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Productivity, production and settlement in precontact Rarotonga, Cook Islands

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Abstract

In order to examine the precontact production system of Rarotonga beyond the limits of the archaeologically visible irrigated taro terraces, a model of potential productivity is created. The model is based on an assessment of the productive potential of soil types and an inventory of precontact crops on Rarotonga. It is used here to examine a number of factors related to production: temporal change in production; reliability of production; the perceived value of land; and settlement. There are a number of limitations to the model as it stands, but its main value lies in its use as a foil against which to examine these other, more interesting aspects of production. The model is based on environmental factors, but the Rarotongan production system is as much a product of history as of environment.

Introduction

Archaeologists working on precontact horticulture[1] in Polynesia have been most interested in taro (*Colocasia esculenta*) production, and most of this interest has concentrated on irrigated taro. The reasons for this are simple enough: firstly because irrigated taro terraces survive as sites in ways that shifting or swamp cultivations do not; secondly these sites are large and impressive as well as being easily surveyed and mapped; and finally because, beginning with Wittfogel (1957), hydraulic agricultural systems have featured strongly in the debate on the role of production in the development of sociopolitical complexity (Kirch 1994:5). These factors were a significant contribution to the research design and field work on which this paper is based, and which is in part reported here (see also Campbell 2000, 2001). However taro terraces form only a minor part of precontact production — horticultural methods that leave no direct archaeological trace were more extensive and contributed more to precontact subsistence (see further below). Even without visible site remains, there are definite clues in the environment that enable us to talk about other aspects of production alongside irrigated taro, and to begin to examine an integrated production system, which is what this paper attempts for the island of Rarotonga in the Southern Cook group.

Rarotonga is a typical Polynesian high island. At roughly 11 x 6 km, with a maximum elevation of 653 m, its topography is characterised by deeply incised valleys surrounded by a continuous coastal plain generally about 1 km wide. Surrounding the island is a fringing reef enclosing a shallow lagoon up to 1 km in width. The *tapere* system of landholding develops out of this concentric resource pattern. *Tapere* are radial land units, each centred on a valley and containing mountain, coastal plain, lagoon and reef resources. Each *tapere* was governed by one or more chiefly *mata'iapo*, who was the (usually) senior (usually) male member of the *ngāti*, or local descent group. *Ariki* were the highest chiefly grade and exercised vital ritual functions in society as well as heading cross-*tapere* alliances. Religious ritual was centred on *marae*, which while not as elaborate as similar structures elsewhere in East Polynesia, are robustly constructed of stone and so survive well as archaeological sites. Less robust house sites are not commonly recorded, particularly on the coastal plain, the zone of modern settlement.

Taro cultivation

With the arrival of the London Missionary Society in 1827 settlement patterns on Rarotonga changed dramatically. Those who wished to take advantage of the new opportunities of religion and literacy were obliged to relocate to coastal villages. This was followed by a dramatic depopulation due to introduced disease, with the result that inland horticulture and settlement were abandoned (Crocombe 1964:67, Lange 1982:148, Walter 1996:93). Taro production declined in general through the nineteenth century as draft animals and iron tools made dryland cropping easier, and crops that stored for long periods and could be traded to ships, such as kumara, were preferred (Crocombe 1964:86). By the early twentieth century Cheesman (1903:266) reported that "a good idea of the former extent of the cultivations can be gathered from the number of abandoned Taro-beds, now mostly overgrown with trees, which stretch far

1 Many, even most, archaeologists have used the term agriculture, which applies to extensive field production, whereas Polynesian production was primarily intensive gardening, focussing on individual plants. Horticulture is the more appropriate term (Leach 1997).

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up the valleys of the larger streams." The establishment of second growth forest indicates many decades since the sites were abandoned.

Since that time many of the taro terraces (or pondfields; in Rarotongan, *repotaro*, a term that refers to both the individual terraces and to the complex of terraces that constitute an independent system) have been brought back into use, a situation which made recording and mapping them very much easier, but complicates their status as precontact sites. A number of informants indicated to me that the *repotaro* in use today are the precontact *repotaro* in most cases, but some showed me occasional terraces that they themselves had built, and it is quite likely that many were rebuilt when they were cleared in the twentieth century. A set of *repotaro* in the Avana Valley were described by Bellwood (1978:83) as being abandoned when he mapped them in the early 1970s, and although they have subsequently been cleared and bought back into use they remain in plan, as far as I could tell from close inspection, exactly as they were when Bellwood surveyed them. Other long abandoned *repotaro* that I observed would need very little work beyond vegetation clearance and repair of the irrigation canal (*aravai*) to be brought back into production. Others are partly destroyed either by being undercut by the stream or by being covered by extensive slopewash, and would require major rebuilding to make them work again. However these are extreme examples, probably damaged beyond repair. Most *repotaro* that I mapped gave the impression of some age. They filled the flat area available to them and so would occupy at least the same extent as the precontact *repotaro*. Some repairs must always be carried out, but beyond this there is little incentive to fix what is not broken. It is a reasonable assumption that the *repotaro* recorded and mapped during the 1997 field season are, by and large, the precontact *repotaro* abandoned some time before Cheesman observed them.

Archaeological fieldwork in 1997 was located in the Takuvaine, Tupapa and Avana Valleys, and was centred on, but not limited to, *repotaro*. The construction of *repotaro* was standard throughout the survey area, and would seem to be fairly standard throughout Oceania (Allen 1991:121). Given the problem of maintaining adequate water control on sloping ground there are a limited number of engineering solutions. Spriggs (1984:130) describes furrow irrigation and Lepofsky (1994:62) describes barrage systems where water was dammed and allowed to flow over the flat area of a natural terrace. These may be precursors to full pondfield construction or represent a variant not found on Rarotonga. Allen (1991) notes variation in the quality and standardisation of pondfield construction on O'ahu, Hawai'i, and relates this to the degree of centralised control of taro production. Pondfields are labour intensive in their construction, but once in place they form a permanent capital works infrastructure which requires little maintenance.

Figure 1. *Repotaro* in Takuvaine, showing terraces following the natural contours.

