural deposition of the rocks and boulders. They also identified that the surface lithic material had effectively stopped surface erosion.

GIS analysis of remote sensing data has been used to identify the locations, extent and densities of the veneer surfaces and stacked boulder concentrations. Ladefoged et al. (2013) proposed that these rock gardens covered between 2.5 % and 12.7 % of the island's land surface. Kovalchik (2014) analysed the same data and identified three density classes (low, medium and high) with a coverage of 9.1 % of the Rapa Nui's land area. Puleston et al. (2017) estimated, based on climate data from a series of weather stations along with surveys of soil chemistry, that approximately 19 % of the island was potentially suitable for dryland sweet potato cultivation.

Sherwood et al. (2019) examined soil within the crater of Rano Raraku where they identified relatively high fertility levels that exceeded the thresholds for successful dryland horticulture identified by the Hawai'i Biocomplexity Project. This led them to propose that this location was a sweet spot for horticulture, which was supported by the amount of macro and microfossil evidence for cultigens they found in the sediments. They also identified terracing on the crater walls that they believed were developed for gardening.

Other studies of the island's soils have looked at these with island-wide perspectives in relation to pre-contact horticulture. The same team involved in the Hawai'i Biocomplexity Project (Ladefoged et al. 2010; Vitousek et al. 2014) examined soils from within and outside pre-contact garden areas and sampled and analysed soil chemistry from the 0-30 cm depth. They reported base saturation rates as a proxy for the other soil chemistry and, drawing on the results from Hawai'i, they proposed 30 % base saturation as a threshold above which horticulture was viable and below which it was not. They found soil fertility was variable across the island. Soils on the south side of the island below 150 m elevation had the highest base saturation levels with base saturation levels declining with altitude, which they concluded was coincident with increasing leaching associated with rainfall increasing with elevation. At Te Niu they found base saturation levels were 22.7 % under the lithic cover within the garden area and 10.5 % outside the garden. At Hanga Ho'onu, on the north-eastern side of the island, the results were variable between the three sampled sites:

- at a rock-veneer garden it was 37.7 % and outside 28.9 %,
- at a boulder-veneer garden it was 25.5 % and 23 %, and
- at a second boulder-veneer garden it was 10.4 % and 7.8% outside the garden.

They concluded that the application of lithic material raised soil nutrients locally, particularly exchangeable Ca cations, compared to surrounding sediments (Vitousek et al. 2014).

Louwagie et al. (2006) carried out a series of land suitability evaluations at nineteen sites (land evaluation units) across Rapa Nui, which they also attempted to frame within traditional soil classes (Louwagie and Langohr 2007). As well as climatic variables (temperature and precipitation) the evaluation considered soil chemistry[4] and the requirements of each of the five cultigens (land utilisation types) throughout their growth cycles, or in the case of sweet potato, two growth cycles since it could be grown twice in a year. The results were used to place each of the LEUs and the LUTs within one of four suitability classes:

- S1 - highly suitable,
- S2 - moderately suitable,
- S3 - marginally suitable, and
- N - not suitable.

In general, Louwagie et al. (2006) identified that the soils were moderately or marginally suitable for the known crops. Their analyses and modelling found sweet potatoes were typically S1, bananas were S2 and yam was S2 but with temperature a limiting factor. *Taro* and yam were also S2 but with rainfall as the limiting factor and if this were below 1000 mm p/a then they became marginal (S3). Therefore, both *taro* and yam were marginal at lower elevations. In optimal situations sugar cane was S2 but was limited by both rainfall and temperature and could be S3 outside these areas. Louwagie et al. (2006) concluded that soil nutrient availability, which is fundamentally tied to the island's geology, was the most important limiting variable rather than soil moisture and that some areas were entirely unsuitable for cultivation of any of the cultigens. One of these areas was Vaitoa where they noted there was evidence for lithic surface covering along with temples and chiefly house complexes. In explaining this paradox, they proposed that elite requirements for surplus production motivated the exploitation of soils they rated as unsuitable. The lithic veneer

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[4] Although the potential hiostorical role of seabird guano in enriching the soils with phosphorus is not canvassed.

surfaces were a response to the limiting variables but they also proposed that land use planning practices were probably also important in risk minimisation.

Typically, the explanations for the introduction of the lithic elements, especially the veneer surface, stacked boulder arrangements and the so-called lithic mulch are (Bork et al. 2004; Wozniak 1999):

- reduction in the effects of wind and evaporation,
- increases in soil moisture content,
- reduction in splash erosion,
- reduction in surface run-off because of increased surface roughness,
- protection against wind erosion and water erosion,
- storage of heat and reduction in diurnal temperature amplitude,
- intensification of the sprouts and roots of cultivated plants by mechanical resistance of the stones,
- suppression of weeds,
- encouragement of beneficial soil microflora and fauna.

Some of these explanations draw directly on the work of Lightfoot examining the use of lithic mulching in arid environments (Lightfoot 1994, 1996; Lightfoot and Eddy 1994). More recent work (Ladefoged et al. 2010; Louwagie et al. 2006; Vitousek et al. 2014) has added the concept of farming the rock and exploitation of environmental sweet spots to these. The addition of lithic mulch was also a response to the deforestation of the island and the loss of shelter and nutrient storage that this represented.

2.4 Summary

Polynesian horticulture within the tropics was diverse both in plant species employed and the environmental niches utilised in what are generally accepted as risk minimisation strategies. However, once Polynesian horticulture was shifted to the sub-tropics, diversified strategies employing a range of plants species that could be tailored to an island's landform and geology, became simplified in response to the shrinking diversity in plant species imposed by climatic constraints. This trend correlates with rising latitudes which induced a net effect whereby, as the range of viable cultigens shrank, the need to manage increasing risk rose.

While Hawaii lies immediately south of the Tropic of Cancer and is strictly within the tropics, the archipelago's geography means that significant parts of the horticultural landscape were effectively sub-tropical and this, as much as its location at the northern corner of the Polynesian triangle, places it within marginal eastern Polynesia in the context of horticulture. Hawai'i reflects a common trait among marginal eastern Polynesian island horticultural systems; a decline in the importance of tropical tree crops, particularly the otherwise important coconut and breadfruit trees. Both tree crops are absent elsewhere in sub-tropical eastern Polynesia. Increasing reliance on sweet potato replaced traditional primary root crops, *taro* and yam, and also breadfruit. While not absent from tropical eastern Polynesia sweet potato's role in the tropics was to complement the major crops by allowing supplementary gardens in marginal environments, particularly in the Marquesas where they were used to buffer unpredictable precipitation. It has been established that increased reliance on sweet potato was because of its greater tolerance for a cooler climate, variable rainfall and lower soil nutrient levels. Nonetheless, in order to maximise and stabilise yield in the higher latitudes, Polynesians had to undertake a series of strategies to maximise and stabilise production centred on sweet potato. In Hawai'i this involved the development of walled field gardens targeting an environmental sweet-spot around 300-600 m above sea level. On Rapa Nui intensive lithic mulching and walled garden enclosures were used to combat the absence of shelter from desiccating winds and unpredictable rainfall, along with the proposed release of valuable nutrients into otherwise nutrient poor soils. *Taro* and banana continued to play an important economic role in the sub-tropics providing a form of "rump" diversity as the example of Rapa-iti makes clear. Yam also persisted but as latitudes rose its role diminished to the margins of production.

3 The archaeology of Māori horticulture

3.1 Introduction and theoretical aspects

The first historic records we have relating to New Zealand horticulture are those of Cook and other eighteenth century European explorers (Davidson 1984). Early European visitors identified five of the tropical plant species being grown in New Zealand, *kūmara* (*Ipomoea batatas*), gourd/*hue* (*lagenaria siceraria*), yam/*uwhi* (Dioscorea alata), *taro* (*Colocasia esculenta*), paper mulberry/*aute* (*Broussonetia papyrifera*), *ti pore* (*Cordyline fruticosa*); the same array of species found in Rapa Nui, with the exception of banana. Of these, *kūmara*, gourd and *taro* were widely grown across the North Island and to a lesser extent the upper half of the South Island (Barber 2004). Others, yam, *aute* and *ti pore* appear to have been isolated and rare restricted largely to northern North Island (Barber 2004; Furey 2006) Although *ti* was a staple in the southern half of the South Island this was the native *Cordyline australis* (Fankhauser 1986). Early ethnological thought on the timing and nature of horticulture, as expressed by Best (1925), Buck (1950) and Duff (1956) (who also relied on early archaeological data), was that the early settlement culture of New Zealand was without horticulture and existed through hunting and gathering: the "Moa-hunters" period. These people were overwhelmed by a later migration of agriculturalists, reflecting the arrival of the "Classic Māori' culture. This notion is summed up in this statement by Duff:

> "Māori and Moriori traditions support the theory that the first settlers in these islands did not succeed in acclimatising food plants, and the great superiority established over the local people by the probably few migrants of the period which culminated in the Fleet of the thirteen hundreds was possibly due more to their successful introduction of these crops than to their much vaunted military prowess" (Duff 1956: 8).

Golson (1959: 44-45) cast doubt on this scheme by pointing out its reliance on negative evidence and that Duff in particular had been influenced by evidence from the southern part of New Zealand, where horticulture was unlikely to have featured. He also identified potentially Archaic Phase[5] storage pits on Coromandel Peninsula in northern New Zealand. And, as Green (1972) later pointed out, there was the implicit question of why migrating

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[5] The Archaic Phase was proposed by Golson (1959) as an alternative to Duff's (1956) term Moa-hunter period. The Archaic Phase refers to the period of intial Polynesian settlement where an Eastern Polynesian form of material culture was employed. Alternate terms for this phase, such as Colonisation and Settlement have been proposed (Anderson 2016) but have not achieved currency despite greater suitability.

Polynesians would retain elements of their homeland material culture but abandon a fundamental element of their economy.

Yen (1961) wrote an important paper, inspired by Goldson's 1959 and 1960 papers, which was a watershed in discussions on the introduction of Polynesian horticulture to New Zealand. From the perspective of an ethnobotanist, Yen introduced the notion of a period of adaptation for the successful transfer of Polynesian horticulture before the technology could be systematically practiced in New Zealand. He pointed out that although two crops of *kūmara* could be grown a year in the tropical Pacific only one could be grown in New Zealand and that this necessitated a storage period reflected in the development of crop storage pits. He noted that it was becoming apparent that climate had changed since Polynesians arrived in New Zealand and that evidence indicated the climate had cooled after settlement. Yen proposed a three stage model for horticultural development:

1. Introductory – This was when plants from the tropical corpus were brought to New Zealand and attempts were made to grow them employing "growing methods brought with the plants from their provenances" (Yen 1961: 345).
2. Experimental – In addition to the difficulties in growing tropical plants in temperate New Zealand the cooling of the climate increased the need to be able to protect plants and it was during this stage that crop storage technology was developed. Some crop species became extinct or rare.
3. Systematic – This represents the development of a "stable agricultural system" (Yen 1961: 346) where by "European contact, methods of growing kumara, and perhaps *taro*, as major contributions to the Māori economy were well established" (Yen 1961: 346).

Through the 1960s and 1970s the orthodoxy espoused by Duff and others was increasingly challenged. Green and Shawcross (Green 1970; Green and Shawcross 1962) proposed that Māori culture transitioned through six phases, where they allowed for horticulture to be present in the Settlement Phase but the potential failure of crop introductions a characteristic. Yen's Introductory Stage was incorporated into the succeeding Developmental Stage where horticulture was a supplementary source of food. It was not until the third phase, the Experimental, when driven by deteriorating climate, storage pits were developed and systematic *kūmara* focused horticulture could commence in the Proto-Māori phase. Groube (1967, 1971) proposed that the first two stages of Yen's model could be achieved in as little as two generations, and that horticulture underwent adaptation during the Archaic phase in Northland before the technology was transmitted to increasingly more marginal areas. Law (1970), by identifying an array of mechanisms or scenarios for horticulture's successful establishment in New Zealand, challenged the belief that horticultural transfer, or more specifically that of *kūmara* itself, was not possible at the time of early settlement because of the climate. He also made the obvious point that any proposition of introduction during a later migration would not obviate the problems with establishment of tropical plants in a temperate climate present at an earlier period while also questioning the reliability of the climate variation data Yen had relied upon. Law (1970: 123) proposed that "far more important factors [than climate] in the spread of kumara through New Zealand are the timing of the development and adaptation of the techniques or propagation and storage, the decline of other resources through extinction and through limitations of supply, the discovery of areas with advantageous microclimates and soils, ...". Simmons' (1969: 7) review of Māori traditional history led him to conclude:

> "A thorough check of the authenticity of the records of traditions leaves a solid core of authentic tribal traditions referring to the origin of the tribes inhabiting Bay of Plenty-Rotorua, Waikato, Hawke's Bay and Southern Taranaki – all of which state that kumara has been cultivated in those areas since they were first settled. None of these areas is suitable for growing kumara without storage in the winter".

B. F. and H. M. Leach's (1979) Wairarapa Project was a model for whole-of-landscape approaches to archaeological research, especially with its emphasis on horticulture and innovation for New Zealand archaeology. The results of this project, located in a marginal climate for *kūmara* cultivation, included radiocarbon dates and material culture that tied the chronology of horticulture to the Archaic phase. H. M. Leach (1979a & b) refined Yen's 1961 model to allow for the effects of climate change with consequent contraction of areas where horticulture could be practiced. Leach's model increased Yen's three stages to five:

1. Introduction
2. Experimentation
3. Regional consolidation
4. Expansion from secondary centres
5. Retrenchment
6. Revival

In Leach's (1979b: 246-247) model the Introductory Stage literally refers to "the introduction of a range of Polynesian cultigens as well as a wide repertoire of gardening techniques" while the succeeding Experimental Stage allowed for the development of "short-term storage devices for yams and kumara". After this, horticulture was able to expand from an implied optimal zone where the first two stages occurred around the North Island "as far as Wairarapa" in the south. The fourth stage, Regional Consolidation, draws on putative regional variation in storage pit forms and when regional variants of *kūmara* were developed. However, the evidence for this has never materialised and the general picture is for variation in storage pit form from site to site and even within sites. This appears to weaken her basis for this construction. The purpose of the next stage, Expansion from secondary centres seems difficult to grasp simply on the basis of what or where the secondary centres may have been; something that Leach herself admitted. Leach (1979b: 247) noted that this stage and the previous "may be equivalent to Yen's third stage of systematic agriculture". The final stage, Retrenchment, was based on the archaeological evidence for abandonment of the Palliser Bay gardens and its proposed conjunction with a period of climatic deterioration. This is a notable contrast to Law's (1970) scepticism about the evidence for climatic change and its effect. The last stage is the revival of Māori horticulture in the nineteenth century with the arrival of new crops and tools, which permitted re-expansion back into what had previously been outside the margins for horticulture using tropical plants. Leach (1978b: 247) provided a caveat to her model:

> "This model does not imply that each stage was reached simultaneously in every area, nor that each area experienced every stage".

In some sense this was an admission that the model was to some extent regionally relevant rather than entirely nationally applicable.

3.2 Historical descriptions of *kūmara* cultivation and soil modification in New Zealand

The ethnographic and historical literature on Māori agriculture is substantial and includes a number of references to the addition of coarse material, sand and gravel, to gardens. It is this early historical and ethnographic material which informs us about Māori agronomy, and which, in turn we use to inform the archaeology. Many of these accounts are often frustrating for the level of superficiality about method and motives. Walton (1982) examined this resource and detailed a range of significant short-comings. Fundamentally, Walton proposes that, with the exception of a handful of accounts that are both early (1830s to 1840s) and apparently, or probably, related to first-hand observation, the majority of accounts are unreliable. Walton details how many of the notions described in published accounts are un-attributed repetitions of the early accounts, which effectively built-up a spurious level of authority for many of the ideas relating to Māori agriculture and particularly the addition of sand and gravel to parent soils (Walton 1982).

Walton considered the example of the idea that sand and gravel were added to ameliorate soils described as “heavy”, “stiff” or clay soils. This includes references to Māori-made soils of the Waikato where addition of sand and gravel was also to rectify such parent soils, but which we know from the work of soil scientists and archaeologists to have been free-draining loams, in actuality. Here Walton proposed that anything after Yate (1835) was simply copying his account of improving a clay soil in Northland. Another of Walton’s examples was the proliferation of the idea that Māori laid 6 inches (15 cm) of coarse material on the surface of parent soils, which he traces to Taylor (1855) and which was taken up and repeated by subsequent scholars in the late nineteenth and early twentieth centuries. Walton identified fundamental problems with the ethnographic literature; that most of the information in the often-cited accounts is not well-established because it lacks evidence of direct observation or reference to sources. In addition, these accounts have then been regularly repeated and have proliferated through the literature over time up to the current period.

Therefore, although a number of nineteenth century accounts describe the addition of sand and gravel to soil by Māori only a few are worth referring to here. Walton (1982) attributed most of the reliable written material to Yate (1835), Taylor (1855), Shortland (1842, 1856) and Wakefield (1845) and reserved his opinion on Colenso (1868, 1880), saying that it was hard to determine how much of Colenso’s material was the result of direct observation. Other popular sources, Stack (1898), Walsh (1902) and Best (1976) were all considered by Walton to simply repeat variations of earlier accounts. In most cases these are unattributed, although Walsh stated that he relied on several earlier sources.

Yate provided this information:

> "Their kumera-grounds are kept very neat and free from weeds: the land is prepared with a small stick, and pulverised between the hands: the ground is then made up into hillocks, about the size of small mole-hills, in the middle of which the seed is placed. The soil to which this vegetable [kumara] is partial is light and sandy; where this is not the nature of the soil, the natives make it light by carrying the sand from the banks of rivers, having found by experience that sand or small gravel is the best meliorator of a clayey soil, as it destroys its cohesive qualities and prevents its returning to its original state of tenacity, keeping it always porous, and consequently causing it to imbibe more readily of, and in greater quantities, the light showers of rain with which they are visited in the summer, or the heavy dews or watery vapours which nightly visit them throughout the year" (Yate 1835: 132).

Given that Yate's residence was in what became North Auckland (later Northland) Province we must assume that this related to a local problem with scarcity of friable soil. Like Yate, his contemporary, Richard Taylor's experience was largely of Northland before transferring further south to Wanganui in 1843. Taylor's reference to Māori cultivation is not extensive.

> "The *kumara* requires not only a warm aspect, but also, in general, an artificial soil; sand or gravel being laid on the ground to the depth of six inches. So also the *taro*, which needs the aid of bush screens and other expedients to make it flourish. These also soon exhaust the soil; three years' cropping with *kumara* being, in general, all that can be obtained from one spot. The place is then abandoned, and another selected; but this abandonment is only for a certain space of time. Instead of turning up the soil, and suffering it to lay in fallow a season, their method of renewing it is to allow it to remain unoccupied until it is covered with a certain growth of wood, if situated in wood land, or of fern, if situated in fern land, which requires a period of from seven to fourteen years, when the spot is again cleared and planted. Thus, many places, which appear never to have been touched by the hand of man, are pointed out as having been the farms of some ancestor, and, when the place is more closely regarded, it will be found destitute of all old timber. The *kumara, taro*, and even potatoe [sic] grounds, are generally selected on the sides of hills, having a northern aspect; by this declivity towards the sun, they gain an increased degree of heat." (Taylor 1855: 378.)

Wakefield presented what is explicitly a first-hand account of some terraced gardens in the Paekakariki/Pukerua Bay district on the southwest coast of North Island:

> "… some neat plantations of the *kumera* [sic], or sweet potato, betrayed the neighbourhood of a settlement. They extended about thirty yards up the face of the hill, in terraces formed by logs of wood laid horizontally, and supported by large pegs. The terraces were covered with sand from off the beach, which the natives assured me was the best soil for the growth of the *kumera* [sic]. In storms, these plantations must be covered with salt spray, and swept by the north-west wind ..." (Wakefield 1845: Vol 1, 225-226).

Wakefield's description, although intriguing, provides no useful detail about how it was applied, especially in relation to the crop.

The only first-hand account we have of the Waikato system comes from Shortland who visited the Waikato in 1842 and wrote two versions of the same experience.

> "The land which we travelled the last few days was good, with woods and swamps scattered over it, which latter are highly prized by the natives on account of their eel fisheries. This last day we travelled through several kaingas, which had been in cultivation in Pohipohi's younger day, at the surface of the ground in those places was thickly strewd with gravel, chiefly pumice (punga punga). Several deep pits were pointed out from which this has been dug and mixed with soil to render it fit for cultivation of the kumara" (Shortland 1842. Manuscript book 4, 3 October 1842).

> "Their knowledge of the art of horticulture was not inconsiderable; for they even employed the method of forming an artificial soil by mixing sand with the natural soil in order to make it light and porous, and so render it more suitable to the growth of the sweet potato. In parts of the Waikato district, where this plant was formerly cultivated, the traveller frequently meets with large excavations, from twenty to thirty feet in depth, like the gravel pits one is accustomed to see in England near public roads: and in reply to his enquiries, he learns to his surprise that they were formed by those who resorted there, year after year, to procure sand for manuring the ground in the manner described" (Shortland 1856: 202–203).

Shortland's description is valuable because it refers to the Waikato system, although it only gives a general picture of the process. While the two descriptions are very similar they do differ. In his 1856 publication Shortland informs us that it was done to make the soil "light and porous", he elaborated on the size of the borrow pits, adds a reference to "those who resorted there, year after year, to procure sand" and likened the adding of sand to manuring. How much these additional remarks result from Shortland's own observations or information from his local companions, or are unattributed ascriptions to others, as Walton (1982) suggests, is impossible to determine. Of his remarks, Shortland's reference to the use of pumice gravel and the mixing of it into the soil can probably be relied on to reflect his observations. However, the archaeological record casts some doubt on the accuracy of his reference to soil mixing and raises the possibility that this element of the narrative is potentially a memory of his own observations or a flawed relation of information from his companions.

Yate was clearly referring to the improvement of clay soils to improve texture and moisture retention in the Northland region where he was based. Shortland's comments are most relevant but ambiguous, proposing that this labour-intensive process was undertaken to improve the soil. Altogether, other than the general nature of improving soil texture and possibly soil temperature we are left with only a sketchy understanding of both the process and the intent behind it.

3.3 Archaeological investigations of Māori-made soils

Exploration of Māori horticulture began with the identification in the late nineteenth and early twentieth centuries by soil scientists of soils manipulated by Māori (Bishop 1924; Grange et al. 1939; Rigg & Bruce 1923). Also in the early twentieth century this was accompanied by reports of a variety of archaeological remains in various parts of New Zealand understood to be associated with aspects of Māori horticulture, published in peer-reviewed and non-peer reviewed journals and books (e.g. Best 1976, originally published in 1925). Many of the archaeological features identified in these publications and assigned to Māori horticulture had attributes familiar from tropical Polynesia including terraces, arrangements of rocks and stones in rows, walls, heaps, mounds and alignments, terraces and ditches including those resembling raised bed swamp *taro* systems. Barber (2004), Davidson (1984), Furey (2006) and Walton (1999) provide detailed summaries of this evidence, its nature and distribution of the various aspects around New Zealand. Their analyses of the literature and information contained in the national archaeological site recording database makes it clear that most of the archaeology relating to Māori horticulture is found in the northern half of the North Island. The archaeology to the south of this becomes increasingly sparse as latitudes increase as far south as Banks Peninsula, which represents the southern limit of Māori horticulture. In addition to the tropical Polynesian analogues two other classes, crop storage pits and made soils, are unique to New Zealand and considered to be specific adaptive innovations responding to the challenges of a temperate climate.

Walton (1999), in the New Zealand Archaeological Association site recording handbook, described two types of soils under the heading "Garden Soils". The first is what might be called a mixed soil resulting from tillage but which is not given a specific name and the second is what he terms "Made soils"; "artificially made soils containing added sand or gravel" (Walton 1999: 67). Others names used are Māori plaggen soils (e.g. Davidson 1984; Furey 2006; McFadgen 1980a) and modified soils (e.g. Barber 2004; Furey 2006). Plaggen as a term has regional relevance to northern Europe and includes soils that have organic and mineral additives and so is not used here. Applying the term modified appears inadequately non-specific, generally it could be argued that all soils in an archaeological context are modified in some manner, but more specifically it may just as easily refer to Walton's first class of garden soil as much as his second. In this context "Māori-made soil", or more simply "made soil" are preferred.

Definitions of Māori-made soils, when offered, tend to be perfunctory, such as this by Walton (1978: 1):

> " 'Māori' or 'made' soils are distinguished from surrounding soils by the presence of deliberately added sand or gravelly sand".

McFadgen (1980a) described, rather than defined, what he called Māori plaggen soils but this may be summarised into a useful definition. The soils in question contain coarse mineral particles, sand and/or gravel, present in a distinct layer:

- where coarse material has been transported through human agency
- that contains coarse materials that are "out of place in the sedimentary history of the site" (McFadgen 1980a: 4) and that may sometimes:
    - be buried
    - be associated with a hummocky ground surface

- have a poorly defined lower boundary

McFadgen (1980a) identified two variants with the morphologies of Māori-made soils. The first was “a layer of transported sediments between about 20 cm and 30 cm thick spread over, but poorly mixed with, a former ground soil or sedimentary layer” or with the former topsoil preserved as a buried soil (McFadgen 1980a: 4). Transported sand and gravel make up nearly all of this soil layer. The second variant was a soil formed by the mixing of the transported coarse material with the parent soil with varying proportions divided between the additives and the parent material.

3.3.1 Archaeological reports and descriptions of made soils in New Zealand

3.3.1.1 Northland

Excavations at Moturua Island in the Bay of Islands (Groube 1966; Johnson 1997; Peters 1975) have identified two areas of soils made by the addition of beach sand and gravels (along with water-worn flake artefacts and shells), one associated with a slope garden and the other a garden on the flat behind the beach. At another site at Whangaruru Harbour (northern North Island) two sets of bowl-shaped hollows (BSHs) were found by J Carpenter (personal communication, 2018). These appear to have been formed from transported beach sand being placed in hollows dug into silty alluvium 50 m from the beach, with each feature approximately 20-30 cm in diameter and 10 cm deep.

3.3.1.2 Auckland

Auckland’s “stonefields” horticultural system is well-known (Bulmer 1989; Sullivan 1985) for a different form of lithic horticultural landscape featuring stone rows and stone mounds of varying sizes. However, reports of Māori-made soils are confined to islands in the Hauraki Gulf. Law (1975a & b) identified a made soil at Rocky Bay on Waiheke Island, in the Auckland Harbour, which was also formed by the addition of beach gravel and sand. From Law’s description it appears that this material was mixed with the local parent soil to some degree and probably represented gardening over multiple episodes. Nichol (1981) also reported a similar made soil from the Sunde site on Motutapu Island, another site in the Auckland Harbour, where he identified a dark brown upper unit and a lower pale yellow unit. Nichol’s description is unclear but it appears that the added material was in the form of both sand and gravel and included water-rolled shells. He also believed this material came from the beach, although he also mentioned the possibility that it was quarried from a nearby stream bank. It is also uncertain from his description whether these deposits were mixed with the recently fallen tephra or were distinct, or whether the two made soil units were stratigraphically contiguous.

3.3.1.3 Bay of Plenty

A single example of made soil is described from the Bay of Plenty at Kauri Point *Pā* where a layer of beach sand, finely crushed shell and charcoal was introduced to form a garden soil early in the sequence of the site's development (Ambrose n.d.; Schofield 1961). This made soil was extensive across the site prior to the construction of the *pā* and up to 60 cm thick.

3.3.1.4 Waikato

Clarke (1977) reviewed the ethno-historic literature referring to the agricultural practices in the Waikato from 1830 to 1860 and considered references to the crops grown, their relative importance, and associated cultural practices. He was able to find little information about the agronomic practices associated with made soils. Clarke found that while *kūmara* remained a significant crop at this time it was being overtaken by introduced crops; maize, wheat and white potatoes. However, Clarke noted that traditional rituals and rules of tapu associated with cultivation of *kūmara* were still being followed at this time. The only descriptions of made soils in the Waikato at this time is the ones already quoted from Shortland based on his observations in 1842. He also made this comment describing forest clearance as part of the swidden agricultural process in the succeeding passage to those quoted above:

> "Suppose a wood is the spot selected - the first work is to cut down all the small trees and brush-wood, after which the larger trees are felled, till a sufficient space has been cleared. This is done in July. The trees and branches are left to lie on the ground till January or February of the year following, at which time, having become dry, they are set on fire. Nothing more is done until the following September, when the larger logs, only partly consumed by the fire, are split up into small pieces, gathered into heaps, and burnt".

While Shortland is referring to swiddens for the "common potato", rather than the *kūmara*, it seems reasonable that the same process was followed regardless of the crop to be grown. Interestingly, Clarke's (1977) sources often refer to potatoes being more demanding of fertility than *kūmara*.

Following Shortland the next description of Māori-made soils is from the Department of Scientific and Industrial Research (DSIR) soil survey report on Waipa County (Grange et al. 1939) where soils were identified and mapped and the report classified them as the distinct Māori Series[6] of soils. Soil scientists continued to map Māori-made soils as part of soil survey work until the DSIR was disbanded in 1992 (Bruce 1978, 1979; McLeod 1984). Soil survey data is discussed in detail in Chapter 4. Taylor, based on available soil survey data stated there were 1797 acres (727 ha) in the northern part of Waipa County "and a similar amount in the southern part of Waikato County" which indicates that approximately 1500 ha had been recorded and noted there were large areas that had not been surveyed (Taylor 1958: 77). He added that he estimated there were probably approximately 2000 ha "on the mid-Waikato plain"; it is uncertain if this included the surveyed areas or not (Taylor 1958: 77). He provided a generalised description of a made soil found in the Waikato:

> "... the most frequent soil profile is none to ten inches of black fine gravelly sand with much charcoal throughout, resting on an older soil. In most places, the black gravelly sand rests on the Horotiu soil, a well-drained yellow-brown loam..." (Taylor 1958: 77).

It is clear from Taylor's description that the sand and gravel was laid on the parent soil and not mixed with it and that the black colour was the result of added charcoal. He noted that the areas of made soil ranged from 0.2 ha to 200 ha but that patches of 2 to 4 ha were common, and that adjacent to these were pits 2.4 m to 3 m deep with some up to 8 m or more deep (Taylor 1958: 77). Taylor believed these measures provided a loose, well aerated, and warm soil "almost perfect for the growth of kumara" overlying a firm but well drained parent soil with good water holding properties.

Law (1968) reported on made soil identified during geotechnical testing on the banks of the Waikato River on the lower Waikato Basin, downstream from Huntly. The made soils were found on the higher (i.e. flood-free) areas of the levees on both banks and where sand and gravel had been added to silt soils and which were mixed to 2 feet (60 cm) depth, with charcoal present. He identified 220 acres (89 ha) of made soils. Law also identified borrow pits but noted that the landforms made their distinction from natural features difficult.

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[6] Later renamed as the Tamahere series (Bruce 1978).

A second area of Māori-made soils is present in the Waikato region, in the Ruapuke/Aotea district on the west coast (Walton 1978, 1983). Here relict dune systems mantled in tephra are the site of soil modification with borrow pits and the associated made soil found from Ruapuke to south Manuaitu along the coasts for 10 km and stretching between 1 km and 4 km inland. This landscape is also characterised by terraces that appear to have had a primarily agricultural function and sometimes contain made soil. The parent soils are free-draining Tuahu sandy loams formed on the tephra mantle. Borrow pits are "conspicuous and are found in large number strung out along the tops and sides of the tephra-mantled dunes" (Walton 1983: 89). Walton was able to identify 380 borrow pits in this area from field observation and aerial photography with the pits accessing the fine dune sand underlying the tephra (Walton 1978). Based on a selection of 18 measured borrow pits with a mean area of 276 m^2 Walton estimated approximately 102,000 m^3 of sand was quarried. Typically, the Māori-made soils are 40 - 50 cm deep and the process of adding sand resulted in a loamy sand with approximately 65 % of the Māori-made soil made up of the quarried sand, or in other words, "in a 40 cm horizon this would mean some 25 cm of added sand" (Walton 1978: 30) with charcoal proportions generally very low and finely fragmented. Although not specifically stated by Walton it appears that the quarried sand was mixed with the parent loam.

3.3.1.5 Taranaki

Buist (1964) described the distribution of borrow pits in North Taranaki as confined to river terraces in the area between Waitara River and the Mimi River, and spread over a distance of approximately 23 km. Walton (1984) extended this area further west, to the Waiongona River valley. Walton reported on the results of investigations of the borrows pits and adjacent soils at Q19/187 on river terraces of the Waitara River. The parent soils are coarse alluvium with wide variation from sands and gravelly sands to sandy loams, and are all consistently friable and well-drained. On the intermediate terrace the borrow pits were located on the shoulder of the scarp with large stones left around the pits indicating some size preference. Walton commented that the addition of the quarried material made no apparent difference to the texture of the parent soils. In some places a buried topsoil was found under the added material:

> "Depth (cm)
> 0-20 topsoil formed in added sand and gravel
> 20-40 raw added sand and gravel

40-60	buried original topsoil
on	sand and gravel - many metres deep” (Walton 1984: 58)

On what Walton described as a bench formed from a colluvium of re-worked tephra from the upper terrace there is another distinct profile described by Walton:

“0-25 cm	topsoil formed in added sand and gravel
25-35 cm	raw added sand and gravel
on	loam derived volcanic ash” (Walton 1984: 58)

In both descriptions it is clear that the added material sits over the parent soils, which are already friable and well-drained, and is not mixed with them. This is the only report describing the borrow pits and made soils of north Taranaki and it is not known how representative this site is. From both Walton’s (1984, 2000) and Buist’s (1964) descriptions the impression is that borrow pits are either in small clusters, or found as isolates.

Borrow pits and associated made soils are found on South Taranaki stretching over 40 km between Manawapou and Waitotara, which Buist aggregated into 70 sites, either individual borrow pits or clusters (Buist 1993). The borrow pits are found on relict Pleistocene dune systems mantled in tephra, much the same as those at Aotea, where the parent soil is a sandy loam with an A horizon generally 30 cm thick. In one place Walton (1978) identified the tephra mantles as 95 cm thick but it is uncertain if this is typical. The borrow pits vary in size and are found on the crest of the dunes and on their, slopes, again similar to Aotea. Investigations occurred at three places with the made soil, a loamy sand, variously 60 cm, 35 cm and 55 cm thick at each site (Walton and Cassels 1992). Both Walton and Cassels (1992) and Buist (1993) comment on the hummocky ground surface in places close to the borrow pits. At one of the sites investigated by Walton and Cassels (Q21/234) the hummocky surface reflected the varying thickness of the added sand leading them to comment that coarse material appeared to have been applied to make mounds or beds rather than as mulch. Both Walton and Cassels (1992) and Buist (1993) noted that crop storage pits are both common and more widespread in the south Taranaki landscape than borrow pits, leading them to propose that made soils formed only one class of gardened soil in the district.

A unique reference to Māori "compost" was made by Bishop (1924: 317) in western Taranaki where he described a "heap on the banks of the Hangatahua (Stony) River". While it appears that Bishop did not examine the heap in the field, his analysis and description of the constituents of a sample from the heap demonstrate he was clearly not referring to composted vegetable matter typically considered to be compost. Bishop undertook a particle size examination of a sample of the "compost" and compared it directly with an equivalent sample of a Māori-made soil from Waimea in Nelson (see Rigg and Bruce 1923 below in the discussion relating to the Nelson region). He noted the sample was dark, which he attributed to charcoal and the presence of ironsand. The coarse grain range[7], including fine gravel, coarse sand and fine sand accounted for 93 % of the "compost" with very little silt or clay. In comparison the 73 % of the soil sample from the Waimea Plain in Nelson (see below) comprised sand and gravel with a higher proportion of silt and clay. Bishop also analysed the soil chemistry which he compared to the Waimea made soils and generalised average Taranaki soils. Nitrogen was lower than the Waimea samples and similar to the Taranaki soils. Rates for phosphorus were very high; seven times that for the generalised Taranaki measures and over twice that for the Waimea made soil sample. However, the potassium levels were lower than the Waimea and Taranaki samples. Bishop (1924: 319) proposed that the soil chemistry along with the presence of charcoal pointed "clearly to the incorporation of ashes, obtained by burning wood or other vegetable matter" and ascribed to low levels of potash to its water solubility and consequent leaching. This example from Okato in western Taranaki suggests that Māori-made soils were more widespread in Taranaki than has been described and were also developed, at least in this case, through complex processes.

3.3.1.6 Hawkes Bay

At Waipatiki in Hawkes Bay, Walton identified a group of circular depressions in a dune swale in a small valley approximately 250 m from the existing shoreline. Walton described them as follows:

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[7] Bishop (1924) does not specify the grain size ranges he employed, nor specifically whether he used the Wentworth scale (Wentworth 1922) or an earlier one as seems likely given the date of Wentworth's publication. If he was using either the US Bureau of Soils or the Udden scales, as seems likey then these correspond to very coarse sand through to fine sand in the Wentworth scale and the Krumbein phi scale.

> "Twelve circular features about 60 [600[8]] mm diameter had been exposed in plan in the subsoil. There were smaller circular holes, generally about half that diameter or smaller. The fill of the features was raw white sand and this stood out against the grey sand substratum in which they occur. The features appeared to conform to a pattern but the view was too restricted to be sure what the layout might be. Nothing was seen to indicate what the features might look like in section and there was nothing to indicate their antiquity" (Walton 2007: 27).

Walton proposed that these were agricultural in function and that the activity represented was the growing of *taro*, which he based on a review of the ethnohistoric literature.

Jones (2012) reported a similar find site, Y19/119 on Mahia Peninsula at the northern end of the bay. No other evidence for the application of transported coarse material is known in Hawkes Bay. The site was located on the floor of a small valley approximately 500 m from the shore. Jones excavated three areas and found a series of small circular concave depressions approximately 30 cm in diameter laid out in rows and filled with beach gravel. In areas A and B Jones found 20 of these features in rows oriented at 30º to north 73 cm apart (centre to centre) and in area B, Jones (2012: 8) noted "there are a number of paired circles which indicates repeated re-use". He estimated these features probably covered an area of 6000 m^2. Jones recorded a series of three soil profiles, one for each area:

> "Area A
>
> (cm below surface)
> 0-25 grey silt loam topsoil copious gravels at base, concentrated at bottom
> 25-45 grey silty clay (depression dug about 50 cm in the subsoil)
>
> Area B
>
> (cm below surface)
> 0-20 clay silt loam soil wash
> 20-42 dark silt loam copious gravels at base

---

[8] It is clear from the rest of the article and from personal communication with Walton that the diameter was 600 mm. It is also important to understand that Walton accidently encountered these features which were exposed on a development site.

42-50 grey silty clay (depressions dug about 5 cm into the subsoil)

Area C

(cm below surface)
0-20 disturbed clay fill
20-35 grey silt loam with concentrated gravels at base
35-50 grey silty clay (depressions dug about 5 cm into the subsoil)" (Walton 2012: 7-8)

The parent soil in this instance was poorly drained silt clay with the hollows dug into it and filled with gravel, with gravel also being present in the overlying silt loam suggesting that the hollows may have been truncated and the gravel spread before soil forming processes developed the topsoil.

3.3.1.7 Wellington/Wairarapa

McFadgen (1980a) describes three sites in the lower North Island where gravel and sand have been added to the soil, at Makara and Pauatahanui on the west coast and Okoropunga on the east coast. Of these McFadgen (personal communication) now believes the Makara example is the result of colluvial processes and there must be doubts raised about the Pauatahanui site based on McFadgen's description. At Pauatahanui rounded un-weathered gravel is present at low density (<10 %) in the sediment with low densities of charcoal mixed uniformly through the layer. At Okoropunga an area of 0.7 ha of made soils with adjacent borrow pits is present within a much larger garden site characterised by stone row systems (McFadgen 1980b). The added material is described as marine gravels visible in profile as a distinct layer with a hummocky surface. The made soil unit directly overlies a buried topsoil and the parent soil was well-drained silty sand on gravel.

3.3.1.8 Nelson

Māori-made soils are found in three areas in Nelson: on the Tasman Bay lowlands, Waimea, Riwaka and Motueka covering a total area of 1000 acres (405 ha) (Chittenden et al. 1966). Rigg and Bruce (1923: 87), referring to the Waimea Plains, provided the first detailed description of a Māori-made soil describing the soil profile as:

“No.1	Fine gravelly sand	thickness 10 in to 16 in [25-40 cm]
No.2	Loam	thickness 18 in [45 cm]
No.3	Fine sand	thickness 10 in to 30 in [25-76 cm]
No.4	Coarse sand and gravel	thickness several feet”

Unit 1 is the made soil with Unit 2 the parent soil. At Waimea the parent soil was a greyish-brown silt loam and at Riwaka and Motueka the parent soil was pale greyish-brown sandy loam. The made soil was black and examination of the made soil later showed the material overlay the silt loam and was not mixed with it; the made soil layer had a low proportion of silt. Rigg and Bruce (1923) also noted the unusually high fertility of these soils compared to the other local soils, including the parent soils. They noted the made soil had substantially elevated phosphate and potassium, adequate levels of calcium and was slightly acid. They queried whether this was a natural state or had been induced by Māori. Rigg and Bruce noted that the substrate (Units 3 and 4) was rich in phosphorus compared to the silt loam (Unit 2). They proposed that the high levels of charcoal in the made soil unit were a result of burnt wood, which they suggested had been carried from the nearby hills, and that this had provided ash rich in nutrients. They reported experiments with burning mānuka (*Leptospermum scoparium*) and bracken (*Pteridium escultentum*) had shown the ash contained 1.1 % phosphoric acid and 8-17 % potash. Referring to the borrow pits they noted that gravel has been sorted with clasts larger than 1 1/2 inches (37 mm) were excluded and piled in and around the pits (Rigg and Bruce 1923: 87).

Challis (1976, 1978) later examined made soils at Motueka identifying 115 ha in the district, although he suggested this was an underestimate. Challis (1976: 250–252) described the profiles of 6 test pits excavated within and adjacent to an area of made soils on the floodplain of the Motueka River. One of the test pits was located in a 30 m diameter depression thought to be a borrow pit, two were dug into unmodified soil and three within the area of made soils. The parent soil was a brown fine sandy loam described as imperfectly drained, while the made soil was a dark brown sandy loam including coarse sand and gravel along with charcoal. The main body of the made soils was within a paddock that had been ploughed regularly and Challis sited his test pits both within the ploughed zone and adjacent to the fence where ploughing had not occurred. It is his description of these test pits that are the most useful because they describe soils unaffected by recent activities. These are reproduced in summary in Table 3.1. Challis also noted a distinct boundary between the made soil and the underlying

B horizon, which differed from the indistinct boundaries between the A and B horizons in the unmodified soils. The test pit within the large borrow pit exhibited a disrupted soil profile in comparison to the Test pits 4 and 5 (in unmodified soils) which Challis interpreted as the fill of a borrow pit. Challis concluded that evidence indicated the A_{12} horizon was a transported made soil. However, the profile description of the made soil describes a discrete layer over the B horizon. Challis (1976: 252) commented that it had "become well mixed into an A horizon with significantly improved friability and drainage". Although the charcoal was generally finely fragmented, one piece was identified as rimu, a tree representing climax forest. Challis proposed that the existing topsoil overlying the made soil adjacent to the fence, the A_{11} horizon, had developed as a result of wind build-up of silt but it is equally possible that this had resulted from soil forming processes, pedogenesis, which had not been interrupted by repeated ploughing.

Table 3.1: Adapted description of Test-pits 4 and 1 from Challis (1976: 252). A_{12} is the made soil layer.

Test pit 4 - unmodified soil				**Test pit 1 - made soil**		
A_1	0–24 cm	dk. yellowish-brown silt loam		A_{11}	0–21 cm	dk. brown sandy loam with coarse sand and gravel
				A_{12}	21–37.5 cm	dk. brown sandy loam with charcoal, coarse sand and gravel
B_2	24–35 cm	yellowish-brown silt loam		B_2	37.5–52 cm	dk. yellowish-brown silt loam
C_{21}	35–52.5 cm	mottled brown fine sandy silt		C_{21}	52–100 cm	light buff fine sandy silt
C_{22}	52.5+ cm	light greyish-brown medium sand		C_{22}	100+ cm	light brown fine sandy silt with clay, mottled grey and orange

Challis (1976: 253) analysed the soil chemistry, noting the paddock was occasionally fertilised, and found that the made soils had lower potassium and phosphorus than the unmodified soils and were also slightly more acid, although the soils locally were generally only mildly acid. He also noted phosphorus was at higher levels in the B horizon, which he attributed to leaching. Challis also measured the minimum soil temperature and the maximum soil temperature at 4 pm daily over a two-month period in what would have been the *kūmara* growing season for both the made soils and the parent soil. The average difference in the soil temperature at 4 pm was 1.4° F and the average difference for the soil minimum was 0.6° F and found that the made soil warmed slightly faster in periods of increasing temperature. By converting the temperature measurements to heat units the made soil was 13 % better than the unmodified soils which meant it was 11 days faster at reaching 18º C and 4 days faster at reaching 19º C. Challis believed this distinct difference in the soil temperature was sufficient to add a week of growing time at the beginning of the season allowing earlier planting (Challis 1976: 254).

At Appleby in the Waimea floodplain, Barber (2010) examined a roadside profile where he identified two cultivated soils. One was a made-soil of the type described by Rigg and Bruce (1923) and the other, which was effectively contiguous with the made-soil, is described as a cultivated soil, presumably mixed in appearance. Barber did not describe it in detail but noted that the made-soil was superimposed where they overlap. Although Barber did not fully report the results of mechanical sorting he stated that the made-soil layer contained only 39 % of material finer than 2 mm, while for the parent soil 97 % of it was finer than 2 mm. It is worth noting that very coarse sand ranges from 2 mm to 1 mm, therefore Barber's finer fraction includes coarse material that may have been part of the quarried material. Barber (2010, 81-82) argued that the added material was "concerned primarily with thermal and drainage improvements in seasonal kumara production"; although the parent soils are well-drained.

Barber (2013, 42) also reported, in passing, a possible made-soil at Tata Beach in Golden Bay where beach gravel was incorporated into the sandy loam.

Interestingly, Barber (2013) proposed that at Triangle Flat at the southern end of Farewell Spit (Golden Bay) there is a variation in use of lithic material (sand and gravel) as an additive in the horticultural process. Here Barber identified a black sandy soil including charcoal that was visibly and texturally distinct from the underlying natural beach ridge, which is composed of water-worn cockles (*Austrovenus stutchburyi*) within a brown or yellow sand matrix. The black soil he interpreted as a soil used for cultivating *kūmara*, which draws on the identification of *kūmara* starch grains recovered from the matrix (Barber 2013: 44). Barber also identified a series of holes penetrating into the underlying beach ridge sediments filled with the black sandy matrix that he interprets as deliberately formed "planting pits". The planting pits are variable in size, form and profile but none are wider than 60 cm and all intrude between 10 and 20 cm into the substrate. Although Barber equated these to the bowl-shaped hollows found in the Waikato (citing Gumbley et al. 2004) they differ from the Waikato examples, which are regular in form and profile as well as arranged regularly in rows. Barber (2013: 45) argued that a single series of five of the features in a row represents evidence that these depressions conform "to historical descriptions of Māori *kūmara* cultivation fields" but the evidence presented is weak given the small area excavated and the absence of multiple rows. Barber specifically makes arguments for two episodes of the use of shell mulch based on his interpretation of the stratigraphy. An earlier event represented by either shell scatters or small concentrations of shell close to the tops of the "planting pits". A later event is represented by a discontinuous, but extensive, thin layer (2-6 cm) of water-rolled and broken cockle shells, sometimes including a brown sand matrix, some centimetres above the tops of the "planting pits" and a similar distance below the ground surface. It appears from Barber's description the matrix above and below this discontinuous shell unit is much the same, in other words the horticultural soil is very similar to the current topsoil that overlies the shell unit. Barber also noted that the shell layer is both discontinuous and covers only some of the "planting pits". He (2013: 45) interpreted the lower, and earlier, sparse shell elements as evidence for "shell mounding above structurally associated black sand depressions" (i.e. the "planting pits"). The upper shell unit is introduced as a later event when "beach shell sediment was extended to cover larger cultivation surfaces and more shallow planting depressions in the shelly substrate" (Barber 2013: 45). Barber also referred to mounding with apparent reference to the lower scattered shell deposits:

> "However, extensive shell surfaces that were mounded above young plants would have helped secure seedlings and stabilise upper shallow, upper A-Horizon planting matrix against stronger and persistent eighteenth century winds in the first instance" (Barber 2013: 49).

Barber proposed that the upper shell unit was quarried and deliberately transported from natural deposits, either the beach ridge itself or from presumably intertidal shell banks. The advantages of adding the shell to the ground surface would have been to retain moisture and stabilise the sandy matrix in windy conditions. It would also help to control weeds and moderate soil temperature fluctuation (Barber 2013: 49). This complex argument relies on over-interpretation of the data offered and does not establish a credible line of evidence based on that data. For example, the lower lenses of scattered shells or small concentrations of water-worn cockle shells may be accounted for through disturbance during formation of the irregular depressions referred to as "planting pits". The argument of the shell mulch is not convincing. At harvest a mulch layer would, of necessity, be destroyed to access and recover the tubers. Much the same argument can be made with reference to the proposed lower and earlier shell deposits representing former mounds. The irregular "planting pits" themselves do not appear to be “planting pits”; *kūmara* are typically referred to as growing in mounds or *puke* by Māori (e.g. Best 1976).

At a site on the northern side of Greville Harbour on D’Urville Island, Wellman (1962) reported a more or less widespread deposit of pebbles associated with the earliest occupation layers, which also contained moa bone and early artefacts on the sand plain. Given the sandy nature of the parent soils along with the stratigraphy he concluded that the pebble layers were related to the gardening of *kūmara* by the same people who were hunting moa. He did not explicitly state whether the pebbles were a distinct layer or mixed with soil. In the description of his Section A, the pebbles were in a 15 cm thick layer described as “soily sand with pebbles”. This was sandwiched between a lower layer of “blown sand with powdery dog dung, charcoal” and an overlying layer described as an “occupation layer, moa bones, many baked argillite flakes”, suggesting that the pebbles were mixed with a loamy sand (Wellman 1962: 62).