To construct *repotaro* an area, rarely larger than 20 x 20 m and usually much smaller, is levelled and enclosed within walls of earth and stacked stone to form a terrace, the floor of each terrace being some 200 or 300 mm lower than the enclosing walls. Allen (1991:127) points out that smaller terraces allow for better water control, especially during heavy rains. A series of such terraces, stepping down one below the other following the natural contours of the valley floor, form each system. Water is dammed upstream and let into the uppermost terrace of the system by the *aravai*, which may be up to 60 m long, where it covers the bottom of the terrace to a shallow depth. It is allowed to flow from terrace to terrace by smaller *aravai* that pierce the terrace walls. The *repotaro* therefore resemble small scale rice paddies. The size of each *repotaro* complex is restricted by the available area of reasonably flat land on the valley floor and the amount of water that can be fed into a system by a single main *aravai*. Hillsides were not converted to irrigated taro production, as they have been in, for instance, New Caledonia. Higher up the Takuvaine Valley the valley floor is quite uneven and *repotaro* are constructed on relatively steep slopes, though not on the valley sides.

A particular restriction on modern *repotaro* production is where artificial water shortages due to the installation of domestic water intakes upstream of the *repotaro* have led to their again being abandoned. This is particularly the case in the Tupapa and Avana Valleys, where the cutting of service roads has also impacted on both horticulture and archaeology. In Takuvaine the water intake is below the surveyed *repotaro*.

Most taro production on Rarotonga today, as in the precontact period, takes place on the coastal plain. In the precontact period taro was grown in swamps which were drained by piling up soil and vegetation into islands some 200 or 300 mm above the water level, on which the taro was planted. Taro cannot grow in warm stagnant water, so this system was used to create a suitably moist environment from a permanently wet one. This contrasts

Figure 2. Swamp taro cultivation.

with the irrigated terraces of the valleys, where flowing water constantly irrigates the taro without becoming stagnant and causing it to rot. Both systems are in operation on Rarotonga today, although many of the swamps are being drained for the production of newly introduced dryland cultivars.

The earliest historic descriptions of taro beds fit neither of these cultivation methods. The missionary Charles Pitman describes "several taro patches have been dug by [Pa Ariki], & in order to be well watered he has dug down fm. the mountain which yields an abundance of good water & makes the taro yield abundantly (1832 II:86)", and "a great many people were digging extensive trenches for the water to run into the patches from the Mountains (1833 II:132)." Here Pitman is evidently describing a different kind of irrigation than the taro terraces of the valleys. Spriggs (1984:123) differentiates pondfield irrigation in terraces of the type already described, from island bed irrigation. In the latter the ground is neither sufficiently sloping to allow a sufficient through flow of water to construct terraces, nor is it permanently wet and swampy. Rather channels are dug around raised rectangular beds and water is introduced into the channels to form a system much like swamp cultivation in appearance, with the surrounding water soaking the island beds without rotting the taro corms. This would seem to be the cultivation method that Pitman witnessed in operation. The fully integrated precontact taro production system then would have consisted of pondfield terraces on the sloping valley floors — the smallest component of the system — giving way to island bed cultivation at the valley mouths and on the natural terraces, which in turn graded into true swamp cultivation. Only pondfield terraces leave the kinds of remains that constitute archaeological sites.

Spriggs (1984) has given a range of productivity figures for the different methods of taro cultivation, based on fieldwork in western Oceania, but nonetheless relevant to Rarotonga. Yields in the range of 32–58 tonnes/hectare would seem to be expected for all cultivation systems. Island bed cultivation requires more extensive fallowing than other systems and hence greater labour inputs due to more frequent initial preparation. Kirch (1994:155) records a fallow period of one to three years after seven years harvest in pondfields on Futuna, but my Rarotongan informants claimed no fallow was necessary, the soil being constantly replenished with new alluvial material. In practice pondfields are fallowed on Rarotonga — during my visit 35% of pondfields (not counting those that could not be mapped for various reasons) in Takuvaine, the only fully functional valley system on the island, were unused — though the reasons given were not agronomic, for instance rights to land could be disputed, planters could be off the island, etc. An assumed precontact cropping regime on a ten year cycle with cultivation followed by one or two years fallow would not be overgenerous. Assuming two or three years cultivation followed by two or three years fallow for island beds, the following approximate figures are obtained — constant (100%) cultivation in swamp beds, 50% in island beds and perhaps 85% in pondfields at any one time.

Repotaro were mapped by DGPS. Because of limited GPS satellite visibility it was not always possible to map them fully, resulting in many being only partly recorded. In the Tupapa Valley some, but not all, complexes were completed with tape and compass, and all dams (*matavai*) and main *aravai* were mapped with tape and compass. This extra work was only carried out as time permitted, and was not done in Takuvaine. All *repotaro* mapped in the Avana Valley were done with tape and compass due to limited GPS satellite visibility. Many had been long abandoned and were located under mature forest.

In Takuvaine many terraces were in fallow and covered by low dense bush, making mapping impossible. The Takuvaine stream has at least two tributaries large enough to contain *repotaro*, which were similarly overgrown. *Repotaro* also occur in the three other largest streams on the island — Avatiu, Matavera and Turangi — which were not recorded during the 1997 field season. Bellwood (1978:87) recorded four terrace systems in the latter, one of which has subsequently been destroyed by domestic water supply works. He also described a single *repotaro* system in the Maungaroa Valley, which he thought was a modern site (Bellwood 1969:519). The survey results are fully reported elsewhere (Campbell 2001), but a brief summary of the mapped *repotaro* in each valley is presented in Table 1.

Production systems

As noted above pondfield taro formed only a minor part of the production system. Any description of precontact production must therefore look more widely if it is to avoid presenting a misleading picture. Although they are the only part of the production system that remains

Takuvaine Valley

Site Number	No. of terraces	No. fully mapped[a]	Min. size (m^2)[b]	Max. size (m^2)[b]	Total cultivable area[b]
RAR111	30	30	2	94	622
RAR112	20	17	4	174	702
RAR113	6	6	3	90	270
RAR114	9	9	2	41	126
RAR115	27	27	1	245	182
RAR116	51	47	5	203	1999
RAR117	13	13	7	154	517
RAR118	15	13	5	83	480
RAR119	12	12	13	143	820
RAR120	9	9	6	44	219
RAR121	26	25	4	143	1323
RAR122	17	17	5	57	456
RAR123	19	19	7	75	510
RAR124	12	12	6	48	292

Notes:

a Due to vegetation cover obscuring the GPS, some terraces were only partly mapped or nor mapped at all.

b Fully mapped terraces only. Areas are given to the nearest m^2.

RAR111 & 112: These sites are immediately adjacent to each other, but are supplied with water by separate *aravai*, and so are recorded separately.

RAR116: Further *repotaro* were situated beneath trees where they could not be mapped by GPS.

RAR118: Further *repotaro* were not visible under heavy scrub cover.

Tupapa Valley

Site Number	No. of terraces	No. fully mapped	Min. size (m^2)	Max. size (m^2)	Total cultivable area
RAR125	17	8	24	110	497
RAR126	13	9	17.45	155	548
RAR127	7	7	18	201	725
RAR128	6	0	–	–	–
RAR129	9	9	13	77	446
RAR130	16	15	11	153	1038
RAR131	13	10	36	134	746
RAR132	14	14	26	172	1005
RAR133	5	5	27	284	523
RAR134	2	2	52	101	153
RAR135	3	2	15	136	151
RAR136	5	5	59	188	582
RAR137	10	9	10	79	337
RAR138	4	4	72	129	403
RAR139	3	3	53	138	258
RAR140	3	3	16	44	101
RAR141	15	15	4	77	460
RAR142	4	3	25	70	154

Notes:

RAR125: This site has evidently been abandoned for a few years and the edges of the site were heavily overgrown and could not be mapped.

RAR128: This site is connected to RAR129, but is completely abandoned and partly destroyed. An *aravai* from a small tributary stream leads into the site, but could have only flowed seasonally. The main water source must have been from RAR129.

RAR136: Two of the terraces in this site were made very recently (Bobby Turua personal communication, 1997). The rest of the site was built in the early 1900s, but it is not clear whether this was a new construction at the time, or repairs on *repotaro* that had previously been abandoned.

RAR139: Fully abandoned.

RAR140: Abandoned and densely overgrown.

RAR141: This set of *repotaro*, above the water intake, is the only set still fully working in the Tupapa Valley.

RAR142: Abandoned and partly destroyed.

Avana Valley

Site Number	No. of terraces	No. fully mapped	Min. size (m^2)	Max. size (m^2)	Total cultivable area
RAR143	11	11	8	92	495
RAR144	12	12	8	120	617
RAR145	1	0	–	–	–
RAR146	9	9	7	40	181
RAR174	3	2	142	188	330
RAR175	3	0	–	–	–

Notes:

RAR143 and 144: These abandoned *repotaro* are being bought back into production

RAR175: The main *aravai* for these *repotaro* have evidently been recut twice, indicating episodes of reconstruction. This may arise either from the stream cutting its level lower than the *matavai*, or from reconstruction after destruction by flooding. The Avana is the largest stream on Rarotonga and its valley is fairly narrow, so that it floods quite easily.

Table 1. Summary statistics for surveyed repotaro systems

visible as archaeological sites there is sufficient evidence from more indirect sources to enable us to reconstruct some wider aspects of precontact production.

Other precontact crops

The missionary Aaron Buzacott, in comparing the Rarotongan diet prior to the establishment of permanent missions with the diet at the time he left the island, trumpets the missionary achievement

> In 1828 the natives lived upon cocoa-nuts, bread fruit, bananas, and taro (wild arum), with what fish they could catch. The original breed of pigs was very small, and pork was rarely tasted by the middle class, never by the poor.
>
> In 1857, cattle, a better and more prolific breed of

Figure 3. Bananas planted on the banks of *repotaro*.

> pigs, turkeys, fowls, Muscovy ducks, sweet potatoes, beans, oranges, limes, citrons, tomatoes, turnips, loquet, custard apples, pineapples, coffee, Indian corn, carrots, cabbages, arrowroot, rice, and tapioca, had been introduced into the island. It is worthy of note that the diet of 1828 was such as a hurricane could and would utterly destroy, while many of the new articles of consumption were capable of being prepared and kept with care for almost any length of time. (Buzacott 1985:240)

Despite the propagandistic nature of this statement — many of the new crops were only of minor importance and many minor precontact crops are omitted — Buzacott is correct in stressing the essentially limited precontact diet, with only four staple vegetable crops and "what fish [including all sea and ocean resources] they could catch."

Of the taros or aroids *Colocasia* was the main focus of production, though kape (*Alocasia macrorrhiza*, giant taro) was also grown. This species does not require so damp a medium as *Colocasia* and was, and still is, planted on the banks of pondfields and grows wild in forest clearings. It is rarely eaten today, and may have been most important as a famine food (Thaman 1984:115).

Bananas were, along with taro, the most important crop on Rarotonga at the time the missionaries arrived there. They are frequently mentioned by the early missionaries, and it seems likely that most dryland cultivation was based around them. In the precontact period bananas on Rarotonga were of two kinds. Most important was meika, the common banana (*Musa acuminata x balbisiana*). Those growing today are probably not native varieties (Massal and Barrau 1956). Meika would have been grown extensively on dryland plots with interplantings of kape, ti, yams, breadfruit and coconuts. They would also have been interplanted between taro beds and pondfields as they are today, and have been planted in swidden fields in the first year of fallow.

The other type of banana was the ‘utū (often called plantain), the wild progenitors of which are not well known (Simmonds 1966:66), but which is sometimes referred to as *Musa fehi*. In Rarotonga they do not, as far as I am aware, persist in any numbers anywhere but were formerly abundant in dense groves on talus slopes in the mountains (Cheesman 1903:268). In the precontact period they would have been an important resource. Pitman (1832 I:361) records that the root of the ‘utū (puouou) was an important famine food.

The importance of kuru (*Artocarpus altilis*, breadfruit) in the precontact period is hard to gauge for Rarotonga. While Pitman (1828 I:91) reported that most breadfruit trees had been destroyed in precontact warfare he does not say, nor would he know, how many that was, and given his interest in making the greatest contrast between the heathen and Christian states of his converts, some exaggeration must be expected. Breadfruit may be stored long term in lined pits as a fermented paste called *ma‘i* (Savage 1980:129), which is an important food and famine resource elsewhere in East Polynesia. *Ma‘i* pits have not been located archaeologically on Rarotonga, but they have not been sought by archaeologists. Breadfruit on Rarotonga crops for only single short period each year and yields would have been lower than on warmer islands.

The nū (*Cocos nucifera*, coconut) was another important crop that was largely destroyed in war prior to the arrival of the missionaries (Pitman 1828 I:91). Coconuts would have been commonly grown on the gravelly soils of the hurricane beach ridge, which would have supported few other food plants apart from breadfruit, and anywhere to elevations of 100 m or more. Green coconut was an important source of drinking water, especially during drought, and the flesh of mature coconuts was processed to yield coconut cream, an important condiment throughout Polynesia (Massal and Barrau 1956:28). Coconuts also yield coir (a fibre used for making rope) and thatching for houses.

While yams (*Dioscorea* sp.) rate only a single mention in early historic descriptions of Rarotongan production that I am aware of (Williams and Barrf 1830, quoted below), they would probably have formed an essential part of the swidden cropping regime. McCormack and Künzlé (1995:87) describe two species of naturalised yams (‘oi, *Dioscorea bulbifera*, and pirita, *D. pentaphylla*) occurring at low elevations on the hills, the area where swiddening occurred. Other important Oceanic cultivars, such as *D. alata* and *D. esculenta* (Massal and Barrau 1956:12), are not found on the island today (Gerald McCormack personal communication 2002), but this does not discount their presence at contact.