3.3.1.9 Marlborough

McFadgen (1980a: 9–13) identified two areas of made soils within an agricultural landscape north of the Clarence River mouth that includes stone rows, storage pits and *pā*. One of these areas was found in association with a stone row he was investigating. The soils in these areas were a brownish-black gravelly loamy sand in one case and a brownish-black gravelly coarse sandy loam in the other with charcoal uncommon in both soils. Charcoal was recovered from the interface between the stone row and made soil, which was identified as matai (*Prumnopitys taxifolia*), *Coprosma* sp. and *Hebe* sp. The southern area was mapped as 2.5 ha but had been destroyed in part by this date and McFadgen estimated it was originally approximately 4.5 ha. Immediately seaward of this area of made soil, on the lower coastal terrace was a pit, 280 m long and up to 40 m wide. Following mechanical examination of sediments from the pit, the made soil and the parent loess, he concluded that the composition of the made soil resulted from mixing material quarried from the pit and the loess.

3.3.1.10 Canterbury

The Christchurch/Banks Peninsula district is the southern-most part of the New Zealand with evidence for horticulture, which includes Māori-made soils and borrow pits. These have been identified in three places, at Kaiapoi/Woodend on the northern coastal fringes of

Christchurch, at Okuora on the southern side of Banks Peninsula and a little further south at Taumutu.

The clusters of borrow pits around Woodend were first identified by Stack (1906) but have received very little archaeological attention with only two brief articles describing the clusters of pits in very general terms (Trotter and McCulloch 2001; Walton 1985). Walton reviewed the borrow pit clusters around Woodend and identified 4 or 5 clusters ranging from an isolated individual pit to a group of six. All of these were located on or adjacent to what he described as “young stream deposits” (Walton 1985: 113), presumably levees, which were either gravelly sand or gravelly sandy loam. All of the other surrounding soils that may have been modified by the quarried material were free-draining sandy loams. Walton measured the largest pit he could identify on the aerial photographs and found it was approximately 40 m by 15 m. Trotter and McCulloch (2001) reviewed Walton’s information and noted that the borrow pits include piles of large stones, which implies some selection criteria relating to size of the clasts. They also reviewed evidence for another substantial complex of pits at Tuahiwi a few kilometres to the south-west of the pits at Woodend. No physical examination or mapping of the potential made soils has been undertaken, so there is no record of their nature and extent.

Bassett et al. (2004) carried out a detailed examination of an area of made soils and storage pits at Okuora. The site is located on a north-facing hill-slope which features a cluster of four storage pits at the summit of the hill and another two on the lower slopes. Detailed surveys of the soils over 4 ha of valley and hill-slope identified four areas where gravel was found in the loess-based soils. This identification followed field examination where soil from the upper 15 cm was passed through a 1 mm mesh which trapped material of a grain size larger than coarse sand. Two of the areas of made soils were on the upper slopes and two on the lower slopes. Altogether these mapped areas totalled 10,000 m^2. Analysis of the slope angle found that the locations of the made soils were at the optimum, 22º to 30º, for maximising solar energy at that latitude.

Soil samples were recovered by Bassett et al. (2004) from the upper 15 cm of the soil profile and were subject to particle size analysis. The parent soil was classed as either friable silt loam or sandy loam. Clasts in samples recovered in the field from the made soils were described[9] as around 6 mm. These were compared to samples taken from a probable borrow pit located on a nearby beach ridge. The particle size distribution of the samples from the pit had two modes, one from 6 mm to 4 mm and the second from 4 mm to 0.375 mm with no clasts smaller than 218.75 µm. The same pattern was present among the each of the samples recovered from the four gravelly areas identified during the soil survey.

The borrow pit was 40 m by 29 m and 1.4 m deep. Bassett et al. (2004) estimated 990 m^3 of gravel was quarried from the pit. The gravel clasts from the borrow pit and those from the made soil had the same types of parent rock with similar type distributions. Phytoliths were also analysed from samples taken from the made soil tracts with examples matching comparative examples recovered from *kūmara* leaves and stems.

Little information is available relating to the Taumata site. Trotter and McCulloch (1999) provide a long but low resolution description of the site. In 1982 Trotter visited the site and described it "at least forty [borrow] pits in two lines extending for about 1000 m along an old beach ridge" and he noted that in 1985 Huntly Horn[10] confirmed the presence of made soil adjacent to the borrow pits.

3.4 Summary

It is apparent from the places where Māori-made soils have been identified, including the bowl-shaped hollow features found at Whangaruru and Mahia, that they are found throughout the horticultural range in New Zealand, from Northland to Banks Peninsula. While Challis (1976) demonstrated that adding coarse mineral material to soils in Nelson raised their temperature the presence in northern New Zealand leaves the question of the role of these additives ambiguous. Where the literature is sufficiently informative it is apparent that at 15 localities the made-soils were associated with freely drained parent soils, with only one, at Mahia, poorly drained. Similarly, the literature, where clear, shows that in most places (7) the made soils took the form of discrete layers of sand or gravel with a few (5) where the transported coarse material was mixed with the parent soil. Data on the fertility of made soils is scarce with Rigg and Bruce (1923) along with Bishop (1924) carrying out analyses of soil

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[9] Bassett et al. (2004, 198) described pebbles visible on the surface and went on to say that when the particle size is analysed it "was dominanantly 2.5 ϕ" on the Krumbein phi scale, which is the equivalent of 187.5 µm. In the context of their discussion this seems inconsistent. However, -2.5 ϕ is 6 mm, which appears to be consistent with the general description offered. I have assumed here that a typographic error is responsible for the confusion in Bassett et al.'s text.

[10] Huntly Horn was a soil scientist at Lincoln University, Christchurch.

chemistry indicating the made soils were significantly more fertile than other local soils. However, Challis' (1976) analyses of the soil chemistry at nearby Motueka on similar parent soils to those explored by Rigg and Bruce (1923) showed that potassium and phosphorus were lower in the made soil than the parent soils but that levels of these were raised in the B horizon, which raises questions about leaching and permanency of any improvements in fertility that may occur in association with made soil.

Despite the geography dispersal of the phenomena the poverty of the archaeological examination and analysis of Māori-made soils, at least in any detail, makes it difficult to discern any patters in commonality or distinction. Perhaps the only systems that offer some indication of evidence for commonality are the Ruapuke/Aotea system on the Waikato west coast and the made soil complex in costal South Taranaki. Both systems share characteristics; the exploitation of similar geologies where palaeo-dunes are blanketed with tephra, and where the limited archaeological investigations indicate these two are found as mixed deposits. The veracity of these observations and the implications of these for interpretation of the agronomies requires further examination.

4 Geology, landscape and soils associated with the Waikato Horticultural Complex

4.1 Geology and landform

The Waikato Horticultural Complex traverses three landscape units in a linear format, the Maungatautari Gorge, the Middle Waikato Basin (also known as the Hamilton Basin) and the Lower Waikato Basin (Figure 4.1). While each of these landscape units is distinct they share the principal sedimentary formations and their associated soils. Specifically, all three landscape units include the Taupo Pumice Alluvium (TPA), and the Hinuera Formation.

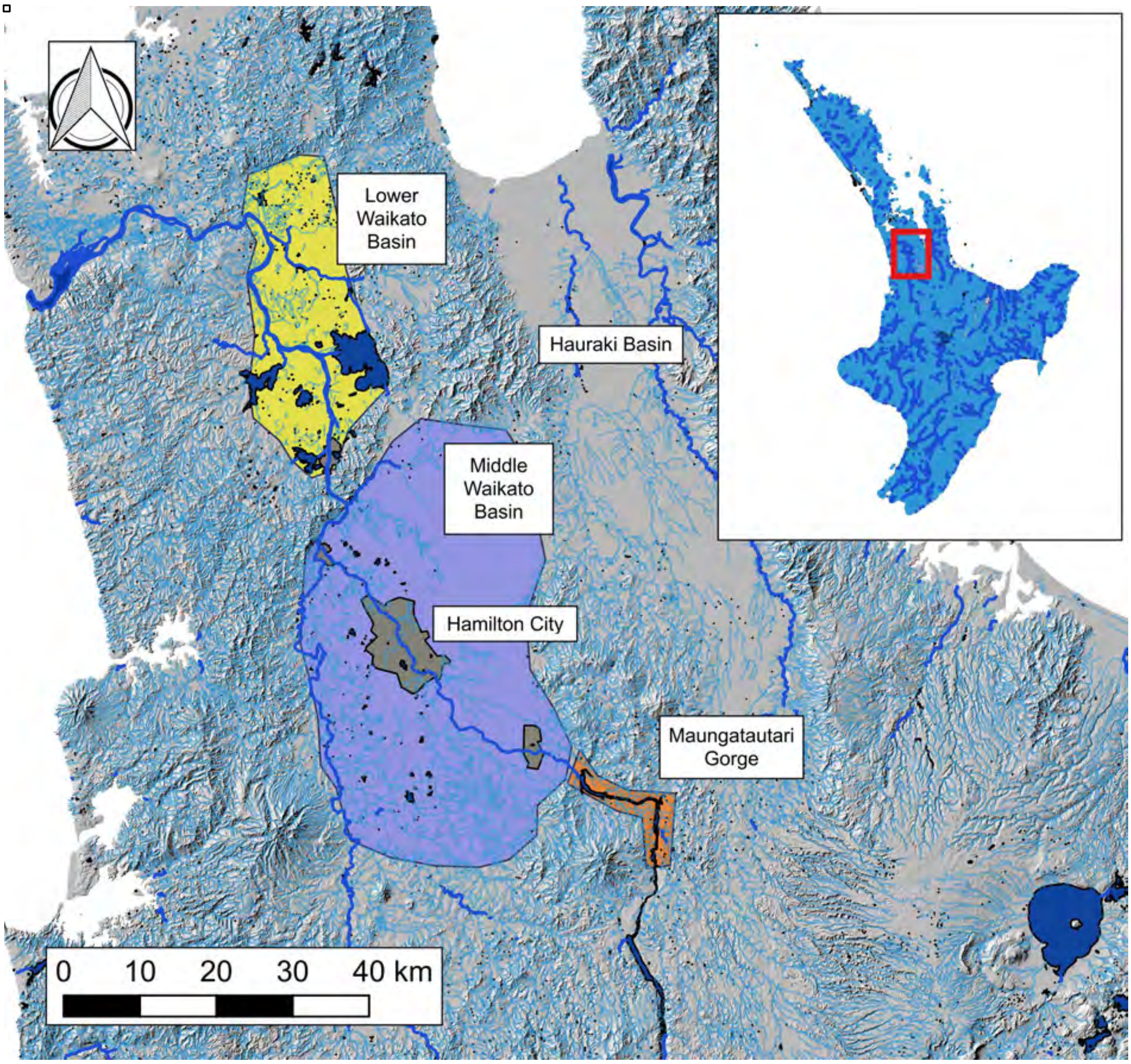

Figure 4.1: Map showing the locations of the three principal landform units where horticultural sites of the Waikato complex are found.

4.1.1 Hinuera Formation

The generally accepted origin of the Hinuera Formation is the on-going volcanism of the Taupō-Rotorua region (Selby 1972: 5; Selby and Lowe 1992: 240) over the last 140,000 years, including the massive Oruanui eruption of Taupō 26,500 years ago, which expelled 530 km^3 of magma, 420 km^3 of tephra and 320 km^3 of pyroclastic density flow deposits (Manville and Wilson 2004). As can be imaged the degree of alteration to the landscape including vegetation was significant with high levels of erosion persisting for several thousand years until the end of the Last Glacial Maxima when the climate ameliorated and re-establishment of forest began. This happened around 18,000 to 14,000 years ago (Selby and Lowe 1992).

As well as terrace formations in the upper Waikato River Valley the Hinuera Formation established two fans, one in the Hauraki Basin and the other in the Middle Waikato Basin (also known as the Hamilton Fan). The formation developed in several pulses with the last supplying sediments that completed the building of the Hamilton Fan and resulted in the current Hinuera Surface. The Hinuera Formation comprises volcanogenic sediments of pumice and rhyolite clasts in the form of small cobble, gravel, sand and silt, with coarse sand the most common (Selby and Lowe 1992: 242). These sediments are cross-bedded, reflecting their origin as a braided river system moving across the surface of the developing fan. This produced a series of levees and bars where coarse material was deposited during high energy events and swales which collected silts in low energy environments. The building of the Hamilton fan ceased about 15,000 years ago (Selby and Lowe 1972: 240).

The Hinuera Surface in the middle Waikato Basin is generally gently inclined, losing approximately 60 m between the outlet of the Maungatautari Gorge at the south end of the basin and the Taupiri Gorge at the northern end. The surface of the formation is relatively flat with emergent remnant hills and is sometimes referred to as the Horotiu Plain. While relatively flat on a macro-level at a small scale the surface undulates between remnant river levees (low ridges) and swales (shallow sinuous depressions), which represent the inter-distributary channels of the braided Waikato River towards the culmination of the alluviation process (Bruce 1979).

Once the sediment load of the river system declined following stabilisation of the catchment the river began to entrench itself through the Hinuera sediments, settling in the present course.

There is some evidence in the form of narrow, wave-cut benches that drainage through the Taupiri Gap at the northern and lowest end of the fan blocked and a lake formed across the northern end of the fan. This probably had implications for the soils developing on this surface through of the deposition of fine material.

Following the stabilisation of the Hinuera Surface it was progressively mantled with tephras, which are between 0.4 m and 0.7 m thick across the Hamilton Fan. The tephra deposits are on the Hinuera Formation terraces adjacent to the Waikato river, reflecting their younger age. The accretion of tephra progressed at an average of 4 mm per century (Lowe 2008).

4.1.2 Taupo Pumice Alluvium

Following the Hatepe Eruption of Taupō in 232 ± 10 AD (2σ), a new alluvial formation developed, the Taupo Pumice Alluvium (TPA) (Hogg et al. 2012). While the Hatepe eruption was significantly smaller than the Oruanui it was still, in all other senses, large. It expelled approximately 105 km^3 of material, generating pyroclastic flows over an 80 km radius covering approximately 20,000 km^2. As well as depositing new and readily erodible material within the catchment of the Waikato River, a dam at the outlet of the re-formed lake collapsed and released a breakout flood estimated to be 20 km^3 of water and sediments, which travelled down the Waikato River bed. As well as transporting the mainly pumiceous material from the recent eruption it also eroded and incorporated sediments to form the Taupo Pumice Alluvium. These sediments were largely trapped within the entrenched river but in places they over-topped the banks around Cambridge and at Tamahere, where the river narrows. Below this it was largely confined to the main river gorge until the junction with the Waipā River where the river emerges from its trench (Lowe and King 2015). In places a veneer of TPA deposits can be found on Hinuera formation terraces. Within the river gorge the TPA formed low terraces and below the trench formed the dominant soil type adjacent to the Waikato River.

The TPA is divided into three sub-types (Kear and Schofield 1978):

1. Melville Pumice Member: pumice, sands, silts and gravels.
2. Hopuhopu Member: current bedded sands.
3. Undifferentiated.

4.2 Principal Landform Units

Māori-made soils are found across three major landform units, the Maungatautari Gorge and into the upper Waikato River valley, the Middle Waikato Basin and the Lower Waikato Basin.

4.2.1 Maungatautari Gorge

In reality, the Manugatautari Gorge zone includes two landform units, the Maungatautari Gorge proper and the lower part of the upper Waikato River valley as far upstream as Arapuni (Figure 4.2). This represents the most southern expression of the Waikato Horticultural Complex.

The Maungatautari Gorge is a gap between the Te Miro range of hills to the north and the Maungatautari Range to the south. Today the gorge is largely filled by the reservoir of the Karapiro Hydroelectric Dam, located at the mouth of the gorge. Through the gorge and up to Arapuni both the Hinuera Formation and the Taupo Pumice Alluvium are represented as terraces (Figure 4.3). For the most part these present as a low terrace of TPA with one or two higher terraces formed from Hinuera Formation sediments:

> “South of the Hinuera Gap towards Arapuni the Hinuera Formation occurs in two sets of highlevel terrace remnants which converge down river towards the gap. The older and higher surface is regarded as that of the earlier Hinuera deposits emplaced before about 24000-19000 years ago, and the lower and younger surface represents deposition after then” (Selby and Lowe 1992: 240).

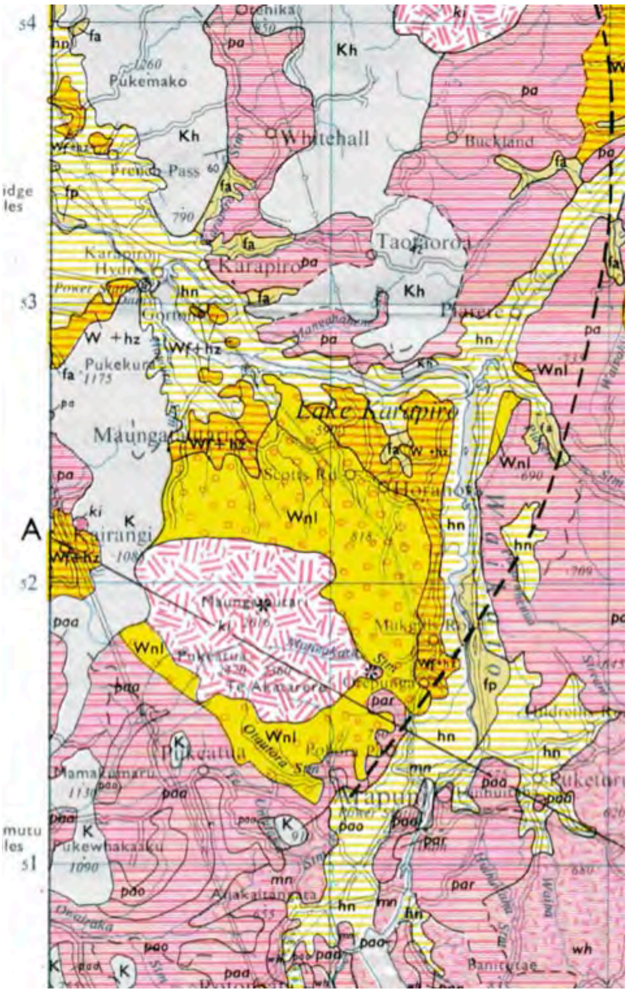

Figure 4.2: Part of Geological Map of New Zealand Sheet 5 (Healy et al. 1964). Hinuera Formation is coded **hn** and the Taupo Pumice Alluvium is coded **fp**. Scale: grid intervals = 9,253 m.

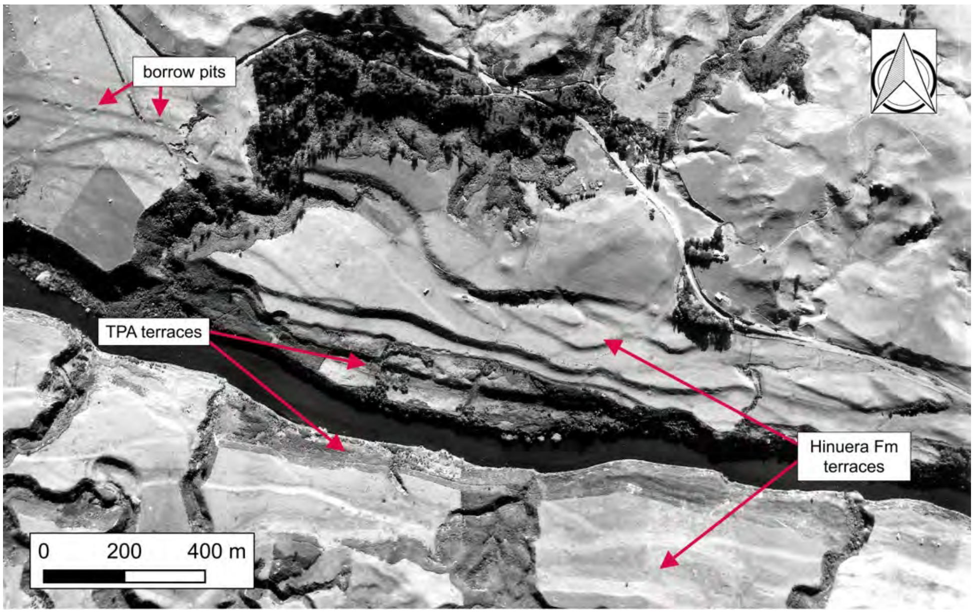

Figure 4.3: Part of a 1943 aerial photograph (SN255/700/9) showing alluvial terraces and borrow pits in the Maungatautari Gorge prior to the flooding of the Karapiro Hydro-electric dam (Background image: Crown copyright).

4.2.2 Middle Waikato Basin

The Middle Waikato Basin is approximately oval and extends for approximately 60 km north-south and 30 km east-west. It is bounded to the east by the Te Miro, Pakaroa and Hangawera Ranges, to the north by the Taupiri and Hakarimata Ranges and to the west by the Kapamahunga Range. In the south it is bounded by a series of low rolling hills.

The Waikato River merges with its principal tributary, the Waipā River at the northern end of the Basin, after which it penetrates through the gap between the Taupiri and Hakarimata

The surface of the Hinuera Formation forms the gently inclined Horotiu Plain with the highest elevation where the Waikato River emerges from the Maungatautari Gorge (80 m ASL) and the lowest point at Taupiri where it enters the Taupiri Gorge (30 m ASL) (Kear and Schofield 1978). Hills that emerge from the surface of the Hinuera Formation represent remnants of the earlier and now-buried hilly landscape (Selby 1972). Upper river terraces are also associated with the Hinuera Formation but lower river terraces are formed by the TPA.

4.2.3 Lower Waikato Basin

The Lower Waikato Basin has received less attention from soil scientists with soil survey data available only for the southern end of the Basin in the area around Huntly township (Bruce 1978). The Lower Waikato Basin is approximately 60 km north-south and 30 km west-east. To the south the basin is bounded by the Hakarimata and Taupiri Ranges while to the west it is bounded by the hills of the range, to the east by the Hapuakohe Range and in the north by the Bombay hills. The Waikato River effectively bisects the basin which is mostly filled with alluvium from the same formations responsible for the alluviation of the Middle Waikato Basin, although these are not deposited as a fan. The surface of the Hinuera Formation in the Lower Waikato Basin is mostly buried by more recent sediments, the Taupo Pumice Alluvium and more recent alluvium. The pattern of sedimentation is described in the geological maps produced by Kear and Schofield (1966, 1968; see Figures 4.4 and 4.5). Like the Middle Waikato Basin remnant hills emerge from the alluvium and levees developed creating bars across valleys forming lakes and associated wetlands, which form significant features of the landscape. Large lakes, such as Whangape, Waikare, Kimihia and Waahi are dominant components of the landscape, second only to the Waikato River. In this landscape the sediments associated with the Hinuera Formation are generally buried by the TPA and subsequent recent alluvium.

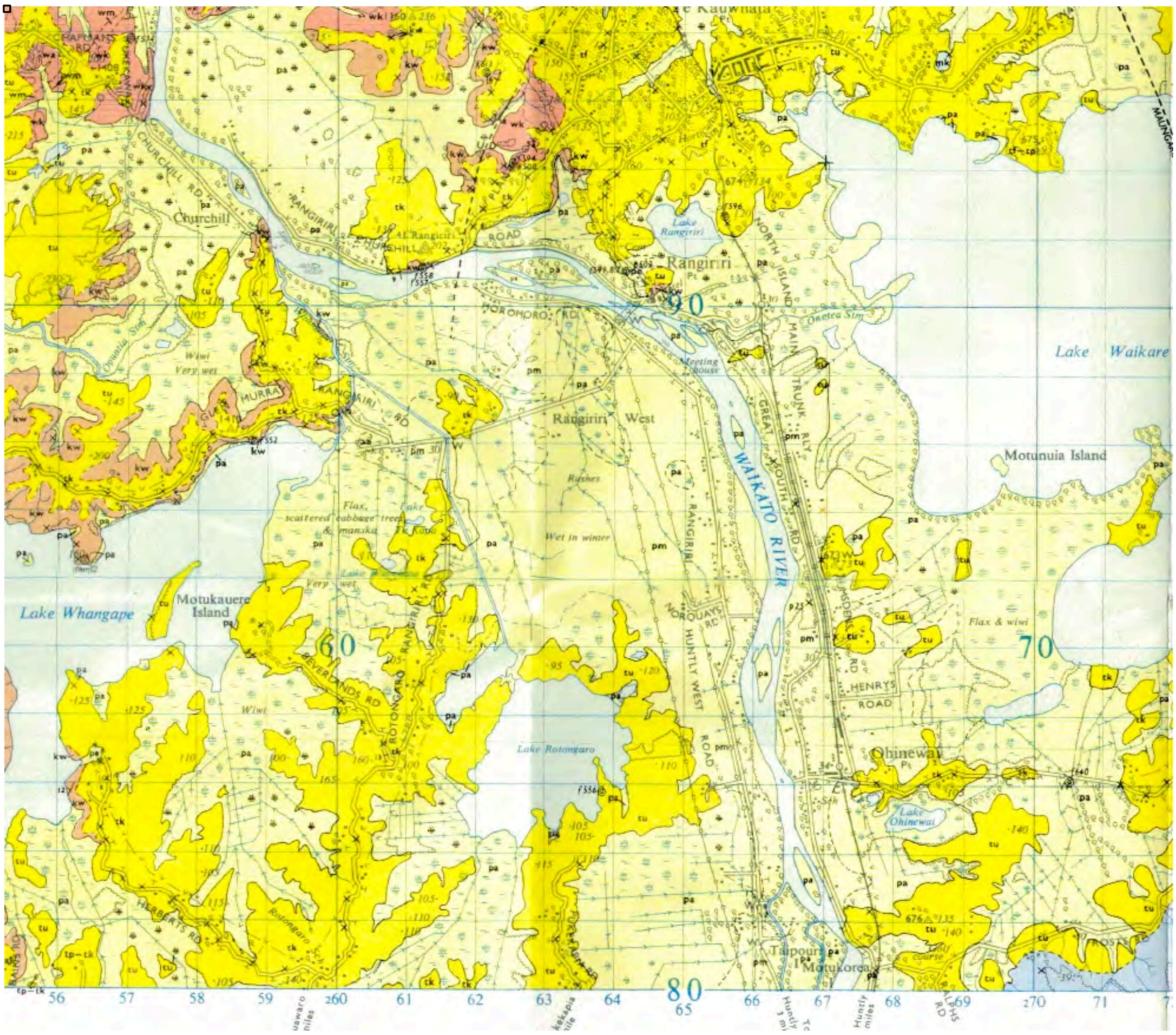

Figure 4.4: Part of Kear & Schofield 1968 showing the alluvial and other geology in the district of Rangiriri and Ohinewai. TPA sediments are annotated **pm** (Melville member), **ps** (Hopuhopu sand member) and **pt** (undifferentiated). Recent alluvium is annotated **pa.** Grid intervals are 900 m. North is to top.

During his soil survey of part of the Raglan County, Bruce (1978) examined the soils on the western side of the Waikato River for a distance of 2.5 km north of Huntly township. Other than this no formal soil survey of the soils on the alluvial deposits within the basin have been described. Bruce (1978: 46) described the TPA terrace, and its associated soils, north of Huntly, where it is 3 m above the river, as follows:

> “North of Huntly, Waikato series forms an almost continuous strip up to 1 km wide. The series has developed on pumiceous alluvium deposited by the Waikato River following the Taupo eruption of c. 130 A.D.”

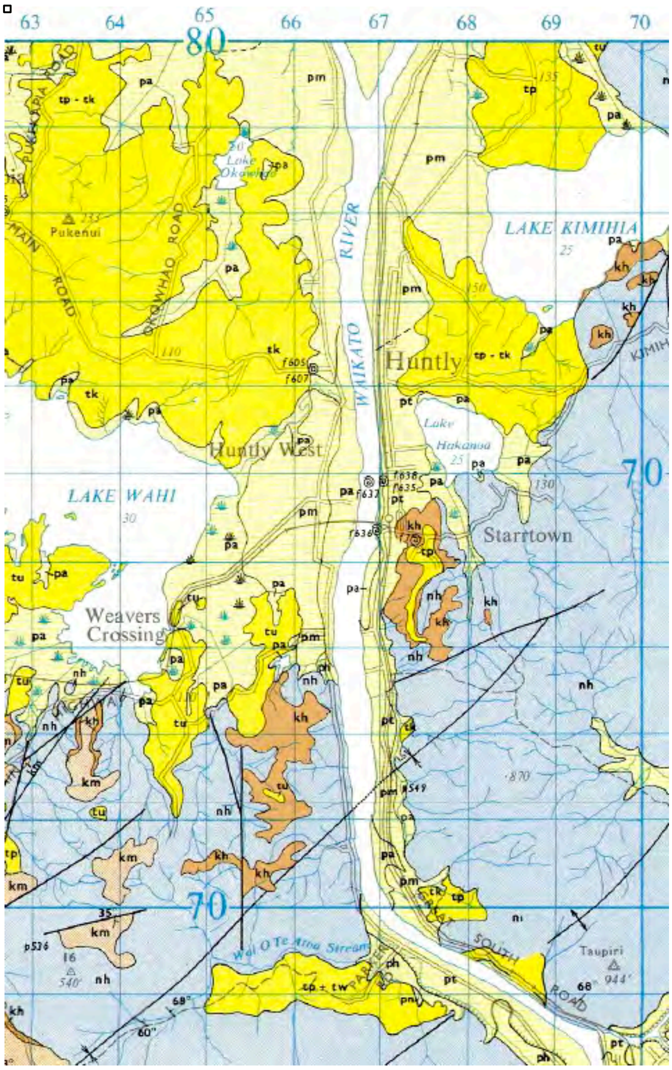

Figure 4.5: Part of Kear & Schofield (1966) showing the alluvial deposits and other geology in the district of Huntly. TPA sediments are annotated **pm** (Melville member), **ps** (Hopuhopu sand member) and **pt** (undifferentiated). Recent alluvium is annotated **pa.** Grid intervals are 900 m. North is to top.

4.3 Soils

Published soil survey information relating to the Hinuera and TPA Formations is restricted to the Middle Waikato Basin, which has been subject to systematic soil survey since the 1930s (Grange et al. 1939). In the valley fifteen soil series have been identified in relation to these formations, with twelve soil series found on the Hinuera Surface, two series found on the TPA river terraces, and two on recent alluvium formed from re-worked Hinuera and TPA sediments (Figures 4.6 & 4.7, Table 4.1).

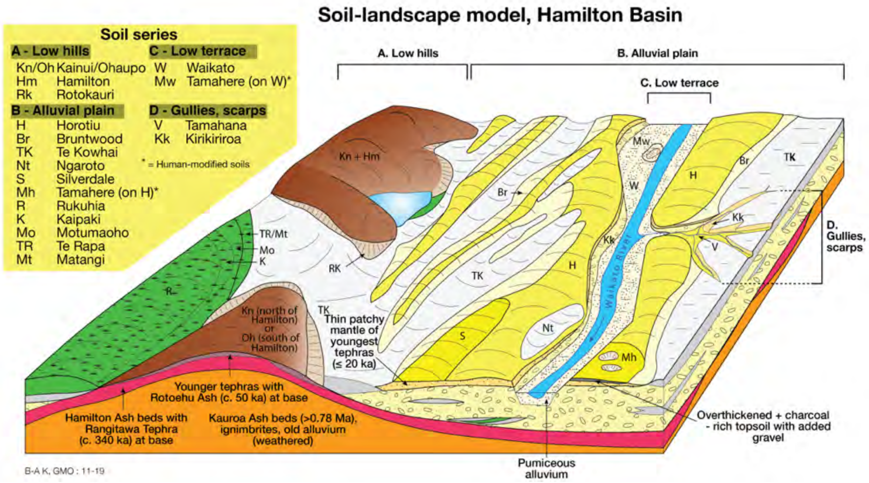

Figure 4.6: Landscape model showing the physiographic distribution of soils within the Hamilton Basin surrounding the Waikato River (Lowe 2008: 72). Note the locations of the Tamahere series soils (Mh and Mw).

Although Māori-made soils were initially classified as the Māori Series this soil series was re-named the Tamahere Series to reflect its local characteristics (Bruce 1979). The Tamahere Series includes two principal sub-classes reflecting the two geological formations where Māori-made soils are found, the Hinuera Formation and the Taupo Pumice Alluvium (TPA).

On the Hinuera Formation principal parent soils belong to Horotiu series with minor involvement of the Bruntwood and Te Kowhai soils. These soils will be described in more detail. On the TPA the parent soils belong to the Waikato series. Both principal soils on each formation (Horotiu and Waikato series) are described as well-drained, while the Bruntwood soils are less well-drained (Bruntwood) and poorly-drained (Te Kowhai) (Bruce 1978, 1979; McLeod 1984).

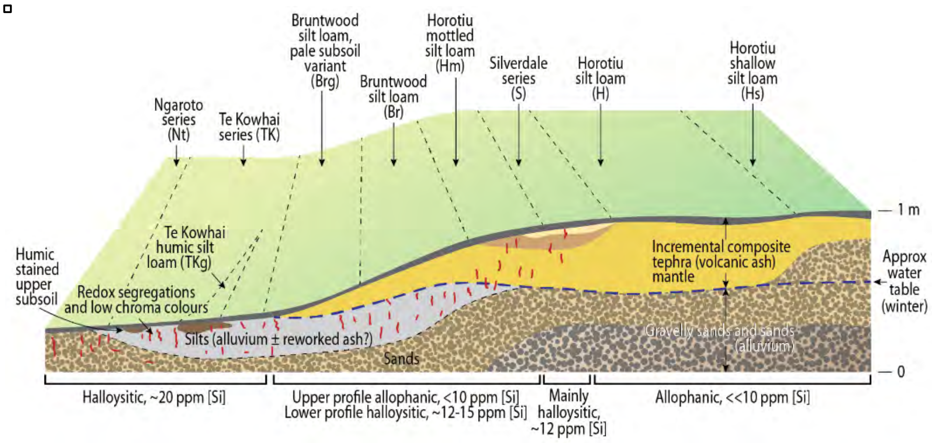

Figure 4.7: Soil/landscape model showing the physiographic relationship between soils on the Hinuera Formation, specifically the Horotiu (H2, H & Hm), Bruntwood (intermediate; BR & BRg) and Te Kowhai (lowest; TK) soil series. The soils range from well-drained (H) at the highest to poorly drained (TK) at the lowest (Updated by D. Lowe from Singleton 1991).

Table 4.1: Soil series found associated with the Hinuera and TPA Formations (Bruce, 1978, 1979; Grange et al. 1939; Lowe 2010; McLeod 1984). * indicates known associations with Tamahere Series (Māori-made soils) as parent soils.

Soil Series	Parent Formation	Physiographic Unit	Drainage
Horotiu*	Hinuera	Fan surface	Well drained
Tamahere (H)		Fan surface	Well drained
Bruntwood*		Fan surface	Imperfectly drained
Silverdale (DL 2010 p.7)		Fan surface	
Te Kowhai*		Fan surface	Poorly drained
Ngaroto (DL 2010:7)		Fan surface	
Matangi (DL 2010:7)		Fan surface	
Eureka		Fan surface	Poorly drained
Puketaha		Fan surface	Imperfectly to poorly drained
Te Rapa (peat)		Fan surface	Poorly drained
Kaipaki (peat)		Fan surface	Very poorly drained
Rukuhia (peat)		Fan surface	Very poorly drained
Waikato*	Taupo Pumice Alluvium	Low river terraces	Well to somewhat excessively drained
Tamahana	Recent Alluvium	Gully bottoms	Poorly drained
Kirikiriroa Complex		Terrace scarps & gully sides	Well to excessively well drained. Many seepages on slopes.

4.3.1 Andisols, Allophane and fertility

The soils discussed here belong to the soil order Andisols, which are recent, generally deep, soils formed on volcanic ejecta (tephra, lapilli, etc) that often undergo up-building pedogensis from cumulative tephra layers as well as top-down pedogenesis. They “are usually light and easily excavated because of their low bulk density and weakly cohesive clay minerals. The high porosity allows roots to penetrate to great depths” (McDaniel et al. 2018: 33–31). In general, they are considered to be high quality and versatile, including possessing good water storage attributes (Lowe and Palmer 2005).

Two sub-orders are relevant to the Waikato region; Vitrands and Udands (Lowe 2016). Vitrands are young, glass dominated and coarse textured soils, such as the soils formed on Taupo Pumice Alluvium. They are classed as Pumice Soils in the N.Z. Soil Classification

(NZSC) (Hewitt 1998) and “are extremely deficient in phosphorus, potassium, sulphur, nitrogen and magnesium and typically deficient also in micronutrients such as cobalt (especially), selenium, copper, boron, iodine and molybdenum” (Lowe and Palmer 2005: 51). Udands are Andisols formed in humid climates, which applies to the soils formed on the Hinuera Surface. Lowe and Palmer (2005: 51) make the following comment about Udands:

> “(Allophanic Soils in NZSC), like their counterparts beyond New Zealand, are generally of high value for food production because they are deep and have outstanding physical properties including free drainage and high porosity and hence good aeration, high friability and good tilth, low bulk densities, stable aggregates, and high plant-available moisture retention.”

Among the wide range of clay minerals found in andisols, allophane is significant in developing soils with useful properties for horticulture. Two of the significant parent soils for Tamahere loam are Horotiu loam and Bruntwood loam, which are both allophanic soils (Figure 4.8). Lowe (2016: 24) describes allophane as follows:

> “Allophane is a nanocrystalline aluminosilicate comprising tiny spherules ~3.5 to 5.0 nm in diameter and with a chemical composition (1–2) SiO2·Al2O3·(2–3)H2O (Abidin et al., 2007; Huang et al., 2016a) (Figs. 17-19). It provides many tephra-derived soils including Allophanic Soils and Pumice Soils with many of their unique chemical and physical properties (McDaniel et al., 2012; Yuan and Wada, 2012). With its small size, extreme surface area (up to ~1200 m2 g−1) (Allbrook 1983, 1985; Huang et al. 2016a; Parfitt 2009; Yuan and Theng 2012), and variable surface-charge characteristics that arise via (OH)Al(OH2) groups at wall perforations of its outer gibbsitic octahedral sheet [Al(OH)3], allophane has strong affinity for water, metal cations, anions, organic molecules and DNA (Harsh 2012; Huang et al. 2014, 2016a, 2016b)”.

This means that “Allophanic Andisols typically contain ~8 % - ~12 % C” (McDaniel et al. 2018: 33). Typically, A horizons formed on Andisols in New Zealand are brown when formed under forest where P-type humic acid is present but black A horizons are formed under bracken fern (*Pteridium esculentum*) and native grasses (e.g. tussock). These horizons are typically ≤20 cm thick and have high carbon contents. Formation of these near-melanic

soils is believed to be related to forest clearance by Māori and the ensuing colonisation of the cleared land by bracken (Lowe and Palmer 2005; McDaniel et al. 2018).
Allpohane's small size, large surface area and chemical structure mean that it has the ability to sorb large amounts of phosphate which is then unavailable for plants and this combined with a freely-drained soil structure means that potassium is leached out of the soil profile (McDaniel et al. 2018; Shoji et al. 1993).

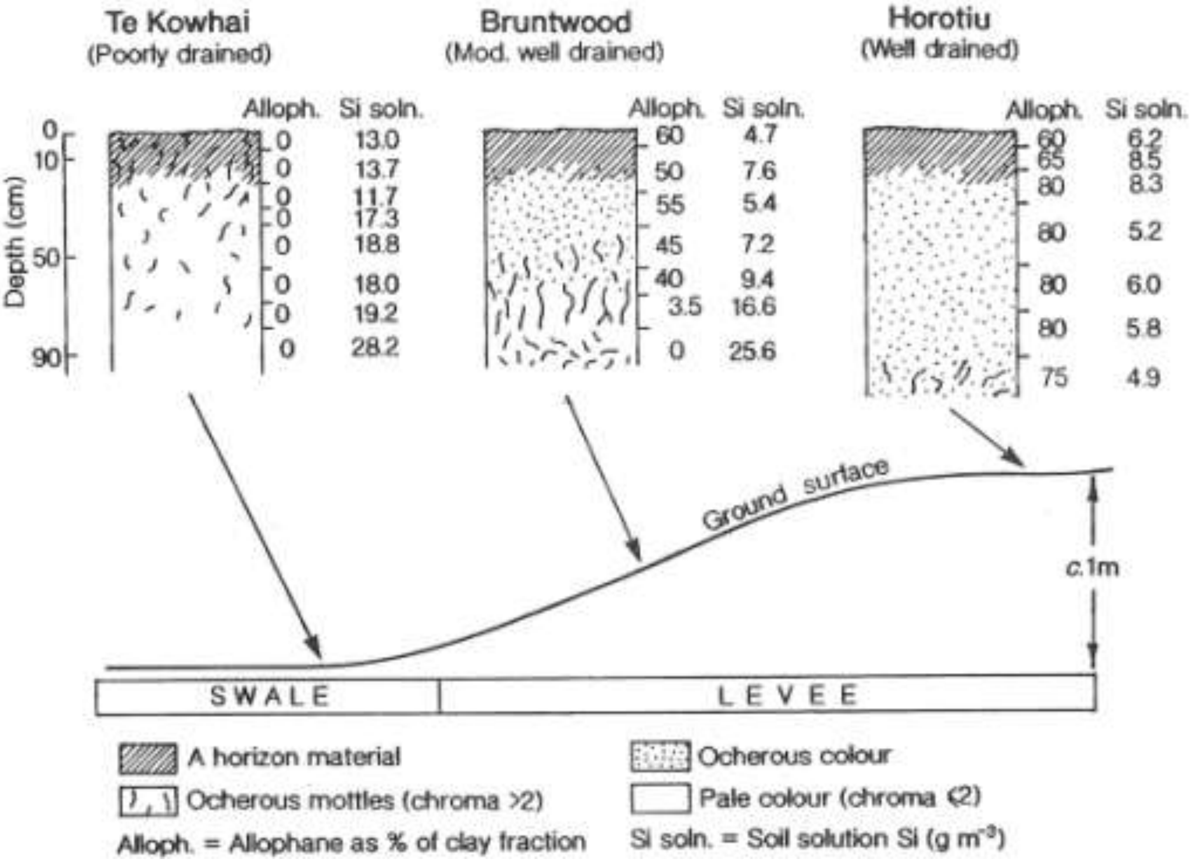

Figure 4.8: Horotiu, Bruntwoood and Te Kowhai soil drainage leaching sequence and associated mineralogical and soil-solution analyses at Ruakura (from Lowe 2008: 75).

4.3.2 Horotiu Series

Horotiu Series soils "are characterised by very friable fluffy topsoils and friable subsoils" (Bruce 1978: 47), with the series composed of several soil types (Bruce 1978, 1979; Grange et al. 1939; Lowe 2010; McLeod 1984):

- Horotiu silt loam
- Horotiu sandy loam
- Horotiu mottled sandy loam

- Horotiu sandy clay loam
- Horotiu gravelly loam
- Horotiu sand
- Horotiu sand with gravel

Soils of the Horotiu Series are consistently well drained and similarly, the soil profile is typically consistent:

- A horizon, 15-20 cm thick and ranging from dark brown to dark greyish-brown;
- B horizon, 40-70 cm deep, (dark) yellowish brown loam;
- C horizon, Hinuera Formation alluvium, rhyolitic and pumiceous sediments (silt, sand and gravel).

Horotiu soils are usually found on remnant levees on the Hinuera Surface and so are slightly higher than surrounding soils (Grange et al. 1939: 32; McLeod 1984: 18). Both Horotiu sand and Horotiu sand with gravel are found on upper river terraces formed on the eroded Hinuera Formation (Bruce 1979: 26). The B horizon is thinner on Horotiu soils on river terraces compared to those on the Hinuera Surface. Since the Hinuera river terraces are younger than the fan surface, the relative thinness reflects the shorter time over which the mantling tephra collected.

Bruce's description of Horotiu sandy loam can be reasonably generalised to the other soils of the series:

> "A profile shows 12 to 15 cm of very dark greyish brown friable sandy loam topsoil, on strong brown friable sandy loam grading down to sandy clay, over current-bedded pumiceous sands. Topsoils have moderately developed nut, granular, and some crumb structure, while subsoils usually have weakly developed or nut and blocky structure.
>
> Horotiu sandy loam is moderately acid, with low levels of exchangeable calcium and potassium, and medium levels of exchangeable magnesium. Percentage base saturation is very low throughout the profile. Cation-exchange capacities in general range from medium to high although the cation-exchange capacity of the 18 to 33 cm horizon (sample SB1855-6, table 6) is very low. Subsequent analyses of Horotiu soils from the Waikato district have shown that these soils contain significant proportions of allophane and have very high phosphate fixation properties. They have very low

> reserves of potassium, and magnesium seems to reach near-deficient levels under conditions of moderately intensive farming" (Bruce 1978: 47).

Lowe's description adds the following:

> "Horotiu soils (Vitric or Typic Hapludands) occur in slightly elevated levees or channel bar positions, manifest as low ridges or mounds, over coarse textured volcanogenic alluvium. They are free-draining and hence have lost silicon in soil solution by leaching and have predominantly allophanic properties. Measurements of Si in soil solution in this soil show concentrations <10 g/m3 (ppm), therefore favouring the formation of Al-rich allophane" (Lowe 2010: 13).

The principal limiting factors for Horotiu soils are their very high phosphorus retention and low potassium reserves (McLeod 1984: 18).

4.3.3 Te Kowhai Series

While Horotiu loams are found on the crests of remnant levees Te Kowhai silt loams are found in slight depressions (swales) and lower parts of the Hinuera surface. Their fundamentally silty nature results in poor drainage. They but are divided into 4 distinct types (McLeod 1984: 5 and 21):

- Te Kowhai silt loam
- Te Kowhai silt loam brown topsoil phase
- Te Kowhai silt loam on pumice sand
- Te Kowhai silt loam peaty phase

Bruce (1979: 25) described Te Kowhai silt loams:

> "A typical profile shows 18 to 20 cm of dark greyish brown to dark grey firm clay loam or silt loam topsoil on light grey to white compact silt loam to fine sandy loam subsoil with prominent reddish-brown mottles. Pockets of manganese and iron concretions are associated with the mottling in many places. The underlying gravelly Hinuera Formation is paler in colour than under Horotiu soils".

4.3.4 Bruntwood Series

Bruntwood soils have a single soil type, silt loam, and are intermediate between Te Kowhai soils and Horotiu soils, both in terms of their physiographic situation on the slopes of the remnant levees and bars, and also in their properties. Bruntwood soils are less well drained than Horotiu soils and better drained than the Te Kowhai soils. Like Horotiu soils they are allophanic and have similar limitations; high phosphorus retention and low potassium reserves along with imperfect drainage (McLeod 1984: 19-20).

4.3.5 Waikato Series

The Waikato Series of soils are the product of the TPA and are physiographically distinct from the soils of the Hinuera Formation. From Arapuni to Ngaruawahia these soils are found on the lower river terraces created from the TPA and as occasional “splashes” of sediment on the lowest of the Hinuera terraces. From Ngaruawahia to Taupiri the TPA terrace is only slightly lower than the adjacent Hinuera terrace and down-river from Huntly the soils formed on the TPA are found on wide levees.

Bruce (1979: 29) described the Waikato Series soils as:

> “The textures of the soils range from gravelly sands and sands to sandy loam. The soils are generally poorly consolidated and horizons are only weakly differentiated. A typical profile consists of 10-12 cm brown to pale yellowish brown loose sand, overlying white pumice sands showing a variety of bedding structures. The soils are well-drained to somewhat excessively drained and tend to dry out rapidly during summer”.

In my experience the Waikato Series soils vary substantially, from soils like those described by Bruce (above) with a weakly developed sandy A horizon, no discernible B horizon overlying current bedded sand and gravel to another distinct form that has a siltier A horizon overlying a distinct B horizon of varying thickness (0.3 – 1+ m) with a distinct boundary conforming to the undulating surface of the C horizon (current bedded sand and gravel). Superficially the second form of Waikato soils appears similar to the Horotiu Series. The B horizon is yellowish-brown, sandy silt and well-drained, however, the soil colour is more variable than a Horotiu soil, with most of the sediments yellowish-brown but with patches of very pale brown. The material is also looser and appears to be sorted to some degree (mostly fine sand and silt, based on field examination). There is a substantial degree of variation in depth (thickness) compared to the Horotiu soils. This manifestation of the Waikato Series soils appears to be associated with the Hopuhopu Member and undifferentiated TPA. These two types of soil are named Waikato sandy gravelly loam and Waikato silt and fine sand (McLeod 1984: 6).

4.3.6 Tamahere Series

Tamahere soils are the class of anthropogenic soils associated with both the Hinuera Formation and the TPA. There soils have been described as Māori transported alluvium over existing soils (Bruce 1978, 1979; McLeod 1984). Originally these Māori-made soils were identified during the Soil Bureau survey of the Waipa County in the 1930s (Grange et al. 1939) and when they were called the Māori Series.

As such there are two major sub-types, those made on the Hinuera Formation and the other formed on the TPA. There is further variation within these depending on the nature of the parent soil. Grange et al. (1939: 39) described the distribution of Tamahere soils within Waipa County thus:

> "Māori gravelly sands occur mainly on the wide flats close to the Waikato and Waipa rivers-most areas of them are located within a mile and a half of the rivers. A few patches are found on the terraces bordering the Waikato River. On the wide flats they are mostly situated on top of the Horotiu soils, as these provide good subsoil drainage and lie above the gravelly-sand beds. In a few places they overlie the Te Kowhai and Whatawhata soils".

The Tamahere soils made on Whatawhata clay loam can be considered a third sub-class since it is alluvium deposited by the Waipa River. Deposits of Whatawhata Clay loam are intermittent along the river from Te Pahu north and Bruce indicates that the areas of Tamahere loam on Whatwhata parent soil are small and mostly not separated on his map from the surrounding parent soils (Horotiu loams, Whatawhata clay loam and Waikato Series). He also made the following comment on evidence for transportation of material "at Māori Point, near Whatawhata, where material from pits on the Waipa flood plain was carried up to the adjacent higher terrace" (Bruce 197: 50).

Grange et al.'s (1939: 39) original description of Tamahere soil was:

> “Māori soils are unusual in that they were made by the Maoris. The artificial soil consists of 9 in. to 10 in. of blackish gravelly sand which rests on old soil, generally of a sandy-loam texture. The gravelly sand was obtained from beds lying 4 ft. to 5 ft. below the surface of the wide flats and of the river terraces. Conical holes up to 15 ft. deep, well displayed to the south of Ngaruawahia, mark the site of these ancient quarries. To build up the supply of plant nutrients in the new soil material the Maoris probably burnt scrub on it”.