Ti (*Cordyline terminalis*) was a plant of only secondary importance. The tuberous roots were cooked for up to three days and yielded a sweet, butterscotch flavoured food that was considered a delicacy (Savage 1980:376). It was cooked with kape to disguise the bitter flavour of the latter (Massal and Barrau 1956:39). Ti, along with kape and meika, were often cultivated on the banks between taro pondfields.

Kumara (*Ipomoea batatas*) was probably at best only of secondary importance on Rarotonga, if it was grown at all. Buzacott (quoted above)[2] claims that it was introduced by the missionaries, but he may be referring to improved varieties.

I'i (*Inocarpus fagifer*, Polynesian chestnut) is a handsome tree that grows to perhaps 20 m in height, and produces a large edible nut in abundance. I'i trees are commonly found as boundary markers throughout the island, and grow wild in the forest. They may have been seasonally important and, with a high protein content, a useful dietary supplement.

There are few clear early historic descriptions of the production system. One that is often quoted is that of Williams (1837:204) who describes, on the coastal plain

> rows of superb chestnut trees, (*inocarpus*,) planted at equal distances, and stretching from the mountain's base to the sea, with a space between each row of about half a mile wide. This space is divided into small taro beds, which are dug four feet deep, and can be irrigated at pleasure. These average about half an acre each. The embankments around each bed are thrown up with a slope, leaving a flat surface upon the top of six or eight feet in width. The lowest parts are planted with taro, and the sides of the embankment with kape or gigantic taro, while on the top are placed, at regular intervals, small beautifully shaped bread-fruit trees.

Similarly a banana planting area would contain breadfruit, ti, perhaps some i'i serving as boundary markers, and numerous other minor resource plants.

Williams and Barff (1830) give another description presenting a picture much like the situation of intensive multicrop house gardening that Lepofsky (1994:51) describes for the Society Islands. They describe

> Almost every individual having his Kaina or small farm cultivated with plantains, ti, taro, yams etc., so that the whole settlement appeared one extensive garden…
>
> The land on each side of the road was cultivated all the way, and on many little farms a house was standing for the accommodation of the owner when he comes to look after his land, food, &c…
>
> Our friends informed us previous to the late sickness scarcely a weed was to be seen on any of the farms…
>
> The houses of the people are on each side of the road surrounded with little gardens in which various kinds of vegetables were growing.

The mixed crop house gardens would have been an important part of the production system, and would have complemented the more extensive crops of taro and bananas further from the main areas of settlement. The picture presented is of intensive cultivation of the lowland, not just in house gardens but all along the coastal plain.

The inland production systems of the valleys are the best understood archaeologically, but little is known about precontact swiddening on Rarotonga. A model similar to that described by Kirch (1994) for Futuna may be assumed, but with an emphasis on banana rather than dryland taro, which does not seem to have been known on Rarotonga in early historic times (Manarangi 1984), though it may have been present but was lost when swiddening was abandoned soon after contact. Swidden on Rarotonga may also have consisted of interplantings of meika, yams and kape during the first year of the cycle, followed by more extensive meika as the swidden was returned to fallow.

Assessing productive potential

The concentric resource zonation on Rarotonga is essentially a result of topography, with erosion and storm deposition forming three discontinuous soil zones on the coastal plain, each with its associated cropping regime (Bellwood 1971:149, Walter 1996:80). Along the coast, storm ridge soils derived from reef corals are suitable for the cultivation of coconut and breadfruit. Most modern settlement is in this zone. Inland of these soils is a zone of poorly drained swamp soils, suitable for island bed and swamp cultivation of taro. The interior margin of the coastal plain and the floors of the larger valleys constitute a band of the various soils of the flood plains, terraces and fans. Many of these soils are suitable for island bed cultivation as well as banana and breadfruit cultivation. These two latter zones are the main horticultural areas. Hill soils of the interior uplands have some nutrient value, and it is on these soils that most swiddening would have taken place, though erosion risks are high (Leslie 1980:33).

Leslie (1980) provides extensive data on Rarotongan soil types, which when combined with the yields and fallow periods of major precontact crops suited to each soil

2 Buzacott was, of course, propagandising the missionary achievement, and it is generally felt that one can never be too critical (for which, rightly or wrongly, read "cynical") when interpreting missionary statements. He refers to kumara on two other occasions. Firstly in an early chapter entitled "Trials and Triumphs", he says that "on one occasion … Taro and sweet potatoes were cooked, and powdered, and mixed with flour, in order to eke out the scanty supply" (1985:39). Although this mention is made early in the chronicle, the phrase "on one occasion" indicates that it falls outside the sequence of events under discussion — it is merely illustrating a general state. The second mention says that "Having procured, at no small trouble, a quantity of sweet potatoes for planting, the natives refused to accept them and to plant them, declaring in true old tory fashion, that their fathers had managed to live without them, why could not they? Entreaties proved vain" (1985:90). This statement seems quite definite, but its overtly political nature, contrasting the conservative heathen with the progressive Christians (and setting us up for the sequel — as soon as the natives realised kumara had commercial value they could hardly plant enough) leaves room for alternative interpretation. Hather and Kirch (1991:889) date subfossil kumara on nearby Mangaia as late as cal. A.D. 1409–1440, so it is quite possible that it was present prehistorically on Rarotonga also. However Buzacott's evidence does indicate, on balance, that it was not present there at contact.