McCraw’s (1967: 70–71) description is similar:

> “On the levees of the present course of the Waikato River and on a few other well drained sites within a mile of the river are the soils used by the Maoris for kumara growing. From pits the Maoris excavated gravels and spread them in a thin layer over Horotiu soils. Manuka and other scrub was brought in and burnt and after cultivation with digging sticks a soil of suitable texture and fertility for kumara was obtained. The sites of these gardens are easily recognised by the presence of the conical holes about 15 ft. deep, these are particularly conspicuous on aerial photographs. The soil can be identified by the 9-10 in. layer of blackish gravelly sand, often containing fragments of charcoal, overlying an old topsoil. Most Māori soils overlie Horotiu soils as these provide good subsoil drainage and lie above gravels suitable for incorporating into the soils.”

Bruce’s (1979: 65) remarks on the qualities of the two principal types, Horotiu Series soils and Waikato Series soils are as follows:

> “Major physical properties are comparable to those of Horotiu soils. Sites of old Māori gardens. ‘Greasy’ surface horizons caused by high carbon content from vegetation burned on garden sites. Slightly raised above surrounding soils. Quarry pits present on some sites. Gravelly material was carried from quarry pits or lower terraces and deposited on garden site to increase friability of soil. Plots range in size from about 0.1 ha to 20 ha and are mainly within 1 km of river [Waikato R.].”
>
> “Physical characteristics comparable to Waikato soils. Māori garden soils of the low [river] terraces”. (Bruce 1979: 65)

Bruce also provided a description of the soil and observations about soil chemistry in his report on the soils of part of Raglan County (1978: 50)[11]:

> "up to 25 cm of black or very dark grey with strongly developed fine nut structure, on a gravelly sand with moderately developed granular and crumb structure and with many charcoal fragments. This built-up horizon rests on the original topsoil which has lost most of its original structure. Subsoils (including original topsoils) vary according to the soil type on which the gravelly sand was spread. A characteristic of Tamahere gravelly sand is the very sharp boundary between topsoil and subsoil. This is attributed to the use of the '*ko*' or digging stick to loosen the soil during cultivation".
>
> "Chemical analysis of a sample of Tamahere gravelly sand taken from near Ngaruawahia (sample SB7821, table 6) shows, in the top 15 cm, low organic carbon and medium total nitrogen contents. Both of these values decrease to very low in the next 15 cm. The top 30 cm was the usual depth cultivated by the Māori and in general, this layer has medium to high levels of Truog-soluble phosphorus, medium to low levels of exchangeable calcium, low levels of exchangeable magnesium, and low to very low levels of exchangeable potassium. Below the cultivated layer the soil has low to very low levels of all these nutrients. Cation exchange capacities are medium to low, decreasing gradually with depth in the cultivated layer but rising again slightly in the buried topsoil".

In summary, Tamahere Series soils have a topsoil formed from enrichment with sand and gravel transported from quarries that accessed the substrate, along with added charcoal. This forms a black to very dark grey gravelly sandy, 20-25 cm thick horizon on a buried topsoil (Ab horizon) originally part of the parent soil and visible as a dark layer at the top of the subsoil (B horizon), which varies according to the parent soil. Horotiu Series soils constitute the substantial majority of the parent soils but a significant percentage of the Waikato Series soils have been modified. The extent of modification of Bruntwood, Te Kowhai and Whatawhata Series soils is limited and mostly relates to migration of Tamahere loam off its

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[11] Bruce stated that profiles used for analyses were selected so they reflected a modal soil of the unit and to minimise variation resulting from land management sites were selected that were un-affected by cultivation or topdressing (Bruce 1978: 40).

Horotiu base and onto soils on the margins. The exceptions to this appear to be in places around Taupiri (e.g. sites recorded in the New Zealand national database as S14/249, S14/250) where the soils generally tend toward silty because they are at the toe of the fan, and in an un-named stream valley in the Horotiu district (sites S14/195, S14/246, S14/247, S14/253) where the parent soil is mostly Te Kowhai silt loam with outcrops of Horotiu soils also modified.

4.4 Summary

Māori-made soils in the Waikato have been classified by soil scientists to the Tamahere Soil Series. These soils rely on the geology of the inland Waikato where sand and gravel are available in alluvium that forms the substrate for both the Hinuera Formation and the Taupo Pumice Alluvium. Almost universally, the Māori-made soils are formed on well-drained parent soils of the Horotiu and Waikato Series and both soil series are conspicuously friable. The Māori-made soil units are distinct horizons of coarse material (sand and gravel) retrieved from the alluvial substrate. The Māori-made soil horizons overly buried topsoil (Ab) horizons.

5 The extent and nature of the Waikato Horticultural Complex

The extent of the Waikato Horticultural Complex is identified and described as a prelude to the description of the attributes of the horticultural complex with the data interrogated further to detail the nature and scale of the enterprise. By considering the identifiable borrow pits as a minimum representation of the actual population we can draw on data from investigations to provide two measures of the scale and intensity of the agronomic processes associated with the development and maintenance of the horticultural system. Archaeological investigations of borrow pits at several sites in the Middle Waikato Basin have provided us with data relating to pits of a range of sizes (and visibilities) that allow a reasonable approximation of the overall quantity of material quarried. Several investigations have provided data that allow the calculation of the area of made soils associated with borrow pits and this can be used to reconstruct the approximate total extent of the Māori-made soils present in the inland Waikato.

The second part of this chapter will look at the elements of these horticultural sites in finer detail. This will involve considering the constituent feature classes as represented in a number of archaeological sites investigated in inland Waikato. It is proposed to organise this in a manner that probably reflects their role in the agronomic process from forest clearance through garden development to abandonment. It has to be admitted that to some extent this organisation will pre-empt the interpretation of the data.

5.1 Extent of the Waikato Horticultural Complex

The two principal diagnostic attributes of the Waikato horticultural complex, Māori-made soils and their associated borrow pits, permit a clear and relatively precise understanding of the spatial distribution of this phenomenon. Without embarking on a detailed description of the characteristics of this class of horticultural sites (this will be described below) the Māori-made soils are distinctive and have been mapped as a specific soil series by soil scientists from the Soil Bureau of the Department of Scientific and Industrial Research; allowing an understanding of the distribution of the sites within the areas mapped and published (Bruce 1978, 1979; Grange et al. 1939; McLeod 1984). In addition, the borrow pits form large and clear depressions in the ground surface that are readily identified in historic aerial photography, particularly from the 1930s and 1940s, before urban expansion, hydro-electric development and intensification of agriculture took hold. Examination of geo-rectified historic aerial photographs permit the identification and plotting of borrow pits within a GIS. A combination of the two approaches, along with a description of the Māori-made soils along the Waikato River below Huntly by Law (1967), which drew on results of a geotechnical survey for flood retention works, have been collated and presented in Figure 5.1.

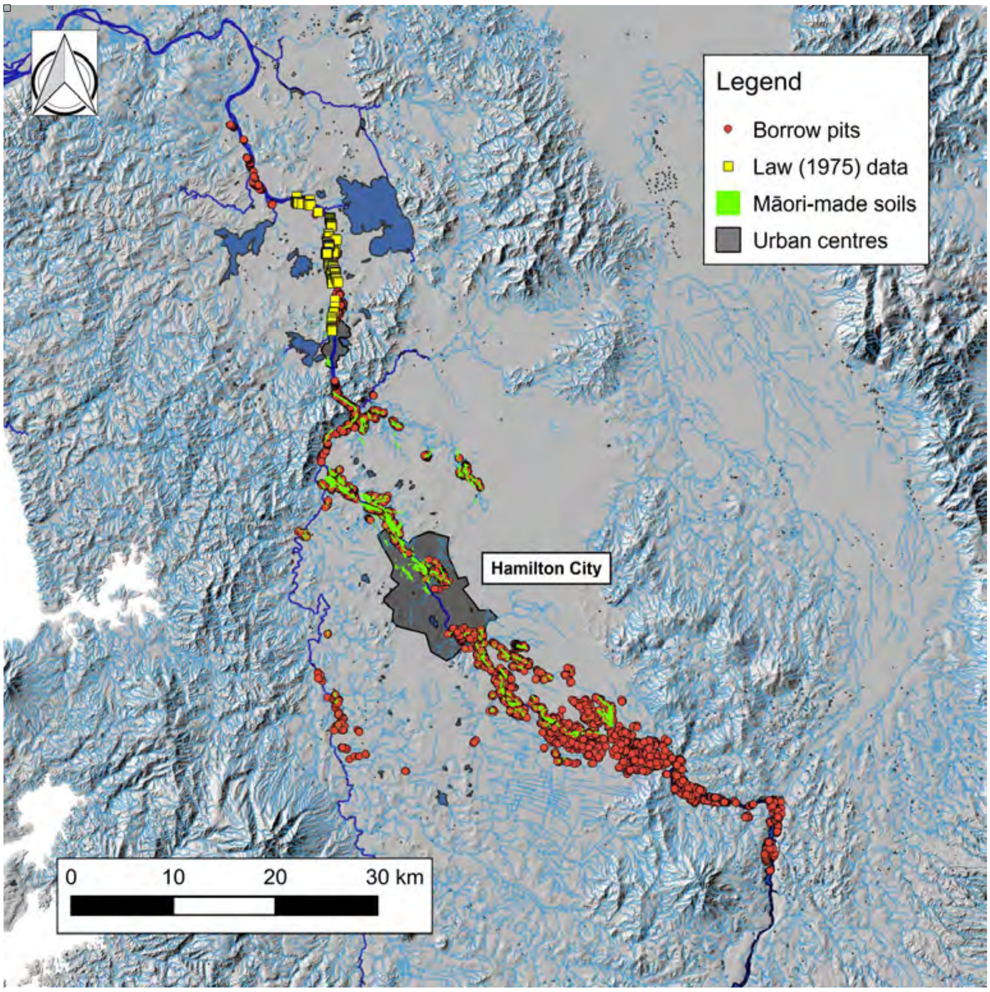

Figure 5.1: Map showing the extent of the Waikato Horticultural Complex. Data represents the locations of borrow pits recorded from historic and recent aerial photographs as well as LiDAR data; Māori-made soils (Tamahere series soils) as mapped by the Soil Bureau of the DSIR (Bruce 1978, 1979; Grange et al. 1939; McLeod 1984); data presented by Law (1975) on made soils in the Lower Waikato Basin. (Note: the gap in the data within Hamilton City reflects the impact of urban development).

As Figure 5.1 demonstrates the distribution of the sites belonging to the Waikato Horticultural Complex is extensive; extending from Arapuni in the south (130 m ASL) and almost to Meremere in the north (5 m ASL), a distance of 110 km. Significant areas of horticultural soils are also found along tributary waterways, particularly the Mangaoneone Stream, the Waipā River and the Komakorau Stream.

5.2 Forest clearance

The features discussed in this section refer to those associated with the clearance of lowland rainforest. These features have all been identified on the basis of the stratigraphic relationships with overlying elements of developed gardens. These stratigraphic relationships have been found to be consistent from site to site and there is some security in identifying them as related to the earliest activities at a number of sites (Figure 5.2).

Broadly, features fall into two classes. The first class is called basin-shaped depressions, which are generally oval in plan with an irregular outline. The second are patches or concentrations of charcoal trapped in the upper element of the B horizon.

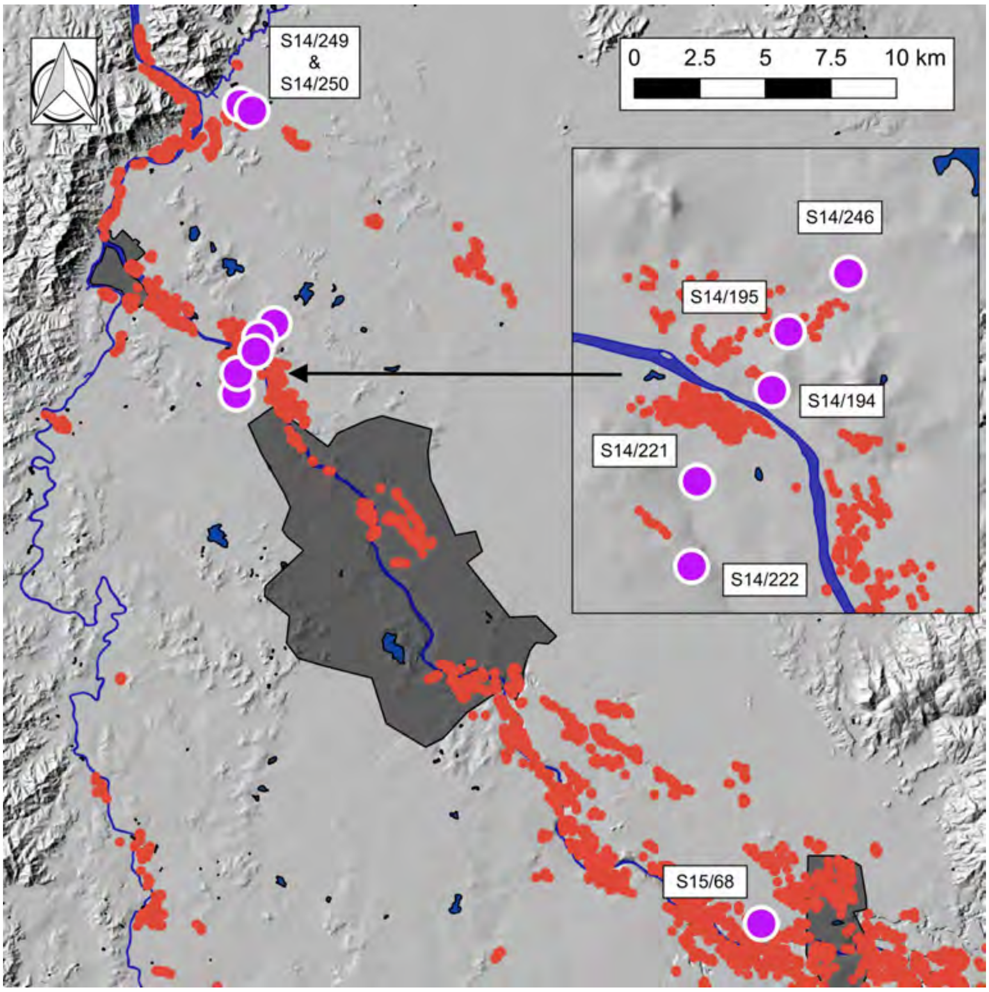

Figure 5.2: Map showing the archaeological sites with evidence relating to the forest clearance phase of garden development referred to in the text.

5.2.1 Basin-shaped Depressions

The feature class, called basin-shaped depressions (BSD), was first recognised by Hoffmann at site S14/221 and S14/222 (Hoffmann 2011, 2013) and have been recognised at several sites since[12].

A descriptive definition of this class of feature was provided in Gumbley and Hoffmann (2013: 23):

> "Basin-shaped depressions are generally oval, although they can be irregular or close to circular. In plan they are visible as an oval area of sand surrounded by a rim or halo of very dark grey, often black, soil that is rich in charcoal. In profile the features have a basin form, where the sand fill lens overlies the dark charcoal-enriched lens. The lower lens may be found as a lenzoid shape in the base of the feature or it may extend up the sides of the depression forming the halo noted above. As well as charcoal the soil was a mixture of topsoil and subsoil. In some cases the lower fill unit and the sides or base of the feature were reddened from heat alteration.
>
> The dimensions of this class of planting pit vary from approximately 0.5 m in diameter to up to 4 x 3 m or 4.7 x 1.9 m. The depth of the features also varied, often depending on the depth of ploughing, between 12 cm and 50 cm. Typically the sand lens occupied a greater proportion of the features depth but sometimes the dark charcoal-rich lens was a similar or slightly greater proportion of the depth. Sometimes this clearly resulted from the truncation of the upper lens from modern cultivation."[13]

Basin-shaped depressions are illustrated in Figures 5.3-5.5, which show the variation and irregularity in this class of feature. The charcoal present in the lower fill unit, when analysed, often includes fine twig material, seeds and bark (see Chapter 7). The reddening from heat alteration is interpreted to result from material burning within the depression. The upper fill unit, which generally constitutes the bulk of the fill, is the transported alluvium quarried from

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[12] S14/194 and S14/195 (Gumbley and Hoffmann 2013), S14/249 (Gumbley and Gainsford 2020b) and S14/250 (Gumbley and Gainsford 2020c), S15/68 (Gumbley and Hutchinson 2014) and S14/246 (Gumbley, personal observation). Campbell and Hudson (2013, 44-45) also describe a feature type with a morphology that indicates that it is also a BSD.

[13] At the time this description was written it was still thought the BSDs were associated with the garden development phase.

the C horizon and can have a gravel component as well as sand, reflecting the nature of the material being quarried.

Figure 5.3: BSD from site S14/249 (Feature 1, east) showing transported alluvium overlying a dark greyish-brown charcoal rich fill lens. Scale is 1 m.

Figure 5.4: BSD from site S14/246 where the garden was formed on poorly drained Te Kowhai silt loam, which provides a high colour contrast between the parent soil, the dark base lens and the transported alluvium fill layer. The area has been repeatedly ploughed with consequent mixing of the upper soil profile. Horizontal scale is 1 m and vertical scales 0.5 m.

It appears reasonable to infer that the transported sand and gravel fill unit to be contemporary with the event where the sand and gravel was applied to the local ground surface as part of the soil making-process. In this sense the upper fill unit is simply that, the material that filled a depression. Consequently, this sequence associates the lower fill with a stage in the development of the garden before the application of the transported alluvium. The nature of the lower fill unit, which is typically a mixture of organic material and “topsoil”, along with the remains of what appears to be leaf litter suggests that this is material that accumulated in the base of a depression existing or formed following the burning of forest and before the development of the gardens proper. The evidence of burning in the bases of these features suggests their formation occurred soon after or even during the principal forest burning event or events. The irregular outline of the features indicates that they were not formal features requiring a regular finish in the same fashion as a crop storage pit.

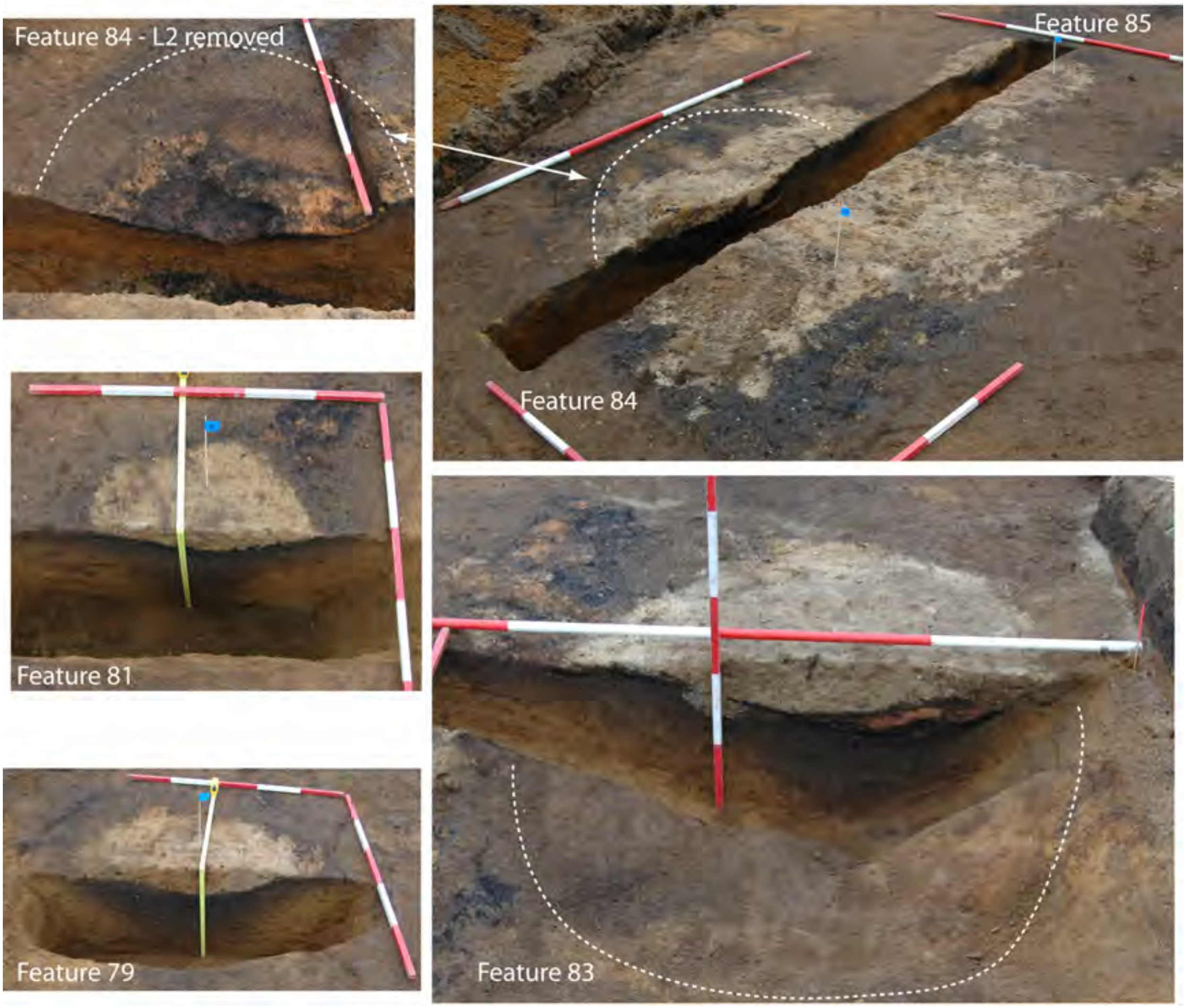

Figure 5.5: A series of BSD images from S14/195 Tract J/K. Scales are 2 m and 1m. L2 refers to the alluvium (sand and gravel) fill unit. Note the distinct charcoal concentrations and the heat altered (reddened) soil elements visible in Features 83 and 84. (Gumbley & Hoffmann 2013: Figure 72: 85).

BSDs, when present, do not form any pattern in relation to other features, whether that is with other BSDs or other classes of feature. BSDs are either found as isolates or in approximate or irregular aggregations.

Nonetheless these features were clearly deliberately excavated. Two potential explanations for these features are feasible. Initially, Hoffmann (2011, 2013) proposed that BSDs were cultivation depressions specifically formed to grow plants in. This was the understanding still preferred when the investigations of S14/194 and S14/195 were undertaken (Gumbley and Hoffmann 2013). The absence of regularity of size and form along with the absence of spatial regularity with other BSDs is relevant. In short, there is an absence of the sort of ordering that might be expected as part of an organised garden.

The second possible explanation relates to the forest clearance process. The general conformity of form and fill patterns, but the lack of regularity suggests that the excavation of the root systems of shrubs and small trees may be a viable interpretation of basin-shaped depressions. The analysis of the charcoal content of samples taken from the basal fill unit from various individual features from several sites has produced a consistent picture; charred twigs, seeds and sometimes bark from forest trees and shrubs is uniform and notable. This, together with the lack of spatial regularity indicates BSDs were deliberate excavations occurring at the time of forest clearance when the ground surface is rich in charcoal and where the soil surface was exposed to the elements after vegetation had been removed. The evidence for in-situ burning is similarly consistent.

The balance of evidence indicates the second proposed explanation is the more likely. BSDs are probably the result of the excavation of the root systems of shrubs and small trees to make room for garden plots.

5.2.2 Charcoal Patches and Concentrations

Charcoal is common in the upper few centimetres of the B horizon within areas of Māori-made soils and can be found in distinct concentrations or patches (Figures 5.6-5.9). Some of the concentrations are amorphous agglomerations of comminuted material that contain charcoal from forest species, often dominated by a single species. Occasionally the species represented is bracken fern, possibly representing a deforested local environment. Other clusters are formed by distinct pieces of charcoal following sinuous patterns on the surface. When these are examined more closely they are present to depth and vertically follow similarly sinuous patterns typical of root systems. When the charcoal from these concentrations is analysed it typically belongs to forest trees, especially *matai*.

Simmons proposed that the charcoal was deliberately produced in what she termed “additive production areas or pits” (Simmons 2013a: 27–28). This is an over-interpretation of the charcoal concentrations that are more compellingly interpreted as charcoal build-up in depressions created following excavation of root-systems.

Figure 5.6: Charred root system found under Māori-made soil at S14/374 (Feature 12). The parent soil is TPA (Hopuhopu member).

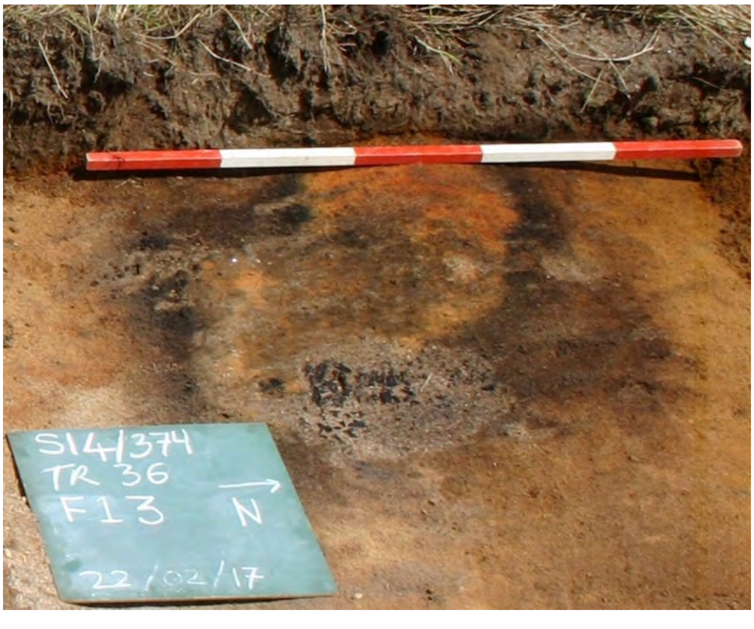

Figure 5.7: Charred root system found under Māori-made soil at S14/374 (Feature 13). Note the heat oxidised soil associated with the charred roots.

Figure 5.8: Amorphous charcoal patch; half-section of F05 in Area 3 at S15/773. Parent soil is Horotiu loam. (Scale = 1 m).

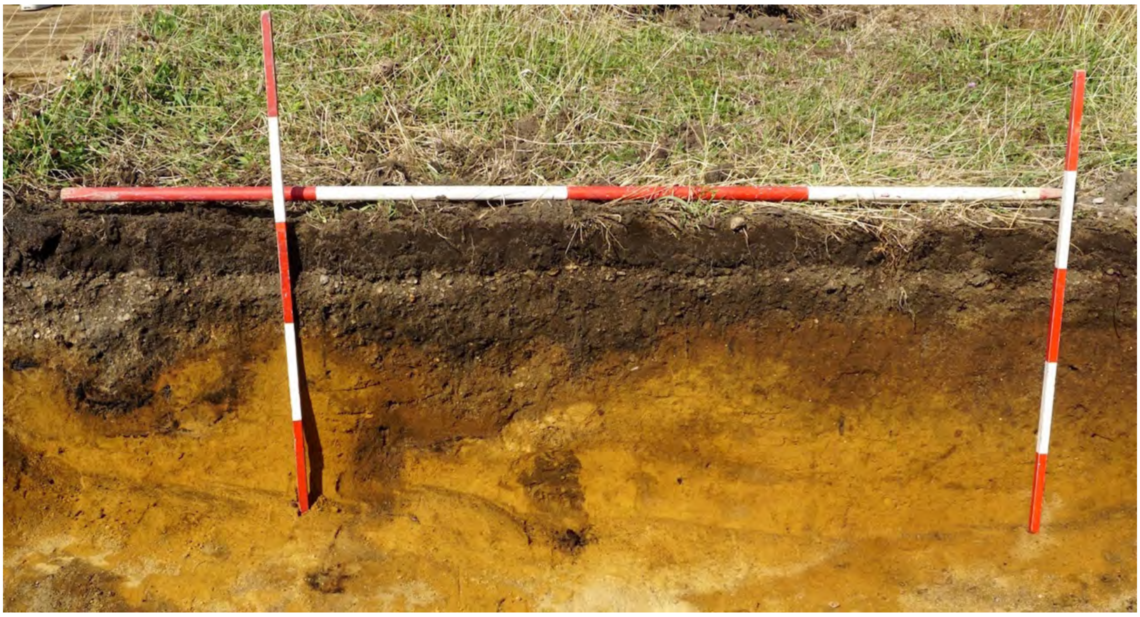

Figure 5.9: S14/424 profile showing an example of charred root systems underlying the Māori-made soils penetrating into the B horizon. The modified upper element of the Ab horizon characteristic of the horizon when under Māori-made soils is visible as darker soil at the right-hand end of the profile. (Horizontal scale = 2m; vertical scales = 1 m).

5.3 Garden development and use

The development of the gardens is represented by the transported alluvium used to form the gardens and which makes them identifiable (Figure 5.10). But the gardens also include an array of archaeological features. These broadly fall into three groups; drainage features, pits and clusters of features representing foci of domestic occupation (typically fireplaces, postholes and pits).

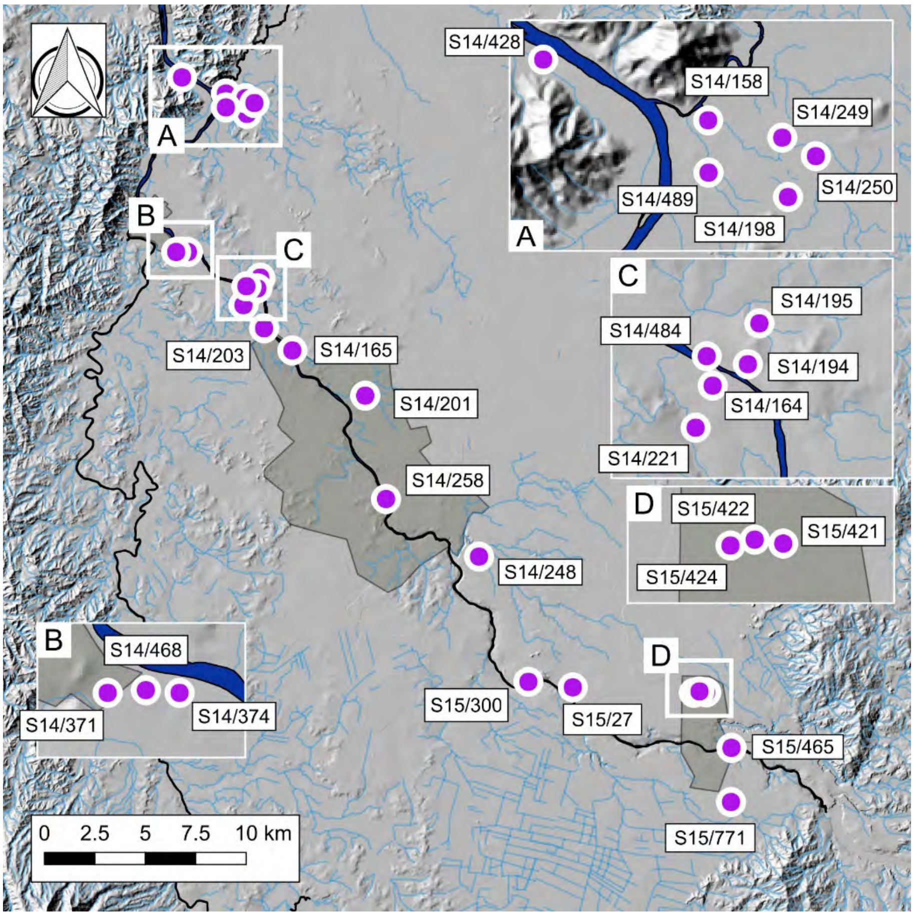

Figure 5.10: Map showing sites relating to the description of garden development. Inset maps refer to boxes sharing the same letter code. Urban centres are shown as grey polygons.

Figure 5.11: Borrow pit at S14/27, Tamahere. The pit is unusually deep at 4 m with only 1-1.5 m of fill in the base (as determined with a soil auger). (Photograph: David Lowe).

5.3.1 Borrow pits

Borrow pits are one of the key landscape features of the Waikato Horticultural Complex, and also the most striking (Figure 5.11). The term borrow pit has been attributed to these features but as Buist (1993) emphasised, they are simply quarries. However, this is now an accepted term and it will be followed here.

Borrow pits present as large oval or near-circular depressions in the landscape. They vary in area and depth and also in shape to some extent. At ground surface these can be as much as 40 m across and typically 1-2 m deep but they may be as deep as 4 m (Figure 5.11). However, typically these pits are found in the range of 10 to 20 m across the longest axis. To some extent the current form and depth of pits can be the result of recent land-use practices (for example stock activity or cultivation) with partial or complete filling commonly affecting the apparent size and depth of borrow pits (Gumbley & Hutchinson 2013).

5.3.1.1 Landscape placement

To some extent the distribution of borrow pits through the landscape can be considered a proxy for the distribution of soils suitable for modification. However, the distribution is also nuanced in relation to the landform, and to some extent in relation to pā, the other major component of the local archaeological landscape.

Gumbley and Hutchinson (2013: 19) considered the population and distribution of borrow pits within Waipā District[14] based on recent imagery (LiDAR and aerial photography) and historic aerial photography (1940s). Waipa District is located at the southern, or upstream, end of the distribution of borrow pits. Their conclusions were:

> "There is a strong correlation between the location of borrow pits and distance from the banks of the Waikato River with 78 % of the borrow pits within 1 km of the river and 51 % within 500 m of the river. In the study area a few sites cluster to the Mangawhero and Mangaone Streams but these represent only a very small part of the resource. The principal exceptions to the otherwise strong clustering to the Waikato River is in the area of Cambridge North and Leamington where borrow pits are found up to 3.5 and 3 km from the river, respectively."

Evidence shows that the same pattern of clustering to the Waikato River is characteristic of the Waikato Horticultural Complex. Considering the entire distribution of borrow pits throughout the inland Waikato it becomes increasingly clear that the "bulge" of borrow pits, and therefore Māori-made soils, in the environs of Cambridge/Leamington is aberrant to the wider pattern. The dominant pattern is for borrow pits, and associated gardens to closely cluster to the Waikato River with secondary foci on tributary streams, particularly where these are navigable.

Borrow pits are mostly found on the surface of alluvial terraces and the plain formed by the Hinuera Surface (Figures 5.12-5.15). They are visible as depressions in the surface once accessing the sand and gravel lying below the tephra mantle. Borrow pits can also be found occupying the escarpments between the river terraces. Those pits sited on the shoulders of the escarpments are generally visible in aerial photography and LiDAR-derived imagery. Evidence from the investigation of S14/194 (Gumbley & Hoffmann 2013) demonstrates quarries were excavated at the toe of escarpments, but these were invisible as surface features. In a variation on this borrow pits have also been identified excavated into the bank of the Komakorau Stream (Gumbley and Gainsford 2020b).

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[14] Waipa District includes approximately half of the Middle Waikato Basin, the Maungatautari Gorge and part of the Upper Waikato Basin.

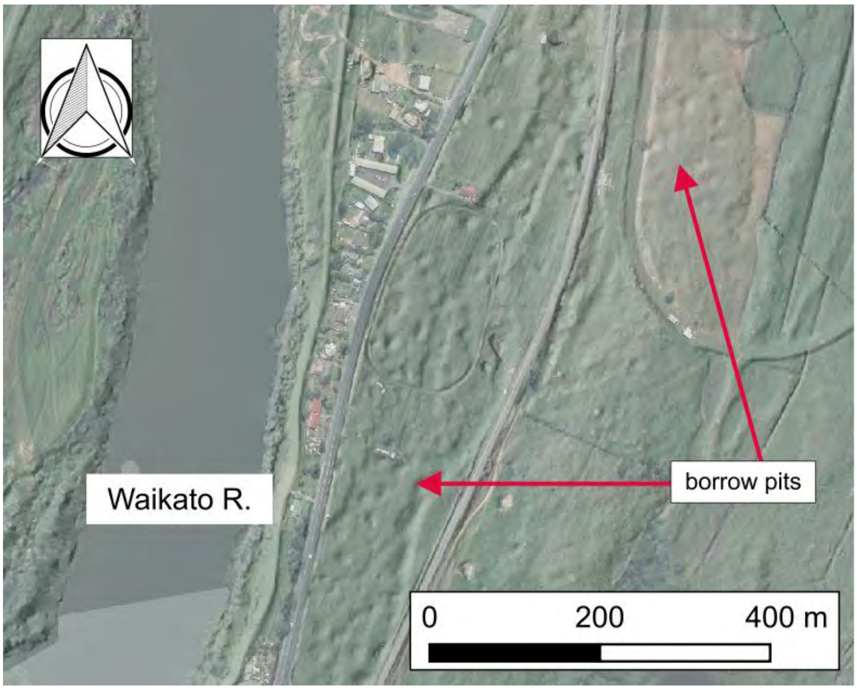

Figure 5.12: Map showing borrow pits on the Taupō Pumice Alluvium immediately down-stream of Huntly on the east (right) bank of the Waikato River. (Source: Waikato Regional Council; 2012 WRAPS aerial imagery overlaid on 2008 LiDAR derived hillshade). (Grid reference NZTM 2000: E1790959, N5844718).

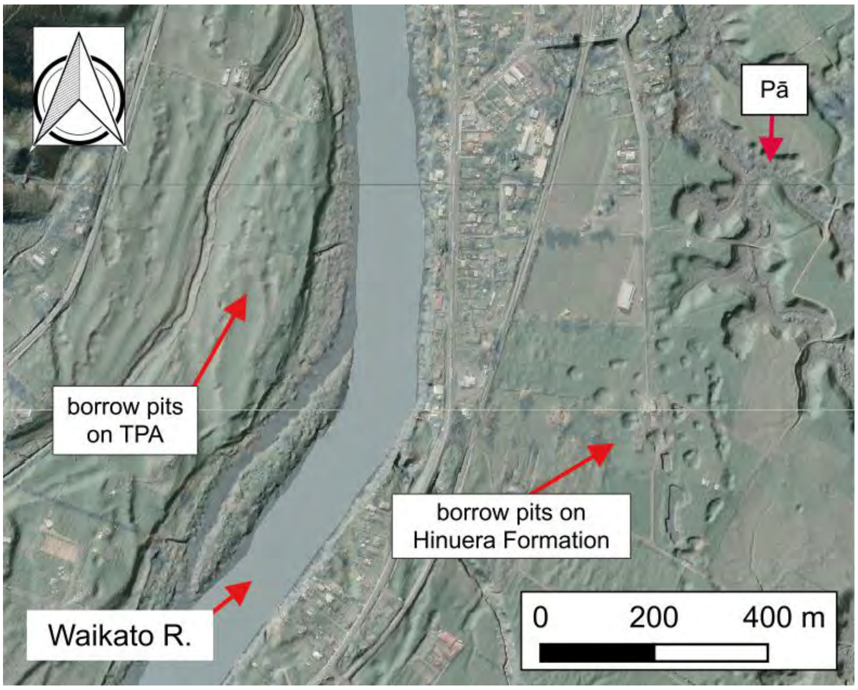

Figure 5.13: Map showing borrow pits at Taupiri located on both the Taupō Pumice Alluvium (TPA) and Hinuera Formation soils. The difference in clarity of definition between the two sets of borrow pits relates to land-use history, with those on the western (left) bank subject to repeated ploughing. (Source: Waikato Regional Council; 2012 WRAPS aerial imagery overlaid on 2008 LiDAR derived hillshade) (Grid reference NZTM 2000: E1793048, N5834079).

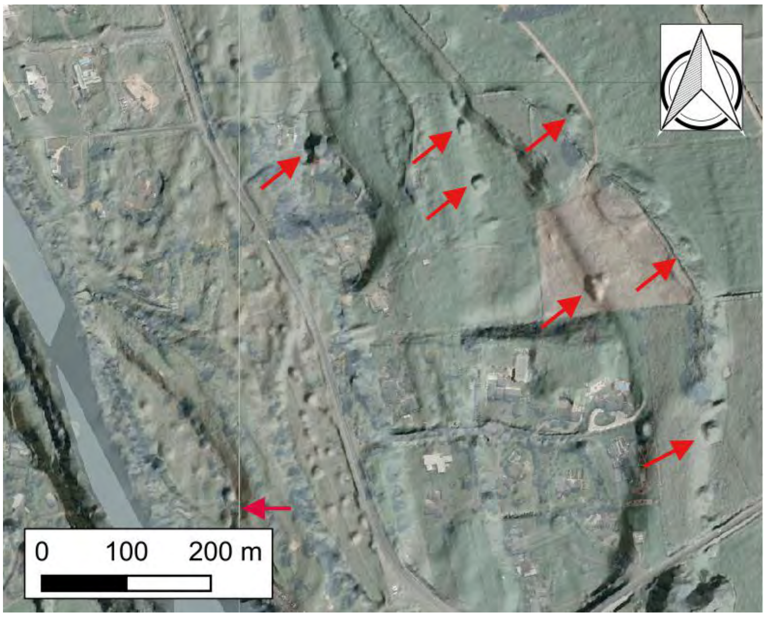

Figure 5.14: Map showing borrow pits at Horotiu located on Hinuera Formation terraces. Borrow pits excavated into the shoulders of the river terraces are highlighted by arrows. Borrow pits are also recognisable on the surface of the river terraces. (Source: Waikato Regional Council; 2012 WRAPS aerial imagery overlaid on 2008 LiDAR derived hillshade) (Grid reference NZTM 2000: E1796150, N5823260).

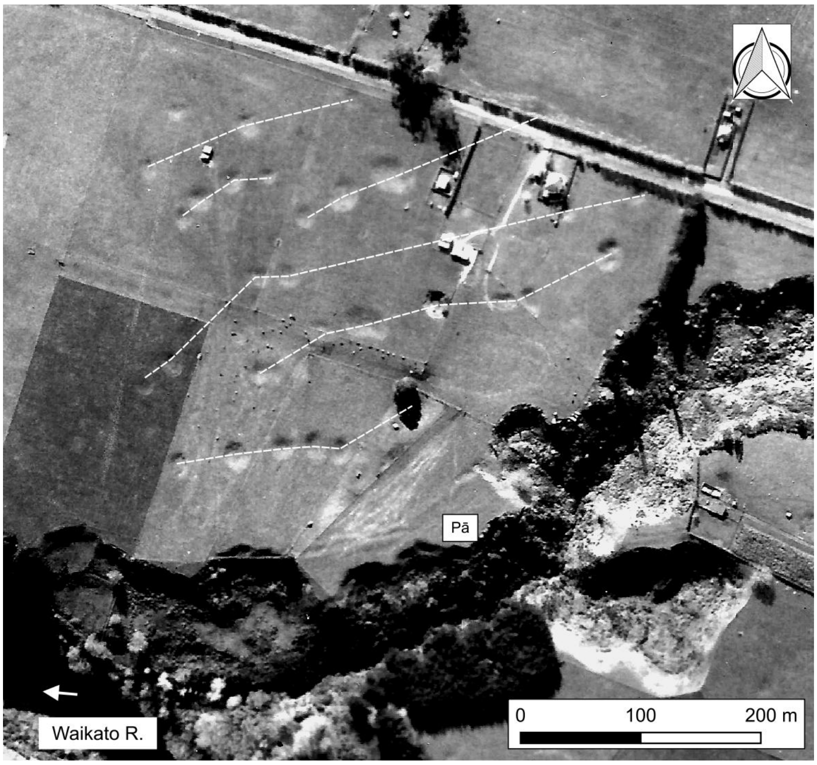

Figure 5.15: 1943 aerial photograph showing a series of borrow pits (S15/27) located on the Hinuera Surface in association with a pā at Tamahere, mid-way between Hamilton and Cambridge. Note the series of rows successively spaced at increasing distance from the pā (S15/26). (Aerial photograph: SN266/834/57, flown 14/6/1943) (Grid reference NZTM 2000: E1810625, N5805660).

A total of 50 borrow pits have been archaeologically investigated and described in reports[15]. The archaeological investigations have demonstrated that there is a wide range of sizes found among borrow pits. It has also shown that smaller borrow pits, those less than 2 m in diameter, are invisible in the surface landscape (Campbell and Harris 2011; Gumbley and Gainsford 2020b; Gumbley and Hoffmann 2013; Gumbley and Laumea 2018).

5.3.1.2 Extraction and fill patterning

Investigated borrow pits tend to reveal a generally typical pattern in their fills. And this may be described as having three parts:

> 1) an upper fill that often appears as a greyish-brown loam, occasionally augmented with modern farm rubbish;
> 2) a very dark grey to black layer that is often rich in charcoal from bracken fern or *mānuka* (a seral shrub species);
> 3) the lowest layer that is often dark yellowish-brown sandy gravelly loam, which often contains plentiful charcoal and occasionally large balks of charred logs.

Unit 1 varies substantially in depth and may include a superior element that represents very recent and deliberate fill. Mostly this unit is interpreted as relatively recent and resulting from farming activities and associated erosion processes.

Unit 2 is not always present but commonly is. As noted the black colour appears to be often associated with the presence of charcoal, which when examined is usually dominated by bracken remains with *mānuka* sometimes forming a secondary element, otherwise occasional pieces from forest species are present. The charcoal in this unit is understood to be a drift or in-wash deposit that included the charcoal from the burning of fern and shrubs, occasionally incorporating relict pieces of forest charcoal present in the environment that have accumulated in the depression. Because of the overwhelming presence of bracken fern, it is

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[15] Campbell & Harris 2011; Campbell& Hudson 2014; Gumbley unpublished data; Gumbley 2009; Gumbley and Gainsford 2020a; Gumbley and Gainsford 2020b; Gumbley & Higham 1999; Gumbley & Higham 2000; Gumbley, Higham & Lowe 2004; Gumbley & Hoffmann 2013; Gumbley & Gainsford 2018; Gumbley & Laumea 2017; Gumbley & Laumea 2019; Gumbley, Laumea, Gainsford 2018; Hoffmann 2011; Keith 2019a; Potts 2019.

probable that the colouration of the layer is also, at least in part, the result of the melanisation of the soil resulting from the Type-A humic acids associated with bracken (Lowe 2016: 30).

Unit 3 is a mixture of the tephritic loam and material from the alluvium. In some cases, it is apparent that the non-coherent alluvium has slumped into the pit from the sides as the quarrying progressed. The slumped material mixed with the overlying tephra that is also slumping into the pit. Charcoal found in this layer is almost entirely comprised of a range of forest species. However, evidence it appears likely, drawing on the fill patterns in small single shaft borrow pits, that the filling process was also deliberate. On top of this human traffic would have served to have compacted and mixed sediments.

Larger borrow pits reveal evidence for development of the pits through the aggregation of a number of smaller sub-units, referred to as shafts (Figures 5.16-5.21). These elements are identifiable close to the base of the borrow pits and are irregular to near-circular and 1-2 m in diameter. In this sense many borrow pits appear to be an aggregation of a number of shafts. In some cases, there is evidence for the coalescing of large pits with other large pits (Campbell and Hudson 2014; Gumbley and Gainsford 2018, Gumbley and Gainsford 2020a, Gumbley and Gainsford 2020b; Gumbley and Higham 1999; Keith 2019).

Figure 5.16: Small single shaft borrow pit from S14/249 (Taupiri). The pit is overlain with Māori-made soil.

Figure 5.17: Borrow pit 1 from S15/424 showing the development of the borrow pit from coalescing shafts. The pit is 24 m x 18 m by 5 m deep (max) or ~ 600 m^3. It is 1 of 12 pits within the site.

Figure 5.18: Partial excavation of a borrow pit at S14/468 (Ngaruawahia) showing the aggregation of shafts into a single pit. Note the black layer which represented a typical example of Unit 2 of the pit fill. Unit 1 above was a recent fill including rubbish from the 1980s. Unit 3 of the fill represents a typical example of the back-fill unit. Bowl-shaped hollows were found immediately under the black layer (Unit 2).

Figure 5.19: Oblique profile photograph of borrow pit 1 at S14/249 (Taupiri). The trench was aligned West-East (to the top-right). Unit 1 of the fill is largely absent, Unit 2 is absent but Unit 3 is typical. It is likely that Units 1 and 2 have been conflated to some extent, particularly following modern cultivation. (Vertical scales = 2 m).

Figure 5.20: Plan view of the north-west corner of borrow pit 1 at S14/249 excavated to approximately 1.25 m depth. This illustrates the excavation of small shafts that eventually aggregate into the single pit. (Long scales = 2 m, short scales = 1 m).

Figure 5.21: Excavation of borrow pit 2 at S15/424 close to the base showing the bases of individual shafts. (Scales = 1 m).

5.3.1.3 Volumes of extracted material

Although 50 borrow pits have been subject to some form of archaeological investigation, data from 25 is sufficiently detailed to reconstruct the quantities of alluvium quarried (Table 5.1). These data come from dimension data recorded from trenches excavated to expose pit cross-sections. It must be acknowledged that the data allows approximations only of volume given that all pits are irregular in form with internally variable depths and variations of shape. Accordingly, some “averaging” has had to be imposed in order to make the calculations. If a pit was circular, or near-circular in plan then calculations were made as per a cylinder. If a pit is oval or near-oval then the plan area was calculated as an ellipse multiplied by the depth. The estimates of volumes extracted include the tephra loam capping the C horizon alluvium as well as the alluvium that was extracted and transported to the gardens. This is considered to be a valid indication of the amount of energy expended. Typically, the capping loam (A and B horizons) is approximately 0.6 m thick.

Table 5.1: Estimates of volumes of material extracted from borrow pits.

Site #	L (m)	W(m)	Dep (m., max)	Area (m2)	Volume (m3)	References/sources
S14/198	5.4	3	1.8	13	23.4	Campbell & Harris 2011
	7.2	5.6	1.65	32	52.8	Campbell & Harris 2011
	9.5	7	1.9	52	98.8	Campbell & Harris 2011
	10	6.5	1.9	51	96.9	Campbell & Harris 2011
	48	6.5	1.5	980	1470	Gumbley & Gainsford 2020a
	12	7.6	2.4	287	688.8	Gumbley & Gainsford 2020a
S14/203	70	25	1.7	1374	2335.8	Gumbley & Higham 1999
S14/201				370	518	Gumbley & Higham 2000; Gumbley, Higham & Lowe 2004
				780	1716	Gumbley & Higham 2000; Gumbley, Higham & Lowe 2004
S15/422	15	15	4		706	Gumbley 2009
	9	9	1.8		115	Gumbley, Laumea, Gainsford 2018
	6	9	1.7	42	71.4	Gumbley, Laumea, Gainsford 2018
S14/195	17	17	4.5		1021	Gumbley & Hoffmann 2013
	8.7	7.2	2.6	49	127.4	Gumbley & Hoffmann 2013
S14/374	41.5	20	1.5	644	966	Gumbley & Gainsford 2018
S14/468	20	20	6.5		2042	Gumbley & Gainsford 2018
S15/465	24	20	2	377	754	Gumbley & Laumea 2019
S15/421	20	10	1.8	628	1130.4	Gumbley, Laumea, Gainsford 2018
S15/424	10	13	2.5	102	255	Potts 2019
	7.2	9	2.5	51	127.5	Potts 2019
	14.3	10	2.9	110	319	Potts 2019
	12.5	8	4	75	300	Unpublished data
	14	8	2	87	174	Unpublished data
	10	10	3		235	Unpublished data
S14/249	20	20	3		942	Unpublished data
				Mean volume	**652**	

With an average volume of 652 m^3 and with a minimum count of 6391 borrow pits then a combined total of 4,166,932 m^3 provides a minimum estimate of the overall quantity of material excavated from within the Waikato Horticultural Complex.

5.3.2 Māori-made soil and planting features

Made-soil is the characterising element of the horticultural system generally represented by soil scientists as a discrete A horizon characterised by very high proportions of sand and gravel along with charcoal. Archaeological investigations of well-preserved areas of a made-soil have identified two manifestations of this phenomenon. The first includes the presence of bowl-shaped hollows (BSHs) first reported by Gumbley et al. (2004), and the second is as a layer of transported alluvium sitting on top of the B horizon.

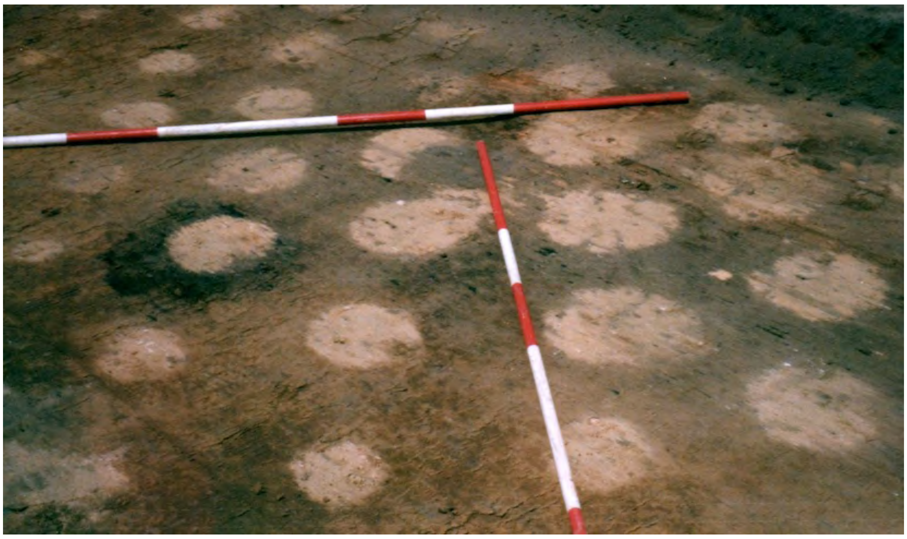

Figure 5.22: Image showing the BSHs uncovered in the southern plot at S14/201. (Scale intervals = 0.5 m and 0.25m).

5.3.2.1 Planting features - bowl-shaped hollows

Planting or growing features have been identified at several sites. Here these are called bowl-shaped hollows (BSHs)[16], which is a morphological descriptor. These features are distinct from the basin shaped depressions described above. BSHs are found excavated into the B

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[16] In some reports and publications these features are referred to as “puke”, which is a misleading term since this word (and variations on it) refer to the mound into which kumara and yam were planted (Best 1976). For this reason the descriptive name 'bowl-shaped hollow' is preferred.

horizon of Horotiu Series soils[17] and they are circular or near-circular in plan but can tend to ovoid. As the name suggests they have a concave cross-section that generally approaches the semi-circular in profile (Figures 5.22-5.32). A number also have dimples in the base, which have been interpreted as the remnants of the use of the digging stick (*kō*) used in a circular fashion to loosen the soil in the BSH before its removal (Figure 5.24). If this is the case the form of a hollow is probably an artefact of the form of the tool used and the fashion in which it is used. Features of this class have been identified at twelve sites[18] within the Middle Waikato Basin and they are distributed from Taupiri in the north to Cambridge in the south.

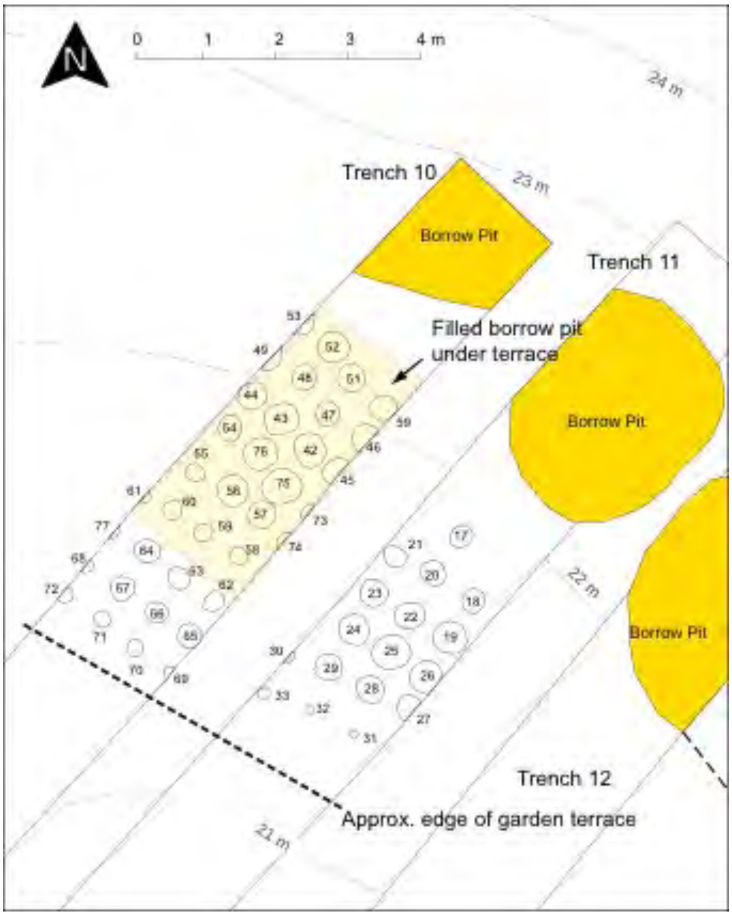

Figure 5.23: S14/194, Area B – Plan showing the layout of the BSHs in Trenches 10 and 11 in a simple two dimensional grid aligned both parallel to the escarpment and perpendicular. Note the filled borrow pit under the garden terrace. (Figure 21 in Gumbley & Hoffmann 2013).

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[17] At three sites (S14/198, S14/468, S14/248) they have been found excavated into the surface of the back-fill unit (3) of borrow pits.

[18] S14/428 (personal observation), S14/158 (Campbell & Harris 2011), S14/198 (Gumbley & Gainsford 202a), S14/468 (Gumbley & Gainsford 2019), S14/371 (Simmons 2017), S14/484 (personal observation), S14/164 (Simmons 2012 & 2013 a & b), S14/165 (Simmons 2008), S14/194 (Gumbley & Hoffmann 2013), S14/201 (Gumbley & Higham 2001; Higham and Gumbley 2003; Gumbley et al. 2004), S14/258 (Phillips & Thorne 2014), S14/248 (personal observation; Grono 2017), S15/465 (Gumbley & Laumea 2019).

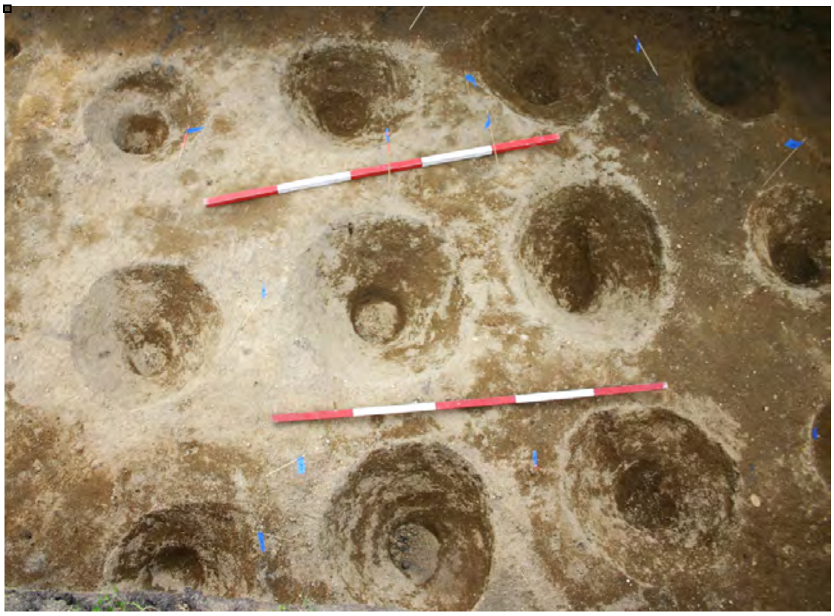

Figure 5.24: S14/194, Trench 11. BSHs following excavation. (Figure 29 in Gumbley & Hoffmann 2013).

Figure 5.25: S14/468. BSHs on the surface of the original back-fill of borrow pit F61. (Figure 43 in Gumbley & Gainsford 2018).

Figure 5.26: S14/468. Vertical view of the BSHs on the surface of the original back-fill of borrow pit F61 following removal of coarse fill from the hollows. (Scales = 1 m).

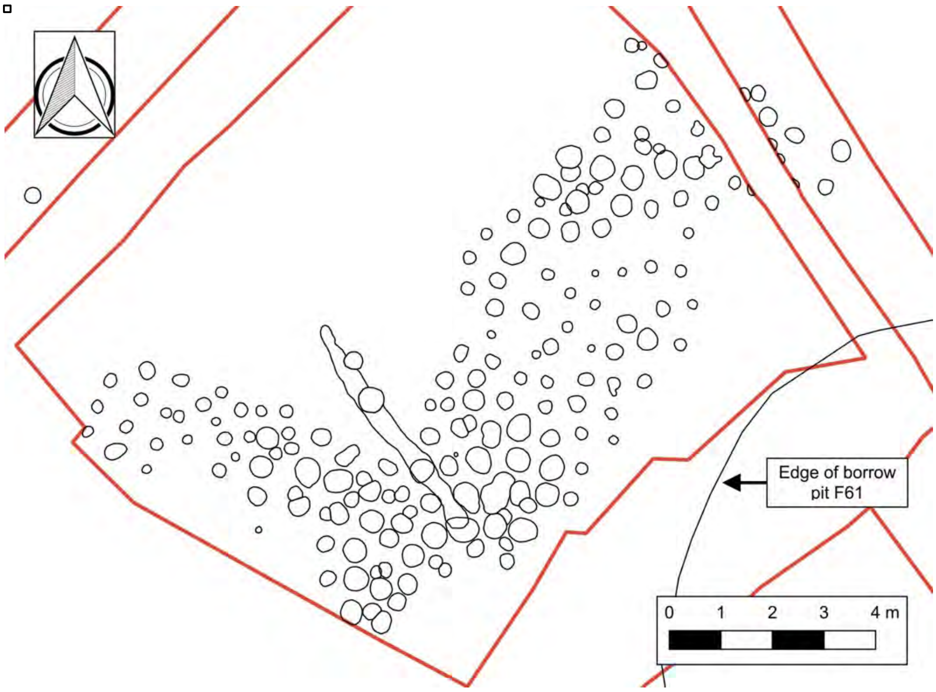

Figure 5.27: Plan showing the BSHs on the surface in Area 1, S14/468 on the NW edge of the borrow pit F61. The complexity of the arrangement of the BSHs indicate the "over-printing" of multiple garden plots. A linear feature, interpreted as a ditch with a deep U-shaped profile, has BSHs formed in the fill of the feature. The variability of BSH sizes is in part related to truncation during excavation with hydraulic excavator, but variability of size also appears to have been an aspect of this suit of features. Red outlines show the excavation areas.

Figure 5.28: Image showing excavated BSHs on the surface of the back-fill of a borrow pit at S14/198 (Taupiri). Scales shown at upper right = 1m. (Drone photography and photogrammetry by Ben Thorne, Datum Archaeology).

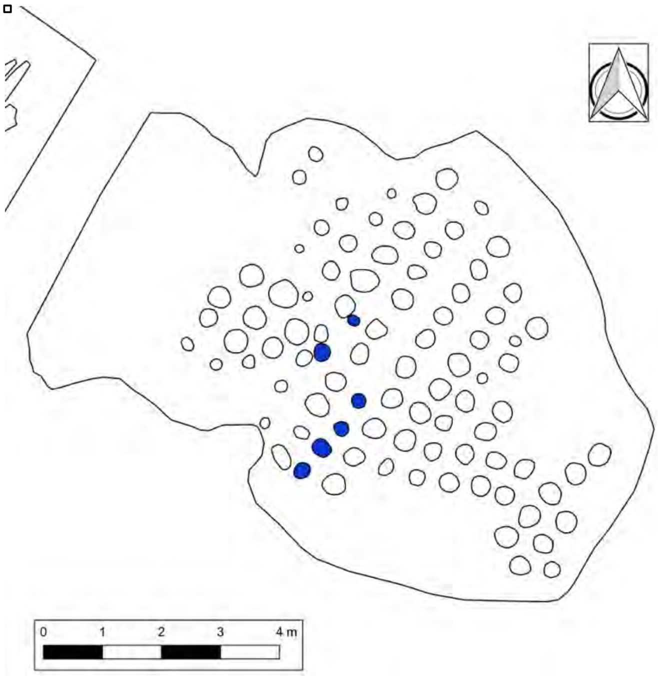

Figure 5.29: Plan showing the distribution and arrangement of the BSHs within the borrow pit at S14/198. Note the alignment of the BSHs in a single rows oriented SW-NE without alignment on a second dimension. There are also “in-fill” BSHs (highlighted in blue) placed to fill gaps between the rows. Note also the variation on the size of the BSHs. The garden probably also extended further to the NW. The enclosing irregular line defined the edge of the borrow pit with a baulk present at the NW end.

Figure 5.30: BSHs at S15/465 showing their distribution and arrangement. Significantly this field of BSH was overlaid with a layer of transported alluvium. This was recognised through the superimposition of the alluvium layer over a lens of spoil from the pit indicated on the plan, which was deposited over several BSHs. The clarity of the arrangement of the BSH on the right-hand (eastern) part of the group reflects their excavation by archaeologists, while those on the left were a truncated sub-set exposed by the earthworks contractor.

Figure 5.31: S14/194, Trench 10. BSH half-sectioned showing a possible remnant loam cap as a surviving element of the growing mound. Scale intervals are 20 cm. (Figure 27 in Gumbley & Hoffmann 2013).

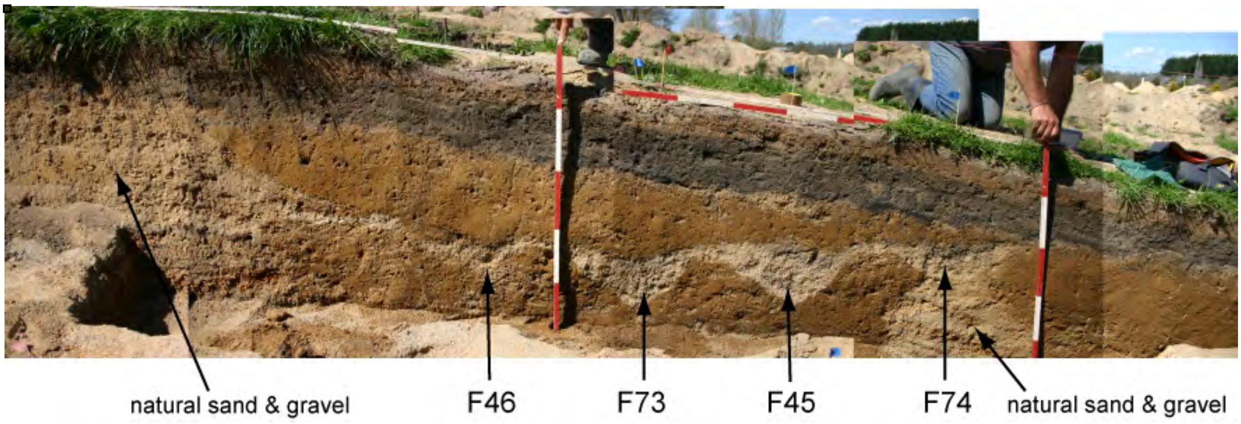

Figure 5.32: S14/194, Trench 10. Trench profile showing the sand and gravel filled BSHs. Note the slump effect of the colluvial loam deposited over the BSHs which probably represents the result of material filling pre-existing depressions in the surface of the hollows. BSHs F46, F73 and F45 were formed on the back-fill of a borrow pit. (Figure 23 in Gumbley & Hoffmann 2013).

BSHs are found as clusters arranged in an orderly fashion, either as simple parallel rows or less commonly in quincunx fashion. At some sites more than one set of alignments are present, indicating multiple garden plots (Figures 5.27 and 5.30).

At five[19] of the thirteen sites where BSHs have been identified, overprinting of BSHs has been recorded, demonstrating reuse of the same area, at least on a plot by plot basis (Figures 5.27 and 5.30). Whether this also represents return to the site after a period of abandonment or fallow is uncertain. In part this results from the sample size in relation to the individual archaeological investigations and also the limited recording methods employed at some sites (e.g. BSH were not recorded using detailed survey methods such as total station survey or drone-based aerial photography). Two adjacent plots were identified at S14/201 on the basis of the varied orientations and spacing (Gumbley et al. 2004) and similar evidence appears in photographs from the investigation at S14/165 (Simmons 2008) but the nature of the recording prevents confident interpretation of the data.

While most of the evidence refers to development of BSH gardens on the native ground surface examples of BSH gardens being formed on the back-filled surface of borrow pits have been found at 3 sites, S14/198 (Gumbley and Gainsford 2020a; Grono 2017 in Appendix C), S14/468 (Gumbley and Gainsford 2018), and S14/248 (Grono 2017 in Appendix C). Aside from the unusual situation of the garden their morphology is the same as those outside the

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[19] S14/158 (Campbell & Harris 2011), S14/468 (Gumbley & Gainsford 2018), S14/164 (Simmons 2012, 2013b), S14/165 (Simmons 2008), S15/465 (Gumbley & Laumea 2019).

borrow pits. At two of the sites, S14/198 and S14/248, BSHs were not found outside the borrow pits but this is probably a consequence of the recent cultivation history of the sites. That is to say, modern cultivation had ploughed out any BSHs present.

Table 5.2: Summary data relating to size of BSHs from four sites.

Site		**Mean**	**Q1**	**Q3**	**Min**	**Max**
S14/468 Area 1	Diameter (cm)	36	30	41.5	14	54
	Depth (cm)	12	9	14	4	22
	Fill volume (L)	–	–	–	–	–
S14/468 BP F61	Diameter (cm)	33	30	36.5	26	40
	Depth (cm)	11	8	15	6	18
	Fill vol. (L)	–	–	–	–	–
S14/194	Diameter (cm)	41	36	45.25	28	56
	Depth (cm)	18	16.25	27.75	1	24
	Fill vol. (lt)	13.8	12	18	4	20
S14/198	Diameter (cm)	31	27	37	12	44
	Depth (cm)	14	11	17	2	26
	Fill vol. (L)	–	–	–	–	–
S15/465	Diameter (cm)	47	42	52	36	59
	Depth (cm)	10	8	13	6	13
	Fill vol. (L)	12	8.5	14	3.5	38

Determining typical dimensions of BSHs is difficult because at most sites modern cultivation has deepened the A horizon and truncated the underlying BSHs to some extent. The BSHs found on the back-fill of borrow pits and the BSHs found at S14/194 are the only examples where a good state of preservation is ensured and therefore the preservation of the original dimensions of BSHs (Figures 5.23-5.26 and 5.28-5.29). Two other sites, S14/468 and S15/465 have areas where BSHs found on the natural surface do not appear to have suffered from modern cultivation. In all cases it is evident that the diameters and depths of individual BSH are variable.

Five sites (S14/468, S14/194, S14/198, S15/465) have sufficiently robust data to permit some understanding of the typical range of sizes of BSHs. Appendix A contains the raw data and the summary of these data are presented in Table 5.2. The mean diameters of the BSHs varied between 31 cm and 47 cm, with the narrowest in the data sets being 27 cm and the widest 59 cm. Mean depths varied between 10 cm and 18 cm with the minimum depth being 2 cm and the deepest being 26 cm. Volumes of fill material were recorded at two sites (S14/194 and S15/465) with the means 12 litres and 13.8 litres and ranging from minimum volume of 3.5 litres and maximum of 38 litres.

As well as the distinct form and arrangement of the features, the pattern of fill is consistent in all cases. The depression is filled with material from the Hinuera alluvium (C horizon), which ranges from sand to sand and gravel. Given the consistent descriptions of *kūmara* being cultivated by Māori in mounds the question arises about evidence for mounding and also for disturbance of the fill deposit that may reflect tuber harvesting. Inevitably one of the problems in addressing the first of these is that any mound raised to form the growing medium for the *kūmara* plant will be destroyed during harvest. Gumbley et al (2004) proposed that the material removed during the formation of the hollow could have been used to form the mound. Since that date attention has been paid to the possible presence of material that was remnant of any mound present.

In all cases, except one, examination of the hollow fill units has found that the fill deposits contain no evidence of disturbance that might reflect the harvest of tubers. Such evidence would be the addition of loam from either the putative mound or from the surrounding soil mass, along with the presence of charcoal which is naturally absent from the Hinuera Formation alluvium (C horizon). This avenue of enquiry is explored in Chapter 6 where soil micromorphological analyses by Grono (2017 in Appendix C) of these environments are considered.

Five sites (S14/194, S14/198, S14/248, S14/468, S15/465[20]) have sufficiently robust data to permit investigation of the arrangement of density of BSHs within garden plots (Figures 5.23-27, 5.28-5.30 and 5.33). Data relating to BSH row separation distances is provided in Appendix A. In all cases BSHs are arrayed in distinguishable rows. Spacing was variable with

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[20] S14/194 - Gumbley & Hoffmann 2013; S14/198 - Gumbley & Gainsford 2020a; S14/468 - Gumbley & Gainsford 2018; S15/465 - Gumbley and Laumea 2019a. Data from S14/248 is unpublished and has been supplied by Sian Keith (Sian Keith Archaeology Ltd).

three sites (S14/194, S14/198, S14/468) sharing similar spacing with a mean of 59 cm from centre to centre, while S14/248 had conspicuously close separations (mean 45 cm) and at S15/465 BSH were distinctly widely spaced (mean 95 cm).

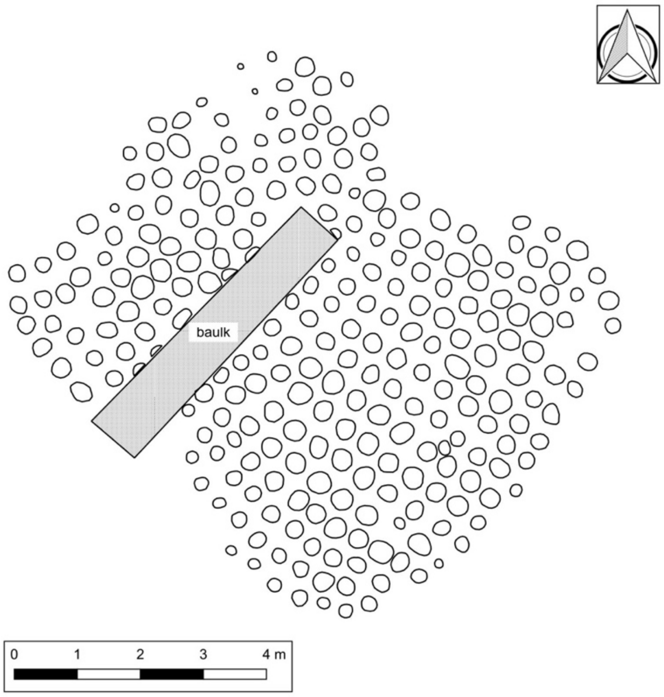

Figure 5.33: S14/248, BSHs recorded on back-fill of borrow pit. Note the regularity of the primary NW-SE row alignment and the tendency for the secondary alignments to be less regular. (Data supplied by Sian Keith, Sian Keith Archaeology Ltd).

Densities were able to be replicated from the five sites by selecting of groups of BSH in clear relation to each other. In the case of S14/198 and S14/248 this included almost complete garden plots. The area of each group was measured and the BSHs within the identified cluster were counted and densities calculated to replicate the number of BSH per hectare. S14/194 (31,754 BSH/ha), S14/198 (32,995 BSH/ha) and S14/468 (30,075 BSH/ha) together had an average density of 31,608 BSH per hectare. Consistent with spacing patterns between BSH identified above S15/465 had a comparatively low density of 15,559 per hectare. S14/248 had a dense pattern of 52,917 BSH per hectare.

The typical pattern is for BSH to be organised in parallel rows (S14/194, S14/198, S15/465). At S14/468 the BSH which were located on the borrow pit fill were organised in parallel rows but the organisation of those on the plan surface, where overprinting did not obscure the patterning, were organised in off-set rows approaching quincunx. A similar pattern is present at S14/248 where both parallel rows and off-set rows are present in the same plot. There is evidence for individual BSH and short rows being inserted to fill spaces between rows.

5.3.2.2 Transported alluvium layers (TAL)

When well preserved, the TALs have a consistent morphology irrespective of whether they are located on Hinuera Formation soil or Taupo Pumice Alluvium. The two best examples available in relation to the two formations are found at S15/424 (Hinuera Formation) and S14/374 (TPA). S15/424 was unusually well-preserved with no evidence of effects from modern cultivation and so presents information not found at other sites. S14/374 is the only archaeologically investigated site of this class explicitly developed from transported alluvium, without the presence of BSHs, on the Taupo Pumice Alluvium[21]. However, it had been affected by cultivation in the 20th century with an accompanying loss of detail above the topsoil/subsoil interface. Preservation of the archaeological remains close to that interface were good in places and where these were closely examined by hand the evidence was consistent with the data from S15/424. Therefore, these descriptions focus on the data recovered from S15/424.

A turf unit, generally 10-15 cm thick, overlies the transported alluvium (Figure 5.35). The turf unit matrix is formed from a well-sorted matrix of medium sand and finer material that is typically dark greyish-brown. Immediately under the turf is a unit of sand/gravel which is also generally dark greyish-brown and from 10-20 cm thick with an abrupt and smooth transition between the horizons. The dark-greyish brown sand/gravel unit in turn overlies a unit of sand/gravel of similar thickness but paler colour (dark yellowish-brown). The paler sand/gravel unit in turn overlies the upper element of the B horizon. The transition is, again, abrupt or distinct but with a wavy shape in profile. Since most Māori-made soils are formed on Horotiu Series soils the description of the B horizon will continue as per this soil class but the pattern for these soils on the Hopuhopu member of the Waikato Series soils (TPA) is the same as the Horotiu soils. The uppermost element of the B horizon is distinctly darker than the main body of the B horizon, ranging from dark yellowish-brown to greyish-brown,

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[21] S14/164 and S15/465 are two other sites investigated on the TPA, however, S14/164 included the remains of BSHs with no evidence of a TAL. S15/465 had the remains of a TAL super-imposed over BSHs, however this aspect was not able to be explored because the topsoil had been affected by modern cultivation and because topsoil removal by earthworks contractors disturbed the remaining parts of the layer significantly.

whereas the main body of the B horizon is yellowish-brown (Figures 5.34-5.35) and distinctly different from the upper B horizon on adjacent unmodified soils (Figure 5.36). Charcoal pieces of varying sizes and in varying concentrations are also present. This element of the B horizon is generally 20-25 cm thick. This layer is often described by soil scientists as a buried topsoil (Ab horizon), which may imply it is a natural soil unit. However, this element of the B horizon is absent in adjacent soils of the same series that do not have a made-soil layer superimposed. When charcoal recovered from this layer is analysed it is heavily dominated by forest species, often canopy species such as matai (Prumnopitys taxifolia) or tawa (*Beilschmiedia tawa*) along with an array of sub-canopy species (refer to Chapter 7 and Appendix E).

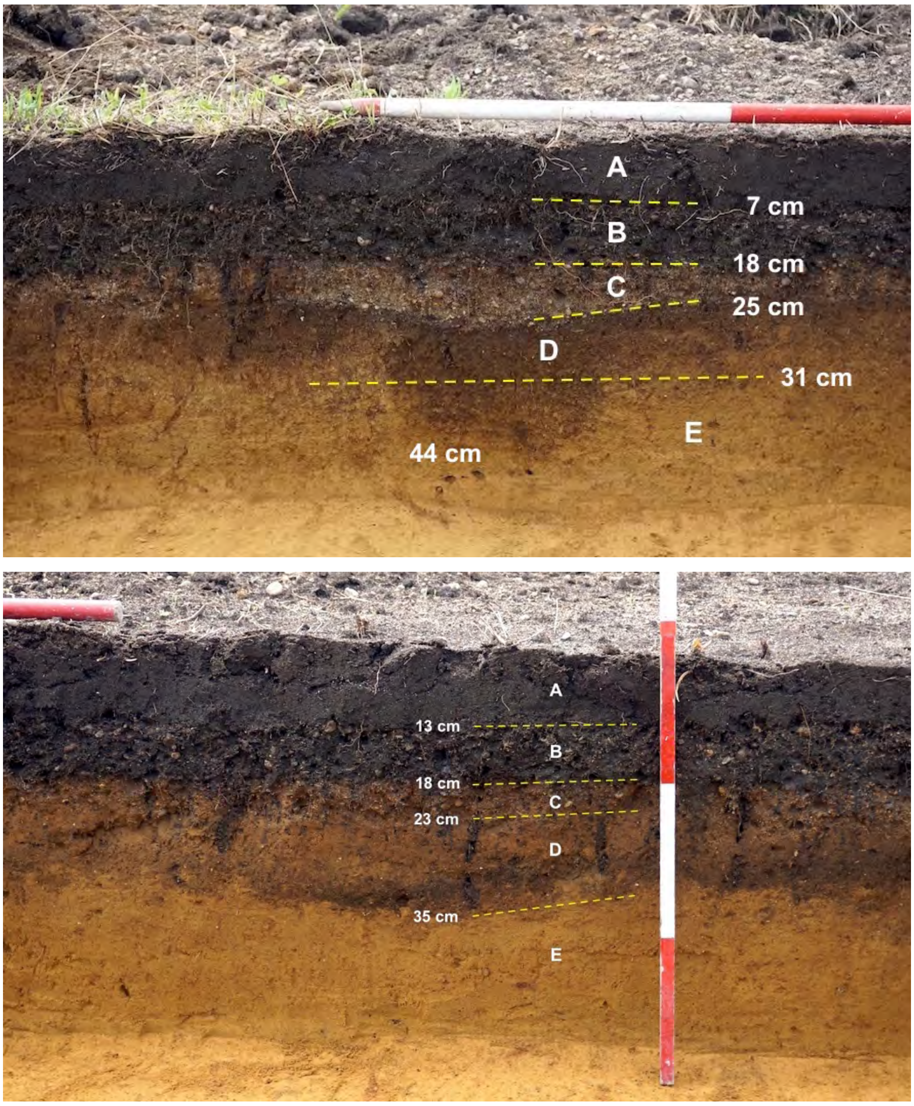

Figure 5.34: S15/424. Example of transported alluvium on a Horotiu parent soil. Images are both from trench LP1 with the upper at 2 m and the lower at 4 m. A = turf, B = darker upper sand and gravel unit, C = paler lower sand and gravel unit, D = upper B horizon (possible Ab), E = B horizon. S15/424 is located at Cambridge North and was located approximately 3 km form the Waikato River. (Horizontal scale interval is 0.5 m and vertical scale units are 0.2 m).

Figure 5.35: S15/424 Cambridge: Trench LP1 showing a typical soil profile describing the Māori-made soil stratigraphy. (Horizontal scale = 2 m, vertical scales = 1 m).

Figure 5.36: An unmodified, or natural soil profile at S15/424.

Bioturbation of the profile is usually clearly apparent with evidence of burrows formed by invertebrates through the lower made-soil layer and the B horizon.

The TAL when exposed is distinctly coarse with sand or gravel dominating depending on the nature of the alluvium quarried (Figure 5.37). Hand excavation of the made-soil layers in plan shows the interface between the two reflects the profile. Excavation of the lower made-soil layer to expose the surface of the B horizon reveals a very irregular surface that might be described as “pock-marked” or undulating. This irregularity in the surface is interpreted as the result of the effect of digging tools and, in some places, what appear to be the moulds of tubers (Figures 5.38-5.40).

Figure 5.37: S15/424. Upper surface of the TAL following removal of turf with trowel for scale.

Figure 5.38: Example of the dimpled upper surface of the B horizon following the removal of the TAL at S15/324, Cambridge.

Figure 5.39: Example of the dimpled upper surface of the B horizon following the removal of the TAL at S15/421, Cambridge.

Figure 5.40: Example of the dimpled interface found at S15/374 at Ngaruawahia, garden site located on Waikato series soil (formed on Taupo Pumice Alluvium)(Gumbley & Gainsford 2018).

5.3.3 Garden plots

Gardens as distinct events are difficult to capture archaeologically. Areas of Māori-made soil had been identified as tracts at S14/194 (Gumbley and Hoffmann 2013) but because the areas had been intensively cultivated and cropped for maize fodder of the preceding two decades the data was compromised and it was not possible to be confident these were not aggregations at the archaeologist's convenience. Because S15/424 was well-preserved there was potential for the identification of garden plots. Data was gathered through two mechanisms to attempt to reconstruct cultivation areas or tracts. The first technique involved a survey using a 25 mm strew-type soil auger to detect transported alluvium and the second involved the examination of the profiles of a network of investigation trenches.

The study area was 13 hectares with 634 soil auger samples with spacing varying between nine and thirteen metres (Figure 5.41). Areas within the study area where the lower topography indicated the presence of old palaeochannels and associated poorly drained soils were not examined during the auger survey although later examination confirmed that made soils were absent in these areas. The northern margins of the study area abutted a large area of poorly-drained Te Kowhai series soil and this boundary formed the northern margin of the Māori-made soils. Of the 634 auger sites 167 identified made soil deposits (Figure 5.42). This was used to define the site S15/424 as 6.2 hectares although this was a convenient aggregation of a cluster of borrow pits and their associated made soils that was objectively distinct from the surrounding borrow pit and made soil clusters.

When trenches were excavated these were restricted to a total area of 8.4 hectares reflecting property boundaries, which includes 80 percent of S15/424. Both sets of data when examined as separate data sets provided contrasting results (Figures 5.41–46, Table 5.3). The soil survey data results combined into a total area of 12.29 hectares that aggregated into six tracts with a median area of 2048 m^2. The trench data indicates there were 8.28 hectares and eleven tracts with a median area of 690 m^2. When the two data sets were interpreted together they showed there were 12.85 hectares of Māori-made soils, slightly more than the total given by the auger data alone and substantially more than the trench data alone. The combined data sets increased to number of tracts to fourteen with a median area of 918 m^2, although they ranged from 97 m^2 to 1913 m^2.

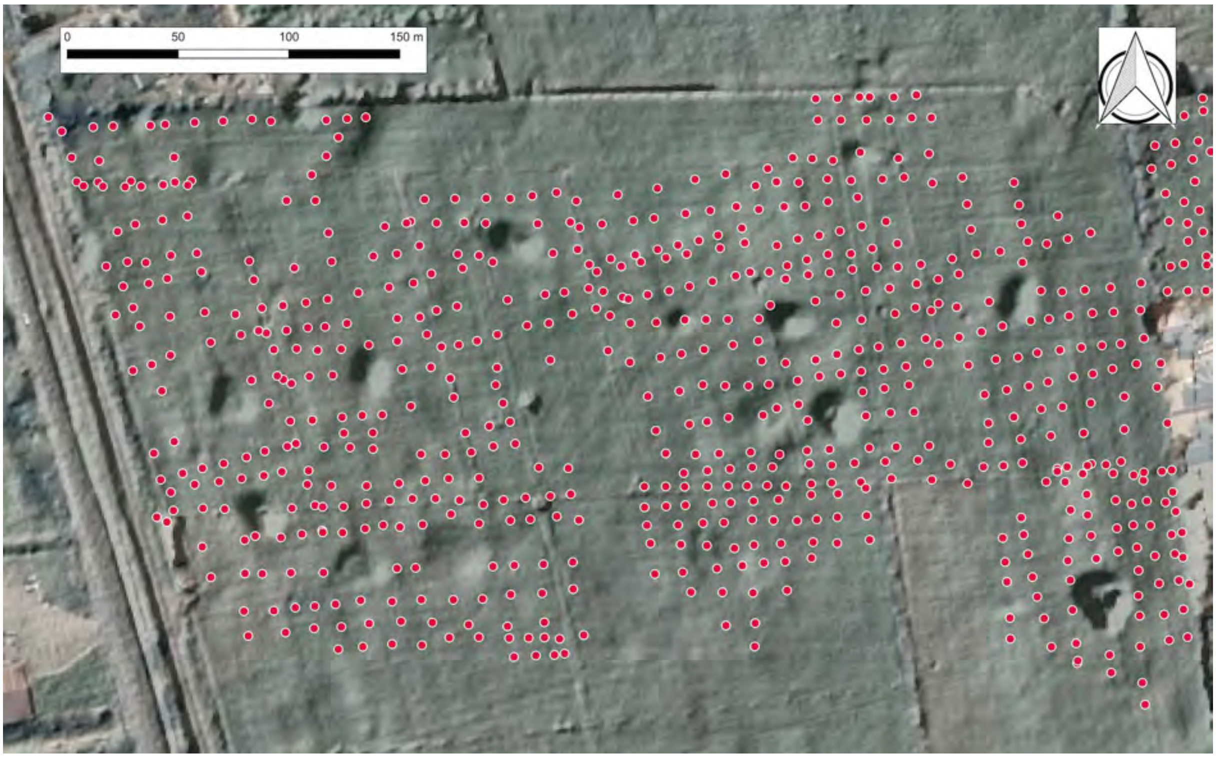

Figure 5.41: S15/424. Map showing the distribution of soil auger survey points.

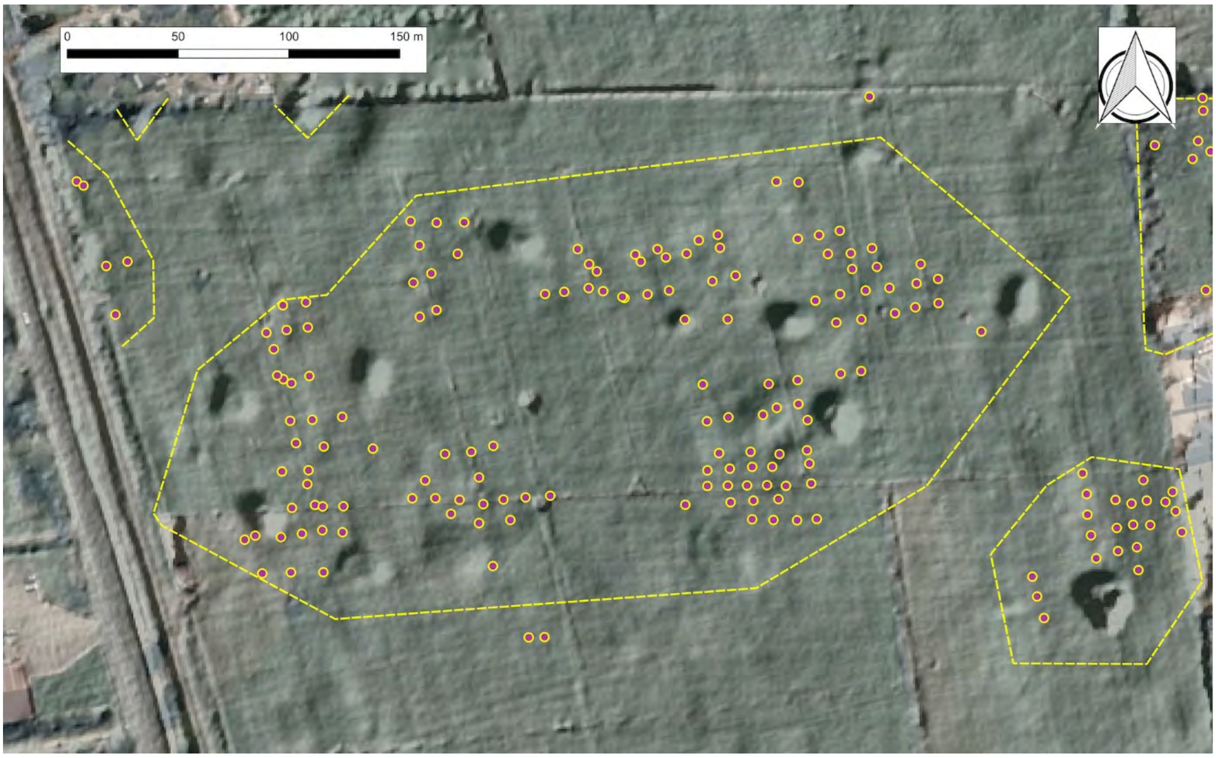

Figure 5.42: S15/424. Map showing the locations of soil auger samples where Māori made soil was identified. The yellow dashed lines indicates the artificial site aggregations with S15/424 central.

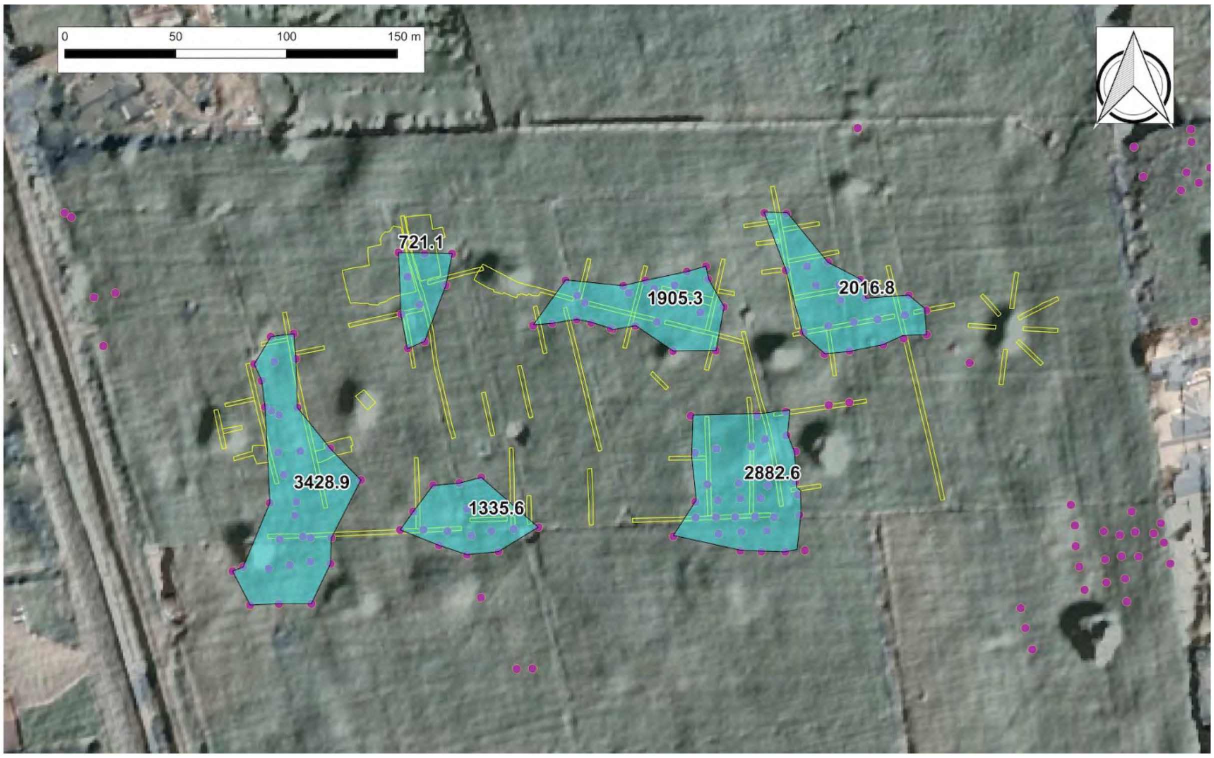

Figure 5.43: S15/424. Māori-made soil tracts derived from soil survey data. Investigation trenches are shown in yellow.

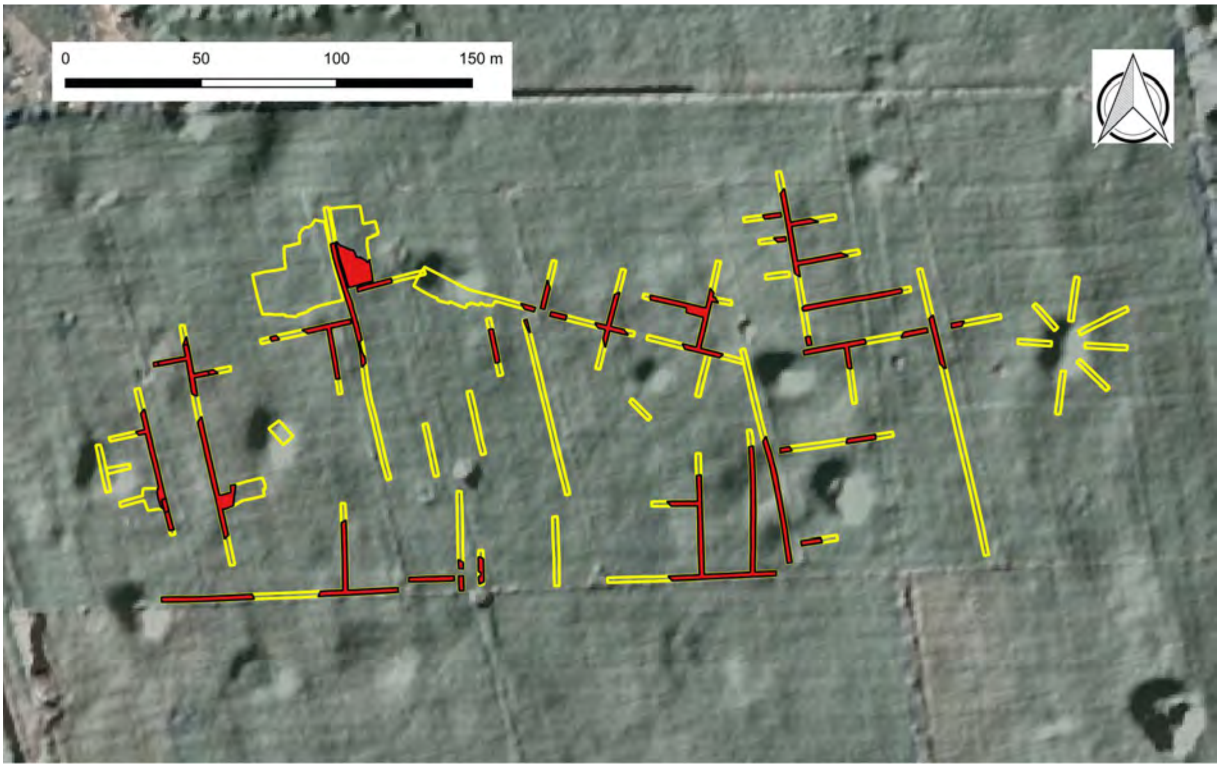

Figure 5.44: S15/424. Made-soil (red) identified in investigations trenches (yellow).

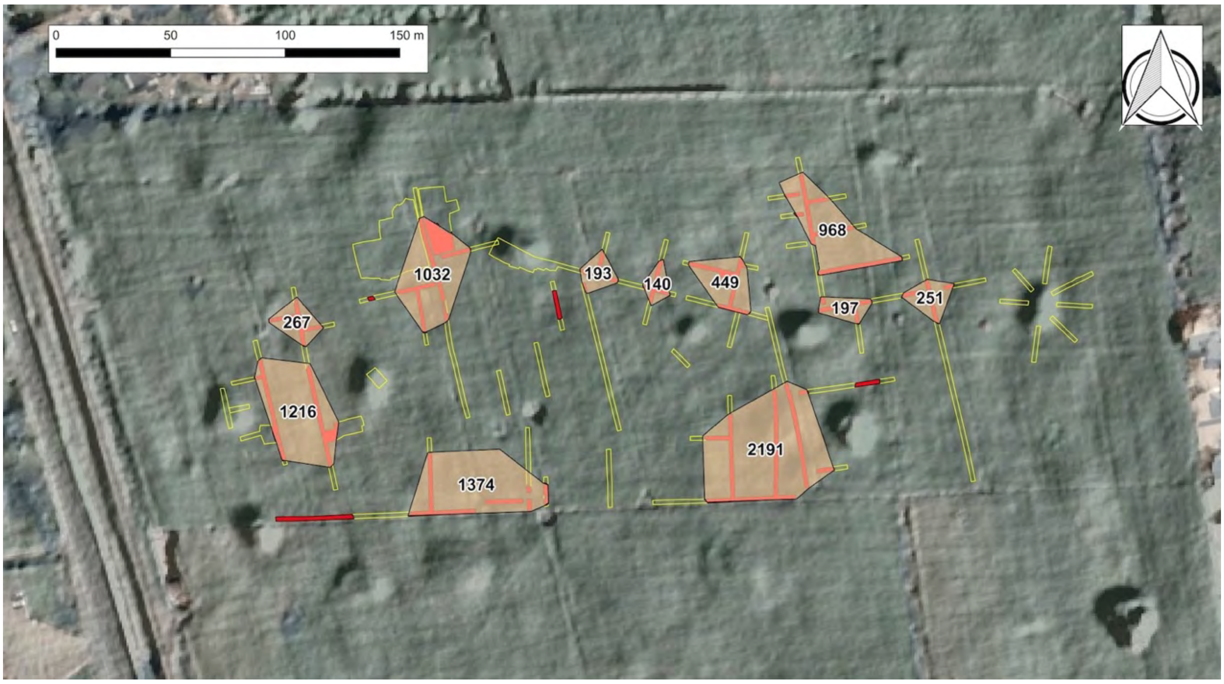

Figure 5.45: S15/424. Made-soil tracts aggregated from trench data.