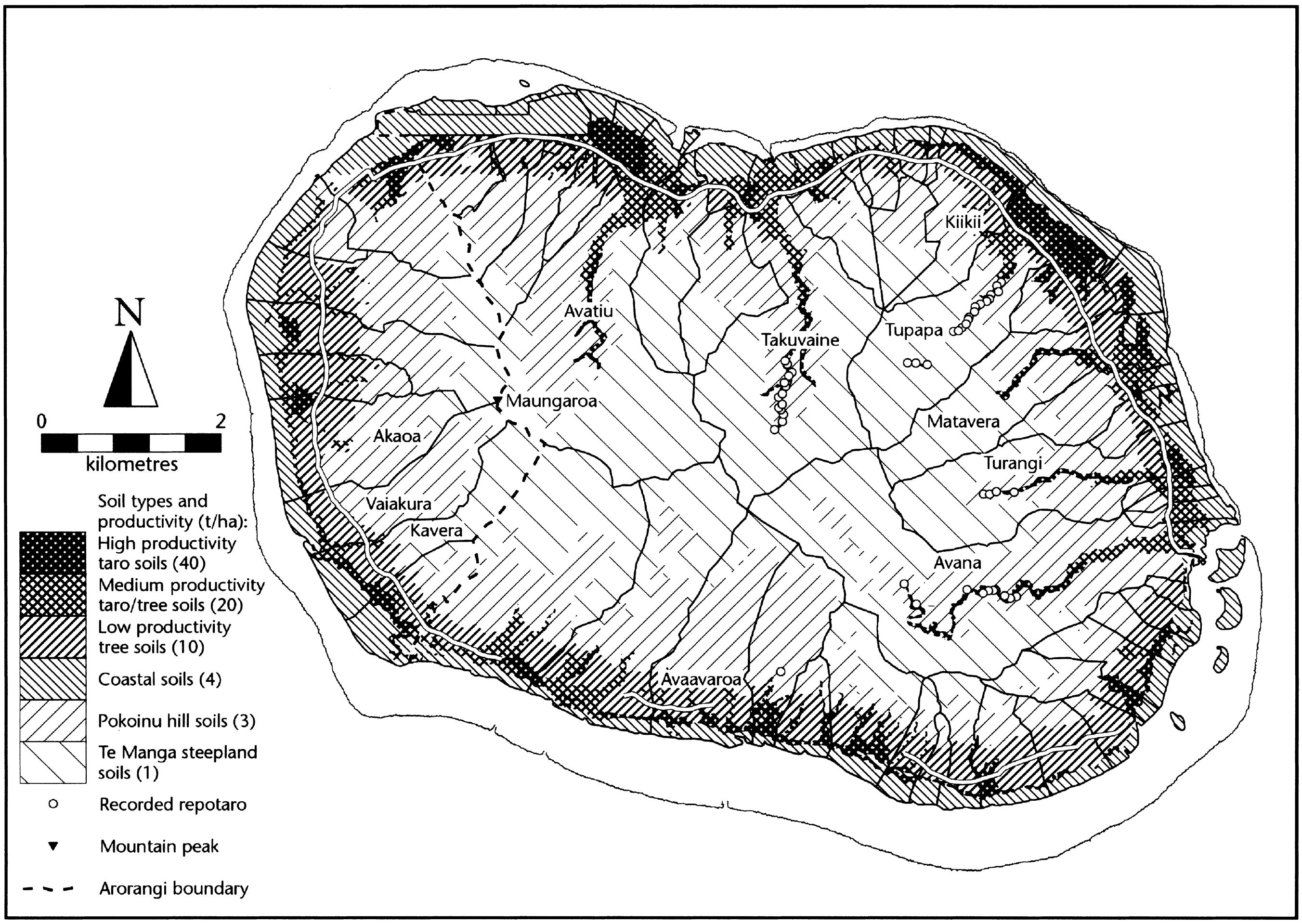

Figure 4. Potential productivity of soils on Rarotonga. Data is derived from Leslie (1980), taro terrace soils in the valleys are my own approximations. Also shown are the Ara Metua, recorded repotaro, tapere and places mentioned in the text. Tapere boundaries are taken from the modern cadastre. The boundary of Arorangi represents the maximum conquest of the Tinomana family, not the modern administrative district.

type provides a rough model of productive potential. These are mapped in Figure 4 in terms of tonnes/hectare. For the high productivity taro soils an average score of 40 t/ha may be assigned, on the basis of Spriggs' data. The Vaikai swamp soils may have produced as much as 50 t/ha without fallow, but the other high productivity soils would have produced less because of the requirements of fallowing. As soil types become increasingly less fertile and their associated cropping regimes require increasingly longer fallow periods, so the assigned productivity score decreases, until the Te Manga Steepland soils, containing only stands of ‘utū, are generously assigned a score of 1 t/ha. Although the productivity scores are expressed in terms of t/ha, they are only loose approximations, better suited to comparing the potential yields of various soil types as ratios than to calculating the actual quantities of those yields.

With this assessment of soil types and their productive potential, along with an examination of the crop types available on precontact Rarotonga, the outline of a model of production begins to form. The remainder of this paper examines one part of this model, the productive potential of soil types, and how it applies in practice. This is referred to as a model, but it is not in itself a true model of production. It remains underdeveloped and limited, but these limitations are themselves instructive, and lead to a more subtle understanding of precontact Rarotongan production.

Limitations of the model

The model presented above is based solely on environmental factors, which is both its strength and its weakness. It could be argued that a closer attention to rainfall patterns, elevation, slope and landform would tighten up the model considerably. The model is based on soil types alone, and clearly these other factors will affect productivity. Of particular importance would be reliability of rainfall and water flow, in conjunction with the size of the catchment for each stream. However no matter how sophisticated the analysis any model based solely on environment will remain flawed. For this reason the model is best considered as a frame of reference and baseline for further analysis, rather than an explanatory device. it is these further analyses, exploring why the model is limited and extending the analysis beyond environment, that are most instructive. In short, the model takes no account of history, which the Rarotongan production system cannot be understood without.

One limitation of the model is immediately apparent. *Actual* production would have been less than the *potential* modelled, for a number of reasons. Many poorer soils would quite probably not have been fully utilised, while some of the better soils were used to construct houses, *marae*, and the infrastructure required to maintain aspects of Rarotongan culture other than the merely utilitarian. The model is based on the yields of food plants only, and other important aspects of the production system are not considered. Medicinal plants are not included. Neither are industrial products, which would nonetheless have formed part of the precontact concept of production, and hence perhaps value of land. These include ‘ara tai (*Pandanus tectorius*) for weaving and ‘aute (*Broussonetia papyrifera*, paper mulberry) for barkcloth. Coconut also had industrial uses, and many trees were prized for their timber, particularly toa (*Casuarina equistifolia*) which grows well on poor coastal soils. Many of the soils that are considered poor from an horticultural viewpoint may have had greater value as sources of wild resources. However on a small, heavily populated island like Rarotonga no part of the ecosystem, at least to low and moderate elevations, would have been undisturbed or not utilised in some way.