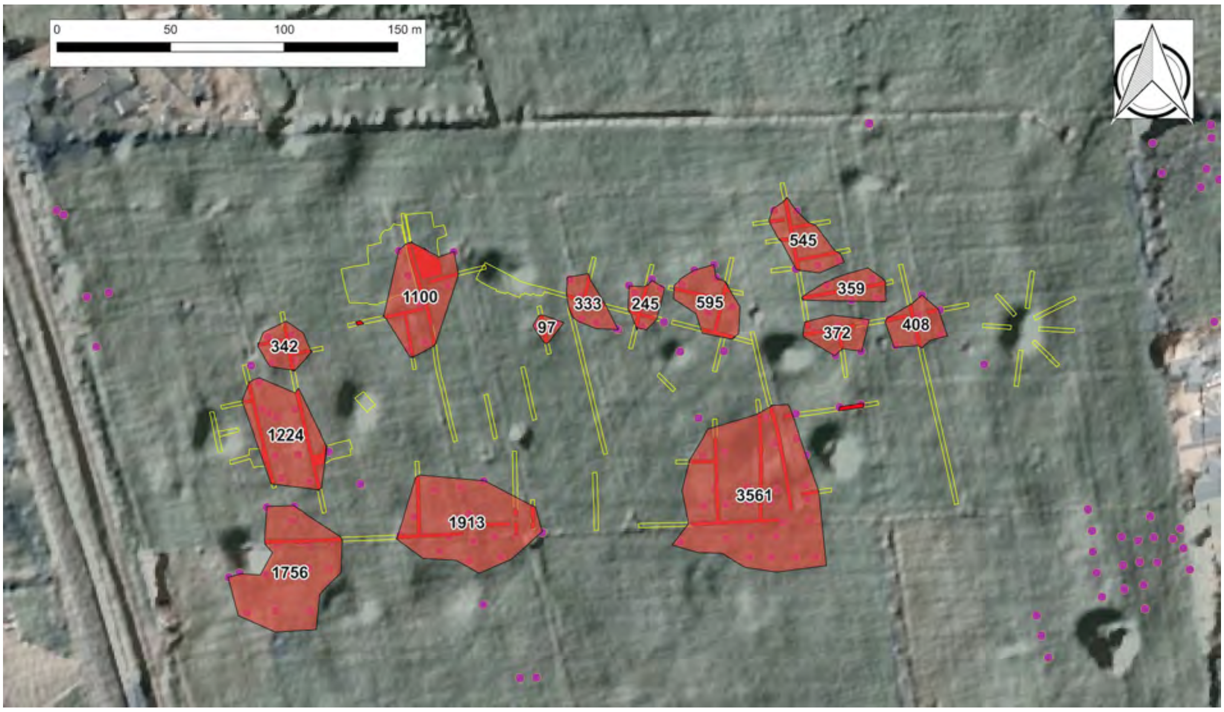

Figure 5.46: S15/424. Made-soil tracts developed through comparison of the soil survey and investigation trench data.

Table 5.3: S15/424. Summary table for data on the size of garden tracts. Note the data from the soil auger survey and trench investigations, when combined disaggregates the tracts to 14 from 6 based on the soil survey data and 11 based on trench data alone.

Auger Data only (m^2)	**Trenches data only (m^2)**	**Auger & Trench combined (m^2)**	
2017	251	545	
1905	197	359	
2883	968	408	
721	2191	372	
3429	449	595	
1336	140	245	
	193	333	
	1032	3561	
	267	97	
	1216	1100	
	1374	342	
		1224	
		1913	
		1756	
12290	**8278**	**12850**	**Total tract areas**
2048	**690**	**918**	**Mean tract area**

5.3.4 Mixed soil units

The mixed soils have been identified at four sites (S14/194, S14/221, S14/489, S15/300)[22] in the belonging to the Waikato Horticultural Complex. Similar soil mixing phenomena have been reported from the Bay or Plenty (Campbell and Farley 2008; Gumbley and Phillips 2004; Jones 1991; Moore 2009) and Taranaki (Bader 2014) where they have been interpreted as associated with cultivation of *kūmara*.

The mixed soils at the three sites share general morphology with specific characteristics varying depending on parent soils. This unit including elements of the subsoil and topsoil enriched with charcoal and all mixed together (Figure 5.47). They vary from very well mixed with a relatively homogeneous appearance to others where the constituent elements were distinct and visible as large mottles or patches that tend toward the appearance of bands. The orientation of the banding in the profile may vary from close to horizontal to inclined up to approximately 45 degrees. The mixed soil units are typically 20 to 40 cm thick but Keith (2019a) recorded a thickness of 65 cm in one trench at S14/489. In all cases the lower boundary of these units is wavy to variable degrees. At S14/195, where the mixed soil units had direct stratigraphic relationship with the TAL units the mixed soils units present as stratigraphically the equivalent of the Ab soil horizon and are a mixture of the Ab and elements of the B horizon. These represent explicit examples of digging over the topsoil and working up the paler subsoil. In this sense these units may represent activities associated with the forest clearance as much as activities associated with garden development.

At S14/195 the mixed soil units were always found under the TAL and did not contained added sand or gravel (Gumbley and Hoffmann 2013). At S14/489 the mixed soils were isolated from the made-soils on poorly drained soils (Keith 2019a). At S14/221 the mixed soils were also separated from but adjacent to the areas of made soils and also contained no sand or gravel. The mixed soil identified by Hoffmann (2012) at S15/300 was located mid-slope immediately below borrow pits dug into the shoulder at the top of the slope and it is likely these result from deposition of tephritic overburden from the quarrying. At the other sites mixed soils were found on level surfaces.

The area of the mixed soil in Tract A at S14/195 (Gumbley and Hoffmann 2013) was

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[22] S14/194 - Gumbley & Hoffmann 2013; S14/221 - Hoffmann 2013; S14/489 - Keith 2019a; S15/300 - Hoffmann 2012.

measured to be 875 m^2 and the area at S14/221 was 500-550 m^2 (Hoffmann 2013). In general, the other areas of mixed soil appear to have been of similar extents and much smaller than the associated areas of made soil.

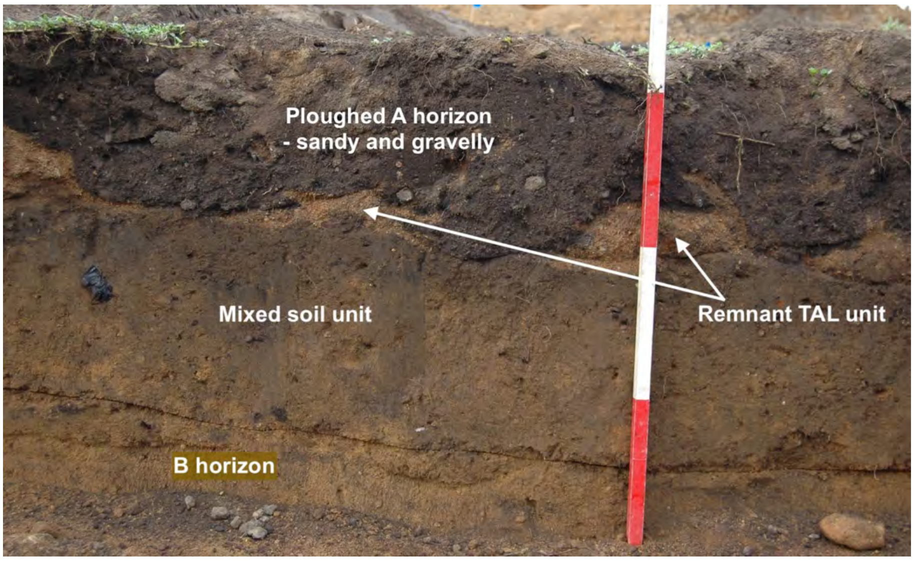

Figure 5.47: S14/195, Tract J/K, Profile E. Mixed soils underlying the TAL unit, which has mostly been ploughed out and mixed with the turf.

5.3.5 Drainage features (drains and sumps)

Features relating to garden drainage have been reported at three sites in the inland Waikato, S14/194 (Gumbley and Hoffmann 2013), S14/203 (Gumbley & Higham 1999) and S14/250 (Gumbley and Gainsford 2020c). In each case these have been found around the peripheries of all otherwise dry horticultural sites. By this it is meant, that most of the associated horticulture had taken place on adjacent, slightly higher and well-drained soils, in particular Horotiu loam but also Bruntwood loam. In each case the drainage features were situated on lower-lying, poorly drained Te Kowhai silt loam. At each site the drains have been relatively shallow, narrow and generally dendritic in pattern, with smaller limb channels feeding a trunk unit carrying the collected water away to a nearby gully or waterway (Figure 5.48). Altogether, the pattern suggests ad hoc solutions to episodic problems rather than as a planned element of the original garden design.

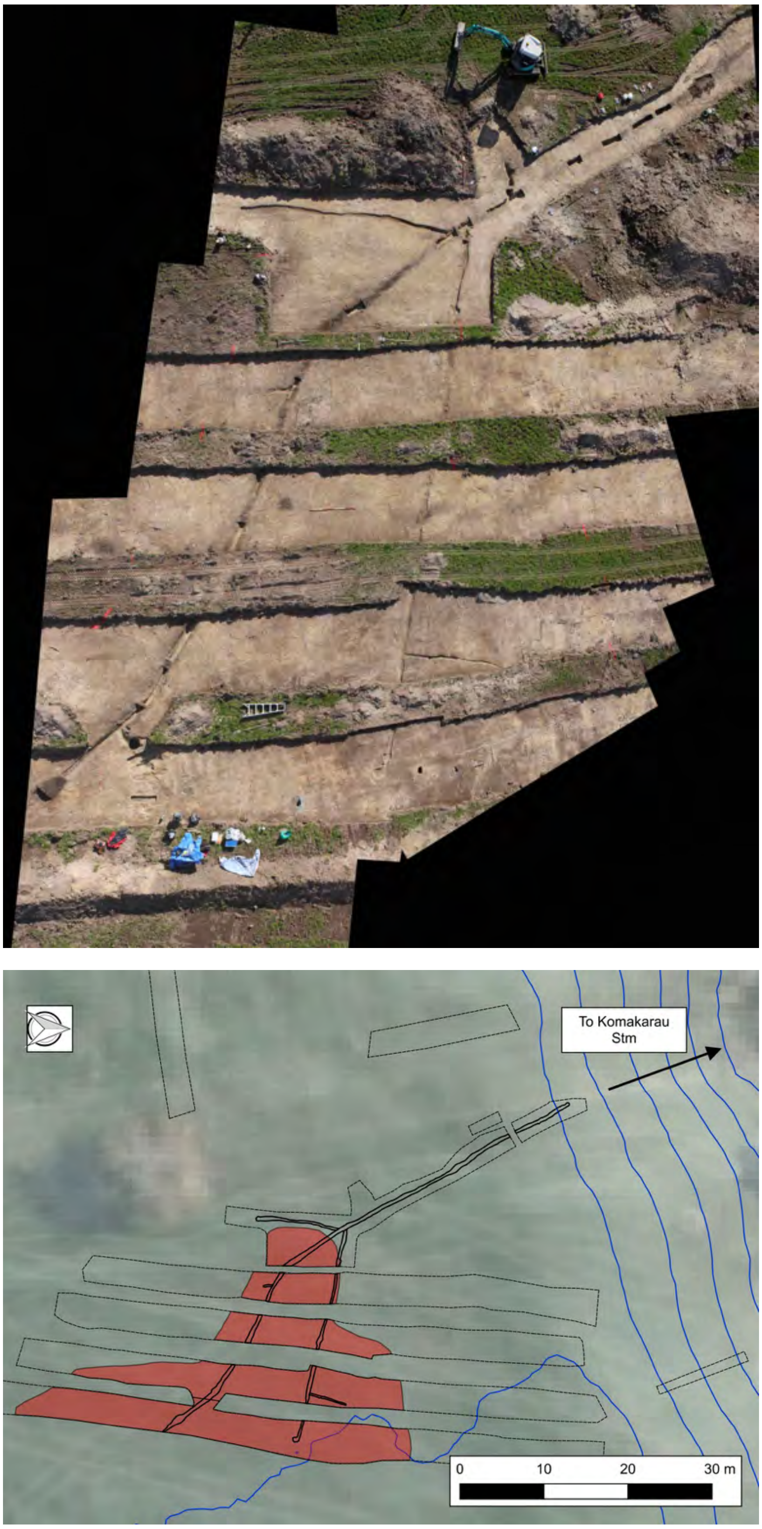

Figure 5.48: S14/250 drainage system. Upper image is a photogrammetric image from drone photography. Lower image shows the drains in relation to the extent of the Māori-made soil. Contours are 1 m intervals. (From Gumbley and Gainsford 2020c; drone photography Ben Thorne, Datum Archaeology.)

5.4 Ancillary elements

5.4.1 Storage pits

Aside from the archaeological features associated with the garden development phase and the forest clearance phase, storage pits of various types are commonly, almost universally associated with the horticultural sites in the inland Waikato. The two principal storage pit classes found in New Zealand, rectangular semi-subterranean storage pits (Figure 5.49) and subterranean bell-shaped pits, are represented in the Waikato, but these pit classes are conspicuously less common then an array of smaller pits found among the gardens. The smaller pits are often bundled into a generalised catchall class called bin pits, a descriptor which really only refers to the passing similarity of these to modern storage bins. In reality these are excavations into the soil with a variety of plan shapes and dimensions, along with a similar range of subsurface forms and dimensions.

As discussed earlier, we know from historical reference that the rectangular and bell-shaped storage pits were used primarily for the seasonal storage of sweet potato (Best 1976). The role of the much smaller bin pits is less well understood and their roles were likely to have been more diverse than the larger pits. For example, pits of this generic class are often found associated with midden sites and in pā, which suggests they may have had role in storing not only vegetable crops but equally could have been for storing other things such as fish or gathered food. To some extent they appear to have operated a little like the modern domestic refrigerator.

Given their direct association with horticulture when they are present among the horticultural sites of the inland Waikato it is very tempting to assume that the primary association relates to the storage of crop or seed material. However, they are also found in the same sites within zones containing features typical of domestic occupation, such as clusters of postholes and fireplaces. In reality these features appear to have been multifunctional with a function consistent with the broader site context in which they are present.

Figure 5.49: S15/771. Rectangular crop storage pits. The uppermost pit was 3.4 x 2.5 m; middle pit was 2.9 x 2 m; bottom pit was 2.9 x 2.3 m (North is to top.) (Gumbley & Laumea 2019b; drone image: Ben Thorne, Datum Archaeology.)

5.4.2 Domestic occupation

While this dissertation is focused on the horticultural system it is important to note that the horticultural sites are often accompanied by zones of domestic occupation. These zones are often located within or immediately adjacent to the horticultural areas themselves. Without going into this aspect of the horticultural cultural cycle in detail they typically consist of distinct clusters of fireplaces, post holes representing structures including shelters, fences and storage pits of various sizes and forms (Figure 5.50). These domestic contexts are interpreted as the seasonally occupied campsites used by the horticulturalists while gardening.

Figure 5.50: S15/424. Drone photograph of the domestic occupation zone of the site. Note the small rectangular crop storage pits and postholes alignments. The principal cooking area was located to the right centre of the photograph. A TAL was deposited over the eastern margin of the domestic zone including the principal cooking area. (North is to top.) (Gumbley & Laumea 2019b; drone image: Ben Thorne, Datum Archaeology.)

5.5 Summary

The staging process of the Waikato Horticultural Complex has left tangible archaeological remains with discrete deposits and features (BSDs and charcoal concentrations) reflecting the initial clearance of forest. The subsequent development and use of the gardens through to their abandonment can also be followed in detail. Borrow pits represent both the largest and most striking elements of the WHC landscape with over 6000 identified, representing at least 4.1 million cubic metres of extracted sand and gravel. The commonalities in their fill patterns described a standardised and repeated process during use until abandonment. Clusters of small pits often coalesced into the larger aggregated pits highly visible in the landscape. The extracted material has been identified in two constituent elements of the gardens, the massive TAL units and the fill units of the discrete BSH features. Both of the phenomena directly represent the remains of the gardens. The BSH offer unique representations of the layout of individual plants within gardens, with plants spaced around 60 cm apart at average densities of 31,600 plants per hectare. Drains are an occasional attribute of gardens and appear as ad hoc remedies where gardens ‘spill-over’ from well-drained soils rather than a planned component. Like all garden systems in New Zealand, except perhaps the explicitly swamp garden systems, crop storage pits are a common feature integral to the horticultural process and are found among or adjacent to the gardens and also co-located with small garden associated kāinga.

6 Geoarchaeology and the Waikato Horticultural Complex

6.1 Introduction

Archaeological data show there are two similar but distinct manifestations of Māori-made soils indicating two parallel agronomic processes with both involving the use of transported sand and gravel. Questions of depositional processes and function of the transported material within the associated archaeological contexts are central to understanding the nature and potential motives for the application of such a labour-intensive process. These questions relate to borrow pits, BSHs and TAL phenomena and are detailed in Table 6.1. The aim of this chapter is to describe and examine the physical characteristics of these phenomena through the lens of geo-archaeological methods. Specifically, the results of two analytical approaches will be described; soil particle size and soil micromorphology. The first were carried out at the soil science laboratory at the University of Waikato (Appendix B), the second by Dr Elle Grono at the School of Archaeology and Anthropology, The Australian National University, Canberra. The soil micromorphology analyses are detailed in reports by Grono found in Appendices C and D.

Table 6.1: Questions pertaining to composition, characteristics and depositional processes relating to archaeological features and contexts identified through archaeological investigation.

Agronomic context	Archaeological context	Question
Borrow pits	Upper fill unit:	Is it formed naturally or through anthropogenesis? What is it composed of?
	Black layer:	What is it composed of? How did it form? What is its relationship to the fill units above and below?
	Lower fill unit:	Is it formed naturally or through anthropogenesis? What is it composed of?
Bowl-shaped hollows		What is the fill of the hollows? Where does the fill come from? Are there any additives to the fill contributed by humans? What was the formation process of the fill? Does it exhibit evidence for disturbance deriving from tuber growth or harvest?

		What is the relationship between the BSH fill and the black layer? Does the black layer contain any evidence for the fabric of a mound?
Transported alluvium layer	A horizon/Turf:	How was this horizon formed? What is its relationship to the transported alluvium layer?
	Transported alluvium layer (TAL):	What is the structure and composition of this layer? What are its formation processes? What are the similarities/ differences between the dark upper sub-unit and the paler lower sub-unit? What is the relationship between the two sub-units?
	Upper B horizon:	What is the nature of the boundary between the TAL and the B horizon? Does this inform us about agronomic practices? What is the nature of the Upper B horizon – was it formed naturally or was it anthropogenic?

6.2 Archaeological sites and geoarchaeological sampling

All of the sites sampled and reported were located on the Hinuera Formation with Horotiu Series loam the parent soil or, in the case of lower borrow pit fill units, sediments derived in part from B horizon loam and the alluvium substrate (C horizon) (Figure 6.1). While the data is specific to sites on the Hinuera Formation, similarities with the sediments of the Taupo Pumice Alluvium mean that the results can be generalised. Where feasible comparisons were made with local unmodified examples of Horotiu loam.

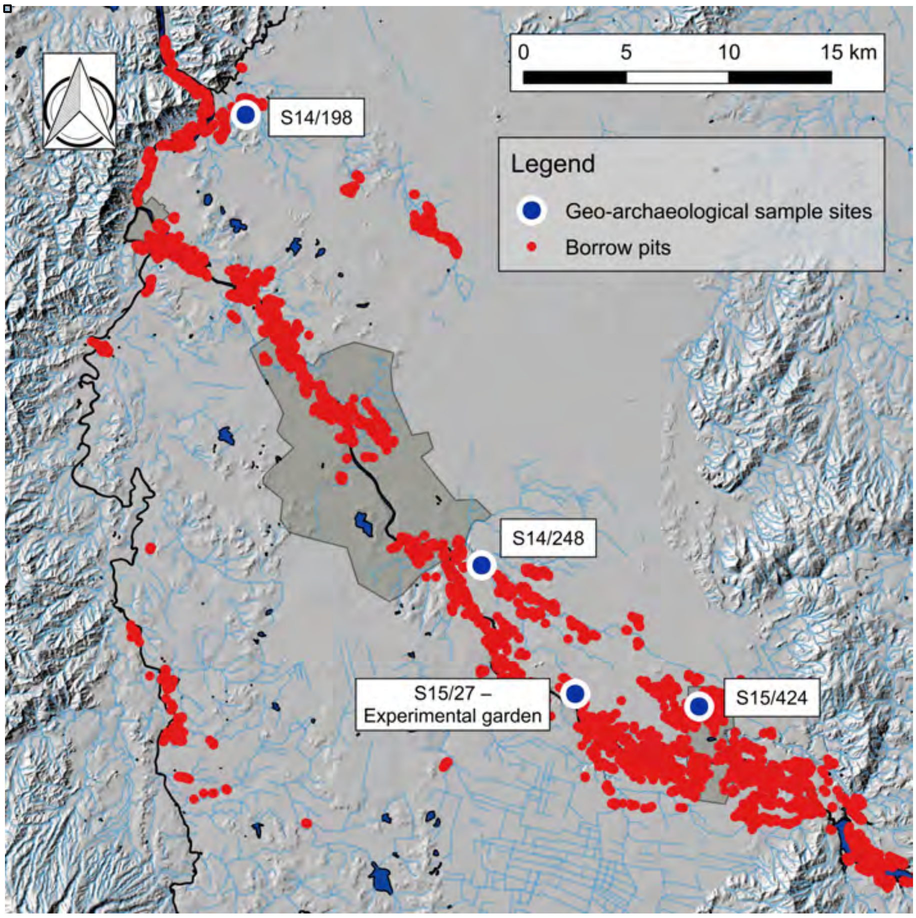

Figure 6.1: Map showing the locations of archaeological sites sampled for geoarchaeological analysis.

6.2.1 S15/424

S15/424 is the best preserved site showing distinct evidence for the TAL (TAL) form of agronomy. This site, until shortly before fieldwork in 2016, had been in the ownership of the same family since the early twentieth century. Jim Burke (personal communication), the most recent member of the family to own the area investigated, stated that his family had not ploughed this area but always managed it as pasture. This was consistent with the absence of any evidence of post-colonial cultivation (i.e. ploughing) during the investigation.

Three sets of sediment samples were recovered for soil particle size analysis. Two of these were recovered from TAL units in Trenches 3 and 4. Five samples were recovered at both locations with one each from the following units:

- A horizon,

- Upper TAL unit,
- Lower TAL unit,
- Upper Ab horizon,
- B horizon.

A reference set of two samples were also recovered from Tr 53 located in an adjacent area where the soil had no evidence for anthropogenesis. These samples were from the A horizon and the B horizon. The TAL layer was visibly differentiated into an upper and lower units based on colour; dark greyish-brown for the upper and dark yellowish-brown for the lower unit.

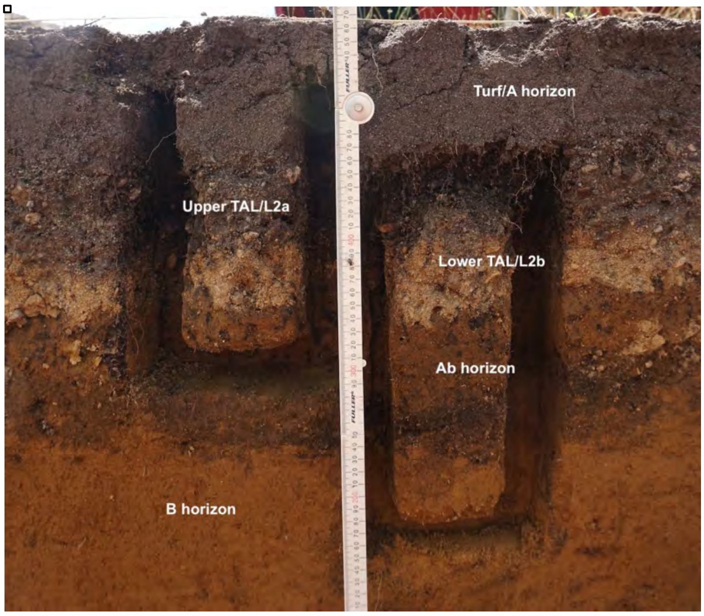

Figure 6.2: S15/424 samples LP1-II (left) and LP1-III (right) prior to the application of plaster bandages to encase the monoliths for micromorphological analysis.

Two sets of monoliths were recovered from two separate trench (Tr) profiles, LP1 and LP2, which sampled the same units as the samples for soil particle size analysis. LP1 had a clear series of 5 units that were covered by the two monoliths. The two monoliths were prepared at LP1 and these were aligned to sample the five visible sediment units (Figure 6.2)

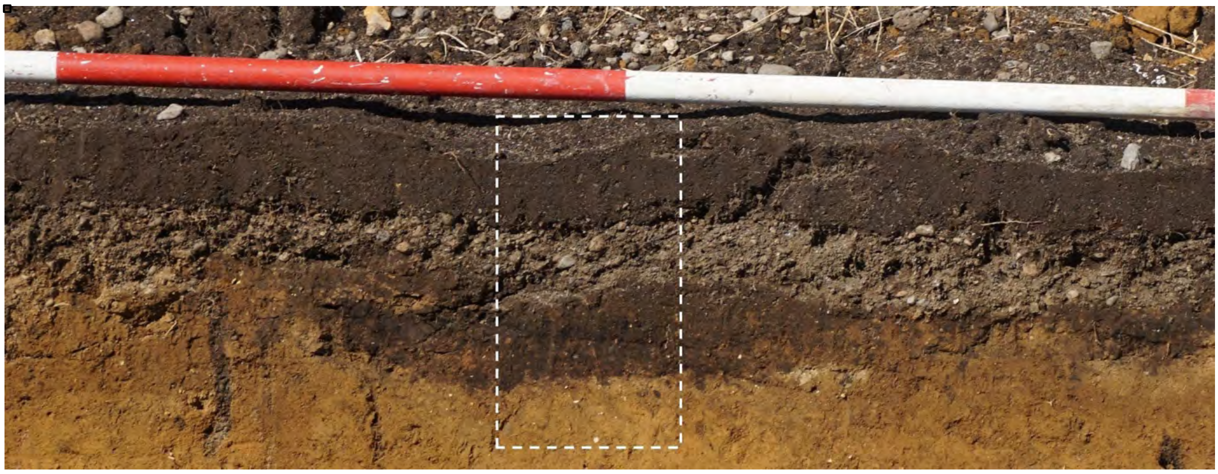

Figure 6.3: Profile atS15/424 from which sample LP2-V was removed. The sample location is outlined in white. Note the concentration of charcoal and orange sediment present in the upper B horizon within the sample area. (Intervals on scale = 0.5 m).

Figure 6.4: Close-up of sample LP2 –V from S15/424 before excavation and plastering of the samples.

LP2 was selected to capture a variation profile to capture samples from a location where visible evidence of what appeared to be burning in-situ with a concentration of charcoal in the upper Ab horizon. One monolith from LP2 was analysed (Figures 6.3 & 6.4).

6.2.2 S15/27

Only small scale archaeological investigations have occurred at S15/27 and an experimental garden was also created adjacent to this site. Sediment sampling for particle size analysis was carried out in the context of both of these activities (Gumbley 2014; see also Chapter 9 for reference to the experimental garden). Altogether 17 samples have been analysed from this site, with all of the samples being recovered from around the northern-most or outer ring of borrow pits. Of the 17 samples, ten were taken from the TAL unit. Of these only one sample site, S03b, showed differentiation of the TAL unit into a darker upper sub-unit and a paler lower sub-unit. The other samples were either from the A horizon/topsoil unit overlying the TAL (2 samples), the B horizon (3 samples) and the C horizon (2 samples). Of the three samples recovered from the B horizon, two were from the area of the experimental garden (i.e. outside the area of made soils) and the third was from immediately under the TAL unit and will have included elements of the upper Ab unit. No differentiation was made between the B horizon and the modified upper Ab horizon.

Soil monoliths were recovered from the experimental garden site to provide comparative material for the micromorphological analysis of sediments from S14/198 and S14/248.

6.2.3 S14/198

The soil micromorphology was carried out on samples from S14/198 in the context of a larger archaeological investigation of a group of borrow pits in which a set of BSHs were found (Gumbley and Gainsford 2020a). This was the second archaeological investigation of this site (Campbell and Harris 2011). The samples were taken from two locations. The first was an exposed profile through a borrow pit where samples were recovered to examine the fill process of the pit. Four monolith samples were taken covering three contexts; the early pit fill unit, the black layer and the upper fill unit, along with the boundaries between these (Figure 6.5). The second set was directed to examining the BSHs and their relationship with surrounding sediments; the sediments into which there were dug (lower borrow pit fill) and the overlying black layer. Two monolith samples were recovered and examined (Figures 6.6 – 6.8).

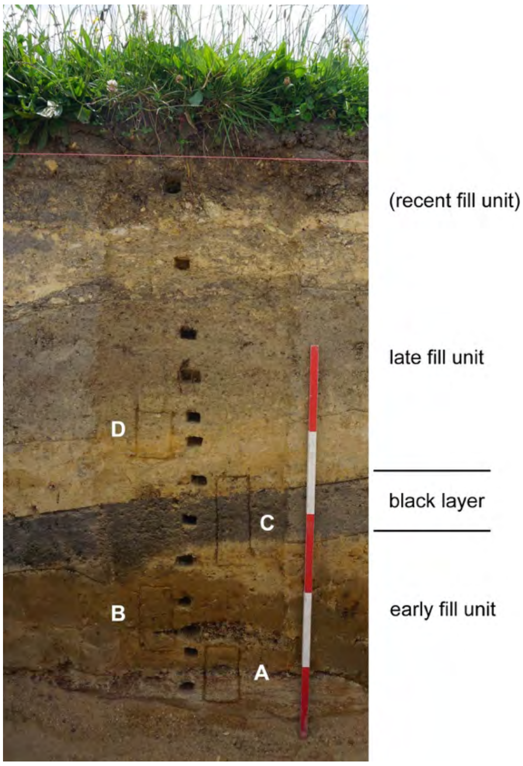

Figure 6.5: Profile of the western baulk of Tr 10 (S14/198) with monolith samples A–D incised into the profile. (Scale = 1 m).

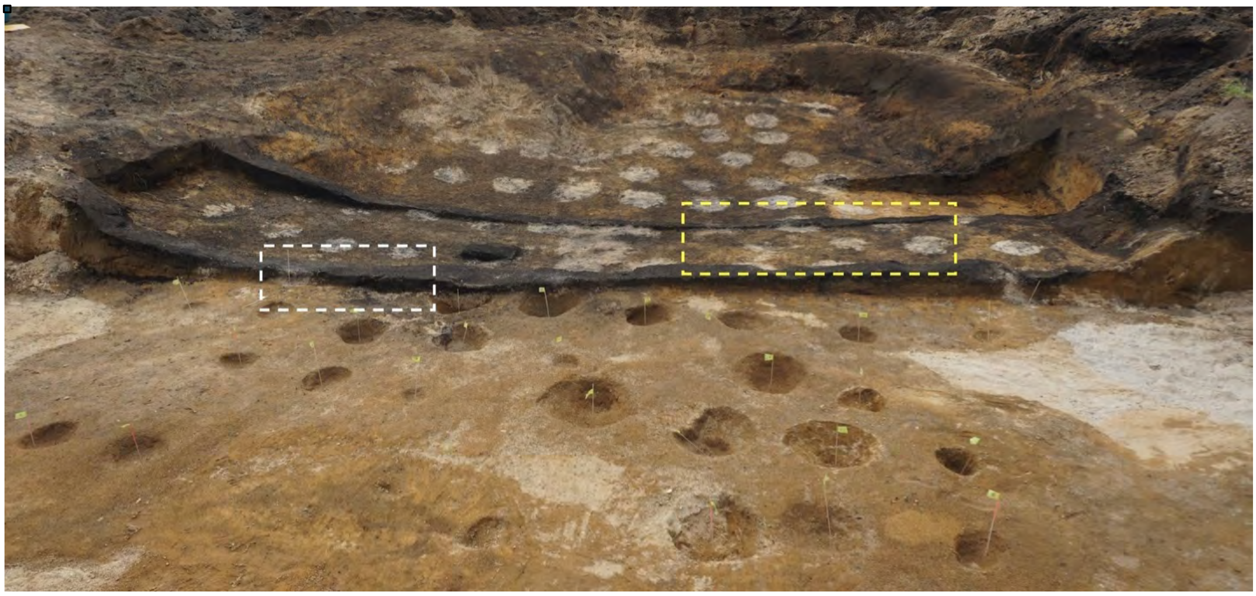

Figure 6.6: Sampling location at S14/198 indicated by white dashed outline at left. The yellow dashed outline shows the location of BSHs with loam remnants on the upper surface of the sand fill.

Figure 6.7: Sample location at S14/198 prepared for sampling.

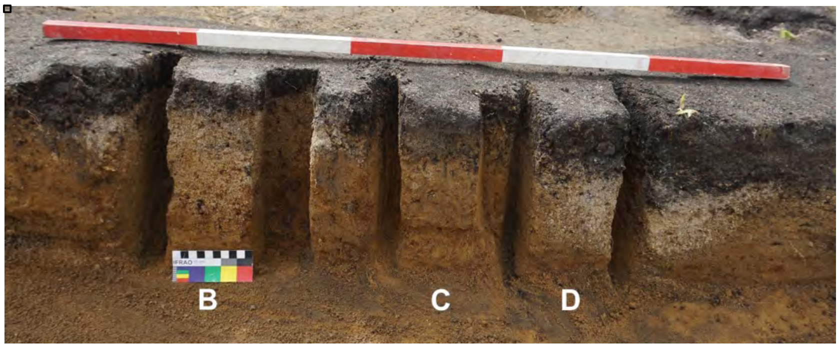

Figure 6.8: Monolith samples from Trench 11 at S14/198 cut prior to application of plaster bandages.

6.2.4 S14/248

Soil monoliths were also recovered from S14/248, which contained two sets of BSHs in adjacent borrow pits. One cross-section profile was selected for sampling (Figure 6.9 & 6.10). Like S14/198 these explored the nature of the BSHs and the surrounding sediments (the early borrow pit fill unit and the black layer) and their relationships.

Figure 6.9: Sampled profile at S14/248 with the two sample locations highlighted. Monoliths A–D on the left and E and F on the right. (Scale = 0.5 m: image E. Grono 2016).

Figure 6.10: S14/248 samples enclosed in plaster bandages. Monoliths A–D (left) and E and F (right). (Scale intervals = 20 cm: images E. Grono 2016).

6.3 Results of geoarchaeological analyses

6.3.1 S15/424 and S15/27: Soil colour and particle size analysis

Soil colours for Māori-made soils are generally predictable with variation dependent on the parent soil and to some degree post-depositional processes. The descriptions in this section are drawn from two sites with Horotiu loam parent soils but only the soil colours from S15/424 were recorded and are described. Soil particle size profiles have been aggregated and condensed into three ad hoc classes to facilitate comparisons. The raw data can be found in Appendix B. Soil particle size data are organised by Wentworth (1922) size class and sorted by Krumbein (1934) phi scale. The three condensed classes are:

- gravel: particles larger than 2 mm (-1 phi),
- sand: particles corresponding to the range of medium to very coarse sand (0.25 – 2mm; 2 – 0 phi),
- fine: fine sand and smaller particles (smaller than 0.25 mm; ≤ 3 phi).

Aggregation of soil particle sample results occurred with the S15/27 data where the results of individual samples for the A horizon, TAL and B horizon were amalgamated and averaged.

Soil colours are based on field observations and examination of recovered samples with descriptions using the Munsell Color System (Munsell Color 2009) (Table 6.2).

Table 6.2: Soil colours for samples from S15/424.

		Munsell colour code		**Colour**	
		Dry	**Wet**	**Dry**	**Wet**
Tr 53 control	A horizon	10YR 5/3	10YR 3/3	brown	dark brown
Tr 53 control	B horizon	10YR 7/6	10YR 5/4	yellow	yellowish-brown
Tr's 3 & 4	A horizon	10YR 3/2	10YR 2/1	very dark greyish-brown	black
Tr's 3 & 4	TAL upper - L2a	10YR 3/2	10YR 2/1	very dark greyish-brown	black
Tr's 3 & 4	TAL lower - L2b	10YR 4/4-5/4	10YR 3/4-4/4	yellowish-brown	dark yellowish-brown
Tr's 3 & 4	Upper Ab horizon	10YR 5/4	10YR 3/2-3/3	yellowish-brown	very dark greyish-brown to dark brown
Tr's 3 & 4	Subsoil - B horizon	10YR 6/6	10YR 5/6	brownish-yellow	yellowish-brown

6.3.1.1 A horizon

A horizons overlying the made soils are darker, almost black, compared to the unmodified A horizon (Table 6.2). They are also significantly coarser with 30-34 % more sand than the control A horizon (15-16 % sand) (Table 6.3). The aggregated samples from S15/27 are distinct from S15/424 with significantly higher proportions of sand. While no evidence for modern cultivation, in the form of plough-marks in the B horizon surface was apparent, it is possible that shallow ploughing had occurred, which would have resulted in mixing coarse material into the A horizon. Alternatively, since the two samples were only 10 m apart more localised activities, such as stock scraping may have had a similar impact.

Table 6.3: A horizon particle size analysis summary for S15/424 and S15/27. Trench 53 control is unrelated to the TAL. Samples from Trenches 3 and 4 overlay TAL units as did the aggregated samples from S15/27. (see Appendix A).

	Wentworth class		v. fine sand and finer	sand	gravel
Site	Phi scale		4 or finer	3 to 0	–1 or coarser
S15/424	Tr 53 control	A hz	84.4	15.6	0
S15/424	Tr 3	A hz	69.79	30.21	0
S15/424	Tr 4	A hz	65.8	34.2	0
S15/27	aggregated	A hz	18	81.2	0.5

6.3.1.2 *Transported alluvium layer (TAL)*

The C horizon (Hinuera alluvium), as the source of the added coarse material, naturally varies in texture corresponding to local variations in the alluvium. The alluvium is typically dominated by sand with gravel sub-dominant and fine material present in low proportions.

Table 6.4: TAL unit particle size analysis summary for S15/424 and S15/27. The TAL unit results from S15/424 are expressed separately for the upper (a) and lower (b) sub-units. These are compared to particle size analysis results for C horizon (Hinuera alluvium) sediments recovered from the area of S15/27. Results for 5 samples TAL from S15/27 have been aggregated and averaged. (see Appendix A).

	Wentworth class		v. fine sand & finer	sand	gravel
Site	Phi scale		4 or finer	3 to 0	–1 or coarser
S15/27 Exp-garden	aggregated	C hz	6.9	53.3	39.8
S15/424	Tr 4	L2a	10.0	28.2	61.8
S15/424	Tr 4	L2b	19.5	37.2	43.3
S15/424	Tr 3	L2a	14.19	15.15	70.66
S15/424	Tr 3	L2b	21.39	28.12	50.48
S15/27	aggregated	L2	12.3	55.2	32.5
S15/27	S03b upper	L2a	8.7	55.6	37.7
S15/27	S03b lower	L2b	5.7	64.8	29.5

The upper and lower TAL units (L2a and L2b) share the same particle size class profile (Table 6.4) despite variation in colour (Table 6.2). C horizon samples show little difference with the TAL units whether considered as separate sub-units or aggregated (Table 6.4). The TAL units vary from the C horizon parent material with a higher proportion of fine material together with a lower proportion of sand.

6.3.1.3 B horizon

The B horizon was examined in two parts at S15/424 where the upper part of the subsoil, the Ab horizon, was sampled and examined as a separate unit to the main body of the B horizon. The two elements of the B horizon were not discriminated at S15/27 while results from two samples from the adjacent experimental garden were aggregated and averaged.

The Ab horizon was darker than the remainder of the B horizon (Table 6.2) with the texture more variable, both finer and coarser than the control sample (Table 6.5). The sample from S15/27 (S01) should be considered to have at least partially included the Ab. This sample also had a substantially elevated level of coarse material, particularly in the fine and medium sand classes, in contrast to the B horizon control samples. The B horizon was shallow at this sample site (18 cm below ground surface) which would have facilitated high levels of bioturbation, re-working sand down into the unit from the TAL.

Table 6.5: B horizon particle size analysis summary. Trench 53 control is unrelated to the TAL. Samples from Trenches 3 and 4 underlay TAL units as did sample S01 from S15/27. Ab units directly underlay the TAL units. (see Appendix B)

	Wentworth class		v. fine sand and finer	sand	gravel
Site	Phi scale		4 or finer	3 to 0	–1 or coarser
S15/424	Tr 53 control	B hz	75.8	24.2	0
S15/424	Tr 3	Ab	63.6	36.4	0
S15/424	Tr 3	B hz	75.6	24.4	0
S15/424	Tr 4	Ab	81.8	18.2	0
S15/424	Tr 4	B hz	72.4	27.6	0
Exp.-garden	aggregated	B hz	63.8	35.5	0.7
S15/27	S01	B hz	34.7	64.5	0.8

6.4 Soil micromorphology: S14/198, S14/248 and S15/424

6.4.1 S14/198 and S14/248

The data for soil monolith samples from S14/198 and S14/248 is described and results discussed in Grono 2017 (reproduced in Appendix C). The following is a summary of Grono's results and discussion as they bear on the questions identified in the introductory section of this chapter. Grono examined seven thin sections from S14/198 with three directed to understanding the fill process of a borrow pit and the other four considering questions relating to BSHs. Another six thin-sections from S14/248 were also examined in relation to processes associated with BSHs. Comparative samples came from the abandoned experimental garden plot referred to elsewhere in this thesis (4 thin sections) and from the C horizon alluvium exposed at S14/198 (1 thin section).

In the examination of the thin section samples associated with the borrow pit fill Grono identified four microfacies (A–D). Grono's observations are summarised in Table 6.6.

Table 6.6: Provenance and summary of observations of microfacies associated with the examination of the borrow pit fill process at S14/198 (Grono 2017: 14–15).

Microfacies	Provenance	Summary of Grono's observations
A	upper fill unit of the borrow pit above the black layer	– evidence for bioturbation common – very low frequency of charcoal – no evidence for anthropogenic activities
B	the boundary between the upper fill unit and the black layer	– 4 mm thick – moderately sorted coarse charcoal and mineral elements – horizontal orientation – probable lag deposit typical of in-wash – indirectly resulting from human activity (local landscape fires)
C	the black layer	– very dark colour – highly organic – minimal charcoal
D	lower fill unit under the black layer	– undeveloped microstructures – lack of pedological development – variable packing and porosity – absence of bioturbation or other evidence of biological activity

Following examination of the thin sections in relation to the BSHs and their surrounding sediments Grono identified three microfacies in the samples from S14/198 and five microfacies in thin sections from S14/248 (Grono 2017: 15-19). The results and observations are described in Table 6.7.

Table 6.7: Provenance and summary of observations of microfacies associated with the examination of the processes associated with BSHs at S14/198 and S14/248 (Grono 2017: 15-19).

Microfacies	Provenance	Summary of Grono's observations
E	S14/198 - black layer overlying bowl-shaped hollow	– rich in micro-charcoal – amorphous organic fine material – weathered tephra – neo-formed clay – abundant evidence for bioturbation – charcoal evidence of local landscape fires – short time period between end of use of the BSH and formation of black layer – admixed boundary between fill of hollows and black layer probably associated with bioturbation – compared to the black layer in in the borrow pit sequence this black layer it is darker and with more organic content.
F	S14/198 - boundary between the side and base of the bowl and the surrounding sediments (fill of borrow pit)	– tephra and clay (weathered tephra) – high heterogeneity – complex microstructure – affected by formation of the hollow – evidence of bioturbation
G	S14/198 - bowl-shaped hollow fill	– fill is coarse grained material (sand and gravel) consistent with the C horizon (Hinuera alluvium) – no microstratigraphy within the fill unit – loose and porous structure consistent with rapid deposition – no evidence for additives (e.g. wood-ash, tephra or charcoal)
H	S14/248 - black layer overlying bowl-shaped hollow	– very heterogeneous compared to E (S14/198) – predominantly composed of organic material and charcoal – abundant charcoal in horizontal orientation – in-situ fracturing of charcoal – low porosity (possibly from trampling) – microstratigraphy lenses of charcoal and sand – sharp boundary between the black layer and bowl-shaped hollow – evidence for bioturbation at the boundary between the black layer and bowl-shaped hollow – possible evidence for the remains of the growing mounds

I	S14/248 - boundary between black layer and fill of hollow	– high porosity – bioturbation – evidence for soil disturbance – high frequency of organic material – evidence for weathering in-situ of tephra
J	S14/248 - fill of hollow	– coarse material (sand and gravel) consistent with the C horizon (Hinuera alluvium) – evidence for disturbance from horticultural activities – loose and porous structure – no microstratigraphy – evidence for rapid filling – no evidence for additives (e.g. wood-ash, tephra or charcoal) – shares attributes with G (S14/198)
K & M	S14/248 - greyish-brown units associated with black layer	– formed through pedogenesis
L	S14/248 - boundary between black layer and lower fill unit of borrow pit	– bioturbation and tephra weathering dominant processes – boundary is diffuse – possible evidence for anthropogenic disturbance

6.4.2 S15/424

While the results from S14/198 and S14/248 refer to examples of the bowl-shaped hollow form of gardening those from S15/424 examine the nature and depositional processes of the transported alluvium form of gardening.

The data for soil monolith samples from S15/424 is described and results discussed in Grono (2020; reproduced in Appendix D). Grono examined eleven thin sections from archaeological contexts and a twelfth from an unmodified soil profile for comparison. Altogether Grono (2020) identified six microfacies (A-F) and results and observations are summarised in Table 6.8.

Table 6.8: Provenance and summary of observations of microfacies associated with the examination of the processes associated with TAL form found at S15/424 (Grono 2020: 4-10).

Microfacies	Provenance	Summary of Grono's observations
A	Turf topsoil (A horizon)	– homogenised unit – evidence of soil fauna excrements – component material randomly arranged – vertical channels – fine amorphous organic matter – fine tephra glass – occasional microcharcoal

		– moderately well sorted fine to medium sand – evidence for bioturbation common
B	upper TAL unit (L2a)	– 4-6 cm thick – distinct upper boundary with the turf – structure porous and loose – poorly sorted, dominated by coarse grain size (0.5–16 mm) – fine fraction has the same characteristics as the fine fraction in the turf and includes occasional microcharcoal – fine fraction product of bioturbation
C	Lower TAL unit (L2b)	– 5-6 cm thick – boundary with mF-C (L2a) distinct on the basis of colour – poorly sorted, dominated by coarse grain size (0.5–16 mm) – structure porous and loose – fine fraction has the same characteristics as the Ab horizon (mF-D) – amorphous organic matter – microcharcoal – iron staining
D	Upper B horizon (Ab)	– 8-13 cm – upper boundary distinct to diffuse – heterogeneous – microstructure predominantly biological in origin – moderate porosity – component material randomly arranged – fine material heterogeneous – elevated microcharcoal – charcoal 2-10 % arranged randomly – fine material predominantly excremental fabrics – fine material admixed by bioturbation – moderately sorted very fine to coarse sand – charcoal ranges from micro to 14 mm – evidence for bioturbation
E	Organic and charcoal rich sub-unit within upper B horizon	– abundant charcoal (micro to 4 mm) – plant residues present – fine material includes charcoal, amorphous organic matter, fine tephra glass, weathered clays arranged as excremental fabrics – mineral grains uncommon
F	B horizon (natural subsoil)	– variable microstructure – component s randomly arranged – moderate porosity – fine to coarse sand – charcoal ≤ 1 mm – amorphous organic matter – clays developed from weathered tephra

6.5 Interpretation of geoarchaeological data

6.5.1 Borrow pits

Grono (2017: 30-31) concluded that the lower fill unit in borrow pits formed through rapid deposition with no evidence for bioturbation or pedogenesis. Rather, it reflected the deliberate filling of the pit.

As a general observation, visible charcoal is common in the lower fill units (microfacies D) of borrow pits, but without discernible pattern. However, the black layer (microfacies C) is a common fill unit distinctive for the regularity of its presence and stratigraphic situation. This layer always overlies the typical lower fill unit described above and usually dips in profile from the sides to the middle, tending to be thicker in the middle and thinning to the edges. Although the unit is always very dark it ranges in colour from black to dark grey. Experience during the recovery of charcoal from black layer samples from a number of borrow pits demonstrate that the frequency of charcoal can be quite variable, with some samples containing very little despite the sediment being black. Most recovered charcoal is from bracken fern with *mānuka* also found with some frequency. Occasional examples of charcoal from forest species are also found.

Grono's examination of the black layer (microfacies C) from four contexts in two separate sites led her to conclude it was formed through pedogenesis in a stable landscape, including the weathering of tephra and accumulation of humic acid staining, which probably developed consequentially to colonisation by bracken fern. This, along with the charcoal information (Chapter 7), indicates natural processes, particularly staining from humic acids, are the probable cause of the layer's andic properties rather than a reflection of high charcoal content alone. The upper surface of the black layer was composed of a lag deposit including charcoal and volcanoclastic sediments washed into the pit. The high organic content and charcoal reflect human inputs into the local environment and revegetation with bracken fern. Grono (2017) also concluded that there was a brief interval between the abandonment of the garden and the formation of the layer. In some areas there was clear evidence of trampling of the surface at S14/248 that were absent at S14/198. Fireplaces were observed in the surface of the black layer at S14/248 (Sian Keith personal communication; personal observation in the field).

The upper layer (microfacies A in Table 6.6) immediately overlying the black layer was composed of tephragenic sediments with ample evidence for bioturbation and in-situ weathering. Grono (2020) concluded it was a natural deposit.

It is common to find more superficial fill deposits in borrow pits, often with clearly imported fill material including historic and recent domestic and farm rubbish.

6.5.2 Bowl-shaped Hollows (BSHs)

Grono (2017) determined that the fill material of the BSHs (microfacies G and J) matched the Hinuera Formation alluvium substrate (C horizon) closely with no evidence for additives such as wood-ash, tephra or charcoal. The arrangement of the fill material indicate the hollow was filled in a single rapid event. The boundary between the upper part of the fill unit and the overlying black layer (microfacies I) was diffuse with evidence for disturbance of the upper margin of the fill unit. Grono found evidence for what she tentatively interpreted as the remains of a loam growing mound (*puke*) on the upper margins of the fill unit. The absence of disturbance deeper than the upper margins of the bowl-shaped hollow fill unit demonstrates that these were undisturbed following deposition. By implication this indicates that the coarse fill in the hollows did not function as a growing medium for tubers. Otherwise substantial disturbance at the time of tuber harvest would be expected.

In addition to the micromorphological evidence, some bowl-shaped hollow fill units at S14/198 had visibly distinct deposits of tephragenic yellowish-brown loamy material present on their upper surfaces. These inclusions were also texturally distinct from the overlying black layer but were similar to the matrix into which the hollows had been dug (Figures 6.11–6.13). In this sense the black layer proved a useful stratigraphic barrier sealing this zone from later disturbance.

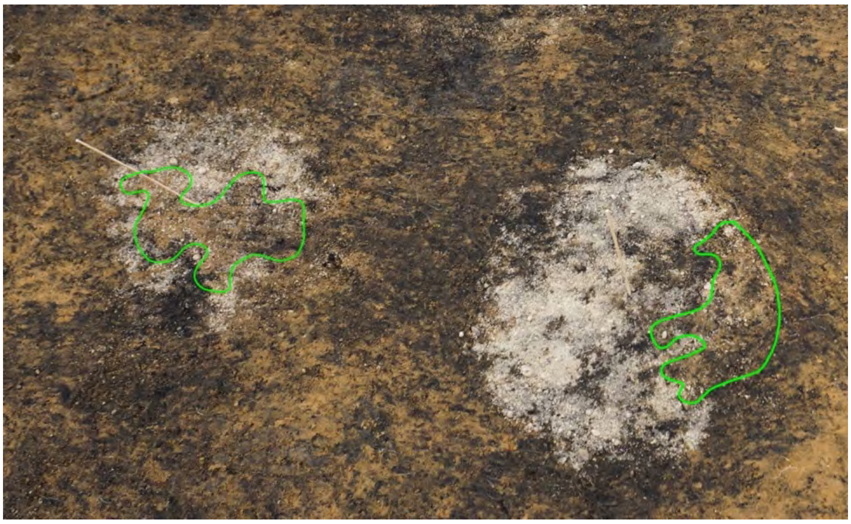

Figure 6.11: Image showing two BSHs (F79 and F78) at S14/198 with fill unexcavated showing loam patches in the upper surface (outlined in green).

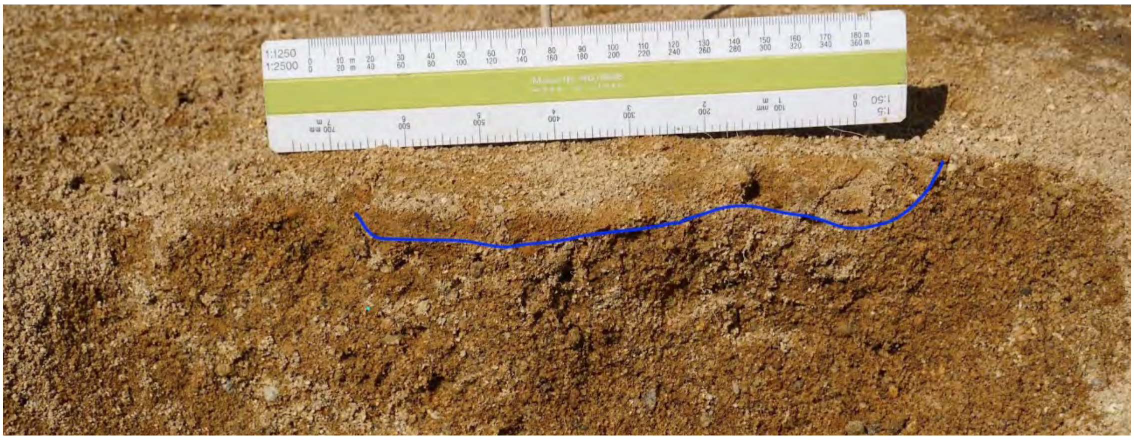

Figure 6.12: Remnant loam cap sitting on sand/gravel fill of bowl-shaped hollow F11 at S14/198. Blue line indicates base of loam cap.

Figure 6.13: Image of bowl-shaped hollow F42 (S14/198) partially excavated. The black layer remains in place adjacent to the BSH (left on image) with part of the loam cap in-situ (centre) and the upper surface of the sand/gravel fill exposed (right).

Again, like the black layer (microfacies E and H) sampled within the borrow pit fill sequence described above, the black layers overlying the sampled BSHs at S14/198 and S14/248 predominantly developed through natural pedogenic processes, predominantly bioturbation but also staining from humic acids. This should be unsurprising given that these were still within a borrow pit, albeit following gardening on the back-fill surface. The effects of human activity could be detected in two aspects of the layers' formation. The first was the inclusion of enhanced levels of charcoal reflecting localised firing of vegetation, including bracken fern. The second was evidence for trampling of the surface of the black layer at S14/248 (microfacies H), which was consistent with the field identification of fireplaces located within the borrow pit depression on the surface of the black layer. Also at S14/248 a less melanic aspect of the black layer (microfacies K and M) was also sampled and analysed and this showed evidence for pedogenic processes without the anthropic overlay. Grono (2017) proposed that evidence indicated there was only a brief interval between the abandonment of the gardens and the formation of the black layer at both S14/198 and S14/248.

6.5.3 Transported alluvium layer (TAL)

The turf layer at S15/424 (microfacies A in Table 6.8) is a soil unit formed through pedogenesis where its melanic appearance results from natural processes rather than a high frequency of charcoal. Its well-sorted sandy composition results from bioturbation moving sand upward from the underlying TAL. Absence from the turf unit of very coarse sand and gravel found in the transported alluvium demonstrates the absence of modern cultivation which would have mixed the turf with the upper part of the TAL.

The TAL can be divided into two sub-units, upper (microfacies B in Table 6.8) and lower (microfacies C in Table 6.8), on the basis of colour, otherwise there is little difference between the upper and lower sub-units. Both are comprised of the same coarse material; sand and gravel. This material is effectively the same as the sand and gravel found in the Hinuera Formation alluvium (C horizon). The minor differences lie in the origin of fine fractions in both sub-units. In the dark upper sub-unit the fine material has the same characteristics as the fine fraction in the turf unit; it was generated by the activities of soil fauna and had been subject to bioturbation. In the lower, paler, sub-unit the fine fraction matches the fine material in the Ab unit and probably resulted from two mechanisms, bioturbation and the mechanical displacement of material through horticultural activities such as crop harvesting. Both the upper and lower sub-units had low frequencies of charcoal and organic matter. Grono (2020) found that the TAL unit as a whole had a structure typical of rapid deposition resulting from deliberate anthropic processes consistent with the dumping of the transported alluvium to form mounds and also with the collapse or dispersal of mounds at harvest. The obvious alternate explanation for the TAL units' functional is as a mulch. However, distinct separation of the TAL material from the underlying subsoil, apart from the minor admixing described below, argues against this. The recovery of a root crop from under a mulch layer would result from the admixing of the coarse material of the TAL with the subsoil as the roots were dug and removed, a phenomenon not witnessed archaeologically to date.

The upper B horizon (microfacies D and E in Table 6.8) has been proposed by soil scientists as the remains of a buried topsoil (Bruce 1978 and 1979; Grange et al. 1939; McCraw 1967) and Grono's (2020) results supported this. This soil unit is only found in association with Māori-made soils and is absent from the same parent soils when adjacent to tracts of made-soil. Charcoal found in this unit is often coarse and present at high frequencies. Archaeologically this may be recognised as visible structures representing recognisable charred roots systems but generally the charcoal is disorganised. This charcoal, when analysed, is derived from a range of forest species rather than reflecting species normally associated with the revegetation (seral) process (Chapter 7). The evidence demonstrates that a major formation process for this unit involved the clearance of forest by fire. The upper margins of this unit have admixing of coarse material from the overlying TAL in a manner consistent with both bioturbation and gardening processes. Grono (2020) also detected evidence for pedogenesis occurring after the forest firing and prior to the development of the garden indicating a time lapse between the two activities.

6.5.4 Frequency of gardening

A general question refers to the frequency of gardening. For example, Leach (1980) proposed that a permanent cycle of cropping followed by fallow before re-establishment of gardens did not occur. The implication is that gardens were often used only once.

Two sites, S14/158 (Campbell and Harris 2011) and S14/468 (Gumbley and Gainsford 2019) have evidence for overlapping sets of BSHs suggesting at least two garden plots at the same location. At S15/465 (Gumbley and Laumea 2019) there is evidence for a field system employing BSHs with a subsequent use of the TAL form. However, at most sites there is an absence of archaeological field data that indicates multiple episodes of gardening. On the basis of the sampling and analyses from S14/198, S14/248 and S15/424, Grono (2020) found no evidence for multiple episodes of disturbance or development consistent with re-use of the sites for gardening and concluded that each sample site probably only experienced a single cycle of gardening followed by rapid colonisation by bracken fern following the cessation of gardening.

7 Taphonomic contexts and wood charcoal significance

7.1 Relevant native plant communities in the Waikato lowlands

The patterns of native plant associations with landforms are generally well understood, despite the near annihilation of the lowland forest in the Waikato region. Of specific interest are the vegetation types found on the alluvial plains, which are further dis-aggregated into the constituent landforms; low mounds or ridges, shallow depressions or swales, and low terraces adjacent to the Waikato River. Of the three landforms pre-European horticulture is found on the low ridges and mounds, and the low terraces adjacent to the river. The poorly drained soils found in the shallow depressions, which are typically Te Kowhai Series soils, seldom have evidence for gardening other than where garden systems on the well-drained low ridges (typically Horotiu series soils) spill over and into the swales or low ground. However, their proximity to the gardened areas (they are commonly adjacent) does mean that species that were found on this landform may also be represented among the charcoal sampled from the gardens.

An inventory of vegetation types which grew on various landforms found in the district is reconstructed by Clarkson et al. 2007 (Tables 7.1-7.2). Vegetation on the low ridges is characterised as mixed conifer-broadleaved forest with 28 characteristic species including trees, shrubs, ferns and lianes. The vegetation in the swales is characterised as *kahikatea* dominated semi-swamp forest with 30 characteristic species; trees, shrubs, lianes, ferns, sedges and grasses. The forest on the low terraces adjacent to the river is characterised as *totara-matai-kowhai* forest with 33 characteristic species; trees, shrubs, ferns and grasses. Of the sites considered in the charcoal data, 18 were located on the low ridges of the Hinuera Formation and two on the low river-side terraces.

Of the sites considered in the charcoal data, 18 were located on the Hinuera Formation surface and two on low river-side terraces.

Table 7.1: Plants found on low ridges on the alluvial plains describing a mixed conifer-broadleaf forest (Clarkson et al. 2007: 6).

Characteristic Species	**Life Form**
Asplenium gracillimum	fern
Blechnum filiforme	fern
cabbage tree (*Cordyline australis*)	tree
fragrant fern (*Microsorum scandens*)	fern
hangehange (*Geniostoma rupestre subsp. ligustrifolium*)	shrub
hen and chicken fern (*Asplenium bulbiferum*)	fern
kahakaha (*Collospermum hastatum*)	epiphyte
kahikatea (*Dacrycarpus dacrydioides*)	tree
kiekie (*Freycinetia banksii*)	scrambler
kowhai (*Sophora microphylla*)	tree
lacebark (*Hoheria sexstylosa*)	tree
mahoe (*Melicytus ramiflorus subsp. ramiflorus*)	tree
matai (*Prumnopitys taxifolia*)	tree
mamaku (*Cyathea medullaris*)	tree fern
Microlaena avenacea	grass
Metrosideros perforata	liane
Oplismenus imbecillis	grass
pate (*Schefflera digitata*)	shrub
pukatea (*Laurelia novae-zelandiae*)	tree
raurekau (*Coprosma grandifolia*)	shrub
rewarewa (*Knightia excelsa*)	tree
ribbonwood (*Plagianthus regius*)	tree
rimu (*Dacrydium cupressinum*)	tree
silver fern (*Cyathea dealbata*)	tree fern
tawa (*Beilschmiedia tawa*)	tree
titoki (*Alectryon excelsus*)	tree
totara (*Podocarpus totara*)	tree
turepo (*Streblus heterophyllus*)	tree

Table 7.2: Plants found on low ridges on the low terraces (TPA) adjacent to the Waikato River describing a totara-matai-kowhai forest (Clarkson et al. 2007: 7-8).

Characteristic Species	**Life Form**
Astelia solandri	epiphyte
Blechnum chambersii	fern
B. filiforme	fern
cabbage tree (*Cordyline australis*)	tree
Coprosma rhamnoides	shrub
C. rigida	shrub
hinau (*Elaeocarpus dentatus*)	tree
kahakaha (*Collospermum hastatum*)	epiphyte
kahikatea (*Dacrycarpus dacrydioides*)	tree
kanuka (*Kunzea ericoides var. ericoides*)	tree
kiekie (*Freycinetia banksii*)	scrambler
kiokio (*Blechnum novae-zelandiae*)	fern
kowhai (*Sophora microphylla*)	tree
lacebark (*Hoheria sexstylos*a)	tree
mahoe (*Melicytus ramiflorus subsp. ramiflorus*)	tree
mamaku (*Cyathea medullaris*)	tree fern
matai (*Prumnopitys taxifolia*)	tree
Melicope simplex	shrub
Microlaena avenacea	grass
northern rata (*Metrosideros robusta*)	tree
Oplismenus imbecillis	grass
Pellaea rotundifolia	fern
Polystichum richardii	fern
raurekau (*Coprosma grandifolia*)	shrub
rewarewa (*Knightia excelsa*)	tree
ribbonwood (*Plagianthus regius*)	tree
rimu (*Dacrydium cupressinum*)	tree
tawa (*Beilschmiedia tawa*)	tree
totara (*Podocarpus totara*)	tree
turepo (*Streblus heterophyllus*)	tree
silver fern (*Cyathea dealbata*)	tree fern
wheki (*Dicksonia squarrosa*)	tree fern
wheki ponga (*Dicksonia fibrosa*)	tree fern

7.2 Taphonomic context types

Chapter 5 describes an array of archaeological features associated with the Waikato Horticultural Complex and sub-groups of these can be assigned to feature classes associated with distinct phases of the agricultural cycle. This, in turn, has enabled taphonomic processes involved in the creation and deposition of archaeological material to be comprehended (Chapter 6). Understanding this facilitates the reconstruction of the inter-relationships between the gardeners, the cycle of the gardens and the local environment. The contexts of the sampled charcoal are well understood and can be placed within the horticultural cycle; vegetation clearance, garden development and use, and garden abandonment. This chapter outlines the associations between the archaeological contexts and the plant ecology at the varying phases of the gardening cycle.

Established stratigraphic relationships, as described in Chapter 5, permit the identification of associations between the various classes of archaeological contexts and stages in the horticultural cycle (Table 7.3). For example, those that relate specifically to forest clearance events (basin-shaped depressions and charcoal patches or concentrations located within the Ab horizon). The contexts associated with garden development and use include fill units of borrow pits and storage pits, BSHs, transported alluvium layers, drains and fireplaces) and garden abandonment (charcoal-rich layers capping borrow pits and storage pits). However, charcoal found in these contexts may have been re-worked from their original context to be placed in deposits secondary to their origin contexts.

We know from the established stratigraphic relationships that a set of feature classes predate the garden development. These are basal fill layers in basin-shaped depressions (Figure 7.1), along with charcoal concentrations (Figure 7.2) found in the buried topsoil (Ab horizon). The basal layers of basin-shaped depressions are rich in organic material without clasts of any sort and are understood to be accumulations from in-wash and similar processes with occasional in-situ burning in the depression base. This feature class understood to result from actions to remove the root systems of small trees and shrubs during forest clearance. Therefore, based on the archaeological relationships, charcoal from these contexts, along with any associated plant microfossils, are artefacts of the vegetation present before garden development and use, and probably represent remains of the cleared forest.

Archaeological investigations have demonstrated that borrow pits were back-filled as the extraction proceeded and that these deposits include significant amounts of charcoal and occasionally include charred branches and stems (Figure 7.4). The branches and stems were deliberately transported to the borrow pits, presumably represent debris removed from the gardens. It is probable that ambient charcoal from the immediate vicinity of the borrow pits became incorporated into the back-fill matrix through mechanisms such as in-wash, aeolian re-working and through transportation on gardeners' feet. Possibly the source for this charcoal is residue from forest clearance, which has intruded into later features.

Often, although not universal, a distinct black and often charcoal-rich layer is present overlying the original back-fill layers of borrow pits. This represents a second stage in the filling process reflecting natural processes that have trapped more ambient charcoal created by fires in the environment, which occurred after the borrow pits were back-filled and abandoned.

A similar set of relationships appear to have existed for the crop storage pits (Figure 7.5). Charcoal may be found on the floor of the pit reflecting material used within the pit (e.g. bedding for stored crops[23]) and present at the time of abandonment. Charcoal is also present in pit fill matrices where this can be found as a distinct event of deliberate back-filling in a similar manner to borrow pits. Again, this material probably includes charcoal in the environment local to the pits. Storage pits also often have black organic and often charcoal-rich layers capping the principal fill unit. Although not examined through microstratigraphy it is probable that a similar depositional process has occurred here because of the similarity of the units to those found in borrow pits. It is reasonable to infer that this charcoal represents vegetation present after gardens were abandoned.

BSHs and TALs, which relate specifically to garden use, are formed from the deposition of transported alluvium. Hinuera alluvium is devoid of charcoal and it is very rare in Taupo Pumice Alluvium, and when present has a distinctive baked appearance. Any charcoal from these contexts can be treated as remnants of vegetation present when garden use commenced.

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[23] For example, the springy stems of the vine-like fern *mangemange (Lygodium aticulatum*) have been found as charred remnants on the floors of two crop storage pits at S15/771 (Gumbley et al. 2019b) and another storage pit at S15/423 (Potts 2019). Graham (1922) reported this practice as an eyewitness of flooring in small storage pits near Auckland in the early twentieth century and Wallace (personal communication) reports its common occurrence in charcoal samples from the floors of storage pits. At S15/771 the pit super structures had been removed and prior to re-filling the 'bedding' was burned.

With this in mind it is possible to describe taphonomic paths for charcoal found in different types of feature or context. This is summarised in Table 7.3.

Table 7.3: Taphonomic considerations for charcoal in relation to various feature classes and contexts.

Agricultural cycle stage	**Feature/context class**	**Description**	**Taphonomic association (origin of charcoal)**
FC-1: Forest clearance	Ab horizon (upper unit of the B horizon)	Charcoal from contexts within the upper-most element B horizon (Ab) predate garden formation and are artefacts of the local vegetation prior to the establishment of the cultivation features. Associated feature classes are charcoal concentrations, charred root systems in the Ab horizon. (Figure 7.2)	Pre-garden vegetation
FC-2: Forest clearance	Basal units in basin-shaped depressions	The organic base fill units of basin-shaped depressions are thought to be the accumulations of litter collecting in the depressions formed after removal of tree and shrub root systems. (Figure 7.1)	Pre-garden vegetation
GDU-1: Garden development and use	Transported alluvium layers and bowl-shaped hollows	Sand and gravel quarried from Hinuera Formation alluvium is free from charcoal, and it very rare in the TPA. Therefore, charcoal found in contexts where this material is applied will reflect ambient charcoal rather than ancient material. (Figure 7.3)	Pre-garden vegetation
GDU-2: Garden development and use	Storage pit floors	Charcoal from the floor of storage pits is likely to reflect material gathered and used during use of the storage pits and be contemporary with local gardens. Plant microfossils from the same context (i.e. the floor of the pit) may include remains of the stored crop but will also include microfossils from the adjacent sediments into which the pit was dug.	Garden contemporary vegetation
GDU-3: Garden development and use	Storage & borrow pit back-fill matrices	Charcoal from the original or initial back-fill matrix of a pit is likely to have derived, in the first instance, from the ambient environment, but probably originated from the local clearance of forest. The presence of charred logs within borrow pit fill supports this interpretation.	Pre-garden vegetation

		Microfossil remains present within pit fill contexts will include a significant amount of ancient microfossils originating within the Hinuera Formation alluvium or the less ancient tephras. (Figures 7.4 and 7.5)	
GDU-4: Garden development and use	Fireplaces	In general, it is assumed that the charcoal recovered from fireplaces located within the garden areas was collected from locally available sources and so reflects the types of plants present locally. When a site is located adjacent to a waterway there is also potential for fuel to have been driftwood.	Pre-garden and garden contemporary vegetation
GDU-5: Garden development and use	Basal fill of drains	While the drains are open they will be collecting sediments including charcoal on the floors of drains. It may be expected that any charcoal will reflect the charcoal present in the local environment.	Pre-garden and garden contemporary vegetation
AG-1: Garden abandonment	Black (charcoal-rich) capping layers of storage and borrow pits	Charcoal-rich layers capping the deliberate back-fill deposits of pits are accumulations of charcoal after the pits were abandoned. Therefore, they are likely to include the remains of the revegetation (seral) process. Some of these deposits may include ambient charcoal lingering from prior to the garden abandonment but will include charcoal generated from landscape firing following the end of gardening at the site. (Figures 7.4 and 7.5)	Post-garden vegetation
AG-2: Garden abandonment	Late fill units overlying black layer	Soil collecting in the pit depression. Variable in age and constituents. (Figure 7.4)	Post-garden vegetation

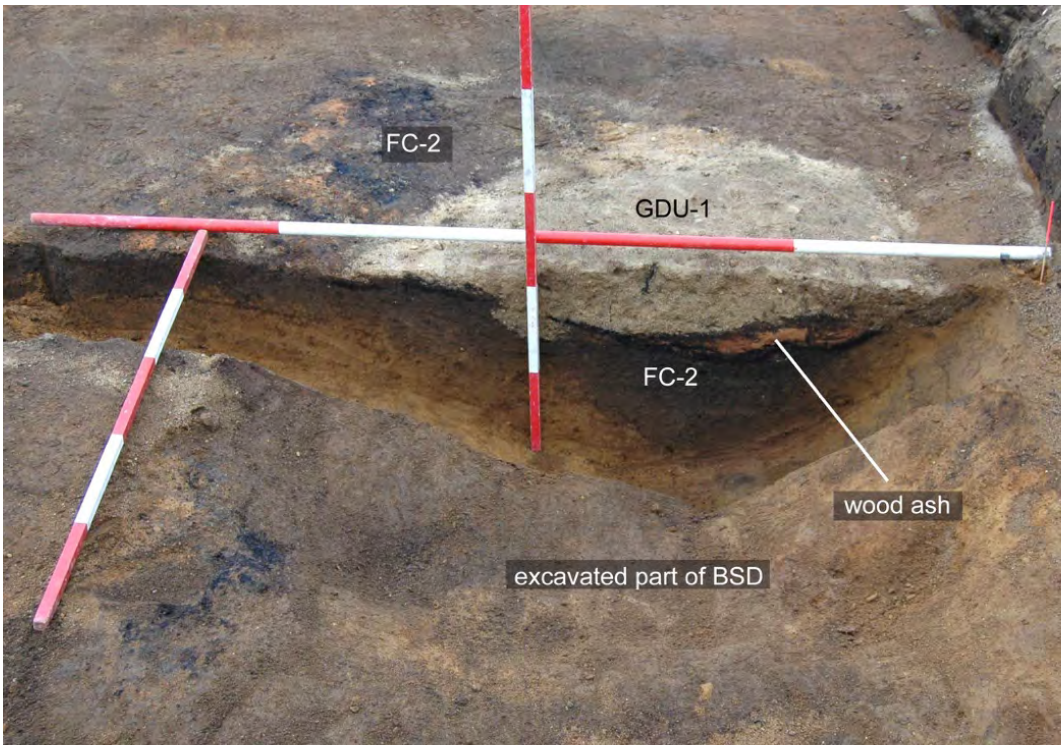

Figure 7.1: S14/195, Tract J/K, F83, basin-shaped depression. The feature is shown hand-excavated and in profile. Note the remains of active burning in the depression represented by the orange remains of wood ash and oxidised soil. FC-2 = forest clearance phase (basal fill unit); GDU-1 = TAL unit. (Horizontal scale = 2 m; other scales = 1 m).

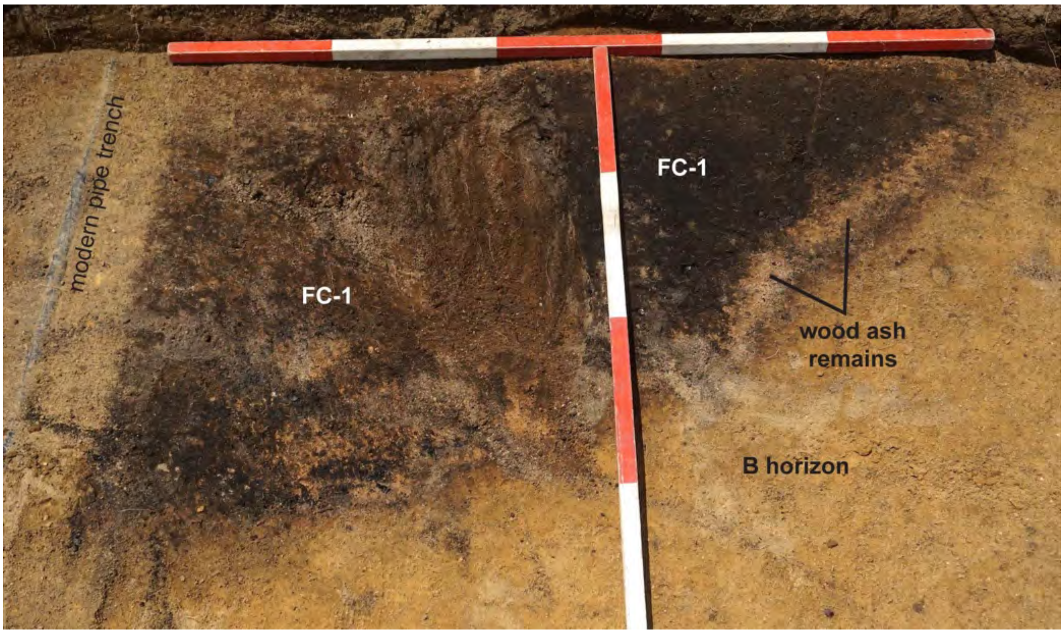

Figure 7.2: S15/773, F03, charcoal concentration on the surface of the Ab horizon representing an example of the FC-1 taphonomic context. FC-1 = charcoal concentration in Ab horizon surface. (Scale intervals = 20 cm).

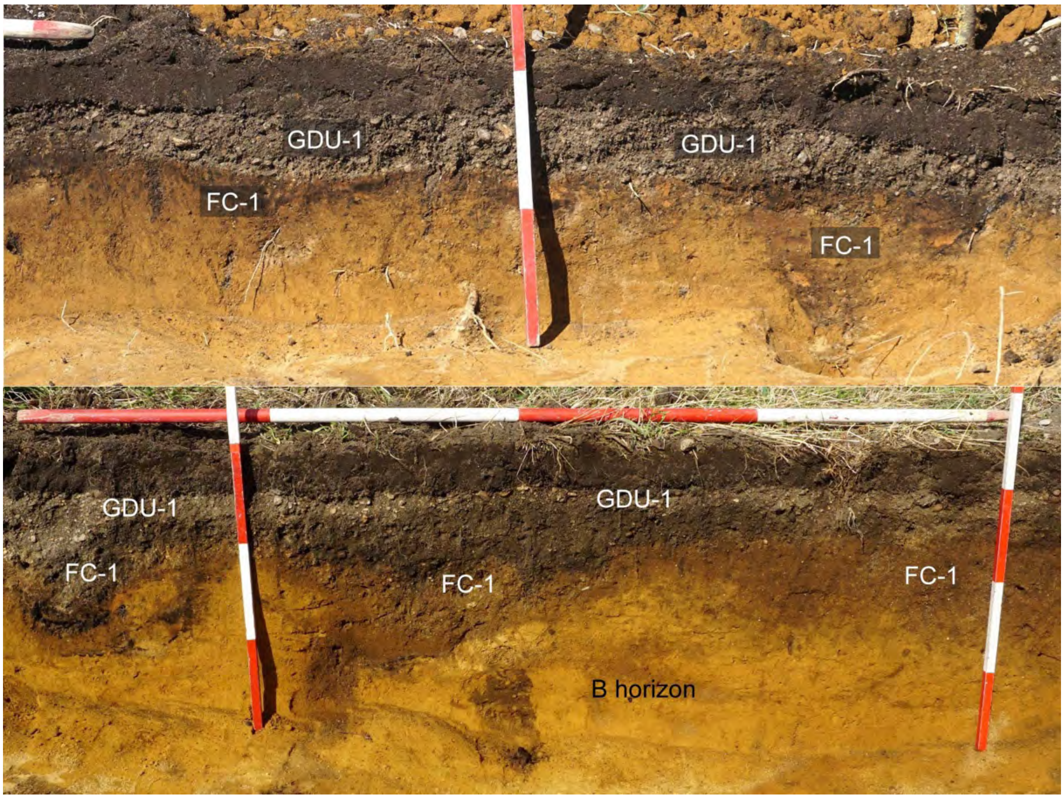

Figure 7.3: S15/424, TAL over buried topsoil (Ab horizon). FC-1 = forest clearance phase (Ab horizon); GDU-1 = TAL unit. (Horizontal scale = 2m; vertical scale intervals = 20 cm).

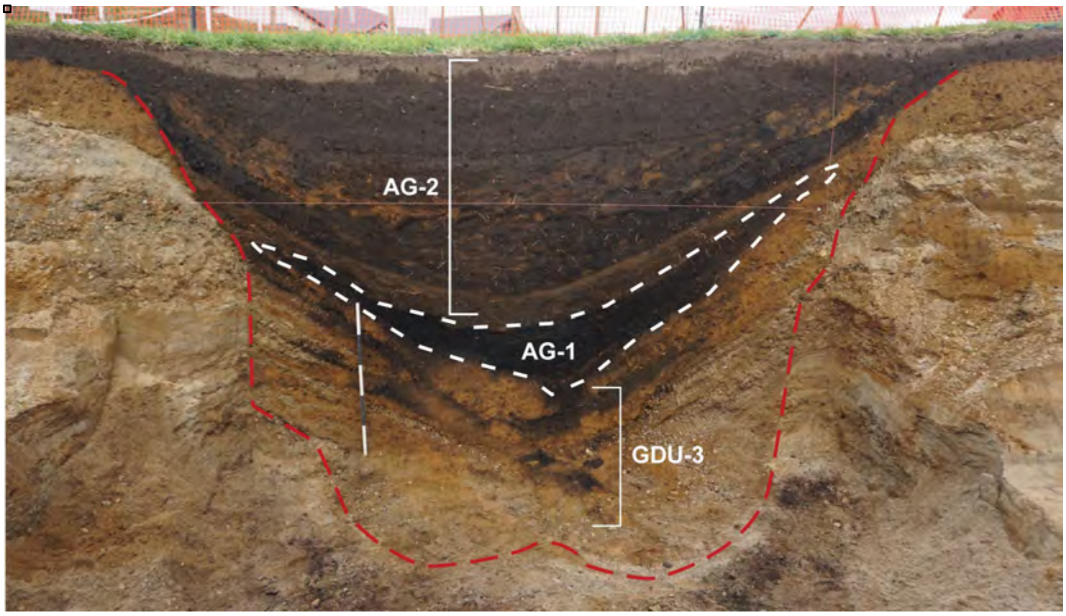

Figure 7.4: S15/639, F200, borrow pit. Pit is outlined in dashed red line. AG-1 = garden abandonment phase 1 (black layer); AG-2 = garden abandonment phase 1 (late fill); GDU-3 = borrow pit back-fill unit.

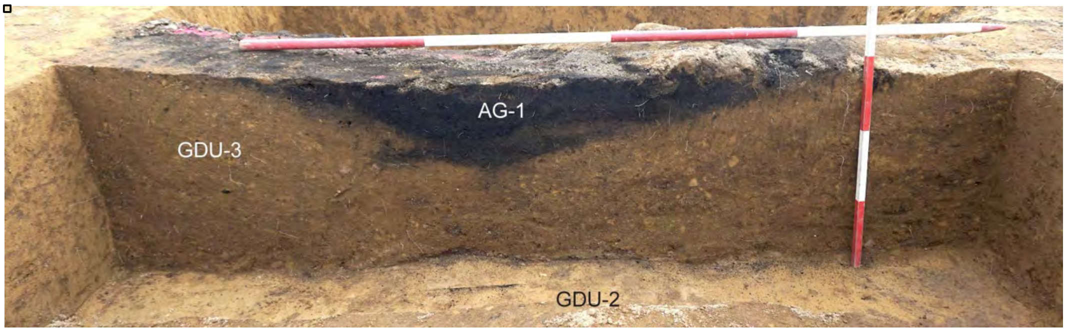

Figure 7.5: S15/771, F01, crop storage pit cross-section. AG-1 = garden abandonment phase 1 (black layer); GDU-3 = crop storage pit back-fill unit. (Horizontal scale = 2 m; vertical scale intervals = 20 cm).

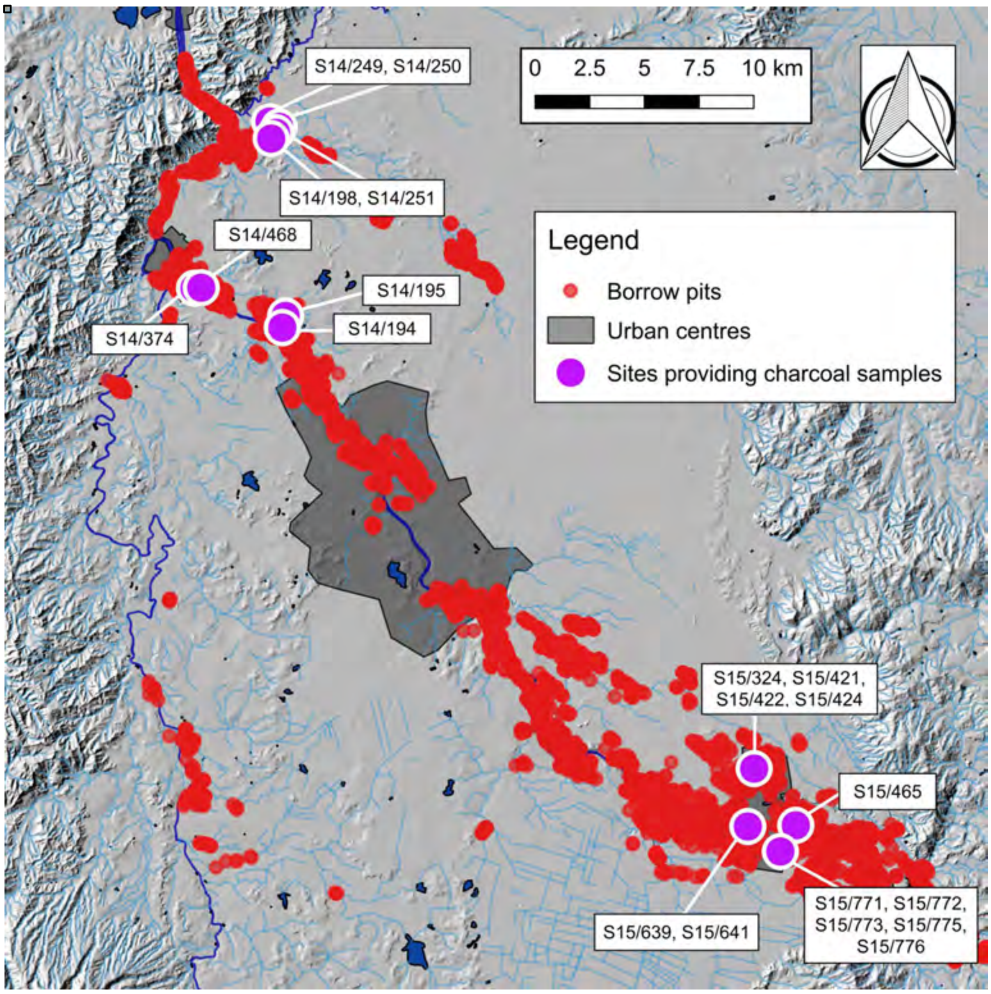

Figure 7.6: Map showing the locations of archaeological sites where charcoal samples discussed in the text were recovered.

7.3 Charcoal identification

Dr Rod Wallace (University of Auckland) analysed 259 charcoal samples from a variety of contexts. Appendix E contains Wallace's charcoal analysis reports (2012a, 2012b, 2015a, 2015b, 2016a, 2016b, 2017a, 2017b, 2017c, 2018, 2019a, 2019b). The data referred to here comes from samples recovered from 20 sites (Figure 7.6); S14/194 (Wallace 2012a), S15/195 (Wallace 2012b), S14/198 (Wallace 2016a), S14/249 (Wallace 2015a, 2015b, 2016a), S14/250 ((Wallace 2016b), S14/251 (Wallace 2015a), S14/374 (Wallace 2017a), S14/468 (Wallace 2017a), S15/465 (Wallace 2018), S15/324 (Wallace 2017b), S15/421 (Wallace 2017b), S15/422 (Wallace 2017b), S15/424 (Wallace 2017b), S15/639 (Wallace 2017c), S15/641 (Wallace 2017c), S15/771 (Wallace 2019a), S15/772 (Wallace 2019a), S15/773 (Wallace 2019a), S15/775 (Wallace 2019b) and S15/776 (Wallace 2019b). The samples recovered from these sites come from a range of feature types and contexts and have been further organised and interpreted in light of the contextual relationships described above (Table 7.4).

Table 7.4: Number of samples acquired from individual sites and organised by taphonomic contexts (as per Table 7.1).

Site	**Taphonomic context**								
	FC-1	**FC-2**	**GDU-3**	**GDU-4**	**GDU-5**	**GDU-1**	**GDU-2**	**AG-1**	**Total/site**
S14/198			4					14	18
S14/249	5	3	4	5					17
S14/250				2	9				11
S14/251			7	3	6				16
S14/374	12		10						22
S14/468	6		2	2		1		1	12
S14/194		9	5		1	5			20
S14/195	1	68	3	5				6	83
S15/421	23								23
S15/422	7		6	3				7	23
S15/424	13		5	11				5	34
S15/324	7		1						8
S15/465	3		5	5		4			17
S15/641	3		1			2		1	7
S15/639			6	2				4	12
S15/771			1				3	3	7
S15/772	3		4			3		1	11
S15/773	4					3		4	11
S15/776	4		4						8
S15/775	11		1	3		3			18
Total/TC	102	80	69	41	16	21	3	46	378

Wallace identified the charcoal to species and these data are used to identify the presence of species associated with plant communities identified by Clarkson et al. (2007) as they co-occur with taphonomic contexts (Table 7.4). The data is used to reproduce the range of species present in specific taphonomic contexts. The range of species identified with specific contexts together provide clear patterns that describe the dominant local plant environments. Wallace has also noted that large pieces of wood may be broken into a number of chunks, while others, such as shrubs may be largely consumed by fire, leaving little charcoal (Wallace 2012a, 2012b, 2015a, 2016b, 2017a, 2017b). It is considered that such a process would bias results so that large trees would be over-represented because of the relatively high frequency of their charcoal.

Table 7.5: Table showing the number of samples for each taphonomic context class that represent the native plant community. This table summarises the data in Table D.2 in Appendix E.

		Conifers	**Broadleaf trees**	**Vines**	**Small trees**	**Shrubs**	**Ferns**	**Monocotyledon**	**Bark (unburnt)**	***Mānuka/tutu***	**Bracken fern**
Taphonomic context classes	**# contexts sampled**	**Forest**	**Forest**	**Forest**	**Forest**	**Forest**	**Forest**	**Forest**		**Forest margins/ shrubland (seral)**	**Forest margins/ fernland (seral)**
FC-1	**84**	45	48	7	9	4		2	1	5	18
FC-2	**42**	43	49	11	15	15	5	1	7		1
# FC samples	**126**	88	97	18	24	19	5	3	8	5	19
%		**70**	**77**	**14**	**19**	**15**	**4**	**2**	**6**	**4**	**15**
GDU-1	**20**	9	15		1	4					
GDU-2	**3**	3	3				3			1	
GDU-3	**41**	34	37	11	16	10		2	3	3	5
GDU-4	**35**	27	47	4	26	19	1	1	3	6	3
GDU-5	**6**	9	3	1	2	2			2	3	
# GDU samples	**105**	82	105	16	45	35	4	3	8	13	8
%		**78**	**100**	**15**	**43**	**33**	**4**	**3**	**8**	**12**	**8**
AG-1	**28**	8	5	1	1	11				6	29
%		**29**	**18**	**4**	**4**	**39**				**21**	**96**

Table 7.5 summarises the representation of plant classes and communities found in the charcoal assemblages from various taphonomic context classes, and is itself a summary of the data contained in Table E.2 in Appendix E.

Samples belonging to forest clearance contexts are dominated by species typical of mature forest environments. A small but distinct proportion of these samples include bracken fern charcoal, a species found on the fringes of forest but commonly associated with the early stages of re-vegetation after forest destruction (Leach 1980). The samples containing bracken are exclusively from those contexts associated with charcoal concentrations on the surface of the Ab horizon and normally in samples exclusively containing bracken fern charcoal, suggesting that these may be the remains of clumps of bracken being burned by gardeners around gardens.

Wallace makes specific reference in several reports to the particular constituents of the base layer of the basin-shaped depressions (2012b, 2016a, 2016b). He noted that the charcoal contained consistently high proportions of charred small diameter twigs, along with unburnt bark and charred seeds. Altogether 27 species were identified in the 43 samples from these contexts (Table 7.3), which represents a diverse range of species with *tawa*, *matai* and *totara* the most commonly identified species, and bracken fern identified in a single sample (Appendix E, Table E.2). Wallace proposed that the mixture of identified plant species and unburnt bark, along with sometimes very fine twigs indicated two things; that the origin of the material was at least partly from forest floor litter and that the fires which burned this material were relatively low heat. He interpreted this as evidence for slash and burn practice with "the 'burn' being a slowly smouldering, oxygen starved fire that yielded the mixture of twiggy charcoal, seeds, ash and un-burnt material found [in the samples]" (Wallace 2012b).

The persistence of charcoal from the forest clearance phase is evident in the data and is exemplified in two examples. At S14/198, charred logs from a *tanekaha* tree were recovered from the base of fill matrices of a borrow pit and evidently represent the clearing of charred logs littering the garden area (Gumbley and Gainsford 2020a). *Tanekaha* charcoal was identified among the black layer capping the same pit, which were dominated by bracken charcoal (Wallace 2016a). These small pieces of *tanekaha* charcoal probably became mobilised from the surrounding ground surface and accumulated inside the depression of the partly back-filled pit. A similar phenomenon was identified at S15/424 (unpublished data), where logs of *matai* were found in the fill of a borrow pit while *matai* charcoal was found in a range of contexts from the same site, including the black layer overlying the original pit back-fill unit (Wallace 2017b). Indeed, Wallace comments in a report on charcoal samples from Cambridge North that "the results were so strikingly similar they warrant palaeo-botanical analysis being carried out on the combined data set" (Wallace 2017b). This comment can just as accurately be referred to all of the charcoal analyses from sites of the Waikato Horticultural Complex. The number and diversity of contexts sampled also demonstrates that this is not a coincidence driven by narrow or constrained sampling protocols.

Samples from the garden development and use phase exhibit a species range profile very similar to the forest clearance phase, where large forest tree species are present in almost every sample. For example, *tawa* is a common canopy tree species in Waikato forest and its representation in samples provides a useful benchmark. Among forest clearance contexts *tawa* is found in 61 % of those samples. Among garden development and use contexts it was found in 66 % of those samples but in garden abandonment contexts *tawa* is found in 11 % of samples (Appendix E, Table E.2). Charcoal from small trees and shrubs is relatively common in garden development and use phase contexts compared to forest clearance. Small trees are found in 43 % of garden development and use contexts and 19 % of forest clearance contexts. In samples from garden development and use phase contexts shrubs are found in 55 %[24] of samples but in 19 %[25] of samples from forest clearance contexts. Shrubs are also a common species class in garden abandonment phase samples with 39 % of samples containing forest shrubs and 21 % containing seral shrubs (*mānuka* and *tutu*). The elevated frequency of shrubs in the garden development phase compared to forest clearance and its similarity to the garden abandonment suggest that some of the shrub charcoal may represent the burning of regenerating shrubs on the fringes of forest close to the gardens and as such may constitute evidence of local vegetation regrowth at the time of garden use.

The species range for contexts relating to the garden abandonment phase is significantly more impoverished compared to the other two taphonomic groups (Table 7.5) and is strongly dominated by bracken fern, a common colonist of open ground in New Zealand, present in 96 % of samples and the exclusive species in most. *Mānuka* and *tutu* are shrubs commonly

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[24] This percantage results from the amalgamation of forest shrubs (33 % of samples) and the seral shrub species *mānuka* and *tutu* (12 % of samples), which grow around the fringes of forest. Refer Table 7.5.
[25] Ditto. 15 % plus 4 % - refer Table 7.5.

recognised as involved in the early stages of the seral process, and are represented in 21 % of samples associated with garden abandonment contexts but are present in only 12 % of the contexts relating to garden development and use. The other 11 species represented are all in low frequency and are all forest species (Appendix E, Table E.2). Their presence is interpreted as ambient relict charcoal accumulating in depressions on the surface of back-filled borrow pits and storage pits rather than as a reflection of forest regrowth. *Matai*, a dense resinous wood, appears to be especially durable as charcoal and is found in 21 % of the sampled contexts (Appendix E, Table E.2) while shrubs and small trees that would be expected to be present in the early stages of forest re-establishment are present in low numbers.

Of the two sites located on the low river-side terraces (S14/374 and S15/465) 19 species were identified from the charcoal and nine[26] of these were among the list of characteristic species identified by Clarkson et al (2007: 8). The 18 sites located on the low ridges of the Hinuera Formation had 12[27] of the 42 identified plants found in list of characteristic plants provided by Clarkson et al. (2007: 6). In both cases most of the missing plants from the lists of characteristic plants are ferns, grasses and shrubs which could be reasonably assumed to leave little or no charcoal.

7.4 Summary

The results have been consolidated into two divisions. The first is those taphonomic context classes containing charcoal predominantly originating from the forest clearance phase. The contexts that contain predominantly charcoal from the garden abandonment phase comprise the second (Table 7.5). The former includes a very diverse range of 46 species, while the second contains charcoal from 13 plant species.

As would be expected contexts relating to forest clearance (FC-1 and FC-2) are overwhelmingly dominated by forest species. The presence of bracken in samples from these contexts, especially charcoal concentrations on the surface of the Ab horizon, is interpreted as the remains of bracken being burned during gardening. Relict charcoal from the forest clearance is interpreted as the source for most of the charcoal found in garden development and use contexts with potential evidence for some burning of shrub and bracken fern

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[26] *Matai, kahikatea, totara, tawa, hinau, rewarewa, rata, mahoe, coprosma sp..*

[27] *Matai, kahikatea, rimu, totara, pukatea, rewarewa, tawa, rata, mahoe, Coprosma sp., pate, kiekie.*

attempting to recolonise land around gardens. Species represented in the identified charcoal from both the forest clearance (FC) and garden development and use (GDU) classes is generally representative of the plant ecology of lowland *tawa*/podocarp forest with *tawa*, the dominant canopy tree also dominating the identified charcoal collection. This species alone is present in 61 % of forest clearance associated samples and 63 % of samples from garden development and use contexts (Appendix E, Table E.2).

The data from the black pit capping layers (AG class) emphasises bracken fern as the principal plant revegetating the local environment after gardens were abandoned accompanied by occasional evidence for *mānuka* shrubs. This demonstrates that the seral process did not progress beyond its earliest stages, probably because of on-going firing of the landscape after the gardening had ceased (Knowles & Beveridge 1982).

8 Plant microfossil evidence for cultigens

8.1 Introduction

Until the development of plant microfossil analyses, particularly the extension of the discipline beyond pollen to include starches, phytoliths and other plant remains it was only possible to identify the presence of cultigens when charred macrobotanical remains could be identified. Examples of charred *kūmara* tubers have been found in an abandoned crop storage pit at Pouerua in New Zealand (Leahy and Nevin 1993; Yen and Head 1993) representing the only instance of such an identification in New Zealand[28]. That such discoveries are rare is emphasised by similar identifications at only three other sites in Polynesia. Charred *kūmara* tubers has been found in Hawai'i (Rosendahl and Yen 1971), charred macrobotanical remains (parenchyma) have also been found at Tangatatau on Mangaia (Hather and Kirch 1991; Kirch et al. 2017) and Skjolsvold (1961) reported charred *kūmara* tubers in association with an umu (earth oven) on Easter Island. None of these isolated finds have been found in a definitively horticultural context. In effect, it is not possible to determine what plants were grown in gardens based solely on charred macrobotanical remains.

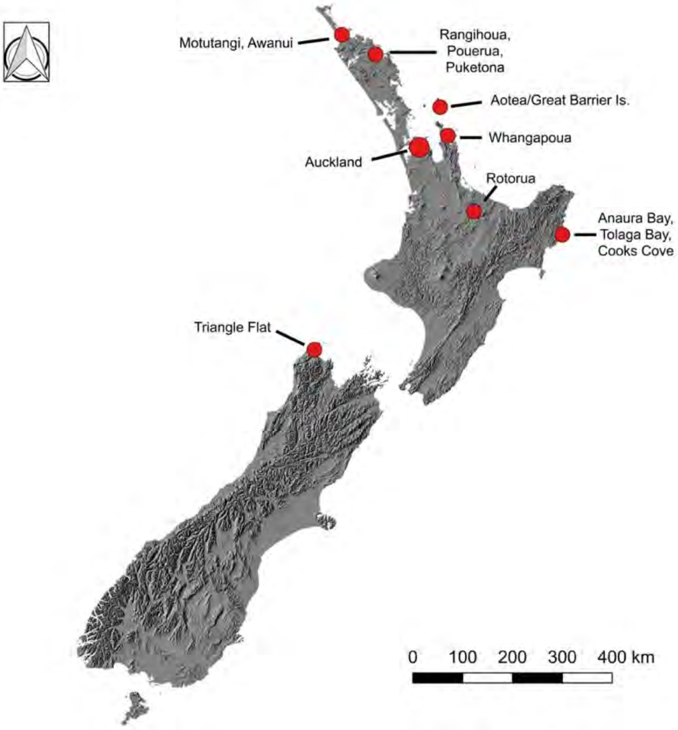

Figure 8.1: Map showing the locations of sites described in Table 8.1.

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[28] Rosendahl and Yen (1971) reported a communication from Groube informing them that he had found charred tubers at Waioneke Pā, near Auckland but this has not been published.

Table 8.1: Published data on plant microfossil remains of Polynesian cultigens in New Zealand. Motutangi and Awanui are raised bed swamp horticultural systems. The other sites are predominantly dry systems and include samples recovered from shell middens. The symbol + indicates presence. (*Kūmara* (*Ipomoea batatas*), *taro* (*Colocasia esculenta*), *hue* (*Lagenaria siceraria*), *aute* (*Broussonetia papyrifera*), Uwhi (*Dioscorea alata*).)