Another factor complicating the model of productivity is temporal change in the production system. An example was furnished in the introduction to this paper of production and settlement changes as a result of contact, but environmental change, and with it change in production, have been occurring since first settlement. Valley floors and swamps, where taro is grown, have been shown elsewhere in Oceania to be dependant on increased alluvial sedimentation and coastal progradation for their development. This alluvium originates in the cleared dryland gardens of the hills and higher valleys. Pondfield construction is not feasible until the originally swampy valley floors have infilled, and swamp cultivation of taro requires that swamps form on the expanding coastal plain. Thus both wet and dry horticulture are part of a single system (Kirch 1994:232, Kirch and Yen 1982:348, Spriggs 1981:118), the extent of taro cultivation in particular being dependant on dryland horticulture. This may also be the case for Rarotonga. Erosion also infills lagoons and sedimentation adversely impacts on reef ecosystems resulting in an ever increasing reliance on horticultural production (Spriggs 1997:99). Production in the precontact period was not a steady state system, but is a constantly evolving, historically conditioned process.

Another example has already been alluded to — the destruction of arboricultural resources in the wars prior to the coming of the gospel. At the time of European contact the most important crops were taro and banana, but this was at the end of a century of warfare. Pitman (1828 I:91) records that the victors “in the last wars cut down all the Cocoa nuts & most of the Kuru’s [breadfruit] of Makea & Tinomana, which the latter cannot forget, a spirit of revenge still lodges in their breast & would gladly if the opportunity offered do the same to their Cocoa nut trees &c.” This must have been a common occurrence. Both breadfruit and coconut require some time to become established, unlike taro or banana which yield within a year, and so their loss would have been difficult to make up quickly. The contribution of these plants to the diet in prolonged periods of relative peace would doubtless have been greater. In times of war semicultivated plants like i‘i and ‘utū, which grow inland in protected valleys, would have been of greater importance, and foods normally reserved for famine use would also have been used more frequently.

There is no ecological reason why taro and bananas were the main crops in the late precontact period, and it would be wrong to search for one. Kirch (1994:304) came to similar conclusions when examining the very varied endpoints of precontact horticulture throughout Polynesia. It is the contingency of historical factors, always operating within the constraints of ecological limitations, that condition these endpoints, not the ecological limitations themselves.

Another factor that must be taken into account in any full model of productivity is reliability of production. On Rarotonga this is mostly dependant on water supply. The model being presented here assumes normal production conditions (whatever they may be), but abnormal conditions due to stochastic environmental variation would have been common. Although mean yearly rainfall is 2100 mm (Clement and Bourget 1992:9) the amount of *useful* rainfall is very much less. Increased evapotranspiration, rapid runoff and small catchment areas mean that many smaller streams will often run dry resulting in, to all intents and purposes, drought conditions. Between 1929 and 1996, ten years registered rainfalls of less than 1500 mm (data supplied by the Cook Islands Meteorological Service). In these years pondfields in minor valleys would have failed to work, and such unreliability of water supply is probably the main reason why pondfields were not constructed there. At the other extreme hurricanes can also cause considerable damage to crops, particularly tree crops and bananas, which are easily blown down. At least ten destructive tropical storms and hurricanes were recorded between 1939 and 1987 (Kerr 1976:93, Revell 1981:52, Gerald McCormack personal communication 1997).

In times of scarcity caused by drought, hurricane or war, famine foods like kape, puouou and wild yams became important. One crop that could survive all but the worst droughts or hurricanes was pondfield taro. The floors of major valleys are relatively protected from hurricane damage (at least compared to the lowlands) and even during the worst water shortages the streams continue to flow. Neither is pondfield taro as open to

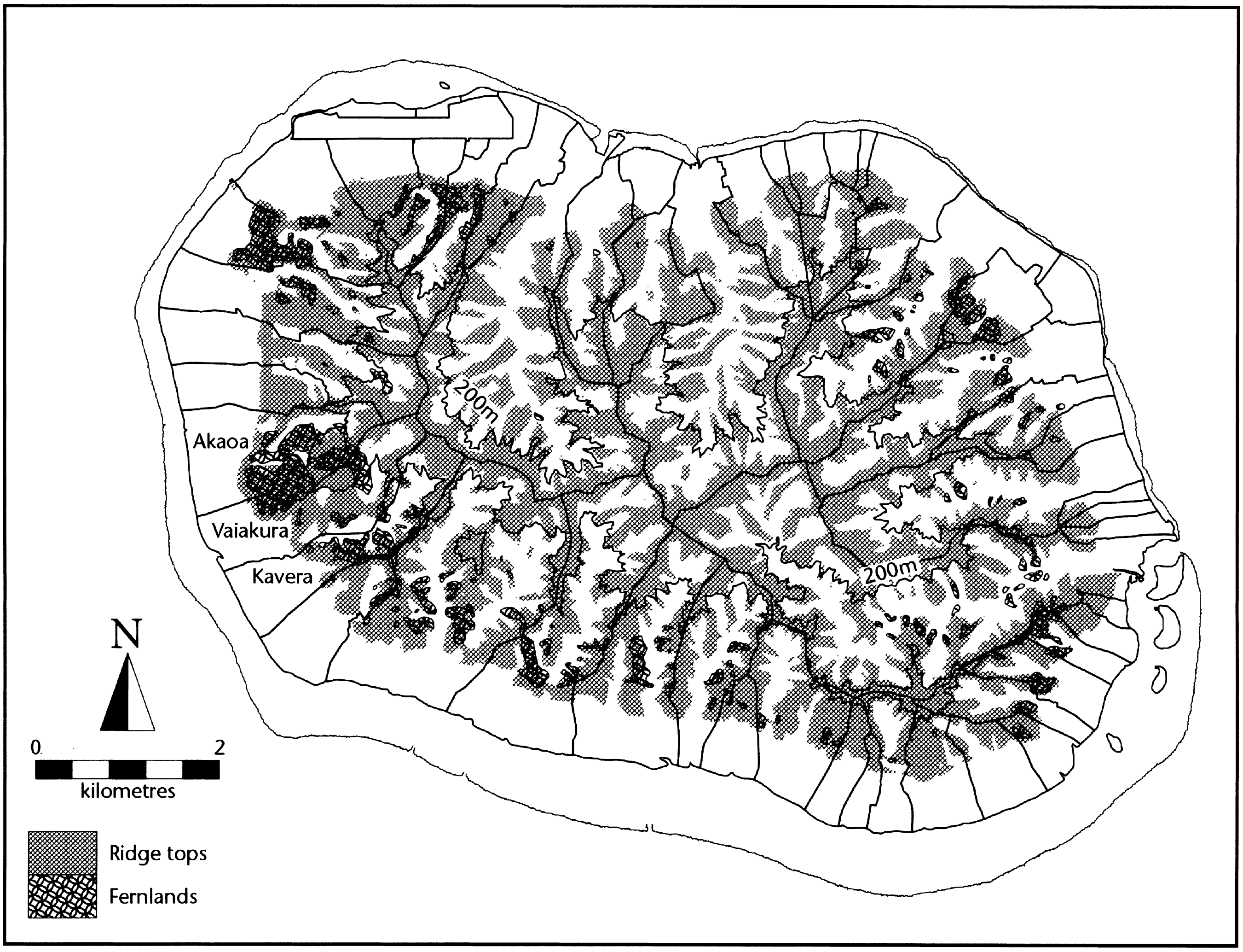

Figure 5. Fernlands mapped against topographic landform.

destruction in times of war as lowland tree crops are, and when it is destroyed it can be brought back into production more quickly. Pondfield taro then represents a reduction of risk, one of the best yielding and reliable crops available to precontact Rarotongans.