Location/site	***Kūmara***	***Taro***	***Hue*/ Bottle gourd**	***Aute*/ Paper mulberry**	***Uwhi*/ Yam**	**Reference**
Motutangi (Northland)	+	+			+	Horrocks and Barber 2005; Horrocks et al. 2007b
Awanui (Northland)		+				Horrocks et al. 2007b
Rangihoua (Bay of Islands)	+	+		+		Horrocks 2004
Pouerua & Puketona, (Northland)	+		+			Horrocks et al. 2000; Horrocks et al. 2004a; Horrocks 2004
Aotea/Great Barrier Island	+		+			Horrocks et al. 2002; Horrocks et al. 2004a; Horrocks 2004
Auckland (4 sites)	+	+				Horrocks and Lawlor 2006
Whangapoua (Coromandel Peninsula)	+					Horrocks et al. 2007a
Ahuahu/Great Mercury Island	+	+				Prebble et al. 2019
Rotorua	+					Campbell and Horrocks 2006; Horrocks et al. 2007a
Anaura Bay (East Coast)	+	+		+	+	Horrocks et al. 2008b
Tolaga Bay & Cooks Cove (East Coast)	+	+				Horrocks et al. 2008a; Horrocks et al. 2011
Triangle Flat, Tasman Bay (South Island)		+				Horrocks et al. 2007c

Application of plant microfossil analyses to sediment samples extracted from archaeological contexts known or suspected to be Māori gardens has become common. The published data relating to New Zealand is, by New Zealand standards reasonably substantial with fifteen papers published[29] (Figure 8.1). While *kūmara* remains are the most commonly reported cultigen, *taro* is also common with bottle gourd, yam and paper mulberry also identified (Table 8.1). Plant microfossil data demonstrates, in a crude fashion, the broad distribution of

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[29] Campbell and Horrocks 2006; Handley et al. 2020; Horrocks et al. 2000; Horrocks et al. 2002; Horrocks 2004; Horrocks et al. 2004a; Horrocks et al. 2004b; Horrocks and Barber 2005; Horrocks and Lawler 2006; Horrocks et al. 2007a; Horrocks et al. 2007b; Horrocks et al. 2008a; Horrocks et al. 2008b; Horrocks et al. 2011; Prebble et al. 2019.

kūmara and *taro* compared to the other remains, which are restricted to the northern part of the North Island.

Recent analysis of sea-bed data from Tasman Bay provides catchment-wide insight into the cultivation of Polynesian cultigens at the north end of South Island. In six core samples from 25-35 m depth a range of plant microfossils from *kūmara* (amyloplasts and xylem vessel fragments from tubers) and *taro* (pollen, xylem vessels and masses, amyloplasts from corm starch, raphides and raphide idioblasts from leaves) were identified (Handley et al. 2020).

8.2 Plant microfossils and the Waikato Horticultural Complex

Plant microfossil analyses have also been widely employed in cultural heritage management. It these data from samples recovered during CHM-driven archaeology on Waikato Horticultural Complex which are included (Figure 8.2). All analyses were carried out by Dr Mark Horrocks. The data applies to 11 sites with data from six sites carried out for Gumbley reproduced in Appendix F and the remainder drawn from cultural heritage management reports. Table 8.2 is a summary of the distribution of the cultigen identified and their remains.

Table 8.2: Sites where identified plant microfossil remains of Polynesian cultigens have been found, classified by cultigen and fossil type. The symbol + represents the number of samples containing cultigen remains.

Site	Kūmara		Taro		Yam		Reference
		microfossil type		microfossil type		microfossil type	
S14/374	++	starch, xylem	+	amyloplasts			Appendix F.1
S14/194	+++ +++	starch, xylem	++	starch			Appendix F.2
S14/195	++++ ++++ +++++	starch, xylem	+++ ++	starch			Appendix F.3
S14/164	+	starch					Horrocks 2012a, Simmons 2013
S14/253			+++	amyloplasts, raphides			Horrocks 2018, Keith 2019
S14/221	++++ ++++	starch, xylem					Horrocks 2012c, Hoffmann 2013
S14/222	+	starch			+	starch	Horrocks 2010, Hoffmann 2011
S14/210	++++	starch					Appendix F.4
S14/470			+	starch, xylem, raphides			Appendix F.5
S15/300	++	starch	++	starch, epidermis			Horrocks 2012b,Hoffmann 2012
S15/424	+++ +++	starch					Appendix F.6

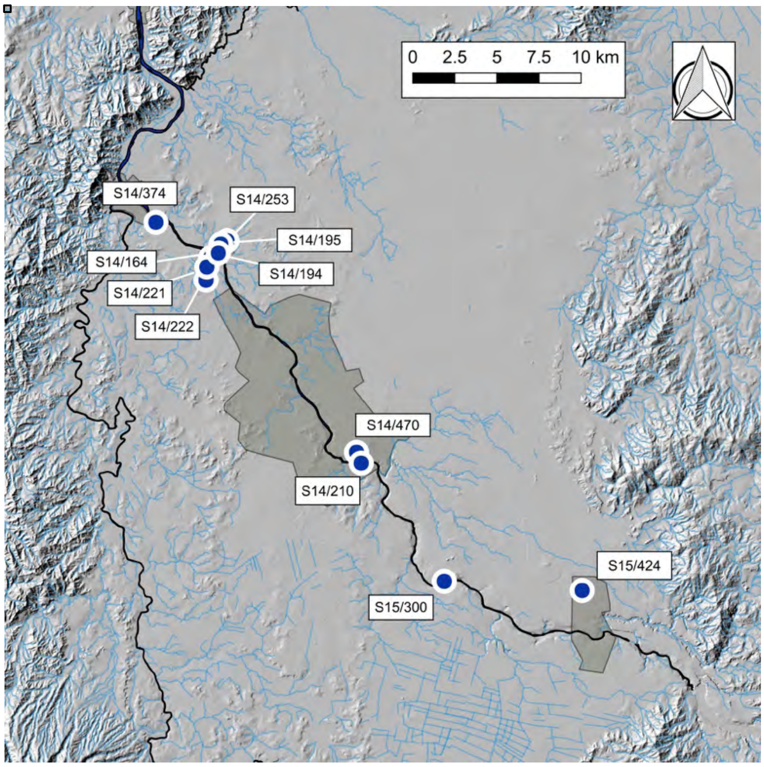

Figure 8.2: Map showing locations of Waikato Horticultural Complex sites where plant microfossil data referring to Polynesian cultigens are described and discussed.

Remains of kūmara were found in nine sites in the Waikato and six sites produced remains of *taro*. Four sites had remains of both. A single sample from S14/222 included a single yam starch grain identified after count (Hoffmann 2011; Horrocks 2010). The frequency of *kūmara* and *taro* microfossils varies from site to site with *kūmara* present in 41 samples and *taro* in 14 samples. At face value this demonstrates that both plants were cultivated in gardens with *kūmara* the predominant plant cultivated. The evidence (Table 8.3) shows that both *taro* and *kūmara* were grown in the same archaeological contexts.

Kūmara microfossils have been identified widely across the Middle Waikato Basin, from Cambridge at the southern margin of the basin to Taupiri at the northern margin, and were found in contexts associated with the gardens proper and from sediments at the base of crop storage pits associated with gardens. Although *taro* microfossil identifications are substantially less frequently found, there is one area that has notable frequency within the Middle Waikato Basin. This is a group of sites (S14/194, S14/195 and S14/253) located in the district of Horotiu on the eastern bank of the Waikato River. S14/194 is located on the bank of the Waikato River and S14/195 and S14/253 are located in an adjacent stream valley.

Table 8.3: Breakdown of plant microfossil sample results by site and context class. K = *kūmara*, T = *taro*, Y = yam. The bowl-shaped hollow fill samples come from the top of the fill unit. (TAL - transported alluvium layer; BSD - Basin-shaped depression; BSH - bowl-shaped hollow).

Site	**TAL**	**BSD alluvium fill**	**BSH fill**	**Mixed soil**	**Ab (upper subsoil)**	**Long pit base fill**	**Bin pit base fill**
S14/374	KK						
S14/194	KKK T		KK T		K		
S14/195		KKKKKKK TTT		KKKKK T		K	T
S14/164			KK				
S14/253	TT					T	
S14/221	KKK			K	KKK	K	
S14/222	K Y						
S14/210	KKKK						
S14/470	T						
S15/300	KK TT						
S15/424	KKKK				KK		

At S14/194, *taro* microfossils were found in samples from Area B, situated on an intermediate river-terrace of the Hinuera Formation where the poorly drained Te Kowhai silt loam was overlain by deep deposits (20-30 cm) of sand and gravel (Gumbley and Hoffmann 2013). This area of the terrace was wet despite a modern drain dug across it. When investigation trenches were excavated on the river-terrace a series of Māori drains were present under the TAL unit. One of the two *taro* identifications found at Area B was recovered from the TAL in the wet area suggesting the thick layer of sand and gravel was used locally to grow *taro*. The second *taro* identification came from artificial, raised terrace garden formed at the toe of the escarpment in the same terrace, adjacent to the TAL. *Kūmara* starch was found in samples recovered from the higher well-drained soils at the southern end of the river-terrace and also the artificial terrace garden. This distribution indicates *kūmara* was grown on the dry parts of the river-terrace where soil was well-drained Horotiu series loams. *Kūmara* microfossils were also found in samples from the upper river terrace where the soils are well-drained loams. A similar pattern of mixed wetland and dryland horticultural remains were identified at S14/484 at a nearby river bank site located 500 m downstream from S14/194 (Potts 2018).

The un-named stream valley, where S14/195 (Gumbley and Hoffmann 2013) and S14/253 (Keith 2019a) were found, flows into the Waikato River a kilometre down-stream from

S14/194. The mouth of the stream valley was defended by a *pā*. While there are a range of tephragenic loams in this valley ranging from well-drained to poorly drained there is a high proportion of poorly drained soil of the Te Kowhai series. The remains of gardening features, predominantly TALs, have been found on soils of both well and poorly drained series in this valley. The use of a small side valley for extensive horticulture is unusual in itself and allied with extensive exploitation of poorly drained soils (along with well drained soils) the valley is unusual in the landscape patterning of the Waikato Horticultural Complex. The identification of an unusually high frequency of *taro* microfossils in samples from this valley also sets the archaeology of the valley and adjacent riverbank add to that exceptionality.

Two sets of samples for plant microfossil analysis were recovered from S15/424 to accompany soil micromorphological and soil particle size analyses of the soil profile with the intention of describing a "type" profile. Each set had samples analysed from the A horizon (turf), the upper and lower elements of the TAL (described as L2a and L2b), the Ab and B horizon. Both sets produced the same results with *kūmara* starch remains found in the TAL units and the Ab samples. *Kūmara* starch in TAL units is unsurprising given the apparent direct association with crop growing and the presence in the Ab horizon is reflective of both the mechanical mixing associated with gardening and bioturbation as identified in the micromorphological analysis (see Chapter 6). This also explains the mechanisms leading to the presence of cultigen remains in samples from the buried topsoil units (Ab horizons) at S14/194 (Gumbley and Hoffmann 2013) and S14/221 (Hoffmann 2013).

8.3 Summary

The plant microfossil data are geographically dispersed across the study area and identify *kūmara* and *taro* as the principal cultigens. In this sense the results conform to the pattern recognisable in the published data for the rest of New Zealand. Most of the Waikato data referring to *taro* come from dryland environments with a single site, S14/194, providing evidence of *taro* in what was apparently a naturally wet environment. Evidence from S14/194 along with information provided for S14/484 in the national site recording database constitute the only confirmed evidence for the cultivation of *taro* in wet environments associated with the Waikato Horticultural Complex. It is probable that this scarcity of evidence reflects the focus of archaeological investigations and sampling on dryland environments rather than the actual frequency of this practice. The Middle and Lower Waikato Basins have an abundance of wetland environments and springs are common along the banks of the Waikato River and its tributaries. All of these environments are potentially suitable for wetland cultivation of *taro*. However, identification around Lake Waikare (Lower Waikato Basin) of probable swamp cultivation systems visible in historical aerial photographs, along with traditional history of *taro* cultivation at the lake (Glen Te Puhi and Tawera Nikau, personal communication) suggest that wetland *taro* cultivation was a more important part of the broader cultivation strategy in both Middle and Lower Waikato Basins than is archaeologically apparent. Nonetheless it is clear that dryland cultivation of *kūmara* and *taro* were the mainstays of the Waikato Horticultural System. The identification of a single yam starch grain in a sample recovered from the TAL unit at S14/222 is exceptional in what was likely to have been a very marginal environment for this tropical plant.

9 Timing of the development and expansion of the Waikato Horticultural Complex

9.1 Introduction

The scale and extent of the Waikato horticultural system begs the question of the timing of the development of this intensified approach to swidden horticulture, and also whether there is any pattern in its spread through the Waikato.

The settlement of the inland Waikato was principally accomplished by descendants of the Tainui Waka[30]. Arrival traditions indicate that the Tainui Waka, along with the Arawa Waka, were among the last colonising waka to reach New Zealand, with the Tainui Waka ultimately settling on the west coast of North Island around Kāwhia and Aotea Harbours (Kelly 2002). Both Jones (Jones and Biggs 1995) and Kelly (2002) place this event in the mid-fourteenth century and both propose migration inland occurred in the second half of the sixteenth century.

The archaeology of New Zealand offers particular challenges because of the short chronology for the settlement by Polynesians, which is inferred to have begun in the mid-thirteenth century. This inference is largely based on proliferation of settlement through Aotearoa/New Zealand by the end of the fourteenth century (Anderson 2016; Anderson et al. 2015; Smith 2019; Wilmshurst et al. 2008). Because radiocarbon dates commonly manifest margins of error which result in calibrated date ranges of close to a century (at 95 %) (Hogg et al. 2017) such a short chronology places considerable stress on the capacity of the technique to produce a level of precision permitting the discernment of events or processes in cultural change before European settlement. This is further exacerbated by the frequency of wiggles in the southern hemisphere atmospheric calibration curve, particularly during the period after 1500 AD (Hogg et al. 2017). Altogether, this makes it difficult to date specific sites closely and makes for a particularly knotty problem determining the comparative ages of sites with others. While there are techniques to address the precision problem (e.g. wiggle-match dating) they are dependent on uncommon situations (e.g. the presence of entire water-logged posts) not found in dryland horticultural environments.

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[30] Ngāti Kahupungapunga, a hapū understood to be descended from the Arawa waka, were already settled in the region of the Puniu River (Jones & Biggs 1995).

Understanding the taphonomic processes relating to charcoal within the horticultural sites has allowed for a much improved understanding of the event being dated. Charcoal for environmental analysis has been collected systematically from a variety of contexts relating to forest clearance (e.g. BSDs and charcoal patches), garden development and use (e.g. borrow pits, made-soil, BSHs), and after garden abandonment. The range of species comprising the charcoal developed during the forest clearance phase is distinct from the range of species identified from charcoal created and deposited after the garden was abandoned. This recognition has allowed radiocarbon dates on charcoal developed during the forest clearance phase to be compared to radiocarbon dates on charcoal associated with the abandonment phase. In the latter case this charcoal came from charcoal-rich soil layers that capped the original back-fill of both types of pit with the back-fill deposit containing charcoal (bracken fern or mānuka[31]) from the forest clearance phase. Recognition of these relationships should allow Bayesian models to be used in the future to constrain the broad error ranges that are otherwise problematic.

Altogether 161 charcoal samples, identified to species, from Waikato horticultural sites have been radiocarbon dated. This chapter is a summary of the radiocarbon dating data found in Appendix G. The charcoal samples came from 34 sites located within the Middle Waikato Basin, extending from Taupiri at the northern end of the basin to Cambridge at the southern end. No dates are available for the horticultural sites in the Lower Waikato Basin, nor from the Maungatawhiri Gorge and the most southern sites at Arapuni. This reflects the limits of archaeological fieldwork, rather than any other form of sampling bias. Twelve of these sites have only 1 or 2 radiocarbon dates and so should be considered unreliable as accurate ages for individual sites but, nonetheless they remain useful when the broader data-set for the horticultural system is examined.

The 161 radiocarbon dates available that describe the chronology of the Waikato Horticultural Complex comprise the bulk of the reliable radiocarbon dates for the inland Waikato (Figure 9.1). Few reliable dates are available for occupation sites where these do not co-occur within horticultural sites. *Pā* are largely absent from this body of dates. In the modern context of CHM driven archaeology *pā* are usually protected from modification with the investigation of

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[31] Bracken fern, *Pteridium esculen*tum; mānuka, *Leptospermum scoparium*.

Rangiriri Pā a single exception (Gumbley 2015). High precision dating of Otāhau Pā (Hogg et al. 2017) at Taupiri provides the sole example of recent research driven dating relating to *pā*.

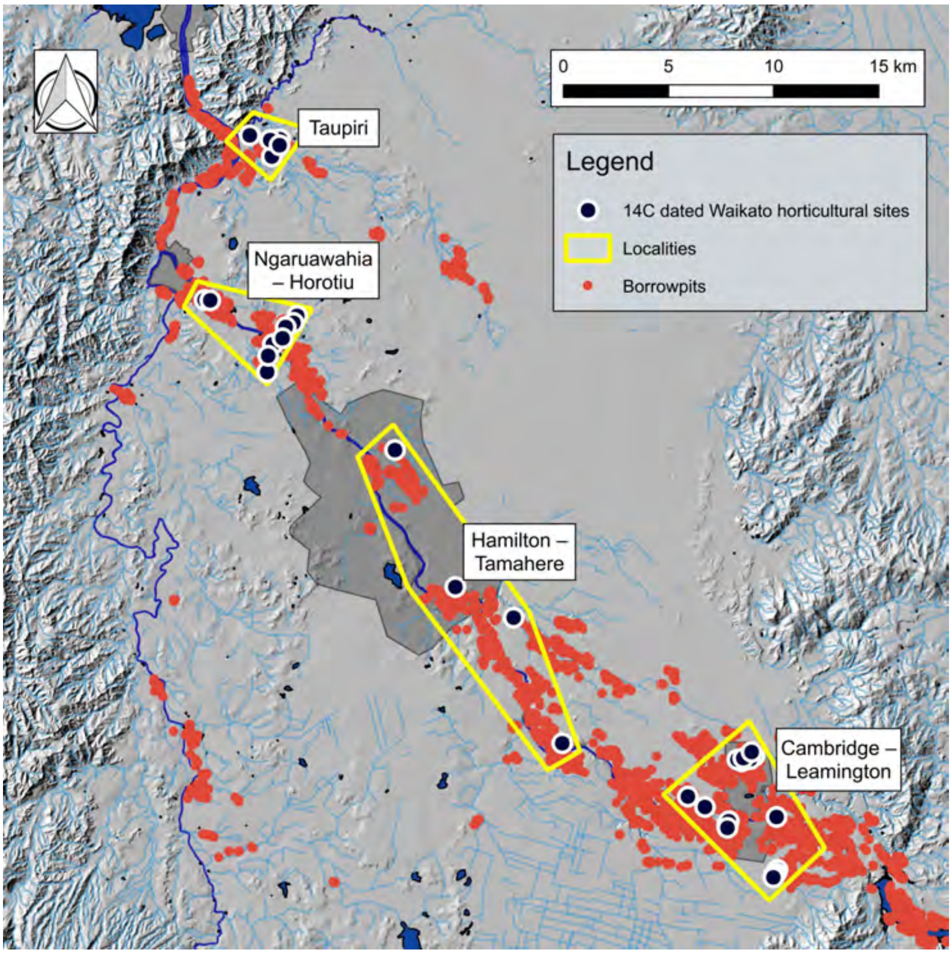

Figure 9.1: Map showing the locations of ^{14}C dated horticultural sites in the middle Waikato Basin.

In considering the available radiocarbon dates, it became clear that despite a consistent protocol which selected samples from short-lived wood with a view to eliminating in-built age bias (Anderson 1991; Higham and Hogg 1997; Wilmshurst et al. 2008) a class of samples had a distinct tendency to provide assays older than other dates from the same site or even context. These were samples of charred wood identified as twig wood from large, long-lived trees such as *tawa, taraire, matai, tōtara, kahikatea, rātā, rewarewa*, and *pukatea*[32]. Although these species grow to considerable ages, the rationale was that their identification as twigs

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[32] Tawa, *Beilschmiedia tawa*; taraire *Beilschmiedia tarairi*; mātai, *Prumnopitys taxifolia*; tōtara, *Podocarpus totara*; rātā, *Metrosideros robusta*; rewarewa, *Knightia excelsia*; pukatea, *Laurelia novae-zelandiae.*

meant that they should not carry any inbuilt age. It is evident that as many as 50 % of these "twig" dates were too old (Appendix G: Section G.2, Table G.4) compared with other dates from the same site or even context, demonstrating a rate of in-built age in this sample class. The net effect of these dates was to make specific sites appear older than they probably were and to shift the overall chronology for the initiation of the horticultural system to an earlier date than was probably the case.

Because of the issues surrounding sample sizes and the potential for in-built age among the "twig" dates considering the radiocarbon data on a site by site basis was unlikely to be fruitful. Similarly, assessing the radiocarbon data as a single mass does not facilitate understanding of the process of distribution of the horticultural practices considered here through the Waikato, even allowing for "twig" effect. However, examining the data on a locality by locality basis provides a resolution where patterns of settlement through time and space may be considered. The localities identified here (Figure 9.1) are the Taupiri locale, the Ngaruawahia/Horotiu locale, the Hamilton/Tamahere locale and the Cambridge/Leamington locale and discussion here is a summary of the data presented in Appendix G.

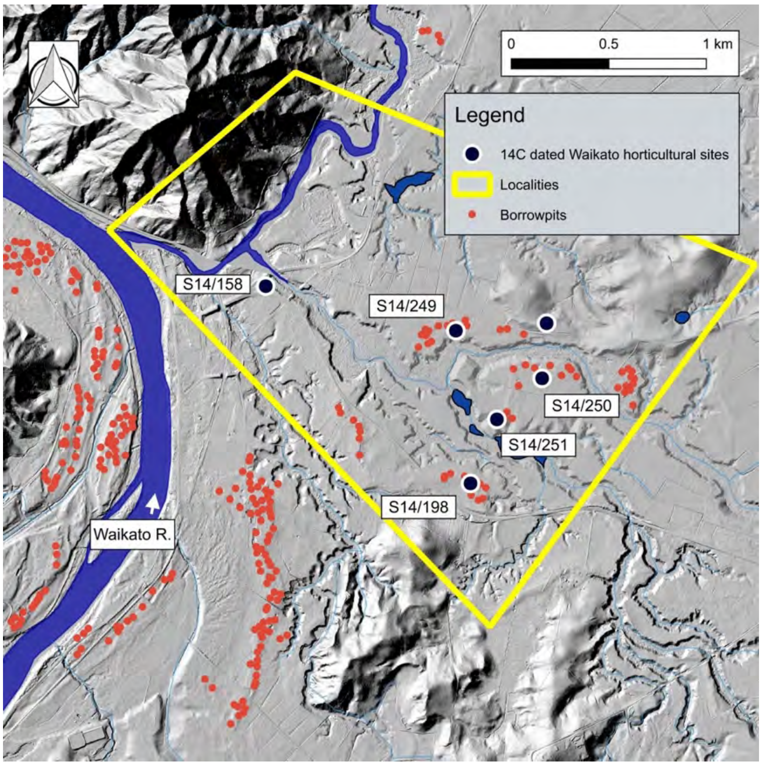

Figure 9.2: Map showing sites within the Taupiri locality that have been ^{14}C dated. (Image background: WRC LiDAR 2008).

9.2 Taupiri

Taupiri is the northern-most of the localities (Figure 9.2) and is situated at the lower end of the gently inclined Hinuera surface at the point where the Waikato River passes through the narrow gap between the Hakarimata and Taupiri Ranges. Fifty-four radiocarbon dates have been developed on samples from five horticultural sites investigated in this area, with all of these sites focused on tributary streams[33] 1-2 km east of the Waikato River. The array of calibrated radiocarbon dates for this area indicate horticulture began to be practiced at some point during the sixteenth century and continuing until the nineteenth century (Appendix G: Table G.1, Figure G.1).

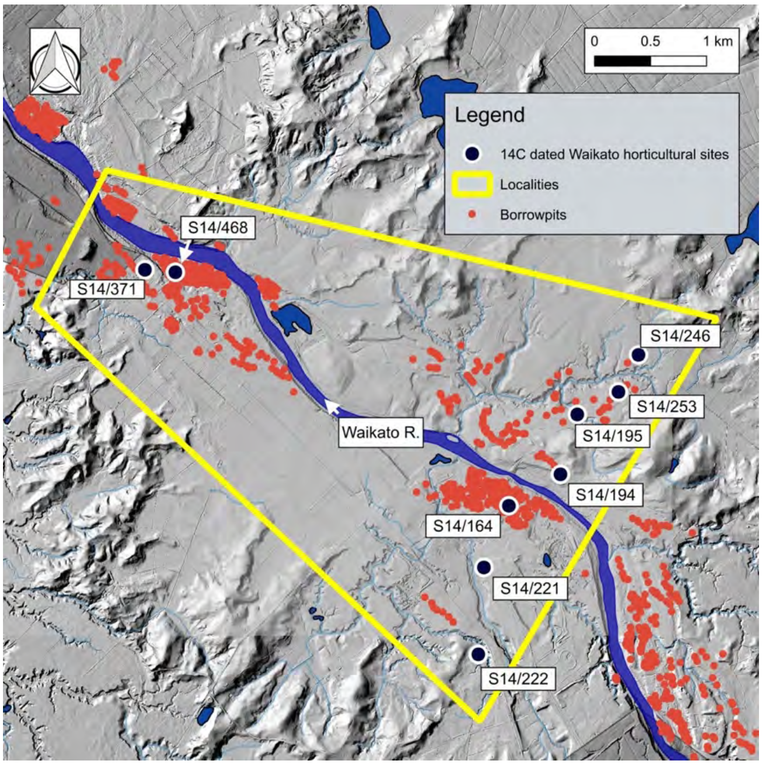

Figure 9.3: Map showing sites within the Ngaruawahia–Horotiu locality that have been ^{14}C dated. (Image background: WRC LiDAR 2008).

9.3 Ngaruawahia/Horotiu

The Ngaruawahia to Horotiu locality (Figure 9.3) stretches between the junction of the Waikato River with its major tributary, the Waipā River, to the northern edge of Hamilton City, a distance of approximately 8 km. In the northern part of this locality the Waikato River has relatively low widely spaced banks with low and wide terraces proximate to the river. At

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[33] The Komakorau Stream and its tributary the Mangatoketoke Stream.

the southern end of this locality the river has begun to become deeply entrenched, with narrow river terraces within a narrowing valley.

Thirty-five samples have been radiocarbon dated from nine sites in the Ngaruawahia to Horotiu section of the river. Twenty of these dates have come from a series of sites within a small tributary valley to the east of the main river valley and another six dates have come from a two small sites located on the margins of another small tributary valley on the western side of the Waikato River. The remaining nine dates come from sites located along the banks of the main river valley.

Like Taupiri, horticulture in this locality commenced at some time during the sixteenth century with evidence for cultivation in the eastern tributary valley to have occurred some 100-150 years later (Appendix G: Table G.1, Figure G.2).

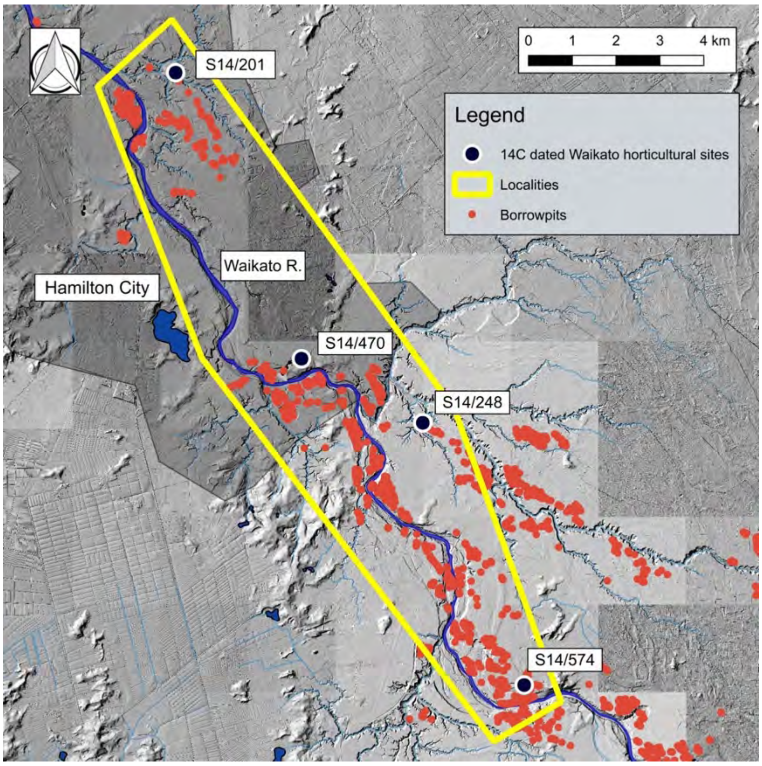

Figure 9.4: Map showing sites within the Hamilton–Tamahere locality that have been ^{14}C dated. (Image background: WRC LiDAR 2008.)

9.4 Hamilton/Tamahere

This locality stretches approximately 18 km along the Waikato River, where it is deeply entrenched with the river terraces narrowing and becoming increasingly elevated. Four archaeological sites have provided 11 radiocarbon dates in this area with six of them coming from a single site[34] (Figure 9.4). These dates follow a similar pattern to the Taupiri and Ngaruawahia/Horotiu with gardening commencing during the sixteenth century (Appendix G: Table G.1, Figure G.2).

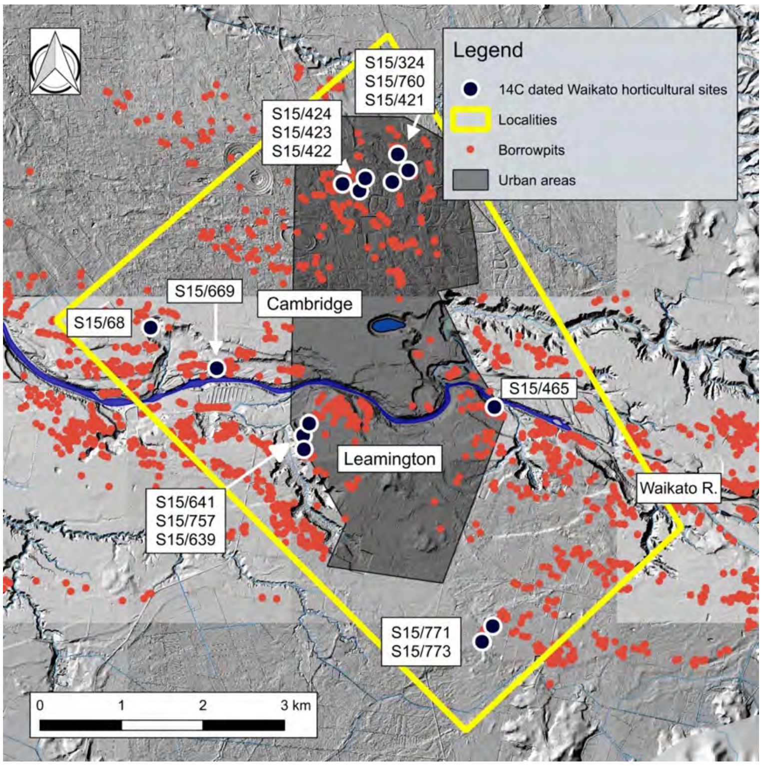

Figure 9.5: Map showing sites within the Cambridge – Leamington locality that have been ^{14}C dated. (Image background: WRC LiDAR 2008).

9.5 Cambridge/Leamington

This area has been the most intensively dated with 61 samples from 14 sites radiocarbon dated. This frequency reflects the density and extent of the horticultural sites found in this area along with a more concerted effort to apply a more effective dating strategy. Here the river is deeply entrenched within a narrow gorge with discontinuous and highly elevated river terraces. Cambridge and Leamington are sited on opposite sides of the Waikato River and, because of the number of dates, it is possible to consider the two areas separately.

Thirty-three samples have been radiocarbon dated from eight sites on the Cambridge (North) side of the Waikato River (Figure 9.5). Six sites were located in Cambridge North,

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[34] S14/470

approximately 2 km from the Waikato River. The remaining two sites were 600 m from the river in one instance (S15/68) and immediately adjacent to it for the other (S15/669). The dates indicate gardening began in Cambridge North in the second half of the seventeenth century, while the dates for the sites closer to the river indicate gardening began there approximately a century earlier, around 1550–1650 AD (Appendix G: Table G.1, Figure G.3).

On the Leamington side of the Waikato River, six sites together have had 28 samples radiocarbon dated. Like Cambridge these are divided between a set of sites approximately 2 km remote from the river and another set from sites close to the river. The dates from the sites closer to the river indicate gardening began there in the period between 1550 and 1650 AD whereas at those sites remote from the river it began in the period 1650–1750 AD and continued into the nineteenth century (Appendix G: Table G.1, Figure G.4).

The results produce a pattern where earlier settlement is close to the river with ages becoming younger with increasing distance from the Waikato River. The Cambridge-Leamington area is notable for its bulge in horticultural site distribution away from the river, a phenomenon not apparent elsewhere in the Waikato. The bulge means that this locality has a higher density of horticultural sites than elsewhere in the Waikato horticultural system. This spatial patterning along with the temporal patterning of early ages adjacent to the river, when compared to the sequences from the other localities demonstrates that horticulture in the Cambridge-Leamington locality has a longer and perhaps more continuous history than elsewhere in the Middle Waikato Basin. These dates are broadly consistent with the evidence from Tainui traditional histories for the migration inland in the second half of the sixteenth century (Jones 1995; Kelly 2002; Assoc. Prof. Tom Roa, personal. communication.). It seems reasonable to propose that it was in Cambridge/Leamington area that the Waikato horticultural system was initially implemented in mid-late sixteenth century.

9.6 Summary

Traditional versions of the settlement of the inland Waikato suggest a period in the second half of the sixteenth century, which is consistent with the earliest radiocarbon dates from the Cambridge-Leamington area. The early radiocarbon dates from sites belonging to the Waikato Horticultural Complex in that area suggest that this system may have been present from soon after the initial settlement of the Cambridge-Leamington area. Presuming that this area constitutes some form of point of origin for the Waikato Horticultural Complex down-river expansion, that expansion was rapid, reaching Taupiri at the northern end of the Middle Waikato Basin within fifty to a hundred years.

10 Experimental gardens: method and results

10.1 Soils and *kūmara* horticulture

In the early twentieth century soil scientists began to identify Māori-made soils and to question the motivation behind such a high level of input required to achieve the nature and scale of the modifications they recognised. In the light of Walton's (1982) analysis of sources, we can see many of the ideas he critiques percolating into the work of early soil scientists when examining made soils.

The earliest were Rigg and Bruce (1923) who identified the Māori-made soils of the Waimea Plain at Nelson in the northern South Island. They commented on the relict levels of fertility of the made soils, even after 60 years of European cultivation, where potassium and phosphorus were present at significantly higher levels than the adjacent unmodified soils. They noted the soil colour differences between the Māori-made soil horizons and their equivalent horizons in the unmodified soils, where the former were close to black when wet and the latter brown. They also noted that the gravel remaining in the quarries was light brown. They attributed the dark colour of the Māori-made soils to high levels of charcoal. To account for both of these phenomena they proposed that "several tons of vegetable matter must have been burnt on each acre" (1923: 90), going on to proffer that the *mānuka* shrubland growing on the nearby Moutere Hills had been cut and transported to the gardens for this purpose. While the former of these two propositions has value as a testable hypothesis the latter is speculative and ignores the role that clearance of in situ forest may have had.

Similar soils to those at Waimea were recognised in the Waikato in the 1930s (Grange et al. 1939; Taylor 1958) although explanations for the phenomenon followed those proposed by Rigg and Bruce. Singleton (1988) again traced much the same source material but addressed the problem of rationale for the addition of coarse transported alluvium to already free draining and friable soil. He acknowledged that the rationale may have involved "religious or traditional" motives, perhaps a perceived need for "a clean pure medium in which to grow the sacred kumara" (1988: 54). He then went on to identify a series of potential advantages familiar to soil scientists:

> "• Increased friability.
> • Improved drainage of poorly drained soils.

- To help raise and maintain higher soil temperature.
- To create a sharp interference [sic; interface] between gravel and buried soil to encourage tuber formation.
- Water could condense on the gravel at night.

Suggestions for adding gravel each year include:

- Providing a disease-free growing medium.
- The gravel contained nutrients" (Singleton 1988: 54).

Together these form the core of a testable hypothesis around which to frame experimental garden plots. It should be noted that there is no evidence in any literature that coarse material was added to a garden annually. We only have Shortland's (1856) reference to people returning annually to the same places, which is not an equivalent to annual re-applications of sand and gravel. Singleton also referred to observations of a made soil profile from near Cambridge in the Waikato. Singleton (1988: 54-56) noted the following:

- An irregular lower boundary to the Māori-made soil horizons;
- No evidence for charcoal or ash on the Māori-made soil horizons;
- Charcoal was present in the upper part of the subsoil (Ab horizon);
- Similarity of the sand in the C horizon to the Māori-made soil horizons;
- Chemical analyses show that the Māori-made soil horizons were high in phosphorus and potassium
- Nitrogen levels are naturally low in the soil.

Based on these observations Singleton made the following points (1988: 54–56):

1. The presence of charcoal in the upper subsoil (Ab horizon) identifies this as "the original soil surface which would have been cleared by burning."
2. "The addition of sand in this case was not necessary to physically improve the soil for root growth. A sharp interface has, however, been created between the added sand and underlying silt loam. The abrupt textural change would be a slight restriction to roots entering lower horizons and could help encourage tuber formation at this interface".

3. The soil chemistry of the made soil horizons would originally have been the same as the C horizon and that the original soil chemistry would have been the same as the upper subsoil (Ab) horizons.
4. The generally low quantities of nutrients in the sand and associated high rates of leaching from this material would have necessitated annual addition of sand to address this.

These observations and comments by Singleton are valuable but it should also be added that the Ab horizons he describes have been, as he identified, “dug and turned” (1988: 54) or in other words cultivated, which raises a question about how much these horizons reflect the original soil since they have also been modified. His comment about the need to add more alluvium annually (Point 4 above) appears speculative and does not necessarily mean that this occurred.

10.2 Experimental gardening of *kūmara* in New Zealand

In the late 1950s and early 1960s a series of experimental gardens, testing rates of kumara growth in different soils have been undertaken for a variety of motives ranging from the exploration of potential for historic varieties in commercial growing to attempts to understand problems Māori may have experienced in cultivating *kūmara* in marginal areas of New Zealand. Douglas Yen, an agronomist with the DSIR (New Zealand) was the first (1961, 1963, 1974) when he undertook the collecting of relict examples of four probable pre-European *kūmara* varieties in the 1950s and went on to experimentally grow these varieties in Auckland along with over 200 other varieties collected in Southeast Asia, Melanesia, Polynesia and South America (1963: 42). The motivation for this research was to understand the potential for a range of sweet potato varieties sourced from a range of locations around the globe to be applied for commercial cultivation. However, Yen recognised the potential for his experimental work to elucidate the emerging questions (e.g. Golson 1959) about Māori adaptation of *kūmara* to New Zealand’s climate. While Yen does not detail the methodology of his experimentation his discussion of the results is valuable because they place the four pre-European varieties in the context of results from the cultivation of the other varieties. Yen noted there was general similarity among the four varieties and that the pre-European varieties were resistant to flowering while varieties from elsewhere did flower, which shows that Auckland, and by extension northern New Zealand is not outside the natural limits for *kūmara* to flower. He also noted that none of the pre-European varieties could be propagated by vine stem cuttings, which was normal elsewhere. Yen found the four old varieties of *kūmara* generally stored well, rating them good to excellent keepers, and proposed that because of the annual cropping regime, varieties which stored poorly would not have reproduced. He also conjectured that storage was probably a desirable trait actively selected for. Yen also found that old varieties only had moderate resistance to cold leading him to suggest the ability to store well was more sort after than frost hardiness. It does not appear from any of his records that Yen applied gravel or sand in any of his experimental work. However, his comments that it would have increased friability and therefore root formation, reflected both agronomic orthodoxy and the opinions of those who had published earlier on the matter.

Huntly Horn (1993) undertook four seasons (1986-1990) of experimental gardening in the centre of the South Island at Christchurch to explore the mechanisms of possible cultivation practices that may have been that were employed to enable successful *kūmara* cultivation at its southernmost margins. Horn used the Rekamaroa variety of sweet potato, one of the pre-European varieties collected by Yen. Horn described it as having “a white flesh and usually rather long straggly and fragile tubers” (1993: 185). Plants were grown in sand from single node leaf cuttings rather than seed tubers, although he did attempt to use seed tubers in the third season of the experiment but many rotted in the ground and sprouting among the remainder was uneven. The cuttings were grown in greenhouses during the winter prior to planting; emphasising the marginal location for the experiment. Horn measured yield as the total weight of the roots regardless of size but he did define usable tubers as “finger thickness or more”. He estimated that approximately 90% of the total root weight was accounted for by usable tubers with tubers generally less than 4 cm in diameter.

Horn employed varying soil treatments including control plots where no treatments were applied. The various treatments were as follows (1993: 186):

1. Two litres of sand spread over a 30 cm diameter area to a depth of 3 cm;
2. Cylindrical pits in the soil re-filled with a soil/sand mixture (the pit sizes and the soil/sand ratios varied each season);
3. Topsoil mounded to 10-12 cm and covered with sand after planting (this was only done in the 1988-89 season and much of the sand eroded off the mounds);
4. A trench 30 cm wide was excavated and lined with polythene along the sides and between each plant, and filled with a soil/sand mix (ratio 2:1);

5. Two trenches, one 30 cm wide and the other 15 cm wide, were dug and similarly lined. These were filled with a mixture of the same materials but at 1:2 (soil/sand).

The last two configurations were developed to restrict access to the soil nutrients. The 15 cm wide trench was employed to restrict the plants access to nutrients by further reducing the amount of available soil.

Because of variations in methodology from year to year the yields could not be directly compared, but the yields during Season 2 were highest, which Horn attributed to the long growing season. The mulched plants consistently provided better yields than the control plots, approximately 30 % (Horn 1993: 188). The results from the plants grown in the pits filled with the soil/sand mix was the same or lower than the control plants. However, the single crop from plants grown in the mounds with sand mulch yielded more root weight than the control plots but fell short of the yield from the mulch plots. Horn noted that Yamaguchi (1983: 124) identified a soil temperature of 15º C as the point when sweet potato will stop growing and gives an optimum mean temperature as 24º C, while Coleman (1978: 7) in a New Zealand Department of Agriculture Bulletin proposed 21º C to be optimal. However, Horn (1993: 187) reported soil temperatures at the research site normally exceed 15º C from November to March and barely exceed 20º C in January. Horn attributed the higher yields from the sand mulch plots to soil warming, although he did not present data for this. He also observed that soil warming would diminish as the canopy grew and progressively shaded the soil and proposed that early soil warmth was important. In concluding the description of his experimental results, Horn (1993: 187-188) observed that sand above the soil surface enhanced yield while sand under the surface diminished yield, and that this effect was exacerbated the greater the proportion of sand in the mix. He attributed this to the consequent dilution of soil and hence lower nutrient availability.

Jan Worrall (1993) undertook a series of experiments to examine the effects of the addition sand, gravel and charcoal to soils with a view to understanding the potential role of such treatments on *kūmara* cultivation. This took the form of two experimental trials also located at Christchurch. Trial 1 had two objectives: to establish whether adding sand, gravel and charcoal changed soil temperature, to quantify this and to assess the effects of varying combinations of these elements to soil temperature (Worrall 1993: 27-52). Various combinations of the three treatments were applied either as a surface layer, or a mixture with the natural soils on a 1:1 ratio. A total of 16 different treatments were applied to the parent soil. The temperature was then measured at 5 cm depth at hourly intervals between 20th February and 8th March 1993. Trial 2 aimed to explore the potential effects of two variables on plant growth; dilution of soil with sand and atmospheric temperature.

Worrall assessed the results of Trial 1 both in terms of the raw results but also within the frame of degree days. Worrall acknowledged that soil temperature was only one factor affecting yield and that soil structure and nutrient levels were also important. Most treatments raised soil temperature above the control, except surface dressing with charcoal, which depressed temperature compared to the control. The greatest heat gain was with either sand, or sand and gravel, added as surface treatments but mixing these elements into the soil also effected substantial rises in soil temperature. Worrall identified four factors in the variance of soil temperature:

- Thermal conductivity,
- Volumetric heat capacity,
- Water retention,
- Surface reflection coefficient.

She also acknowledged that the inter-play between these factors was "complex and difficult" to predict (1993: 41). Sand and gravel have high bulk densities and improve or raise thermal conductivity leading to increases in soil temperature. When mixed into the soil they also decrease porosity, which decreases the amount of air in the soil, and this too increases thermal conductivity. Charcoal, on the other hand has very low bulk density and therefore low thermal conductivity, which means it acted as an insulator when applied to the surface. Volumetric heat capacity affects the rate of heat penetration; the higher the heat capacity, the slower the penetration of heat. Thermal conductivity and heat capacity are antagonistic. Soil moisture is also important because water is denser than air and so has a higher thermal conductivity. Soil moisture levels affect warming during the day but also insulation at night because there is less air to impede conductivity. Since oxygen is important for root development, soil porosity and tuber production are positively correlated. Good drainage aids the maintenance of air in the soil as well as preventing roots from rotting. The addition of coarse material, sand and/or gravel, to the soil medium decreases the overall porosity of the soil but it increases macroporosity, which is desirable because macropores improve drainage and aeration. Therefore, in summary, surface treatments promote moisture retention by suppressing evaporation which then facilitates heat retention. Mixing treatments promote friability, drainage, macroporosity and aeration, which all interact to affect the degree of heat retention.

In the context of Trial 1 Worrall discussed the effect of the length of the growing season also using degree days as a means to illustrate this. Since *kūmara* are perennial they do not reach a maturation stage, therefore the longer the growing season the greater the yield. The implication is that the shorter season imposed with increasing latitude the smaller the yield, both as expressed by tuber size and yield overall. In this context Worrall made the point that "raising of soil temperatures by 1-2 degrees in both autumn and early spring could provide valuable frost protection" (1993: 48), which would extend the growing season. By using degree days for Kerikeri (in the north of New Zealand), Lower Hutt (Wellington) and Christchurch she demonstrated that the degree to which treatment would extend the growing season would vary with latitude, such that the net gain at Kerikeri is over twice that at Christchurch; 55.8 degree days as opposed to 24.8. Given that Yen found the pre-European varieties are not cold tolerant the effect of such treatment becomes increasingly important the higher the latitude if the viability of successful harvests is the principal concern over maximising harvests.

In Trial 2 Worrall (1993: 53-65) quantified the differences in plant growth when the proportions of sand being mixed into the soil was varied; she used 1:2 (sand: soil) and 2:1. She also compared the growth between the Rekamaroa variety of *kūmara* and *kamokamo* (*Cucurbita pepo*) when both the sand/soil medium and the air temperature regimes varied. The warmer temperature raised dry matter yields while the higher sand ratio diminished dry matter yields; probably because dilution of the parent soil diminished the available nutrients.

Worrall's discussion is useful to consider because it informs us again of the complexity of the relationships between the various mechanisms affecting yield (1993: 68-70). Primarily, Worrall proposed that on the whole mixing sand and/or gravel into soil would have had the most benefit to yield through soil warming while, at the same time, dilution of nutrients would have adversely affected plant growth. She noted that optimum amounts of added material would vary with temperature/climate and the nature of the parent soil. These factors probably affected whether the sand or gravel was mixed with the soil or applied to the surface. Worrall also acknowledged an important consequence of this form of soil modification; although adding coarse material might result in "getting better kumara production in a single season, sand and gravel addition may have shortened the cropping period" (1993: 69). In other words, as more sand is added fewer crops could be successfully cultivated in a garden year on year. This gives some insight into the desirability of annual refreshment of sand or gravel to a modified soil. Potentially this practice would diminish yields and further shorten the viability of a garden, hastening the rate of forest clearance and garden development.

While Worrall's experiments provided valuable data to help interpret archaeological data and understand the agronomy of Māori horticulture it had significant short-comings. Trial 1 lasted 16 days rather than a span reflecting a growing season; nor did it employ mounds as described historically and *kūmara* were not grown in plots.

Another significant programme of experimental gardening began in 1999 when botanists Mike Burtenshaw and Graham Harris, along with archaeologists Janet Davidson and Foss Leach developed gardens at Robin Hood Bay on the northern coast of South Island and at Whatarangi in Palliser Bay on the southern coast of North Island. Today both locations are considered to be relatively marginal for *kūmara* cultivation but archaeological and historical records indicate horticulture was practiced in this region before European arrival (Leach and Leach 1979). The methodology and results are detailed in a number of sources (Burtenshaw 2009; Burtenshaw et al 2003; Burtenshaw & Harris 2007; Harris et al. 2000) and are summarised here. The Burtenshaw et al. (2003) and the Burtenshaw and Harris (2007) papers both present results from the gardens with the later paper providing results for gardens up to the 2005/2006 season.

The Robin Hood Bay garden was developed in 1999 adjacent to the site of an archaeologically identified pre-European horticultural site. This garden was joined the following year by the second at Whatarangi, also adjacent to a pre-European horticultural site. The rationale for the choice of locations was the use of soils known to have been employed by Māori for cultivation. The two sites had differing soils and climates although occupy almost the same latitudes. The Robin Hood Bay site was the more sheltered of the two gardens, located 400 m from the shore on a clay loam. The Whatarangi garden was located 60 m from the shore and was exposed to southerly winds, spray drift and was developed on a coarse sandy silt. The same methodology was applied to both locations.

Both experimental plots were 5 x 5 m and included 38 mounds which were each 30 cm high, with a spacing of 80 cm measured from the mound centres and laid out in a quincunx arrangement. No soil treatment took place at either site with the single exception of one mound at Whatarangi in the 2000/2001 season which had a surface treatment of local gravel. The soil was cultivated annually and the soil heaped into mounds before the seed tubers were planted. In the first year at Robin Hood Bay two tubers were planted in each mound; one on the north side and another on the south. After that only a single tuber was planted in each mound. Three of the old varieties rescued by Yen, Taputini, Rekamaroa and Hutihuti, were gardened but only Taputini was consistently gardened in the trial plots. The other two varieties were grown in adjacent plots but were not subject to the same experimental regime. The results detailed by Burtenshaw et al. (2003) and Burtenshaw and Harris (2007) refer specifically to the Taputini variety. Nonetheless comparisons were also noted on the performance of the Rekamaroa and Hutihuti varieties.

During the growing season temperature in the mounds was recorded using thermal cells buried 10 cm deep on the northern and southern sides of the mounds at both sites. Soil samples were taken at planting and harvest from both plots annually to assess soil fertility. The aim was to assess changes in soil fertility and determine the degree of correlation with yield. Labour inputs were also measured with the time taken for each task recorded. Yield was recorded as the weight of tubers produced by each plant, although there is no clear statement of what constituted a tuber mature enough to weigh. Once harvested and weighed, tubers were dried in the sun for a day to cure them before storage indoors, in an un-heated building in Wellington where the temperature varied between 6–27º C (Burtenshaw et al. 2003: 171). The tubers were weighed regularly during storage to understand tuber behaviour during storage and implications of this for seed stock for the following season.

Burtenshaw and Harris (2007) detail the results over 7 seasons for Robin Hood Bay and 6 seasons for Whatarangi. They noted the reliability of Taputini compared to the other varieties, especially the Hutihuti, and suggested that this provides some support for the notion that different varieties possessed qualities that made them more or less suitable for different places. The mean annual labour input (per plot) at Robin Hood Bay was 13.2 hours and for Whatarangi 8.3 hours. Burtenshaw and Harris attributed the variation to the friable soil at Whatarangi which made for easier cultivation.

Table 10.1: Average of yields from experimental gardens at Robin Hood Bay (7 seasons) and Whatarangi (6 seasons) (Burtenshaw & Harris 2007: 241–242).

	tonnes/ha	**range (t/ha)**	**mean/plant (g)**	**mean tuber weight (g)**	**mean no. of productive plants**	**mean growing season (days)**
Robin Hood Bay	10	5–16	613	34	34	178
Whatarangi	14	8–26	908	60	31	178

The difference between yields at the two sites growing the same variety are striking and underline how much local conditions affect yield (Table 10.1). It also highlights the variability from season to season. There were discernible trends in yield at both sites (Burtenshaw & Harris 2007: 241-242). At Robin Hood Bay the yield was relatively stable initially but declined after 2003, while at Whatarangi the reverse occurred with yield increasing. Mineral nutrient levels were low at both sites compared to those currently thought to be needed. Both potassium and phosphorus were very low compared to accepted means, particularly at Whatarangi, which also had very low levels of calcium. Interestingly, across the growing seasons, the levels of fertility did not alter significantly despite annual cropping. For some of the data we only have results from the first season at Whatarangi and the first two seasons at Robin Hood Bay (Burtenshaw et al. 2003). Soil temperature means for the 2000/2001 season were 19.08° C at Robin Hood Bay and 20.34° C for the un-mulched mounds at Whatarangi, while the single mulched mound was 21.29° C.

The results of the storage trial for the winter of 2000 were presented. The total seed tuber weight was 6.95 kg at harvest in April 2000 and 4.37 kg at planting in October 2000. Much of the weight loss prior to August was ascribed to transpiration of water and later weight loss to rot (Burtenshaw et al. 2003). This emphasised to them the importance of curing and storage in the crop cycle. They also noted (Burtenshaw et al. 2000; Burtenshaw 2010) that more care and time needed to be taken in harvesting *kūmara* than with other root crops like potatoes because the tubers are long and brittle.

Burtenshaw and Harris (2007) were impressed by how well adapted Taputini was to nutrient poor soils, noting the higher yield in the nutrient poorer soils at Whatarangi. They compared the yields up to 2005 to data from the FAO which gave the world mean yield as 14.9 t/ha and the average New Zealand mean yield as 13.3 t/ha and noted that the mean yields from both gardens compared well with these. They attributed the higher yield at Whatarangi to the warmer, more friable sandy soil at the site, despite the deficient nutrient levels and noted that, this phenomenon “defies agronomic expectations” (2007: 244). Taputini’s drought resistance also impressed them; the Whatarangi crop yielded 12.2 t/ha in 2000/2001 during a one-in-a-hundred-year drought (Burtenshaw et al. 2003).

10.3 Hooker Road experimental garden

To explore the dynamics of growing a pre-European variety of *kūmara* in the Waikato region on Horotiu silt loam I cultivated an experimental garden plot over three seasons (2010-2013) on land adjacent to recorded pre-European Māori gardens and settlements sites. Unlike earlier attempts at experimental horticulture, which focused on exploring and reconciling the ideas propounded in ethnohistoric literature (see Chapter 3), this experiment was motivated by available archaeological data. In particular, this was focused on the BSH phenomena. In general, the methodology followed that described by Burtenshaw et al. (Burtenshaw 2010; Burtenshaw et al. 2003; Burtenshaw & Harris 2007) but with specific variations in mound matrix and the creation of hollows filled with transported Hinuera Formation alluvium (Figure 10.1). The method and results are detailed in Appendix H and the following is a summary and interpretation of that data.

Four mound styles with varying soil matrices were employed (Figure 10.2). Three constructed on sand and gravel filled hollows and a fourth that was a form of control with a mound of loam made directly on the natural soil surface. The mound matrices used on the BSHs varied; loam, sand and gravel, and the 1:1 mixture of the two. Temperatures were recorded along with yield and during the final season mounds in two rows were treated with wood-ash.

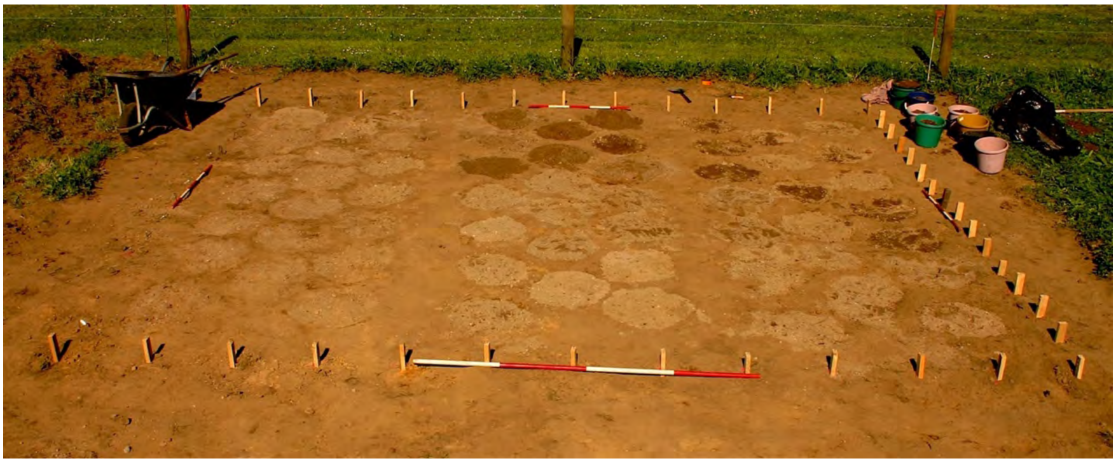

Figure 10.1: Hooker Road garden hollows filled with sand and gravel quarried from the C horizon (Hinuera Formation alluvium) at the start of Season 1.

Figure 10.2: Hooker Road garden mounds placed on top of each of the sand and a gravel filled hollow along with mounds placed on the 4th and 8th rows, which did not have hollows.

Of the four classes of mound, the control mounds consistently produced the lowest yield followed by mounds formed from the 1:1 mixture. The mounds formed from sand and gravel, and loam both produced higher yields but the pattern shifted over time. At the end of Season 1 the loam mounds had a substantially higher yield at harvest than the other mound matrix classes. However, in the second season the sand and gravel mounds produced the highest yield, with the harvest from the loam mound slumping to a level lower than the mixed matrix mounds. For Season 3 the results of the loam and sand-gravel mounds were similar but when allowance is made for the mounds treated with wood-ash, the sand-gravel mounds produced a substantially greater result than the loam mounds.

It was clear that the addition of wood-ash resulted in a significant increase in yield. If the effects from the additional treatment are allowed for, the yield from the loam mounds is reduced to a similar weight to the control mounds and was also lower than the mixed mounds. The sand and gravel mounds maintained the best yield in Season 3.

There is a clear picture of annual reduction in yield from year to year with a reduction of approximately two thirds from Season 1 to Season 2, and a further reduction by approximately half between Season 2 and Season 3. The Season 3 slump would have been greater without the fillip resulting from the addition of wood-ash to some of the mounds. Overall, the harvest from Season 3 was 16% of that in Season 1. The sharp and consistent decline in yields provides an interesting comparison to the fluctuating results found during the Whatarangi/Robin Hood Bay trials (Burtenshaw & Harris 2007). It must be acknowledged that it is possible that such a fluctuating pattern may have resulted if the experimental trial had been continued for a longer period.

The mean temperature during Season 2 was approximately 1.5-2º C cooler than other seasons; a significant difference. Season 3, however, had higher average temperatures than Season 1 but a much lower harvest. The difference appears to be the substantially lower rainfall during Season 3 compared to Seasons 1 and 2, which both had similar rainfall. In so far as a pattern can be discerned it indicates that fertility may be less important than temperature or moisture in the annual cycle. The increase in yield following treatment with wood-ash suggests that the establishment of gardens on land freshly cleared of forest will have benefitted significantly from the flush of nutrients released during the burning of cleared vegetation.

Figure 10.3: Harvest of control mounds (Row 4 Mound A) showing the harvested tubers. Note the tubers that 'embedded' themselves in the under-lying soil (centre-right of image).

While the control mounds were consistently the poorest performers regarding yield they provided an additional and unexpected insight into the growth habits of the tubers. Tubers from control mounds had a distinct tendency to form in the base of the mound and penetrate into the firm subsoil (Figure 10.3). This was something also witnessed with tubers in the other mound-types when they overflowed the BSHs. Tubers that penetrated into the subsoil were significantly more difficult to extract without damage to them, either as a break through the tuber or scraping or similar to the soft skins of the tubers. The brittleness of the tubers was a distinct feature and is also commented on by Harris et al. (2000). Concomitant with this was the phenomenon where tubers in the bowl-shaped hollow mounds would form on top of the sand and gravel fill with only the fibrous roots penetrating the medium (Figure 10.4). This tended to make the tubers shorter and fatter than they would be if they were grown in the type of deeply tilled soil found in home garden plots[35]. Together these indicate a beneficial outcome from the development of the BSHs, the formation of robust tubers within the friable mound matrices that were easier to harvest and handle without damage.

Figure 10.4: Season 2, Row 2 Mound F (loam mound type) showing mound cross-section. Note that the tubers are forming on the surface of the sand and gravel hollow fill, which appeared to constrain their form, making them shorter and fatter. Ruler is 15 cm long.

It was also evident from the experimental gardening that the curing of tubers was important in enhancing durability in storage. The autumn timing of harvest and curing, when days are shortening and weather unpredictable increased risk to the crop when it was vulnerable to damage from rain and frost. Following on from this, it is evident that, as suggested by Burtenshaw et al. (Burtenshaw et al. 2003; Burtenshaw & Harris 2007), the storage phase was crucial in the annual cycle. During storage tubers would probably have required regular curation especially in later winter and early spring, as the storage phase drew on, to prevent potentially calamitous problems with rot. In this sense the harvest of robust and undamaged tubers would have been important for successful storage and preservation of the seed and food tubers.

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[35] Following experience over several seasons by W Gumbley.

10.4 Outcomes of the Hooker Road experimental garden results

It is clear from the experimental gardening research summarised here, along with the results of the Hooker Road experimental garden that the interplay between variables of climate, soils and plant varieties is complex, as Worrall (1993) noted. While the yield from the Whatarangi garden had fluctuated over its long duration of use the yields in the Hooker Road garden exhibited a consistent and spectacular decline over the three seasons. To some extent this could be attributed to particular variations in weather, either dry or cool summers. Nonetheless, yields at the Hooker Road garden were significantly greater than the Whatarangi and Robin Hood Bay gardens with the same *kūmara* variety. As much as four times the Robin Hood Bay and Whatarangi results (Burtenshaw and Harris 2007) in the first season at Hooker Road. The role of nutrients at the Hooker Road garden is enigmatic. While they did not vary significantly over the three seasons the distinct increase in yield in the mounds dressed with wood ash in Season 3 shows that the Taputini variety is responsive to nutrient enrichment, providing some insight into the potential value of nutrients released through forest burning.

An important, and to some extent unexpected[36], outcome was the apparent role of the coarse material filling the hollows. Not only did this contribute to higher yields compared to the control mounds without hollows underneath, it also forced tubers to grow within the mound forming shorter and sturdier tubers that were conspicuously easier to harvest without damage. This, together with Burtenshaw et al.'s (2003) identification of storage preservation issues, underlines how crucial effective harvest and storage are for success over the annual garden cycle. This outcome appears to identify a potentially powerful motive for inputs Māori were prepared to introduce to maximise success in these two stages.

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[36] Noting Singleton's (1988: 54) identification of the potential role of a sharp textural interface in the agronomy.

11 An agronomy in two parts: Discussion of the results

Questions around the introduction and adaptation of Polynesian horticulture to New Zealand have been a recurrent concern in understanding Polynesian settlement of New Zealand. The literature on the settlement of Polynesia repeatedly draws attention to New Zealand's climatic and geological exceptionality within largely tropical Polynesia (Bellwood 1978; Davidson 1979; Kirch 1986, 1989, 1991). The aim of this thesis is to understand the adaptation of Polynesian horticultural practice through the lens of the Waikato Horticultural Complex, founded as it is on the manufacture of soil environments with transported sand and gravel. In this context the Waikato Horticultural Complex is a massive representation of a class of horticultural site found in various parts of New Zealand.

While this research is founded on traditional archaeological field methods it has been supplemented by allied disciplines: soil microstratigraphy, anthracological, plant microfossil analysis, examination of soil sediments (principally soil particle size analysis), and radiocarbon dating. The archaeological data has been contextualised through the results of experimental gardening undertaken over three seasons. Design of the experimental garden drew on archaeological field data to explore the agronomy behind the archaeological remains. The multidisciplinary approach employed in this thesis has facilitated a nuanced understanding of its nature, timing and role. And to address the six objectives as outlined in the introduction.

To reiterate, the objectives of this thesis are:

1. Characterisation of field evidence from investigations of sites forming the Waikato Horticultural Complex to understand the contexts into which transported materials were placed and to determine how they were deployed in the light of taphonomic processes.
2. Establishing the extent of the Waikato Horticultural Complex within the inland Waikato and to understand any possible limiting or enhancing environmental influences.
3. To understand the relationship of the horticultural system with the local environment, particularly within the frame of the swidden process and evaluate evidence for cyclical use.
4. Identifying cultigens grown in the Waikato Horticultural Complex.

5. Determination of the chronology of the Waikato Horticultural Complex with particular concern for identifying when and where this system appeared in the inland Waikato and the timing of its propagation.
6. Understanding the agronomy of the Waikato Horticultural Complex and to contextualise potential motives for the intensified agricultural inputs through the lens of results from an experimental garden.

11.1 Extent and chronology

The scale and extent of the Waikato Horticultural Complex means it stands apart from other horticultural systems identified in New Zealand. With a stretch of 110 km along the Waikato River, including two major inland basins, it is larger than the large scale "stone fields" horticultural landscapes of Auckland and the inland Bay of Islands (Bulmer 1989, 1994; Furey 2006; Sullivan 1985). Other New Zealand horticultural systems based on the manufacture of soils are all significantly smaller. The largest of these is found in south Taranaki, and although extending over 40 km along the coast (Buist 1993) it is still much smaller than the Waikato Horticultural Complex.

The extent of the Waikato Horticultural Complex is fundamentally tied to the geological particularities of the Lower and Middle Waikato Basins. Here free-draining loams with a friable structure overlie abundant reservoirs of sand and gravel. Without this association the agronomy of the Waikato Horticultural Complex would not have been possible.

The system as represented in the Lower Waikato Basin remains uncharacterised beyond the early work undertaken by Law (1968) when he identified made soils and their distribution. From Law's work we know the distribution of sites is closely bound to the banks of the Waikato River where levees are formed from recent alluvia. These provide the only sources of free-draining soil in a landscape where the lowlands are dominated by lakes and peat wetlands and where hill soils are generally poorly drained silt and clay loams.

In the Middle Waikato Basin where suitable soils are significantly more abundant, the distribution of sites is more complex with sites found on soils on low river terraces of recent Taupo Pumice Alluvium and higher terraces and plains of the older Hinuera Formation. Sites remain strongly clustered to the Waikato River and various of its tributaries with 78 percent of sites within one kilometre of the river and 50 percent within 500 m (Gumbley and Hutchinson 2013). This distribution of horticultural sites does not primarily reflect the distribution of soils suitable for conversion. There are extensive tracts of these across the surface of the Hinuera Formation. Rather, it reflects the importance of waterways for transport and access to a range of aquatic resources. In this sense the Waikato River and its tributaries serve as an analogue for coastal and harbour resources.

In this context the apparent concentration of made soils in the Cambridge and Leamington area is conspicuous. Here horticultural sites on opposite banks of the Waikato River are found in density up to four kilometres from the river. There is nothing exceptional about the geology in this area, nor is the climate locally unusual. The “bulge” away from the river reflects frequency of use and implies an extended period of continuous or near continuous gardening steadily expanding away from the Waikato River.

Radiocarbon data indicates that the Cambridge/Leamington area was the early focus for the Waikato Horticultural Complex. Here sites relatively close to the river appear in the early to mid-sixteenth century. Sites distant from the river are consistently much younger with the remotest sites dating to the eighteenth or early nineteenth centuries. Within the constraints of radiocarbon dating precision, the Waikato Horticultural Complex had spread fifty kilometres down the Waikato River, at least as far as Taupiri by the late sixteenth to early seventeenth century.

11.2 From taphonomy to agronomy

Results from soil micromorphological analyses paint a clear picture of depositional processes associated with both the TALs and BSHs. In both systems the core characteristic is the coarse material quarried in nearby borrow pits and transported to the gardens but once there its application follows different paths.

11.2.1 Bowl-shaped hollows (BSHs)

Rare preservation and limited disturbance were key to interpreting these archaeological features. The BSH clusters are unambiguous representations of gardens where the place of individual plants is recognisable. The BSH fields at S14/198 and S14/248 were sealed under succeeding soil development and filling processes, protecting these gardens from later disturbance that has often affected similar gardens on the natural ground surface. Therefore, micromorphological analyses of contexts at these sites have been valuable.

Use of sand and gravel to fill hollows raises obvious questions about the role of the hollows and more particularly the fill unit. Was the fill a growing medium or did it have another role? Is evidence for a growing mound present? Since mounds were, by their nature and function, ephemeral structures destroyed at harvest, they are challenging to identify.

Micromorphology tells us the fill unit was undisturbed other than superficially during crop growth and harvesting. Field observation of BSHs and their fill units shows that other than the loss of the water-bedding micro-features the fill is visibly unaltered from material in alluvial beds. There are no obvious residues of admixed charcoal or any other material, such as loam. Soil micromorphological analyses reinforce this by identifying micro-structures consistent with a single dumping episode. The same analyses did not identify any micro-remains of additives, nor any evidence of biological activity below the upper interface of the fill unit. There is evidence that superficial disturbance of the upper fill has also trapped loam, interpreted as the remains of mounds on the surface of hollows' fills. All overlying units at the sample sites, including the black layer, have developed following natural processes. The black layer's colour results from a high organic content, primarily humic acid staining but also at times high concentrations of bracken charcoal representing succeeding landscape fires of fernland with occasional contributions from seral shrubland.

The question of the representativeness of the gardens in the borrow pit fills needs to be addressed since these appear to be unusual contexts for the gardens. The spacing and arrangement of the BSH in these gardens is generally the same as those found on the ground surface and it appears that the surface of the re-filled borrow pits offered another surface to exploit; one that would have been, on the basis of experience during investigation, a very sheltered and warm location. In fact, although the flowering of *kūmara* in New Zealand is rare[37] it raises the possibility that these environments may have served to promote flowering, which in turn has potential consequences for development of new varieties.

11.2.2 Transported alluvium layers (TAL)

TALs are the second agronomic process manifested in the Waikato Horticultural Complex, and although the bowl-shaped hollow phenomenon is to a great extent unambiguous the TAL systems are enigmatic. Following early nineteenth century reports of the gravel mulch by Taylor (1855) and Wakefield (1845) interpretations of the phenomenon were that layers of

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[37] Flowering of the taputini variety has been identified at the Mangere Mountian education centre garden in Auckland. The plants were growing in a sheltered site adjcent to paving (Ian Lawlor personal communication).

coarse material were the remnants of a mulch. A fundamental problem with this assumption is apparent: where do the plants, or more specifically the tubers, fit into this context?

The identification of an un-ploughed TAL system at S15/424 is also rare. We know from field observation at this site that a sandy turf overlies a TAL (sand and gravel), which is visibly divided by colour into darker and paler sub-units. However, the matrices of both sub-units have the same texture and little visible charcoal. The TAL overlies a buried topsoil containing abundant and often coarse charcoal pieces representing the remains of a range of forest species. The interface between the TAL and the buried topsoil (Ab horizon) is undulating and pock-marked in a manner reflecting the use of cultivating tools and including possible tuber moulds. Mixing of coarse material with the buried topsoil is detectable but confined to the thin interface zone.

Micromorphological analyses confirmed natural pedogenic processes were responsible for topsoil development. The same analyses identified the difference in colour between the upper and lower sub-units of the TAL. These are a consequence of natural processes, involving fine material from the underlying tephragenic horizons being mobilised into the lower unit and the upper unit benefitting from fine organic material being created through biological activity probably accompanied by humic acid staining. Charcoal was found to be rare in both sub-units. The boundary between the TAL and the buried topsoil (Ab horizon) included mixing of coarse material from the alluvium with charcoal and fine sediments from the buried soil. The nature of the mixing and micro-structures created was interpreted by Grono (2020) as being consistent with a single episode of cultivation or harvesting. The buried topsoil unit contained evidence of disturbance and high levels of fine and coarse charcoal along with other organic material, which Grono (2020) interpreted as a topsoil disturbed by and perhaps created by forest clearance using fire.

In summary, the evidence paints a very clear picture of a buried topsoil (Ab horizon) substantially altered during the phase of forest clearance but largely unaffected by the growing and harvesting of the crops. This is overlain by a massive sand and gravel unit (TAL) with the attributes of a deposit that has been dumped and suffered unmistakable manipulation but which had no additives either deliberately or incidentally incorporated into it.

Bearing in mind the archaeological evidence is the result of the gardening process and centuries of weather and soil forming processes, can we interpret what the transported sand

and gravel were used for? There is clearly no substantial mixing of the transported alluvium with the old topsoil. However, if the TAL was employed as a mulch and the buried topsoil were the growing medium we would expect a different pattern to emerge than that observed. Considering a mulch scenario, tubers would be lodged in the buried topsoil and would have to be dug out. This action would have led to a mixing of the mulch with the topsoil, creating a distinct and clearly recognisable depositional unit of some depth with textures ranging from gravel to fine silt and including coarse charcoal and a mottled or mixed appearance, but such units have not been found.

The evidence emphatically points away from the interpretation of TALs as a mulch. However, since this unit speaks of substantial energy expenditure and coordinated activities by the gardening community it must have had an explicit function to justify the cost of quarrying and carrying it. The only viable alternate explanation is that the layer represented the deconstructed remains of the *puke* (mounds) following harvest. This means the transported alluvium was used as a growing medium into which seed tubers were planted. Since the Ab horizon (buried topsoil) was only superficially disturbed by crop raising and harvest its value was probably as a reservoir for the nutrients released when the forest was burned.

With the exception of the three sites where there is over-printing of BSHs there is generally an absence of archaeological evidence for repeated cycles of gardening at the same location. Grono's (2017, 2020) examination of soil micromorphology found no evidence for micro-structures typical of re-use for gardening. Charcoal data derived from sediments associated with post-abandonment fill sequences of borrow pits and crop storage pits describes a consistent post-gardening landscape transformation to fern-land with sporadic evidence for seral shrub colonisation. Both Leach (1980) and Shawcross (1967) consider the difficulty of returning fern-land to cultivation would have been considerable and probably impracticable. Best (1976), Colenso (1880) and Yate (1835) all described cycles of swidden in the context of clearance of seral shrubland after many years of fallow.

It appears that cyclical swidden leading to re-use of gardens was rare in the inland Waikato. A series of factors coalesce to promote this:

1. The difficulty involved in digging out colonising bracken fern would have added a significant quantum of labour input.

2. In a landscape where abundant supplies of high quality Horotiu Series soils were still available to be exploited re-use may have been inefficient, especially if enrichment from wood ash was desired.
3. The tendency for allophanic soils like the Horotiu loams to leach potassium and nitrogen while chemically binding phosphorus will have curtailed the availability of these nutrients even following the nutrient flush following forest burning.

11.3 Structure and Yield

BSHs, representing the remains of individual crop plants, are remarkable relics of an ancient agronomy. They offer us insight into the layout and structure of the gardens with a veracity not possible in the ethnohistoric literature. Their presence provides potential to comprehend the scale and yield of the gardens.

The remnant bowl-shaped hollow gardens provide direct evidence about the arrangement of gardens that allows a comparison with the accounts from, or based on nineteenth century observations of Māori root-crop horticulture (e.g. Best 1976). The historic or early ethnographic literature provides detailed descriptions of the modes of planting and rituals associated with garden development and emphasise a quincunx arrangement of plants but little detail about the proximity of the plants within the garden is included. Best (1976: 152) relates information from his informant Hari Wahanui[38] to the effect that rows were two feet (60 cm) apart. From the description this refers to a measure from centre to centre. Archaeological data from sites S14/194, S14/198 and S14/468 describes rows typically 60 cm apart but with variation from 40 to 70 cm, which accords well with Wahanui's information. S15/465 departs from this pattern with gaps averaging 90 cm and ranging from 60 to 130 cm. At the other end of the scale BSHs at S14/248 are closely spaced, averaging 45 cm with a range from 30 to 70 cm.

While the ethnographic literature (Best 1976; Colenso 1880; Walsh 1902) frequently refers to the regularity of the quincunx arrangement of plants in gardens the archaeological evidence relates a less orderly story. BSHs at S14/194 were arranged in a grid of near-parallel rows (Gumbley and Hoffmann 2013) as were examples in the parts of S15/465 that had not had BSH overprinting or recent damage. At S14/201 (Gumbley et al. 2004) both plots were

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[38] A consistent problem with Best's ethnography is the povery of referencing to sources. Some sources are not cited at all and others such as Hari Wahanui are identified but the date and nature of the communication is not stated. The style of Best's reference to Wahanui indicates communication was through written correspondence.

arranged broadly in quincunx layout but differed in orientation of the secondary rows. Most examples consistently describe layouts approaching parallel rows. Over-printing of the BSHs outside the borrow pit at S14/468 (Gumbley and Gainsford 2018) made it difficult to distinguish patterns but both parallel rows and quincunx-like arrangements in the form of off-set parallel rows appear to be present. The 31 BSHs excavated within the borrow pit at the same site were arranged in parallel rows but imprecisely, with some rows “sliding” into off-sets. The two gardens found in borrow pits, S14/198 and S14/248, both exhibit similar arrangement, fundamentally parallel rows with off-setting. Both of these gardens also included examples of single BSHs or short rows of 2-6 hollows inserted into gaps in the otherwise regular arrangement.

On the basis that each BSH represents a single *kūmara* plant we can use these data to reconstruct plant densities per hectare (Table 11.1) and by cross-referring to data from the Hooker Road experimental garden indications of potential yield may be attempted (Table 11.2).

Densities of BSHs from S14/194, S14/198 and S14/468 are similar and describe plant densities of 30,000 to 33,000 per hectare. Data from undisturbed parts of S15/465 indicates densities of 14,000 to 17,000 plants per hectare. The closely packed BSHs at S14/248 reproduce a comparatively high density of 53,000 plants per hectare.

Employing the optimal yields for loam and sand/gravel mounds from the 2010-2012 gardens at Hooker Road, yields as high as 60 to 76 tonnes per hectare are possible for BSH systems. Even the diminished yields from the 2011-2012 garden season represent substantial tonnages per hectare.

Table 11.1: Summary table of data describing density of bowl-shaped hollows (BSH).

Site	Mean. BSH spacing (cm)	Max. spacing (cm)	Min. Spacing (cm)	BSH/ha
S14/194	61	79	49	31754
S14/468	59	72	41	30075
S14/198	58	92	38	32995
S14/248	45	67	31	52917
S15/465	95	130	62	15559
Mean	63.6	88	44.2	32660

Table 11.2: Estimates of potential yield expressed as tonnes per hectare drawing on yield data from the Hooker Road experimental garden.

Season		**1**		**2**		**3**	
Site	**BSH/ha**	**Loam 2010-2011 (tonnes)** (2.33 kg/plant)	**S-G 2010-2011 (tonnes)** (1.86 kg/plant)	**Loam 2011-2012 (tonnes)** (0.57 kg/plant)	**S-G 2011-2012 (tonnes)** (0.82 kg/plant)	**Loam 2012-2013 (tonnes)** (0.2 kg/plant)	**S-G 2012-2013 (tonnes)** (0.34 kg/plant)
S14/194	31754	73.99	59.06	18.10	26.04	6.35	10.8
S14/468	30075	70.07	55.94	17.14	24.66	6.02	10.23
S14/198	32995	76.88	61.37	18.81	27.06	6.6	11.28
S14/248	52917	123.30	98.43	30.16	43.39	10.58	17.99
S15/465	15559	36.25	28.94	8.87	12.76	3.11	5.29
Mean potential yield	32660	76.10	60.75	18.62	26.78	6.53	11.10

11.4 Two gardening cycles reconstructed

Interpretation of evidence for both the TAL and the BSH systems describe two contemporary and complementary agronomic systems with contrasting processes (Figure 11.1). Following felling and burning of lowland *tawa*/podocarp forest both agronomic systems commence with the opening of borrow pits and quarrying the coarse alluvium to be transported to the gardens. Following this the two systems diverge in a step-wise fashion (Figure 11.1).

Development of BSHs can be perceived to follow these steps:

1. Clear forest,
2. Layout plots and excavate loam from BSHs,
3. Set excavated material aside,
4. Establish (or re-open) a borrow pit and commence quarrying, transport the alluvium to the hollows and fill them,
5. Replace excavated loam as a mound,
6. Plant seed tubers in the mound,
7. Harvest tubers destroying mounds,
8. Abandon garden.

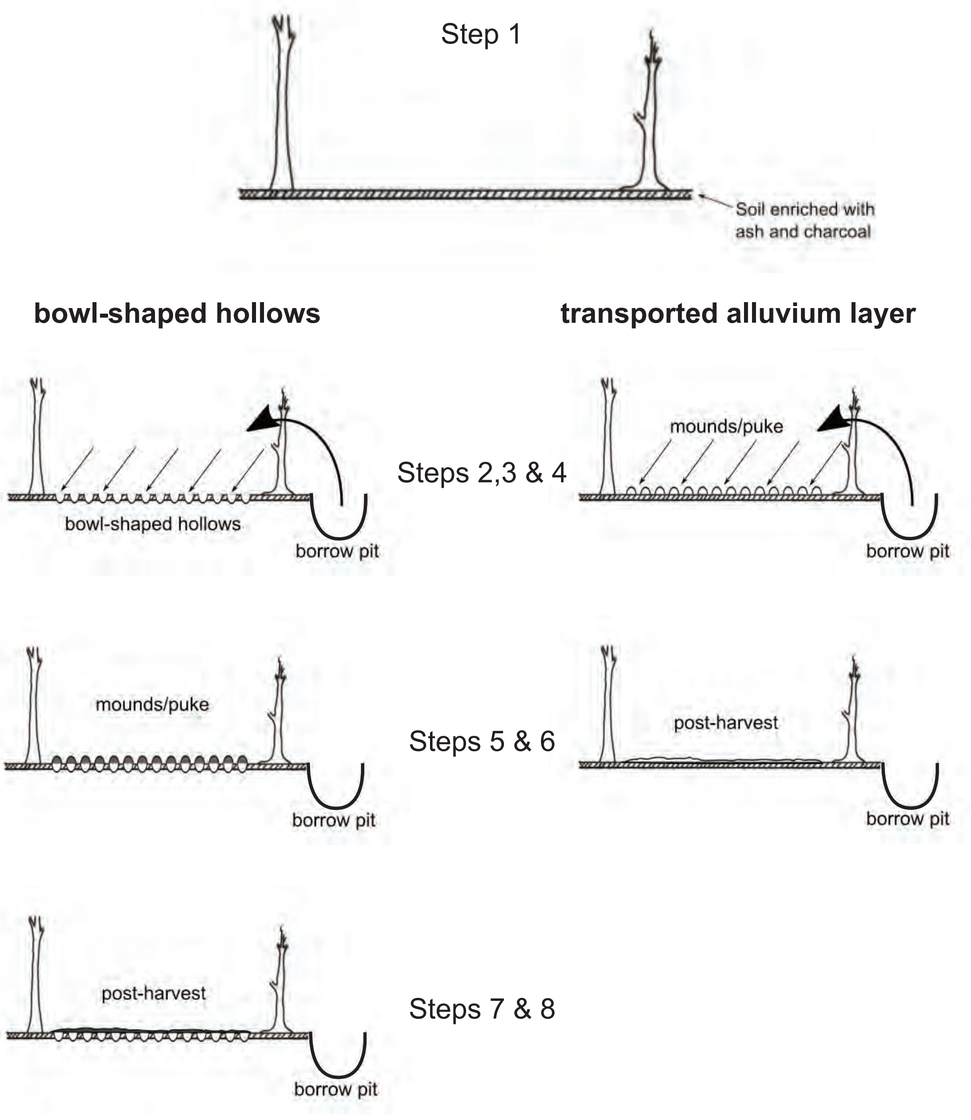

Figure 11.1: Diagram showing the steps involved from forest clearance through garden development, harvest and abandonment for both bowl-shaped hollow and the TAL systems.

For the TAL system, the process differs:

1. Clear forest,
2. Establish (or re-open) a borrow pit and commence quarrying,
3. Transport the alluvium to the garden and form mounds with it,
4. Plant seed tubers in mounds,
5. Harvest tubers destroying mounds,
6. Abandon garden.

While both systems involve significant labour, quarrying and transporting sand and gravel, substantial additional steps are included in the bowl-shaped hollow system compared to the TAL system, which relate directly to the creation and filling of the hollows followed by the replacement of the excavated loam as a mound. The extra steps to develop BSH garden plots would have imposed an added labour burden on the gardening community when developing these gardens compared to the TAL form.

11.5 Plants in the garden

Plant microfossils provide evidence for the cultivation of *kūmara* and *taro* at a number of sites, with tentative evidence from a single sample for yam. The remains of *kūmara* and *tar*o have been recovered from dryland gardens demonstrating a continuity of use of *taro* in swidden cultivation from the tropics with *kūmara* apparently substituting the role of yam (Barber 2012; Leach 2005). *Taro* plant microfossils appear in the record at approximately half the frequency of *kūmara* and it is tempting to regard this as evidence for their relative frequency in cultivation but it must also be recognised that this may also reflect possible sampling bias, albeit one that has not been identified. There is also an inevitable question regarding the possible function BSHs had as a garden form for the cultivation of *taro*. However, with the exception of a single sample recovered from the upper surface of a bowl-shaped hollow at S14/194 all the other *taro* microfossils have been identified in samples associated with the TAL form of the garden. Similarly, the presence of drains at some sites does not appear to relate to the cultivation of *taro* but rather reflect an opportunistic need to de-water poorly drained soil. Put simply interpretation of the relative roles of *kūmara* and *taro* in Waikato Horticultural Complex is limited by the methodology applied to plant microfossil sampling, which has been uniformly at low density capable only of identifying presence rather than patterns of distribution across a garden system. Further research on the role of *taro* is needed.

Data from experimental gardening allows contextualisation of the archaeology and an exploration of the motives and outcomes of the Waikato Horticultural Complex. Although the form of the experiment was designed around data referring to the bowl-shaped hollow system the results nonetheless permit inferences for the TAL system. The results from gardens where coarse material has been employed either as mulch or mixed with the parent soil (Burtenshaw 2010; Burtenshaw et al 2003; Burtenshaw and Harris 2007; Challis 1976; Harris et al 2000; Horn 1993; Worrall 1993) demonstrate additional lithic material improves temperature, particularly if it is placed on the soil rather than mixed with it. Horn (1993) and Worrall (1993) noted mixing sand and gravel with soil would cause a dilution of nutrients diminishing benefits to soil structure or texture. Results from the Hooker Road experimental garden support this with relatively poor results from the mixed material mounds. The implication is that repeated applications of sand or gravel would exacerbate this trend. However, the results of the Robin Hood Bay and Whatarangi experimental gardens (Burtenshaw 2010) along with the Hooker Road garden show that nutrients did not significantly alter over succeeding seasons and in this context appeared unrelated to yield. However, in all cases the nutrients levels were low at the commencement of the experimental gardens at Whatarangi and Hooker Road. It appears that the Taputini variety used in the experimental gardens at Robin Hood Bay, Whatarangi and Hooker Road can provide robust yields despite low nutrient levels and that it is hardy in this respect. Significantly, the effect of the added wood-ash to select mounds in the final year at Hooker Road demonstrated that improved nutrient levels can have significant effect on yield. Liberation of nutrients in ash from burned forest would have been a significant factor in yields. These would have been made available to plants differently in the two systems.

Evidence points to BSHs having loamy mounds as the growing medium and since these were derived from reworked topsoil they would have contained the freshly liberated nutrients. TALs almost certainly started as sand and gravel growing mounds. Given the low nutrient levels in these pumice and rhyolite clasts it seems certain that the underlying topsoil (Ab horizon) would have acted as an important reservoir for nutrients, which would have become available through plant’s feeder roots once they reached the topsoil. This is based on observations at the Hooker Road experimental garden (and my home garden), but also the archaeological observations of tuber moulds in the upper surface of the Ab horizon, which demonstrate that feeder roots could have accessed any nutrients in the Ab horizon. In both cases, but particularly the second, seed tubers would have provided important nutrient and energy stores until soil nutrients could be tapped. In general seed tubers would have imparted a degree of resilience to the crop, especially in the early part of the growing season.

Data for rainfall and soil temperature at Hooker Road indicate both are significant variables that can affect the harvest, along with soil texture which influences both variables. In this respect the sand and gravel mounds have an apparent advantage over the loam mounds, although this only manifested after the first season at Hooker Road. The location of some bowl-shaped hollow gardens in the sheltered depressions of borrow pits probably reflect the use of these environments to raise the soil temperatures of loam mounds[39].

Harvest is arguably the critical phase of the growing season. Experience from the Hooker Road garden demonstrated it is this stage when the crop is at most risk from damage affecting its capacity to successfully store. Damage can occur either mechanically while being dug or from adverse weather when being sun-cured for successful storage. The control mounds, and mounds that overflowed the sand and gravel filled hollows, exhibited a distinct tendency for tubers to form partly within the untilled parent soil. These tubers tended to be long and thin, and were well anchored in the parent soil. Harvesting these tubers required more time and involved greater opportunities for damage. In contrast the tubers formed in mounds over sand and gravel filled hollows formed on the surface of the sand and gravel, apparently a reflection of the abrupt textural interface discouraging root penetration as suggested by Singleton (1988). These tubers tended to be thicker and shorter and because they were enclosed in a loose growing medium (the mound) they were harvested quickly and easily by hand, resulting in fewer breakages and damage to the skin. The contrast in potential storability of tubers is significant. Stout, as opposed to long, thin and often bent tubers, are much less likely to break during handling before and during storage and may potentially be less affected by the desiccation during storage described by Burtenshaw et al. (2003).

11.6 Motivation

The strategies for the two agronomic systems involved in the Waikato Horticultural Complex are multifaceted, reflecting a balancing of the growing environment to ensure access to nutrients, maximisation of soil temperature, and retention of soil moisture. This has occurred in the context of increased labour inputs entailed with the quarrying and transport of coarse material from the alluvial substrate. Together, these two streams of inputs intersect to maximise yield of a crop that will store well. The BSH system had comparatively high inputs at the beginning of the season requiring additional steps during garden preparation but with probable easy harvesting of stouter, stronger tubers in good condition to maximise storage success. The TAL system employed mounds of sand and gravel that were faster and easier to create, and which would have maintained higher average temperatures. Evidence from the archaeology combined with evidence from the control mounds at Hooker Road suggest that

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[39] No evidence of TAL systems has been found in borrow pits to date.

the recovery of tubers in good condition under the TAL system may have required more time and effort than the bowl-shaped hollow system. This interpretation raises the possibility that one of the roles of the bowl-shaped hollow system was providing good quality storable tubers for seed. Certainly both TAL and BSH systems overlap diachronically and spatially and their employment does not reflect any variation in the soil environment. The differentiation can be argued strongly to reflect desired functional outcomes in identical environments.

Motivation for increased labour input generally rests on perceived outcomes and these normally lie in increased production or in risk management to impart resilience to yield. This has been a significant part of the discussion of Polynesian horticultural systems in subtropical environments, whether these are in the highland of Hawai'i or Rapanui. Lightfoot (1996, 1996; Lightfoot and Eddy 1994) describes the advantages of what he terms lithic-mulch agriculture, and which has been relied on in explaining the advantages of adding lithic material for Rapanui (Bork et al 2004; Ladefoged at al. 2013; Louwagie et al. 2006; Wozniak 1999). Barber (2010, 2013) has also referred to Lightfoot in the context of New Zealand horticultural systems.

Lightfoot's definition of lithic mulch extends to include pits, mounds, terraces, ridges and solid layers of lithic material. He notes that lithic mulch systems are "mostly associated with warm and dry regions" and that "areas where lithic mulch was used are relatively marginal for agriculture" (Lightfoot 1994: 177–178). He goes on to add that most sites of lithic mulch agriculture exhibit short duration and limited areas where this technique was applied. It is important to note that Lightfoot's archaeological examples, with the exception of the Māori, refer to systems where cereals were grown, mostly maize, in arid environments. As noted above, the concept of mulching in the context of root crops is problematic when taphonomic processes are considered.

Of particular relevance here is Lightfoot's inclusion of Māori use of sand and gravel in his discussion of these systems, where he refers primarily to Rigg and Bruce's (1923) description of the Waimea Plain system in the northern South Island and also appears to rely on their data. The advantages conferred by applying lithic material to the ground surface (Lightfoot specifically excluded mixing of this material with soil[40]) are:

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[40] The BSH system would be excluded from Lightfoot's definition of a lithic-mulch agricultural system.

- increases in soil moisture by promoting infiltration and reducing evaporation by wind and sun,
- control of weeds,
- raising soil temperature including moderating diurnal temperature changes,
- protection of the soil surface from erosion by wind and rain. (Lightfoot 1994, 1996 and Lightfoot and Eddy 1994)

In a general sense any of these may have served as motives for the development of the transported alluvium system of the Waikato Horticultural Complex. But like Horn (1993) and Worrall (1993), Lightfoot identifies the restriction of soil nutrient renewal with consequent decreases in nutrient levels over time as a disadvantage of lithic mulch.

Lightfoot (1994) adds that these advantages would have been used by Māori primarily to expand arable land with additional roles in arresting declining yield and extending the growing season. More specifically he states:

> “The Māori .... used the strategy to expand agriculture into areas that were otherwise less suitable to the moisture and temperature requirements for their crops.” (Lightfoot 1994: 181).

In the context of the Waimea Plain system it is conceivable that lithic material may have allowed or promoted the cultivation of Polynesian crops at 41ºS by alleviating temperature stress but the argument loses force when applied to the Waikato (37ºS) where suitable soils were abundant, temperatures somewhat milder and the pluvial regime substantial and reliable. Nonetheless, soil moisture retention may have provided useful buffering during short-term moisture deficits which can occur seasonally. However, the identified drought-hardiness of the Taputini variety (Burtenshaw et al. 2003) demonstrates that this may not have been a significant consideration. It is notable that when Lightfoot considered temperature and rainfall variables in such systems globally, Māori horticulture is an outlier, particularly with reference to rainfall (Lightfoot 1994: 179, Figure 5).

One variable that this discussion does highlight is the uncertainty about the degree of the effect imposed by the Little Ice Age on the Waikato. Leach and Leach (1979) considered this to be an important factor in the cessation of horticulture in southern North Island. In Anderson’s (2016) recent summation of the effect of this period of climatic cooling on the extent of Polynesian horticulture in New Zealand, he argues that the limit of southern viability shifted 150 kilometres north from the sixteenth century and describes a generalised adversity with cooling temperatures but not an increase in aridity. Current research on speleothems from the Waikato region may clarify the local effects.

11.7 Conclusions

The establishment of the Waikato Horticultural Complex at some time in the sixteenth century and its continuous replication until the early or mid-nineteenth century speaks to a robust and successful agronomy. Origin inevitably becomes a question. Was it a local innovation or was it imported? There is both an immediate and remote element to this question. Was this an agronomy imported into the inland Waikato from elsewhere in New Zealand? The obvious point of focus here is the similar system located on the west Waikato coast at Aotea Harbour. This area is an origin location for descent groups of the Tainui Waka living in inland Waikato who still have strong links to Aotea Harbour. It is also significant to Tainui descent groups because it is the place where traditions describe the first planting of crops in New Zealand by Whakaotirangi, the wife of the commander of the Tainui Waka, at Aotea after arrival from Hawaiki (Kelly 1949; Jones and Biggs 1995). Although Walton (1978, 1983) undertook archaeological investigations of the Aotea system they were exploratory and provide no clear picture of its nature and timing. In very general terms the Aotea and Waikato systems are similar and contemporary. Intriguingly, there are distinct genealogical links between hapū (clans) at Aotea Harbour and descent groups associated with the Aotea Waka[41] living in both northern and southern Taranaki where Māori-made soils are also found (Diane Bradshaw, personal communication).

More remotely the question is whether the practice was carried with colonists to New Zealand. Evidence considered in Chapter 2 shows that practices similar to BSH and TAL were absent from central Eastern Polynesia, where consensus places the origin of Māori. However, practices similar to "stonefields" systems found in New Zealand are present in Hawai'i, and on Rapanui a range of techniques involving various forms of rock application and arrangements occurred, some of them, such as veneer surfaces and mulched soils, superficially akin to the Māori-made soil phenomena. Barber (2010) has canvassed this concern and considers that rather than direct transfer these represent parallel expressions of experimental responses reflecting marginality for tropical Polynesian horticultural practice. In

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[41] Aotea Harbour is named for the Aotea Waka which arrived at the harbour before departing south to Taranaki. This occurred prior to the arrival of the Tainui Waka.

this sense the Waikato Horticultural Complex represents a continuity in the adaptable nature of Polynesian horticulture at its extreme margin but not as a direct transfer of an established agronomy.

Although the Waikato Horticultural Complex is fundamentally well understood it is difficult to comprehend precisely where it sits in the theoretical schema. Kirch's model for the "development of production systems" has three phases: adaptation, expansion and intensification (1989: 152). The Waikato Horticultural Complex is representative of all 3 elements in the understanding that each component is not exclusive of either of the other two. Nor are the relationships between the three components strictly diachronically dependent. However, it must be conceded that the caveat exists so that components 2 and 3 are not possible if adaptation has not commenced and progressed to some degree. In New Zealand this is demonstrated in Yen's 1961 model, which reflected his agronomic perspective and his consideration of the timing and impact of climatic deterioration (Yen 1961).

Yen divided the adaptation phase into Introductory and Experimental, with a Systematic phase implying the application of the adaptive measures. Without further investigation into other similar systems, particularly that at Aotea it is not possible to know whether the Waikato Horticultural Complex was experimental at the time it first appeared or was an imported technology. Certainly by late prehistory it must be described as systematic.

Leach's (1979b) adaptation of Yen's model, with its nuanced elaboration of Yen's phases, places the Waikato Horticultural Complex beyond the experimental phase. While Leach bases the concept of regional consolidation in what is probably now an outdated notion of storage pit variation, the concept of the overall system being a regional consolidation of earlier experimental horticultural efforts may conceivably fit, but once again the absence of chronological and technological context for the Waikato Horticultural Complex in relation to similar systems in New Zealand leaves this unresolved. Was it a result of expansion from a secondary centre such as Aotea Harbour? Possibly, but it stumbles at the same place as regional consolidation.

Within its inland setting the Waikato Horticultural Complex was an expansive system both at the regional level and at that of the local garden landscape. Both agronomies appear to have been developed early without apparent changes after this early development. The advantages of both agronomies lay in resilience of yield, and in the case of the BSH system emphasising resilience through storage. Compared with the simple control loam mounds in the experimental garden both TAL and BSH systems represent technologies that maximise yield by maintaining moisture levels and soil temperature, with the latter emphasised in the TAL system. At this level the apparent variation in labour input between the two agronomies indicates a practical differentiation in intensity that probably accounts for the apparently more frequent manifestation of TAL relative to BSH systems.

Returning to Kirch's Expansion phase, it can be sustainably argued to apply as a process within the inland Waikato, if not as an expansion from coastal Waikato. The evidence for an early centre in the Cambridge area prior to expansion along the Waikato River is present. Does the Waikato Horticultural Complex represent intensification? It is certainly labour intensive, however, in terms of Brookfield's (1972, 1984, 2001) definitions it lacks the constant of fixed land area, because of the extent of high quality soil not yet exploited. However, it may be interpreted as ascribing "production greater security" (Brookfield 2001: 183) and in this context the Waikato Horticultural Complex can be described as an intensified swidden horticultural system.

How much can we generalise from the Waikato Horticultural Complex? Anthropogenic soils, like those of the Waikato Horticultural Complex, where soils were modified, or augmented through the addition of sand and gravel are a distinctive element of New Zealand's pre-European horticultural landscape, have been remarked upon since the early nineteenth century. Traditionally interpretation of this phenomenon has relied on early historical references, often of dubious reliability (Walton 1982) combined with contributions from soil scientists and archaeologists. Often archaeologists and soil scientists have themselves leaned heavily on the early historical literature initiating a form of self-confirming feedback loop where interpretations of data became constrained by the prior assumptions of the nineteenth century writers. Inevitably this has led to replication of the same assumptions and interpretations. For example, archaeological evidence clearly associates the practice of adding clastic material with well-drained soils but the nineteenth century notion of its association with "heavy" or poorly-drained has been persistent. The results of the research described in this thesis provides a contrast to the earlier research into Māori-made horticultural soils through both the landscape scale of the body of data and through the combination of multiple lines of evidence drawn from various disciplines. The image this creates of the Waikato Horticultural Complex is one of a multi-stranded agronomy of greater complexity than evidence to date has suggested. It also highlights the innovative and adaptive nature of

Polynesian horticultural practices that were challenged to the extreme in the temperate climate of New Zealand. The results of the research serve as a notice that similar levels of complexity may be represented at other Māori-made soil horticultural systems and that these anthropogenic soil environments should not be assumed to follow the patterns identified in the inland Waikato.

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