A final example of the changing nature of production systems is demonstrated in the distribution of fernlands on Rarotonga. Fernlands are a disclimax vegetative community consisting of mainly tuanu'e (*Dicranopteris linearis*). They are the result of soil depletion and erosion through overexploitation of swidden gardens (Kirch 1994:60). The fernlands visible today are generally in the same locations as the precontact fernlands, though smaller in extent. They are kept open by both deliberate and accidental burning, though they are slowly being reclaimed by forest. It should be noted that failed pineapple plantations from the early twentieth century in particular may have formed some new fernlands, and some may be natural in origin.

Fernlands are not evenly distributed on Rarotonga — there are very few in the north of the island for instance, indicating that lowland production was sufficient to feed the population without putting undue stress on swidden lands (Figure 5). Fernlands occur in patches above some of the major valleys on the eastern side of the island, as well as the smaller valleys to the south that would have lacked repotaro, but the most extensive patches of fernland occur in Arorangi District on the west of the island. There is no strong windward/leeward contrast on Rarotonga (Clement and Bourget 1992:6) as in many other Polynesian high islands, so this difference is not accounted for by rainfall.

Using an algorithm for raster GIS (Tomlin 1990:188) land higher than its surroundings can be distinguished from land lower than its surroundings, that is to say, ridge tops can be distinguished from the valley floor and coastal plain (Figure 5). 85% of fernlands are located on ridgetops (a fact that can be confirmed through simple field observation), and almost all of them are located below an elevation of 200 m. Almost all those at elevations above 200 m are in Akaoa, Vaiakura and Kavera Tapere in the south west. These *tapere* also contain some of the largest and best studied site clusters on Rarotonga (Bellwood 1978, Campbell 2000), and it was here that

Tinomana Ariki was besieged in the years immediately prior to the missionary arrival (Campbell 2002a). Tinomana and his people were cut off from lowland and sea resources and so would have been forced to rely heavily on swidden gardening. The result was extreme pressure on the long term viability of their horticultural base, and the extensive soil degradation and fernlands visible today.

One thing I have not attempted to do with the model of productivity is to relate it to the population of the island, either in calculating carrying capacity or population distribution. The early missionaries estimated the population at contact at 7000 (Pitman 1831 I:275), a figure I see no reason not to accept (despite my comment in footnote 2). It would be simple to calculate the comparative productivity of each *tapere* and distribute 7000 people accordingly, but the exercise would seem rather meaningless. Perhaps the best indication of the distribution of population is the distribution of fernlands, assuming that a greater density of fernlands indicates a population similarly beyond the local carrying capacity. The degradation of the horticultural base in Arorangi under conditions of siege is the most advanced example, but the distribution of fernlands in Avana and Turangi Tapere, the home of Kainuku Ariki and Pa Ariki, may hint at some economic reasons why these two were the aggressors in this episode.

Part of the importance of taro terraces in the production system relates to the reduction of risk that they represent. Given that risk is ever present, from drought, hurricane or war, the best production system will be one that is flexible. Overall, this is true of the Rarotongan system, and the degradation of swidden lands in Arorangi when the possibilities of flexibility were greatly reduced, bears this out.

Application of the model

Several factors have been identified as complicating the model of potential productivity, but by examining these factors in light of the model a clearer understanding of the production system has been obtained. These include actual productivity falling short of potential productivity; reliability of production; and temporal change in production. The remainder of this paper will apply both the model and the outline of the production system to two topics closely related to production — the value of land, and settlement.

Productivity and the value of land

Value, applied to land or any other thing abstract or concrete, is largely a culturally based perception. While the value of land may be related to production and productivity these are not the only factors contributing to it, but these other factors are not directly accessible through the archaeological record. For Rarotonga there is a large corpus of ethnohistoric data in the form of the records of the land courts (Campbell 2002a) that can be used to examine some notions of the value of land. The courts were set up by the New Zealand colonial administration in 1903 to formalise land tenure, and the minute books of the hearings record the basis of various claims to land, including its history and its associations with people.

There are some indications that value was closely related to production. For instance one reason given for the conquest of Avaavaroa Tapere was that "Avaavaroa was valuable on a/c of its taro and the mataiapos wanted it" (Maoate 1916 Minute Book [M.B.] VIII:37). Avaavaroa is roughly in the mid range for productivity, containing taro swamp soils, though no terraces. Many of the smaller *tapere* in Ngatangiia, where the conquerors originated, are hardly productive at all, too small to maintain a viable independent population. Avaavaroa offered the *mata'iapo* a firmer productive base and greater independence. This compares to Kirch's (1984) model for Futuna, where the dry east of the island conquered the more productive wet west. Two factors in Kirch's model — the wet/dry contrast, and the greater political integration of the dry — are absent, but there are parallels between the two situations, particularly disparity of production and of reliability of production. Notably Kirch's model is not applicable to Pa and Kainuku making war on Tinomana (discussed above). Another reason for the conquest of Avaavaroa is also given — that "Tinomana asked More and Tangiao to put an end to the rule of Tama Ariki in Avaavaroa" (Te Rei 1904 M.B. I:114). No reason is given for Tinomana expressing this wish, but both environmental (external) factors and contingent (historic, internal) factors are at work here. What is required is a way of more clearly investigating the relationship between environmental factors and the historical outcomes of the land courts.

A simple statistic that can be recorded about each section is whether or not it was contested in the court, and if so, how often. Up until May 1931 (the last records examined) 113 sections, generally but not exclusively unproductive mountain sections, had yet to come before the court. Of the remaining 983 sections over half, 575, were uncontested, with the claimant being awarded the land unopposed. Only four sections were contested as often as three times, all small sections in Arorangi. This was the most contested part of the island in precontact times, from its bloody conquest by the Tinomana family (Io 1906 M.B. II:242, Campbell 2002a) up to the siege of Tinomana on Maungaroa in the last years before the missionary contact. This situation has carried over into the twentieth century, where numerous small sections are frequently contested in the courts. The court system in this respect acts as an analogue to precontact warfare (Campbell 2002a). By contrast the three valleys that formed the study area for the 1997 field survey are all largely uncontested. These are three of the largest, and hence most productive, *tapere* and also the physical and economic base of powerful and stable *ariki*, or in the case of Tupapa of a group of powerful independent *mata'iapo*.

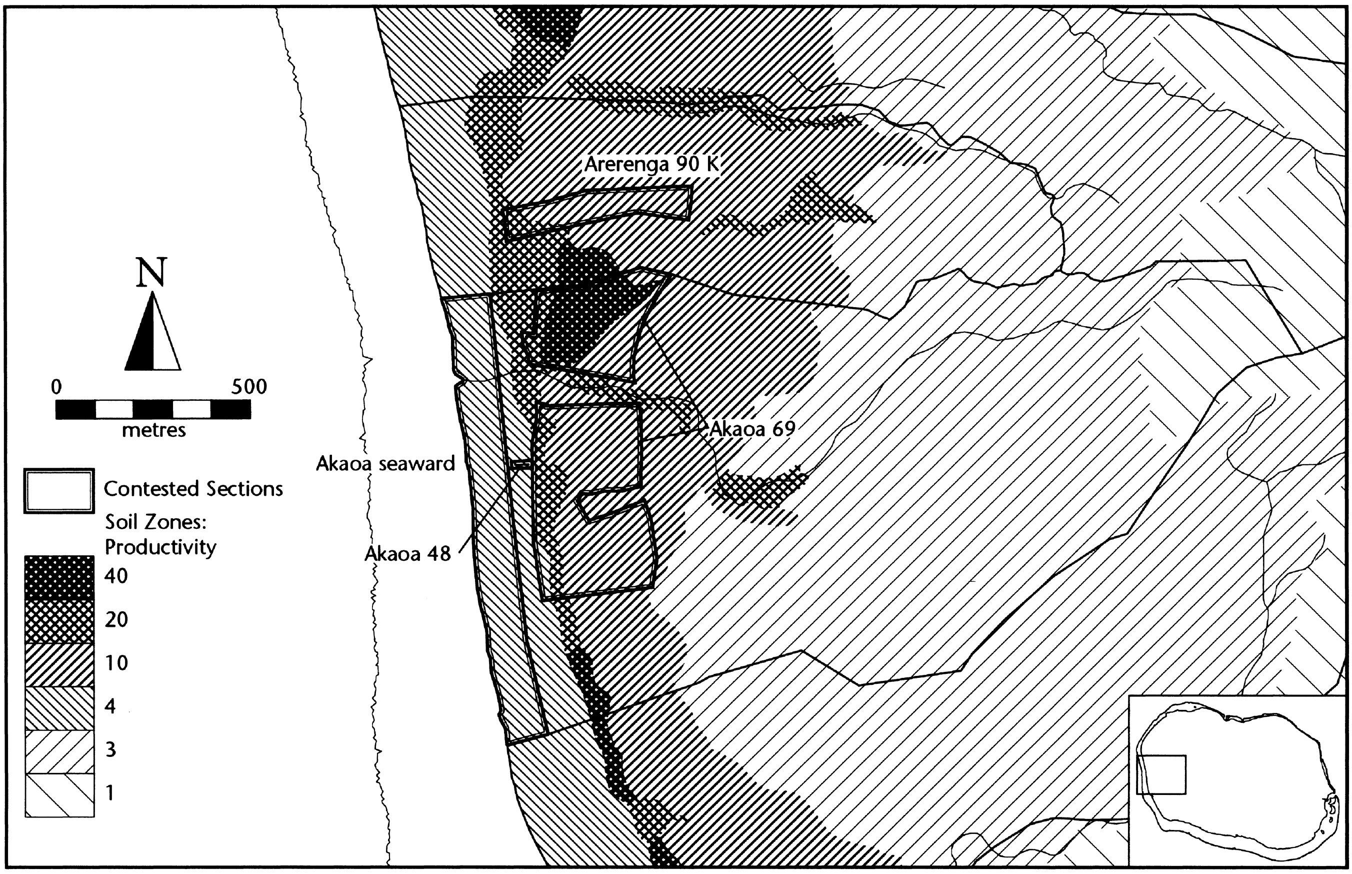

Figure 6. Sections in Arorangi contested with reference to limes, mapped against potential productivity.

These chiefs had strong interests in and historical connections to the land, meaning that their claim to these lands were less likely to be opposed. Because of their size they have a reliable water supply and so contain *repotaro*, the reason for basing survey there in the first place.

The number of times a section was contested might act as a proxy indicator of its perceived value. Clearly sections can be contested for a number of reasons, and it is important to note that sections are not contested where a secure claim already exists. Where a section is contested two or three times it may be merely a continuation of the original dispute. Sections may be contested frequently because the owners have died, while other insecure claims will not be disputed until the death of the current owner. These sorts of reasons are historic in nature, but it seems reasonable to suppose that sections with a higher productivity will, on average, attract more litigation, because the potential economic benefits are higher. In order to test this assumption a Spearman's correlation coefficient was calculated between the number of times each section was contested and the productivity of the section, for all sections. In order to rank all sections whether contested or not, sections that had yet to come before the court were assigned a score of zero contestings, those that came before the court but were not contested were assigned one, and all contested sections the number of times they were actually contested plus one. The Spearman's r score is 0.20. This is unexpectedly low, and would seem to indicate that the productive potential of the land had little direct relationship to perceptions of value, at least as such perceptions are expressed in litigation over land.

Various historical factors are at work here that account for this result. New technologies and techniques can be developed, political structures can change and control and allocation of land and resources can change with them. The model of productivity for Rarotonga is based on precontact crops and economy. By the time of the land courts 70 years of contact had markedly altered systems of production. The dramatic decline in population that occurred soon after contact had barely begun to be reversed by the end of the century. Whereas Williams described "the whole island … in a high state of cultivation" (1837:204) at the start of the twentieth century Cheesman described "the cultivations of the natives — their orange groves and coffee plantations, their banana and taro patches — are either part and parcel of the forest or almost overshadowed by it" (1903:264). Not only the area of cultivation, but the type of cultivation had altered, with new crops, new techniques and a new market. The arrival of Europeans had unforseen consequences for production. While the productive qualities of the soil remained unchanged, the *actual* production, and hence economic potential, of the land had changed.

One new crop that brought previously unproductive lands into production was limes. These were planted in many places on Rarotonga and four case records in the minute books make specific reference to limes planted in Arorangi (Various witnesses 1903 M.B. I:47–61, 1904 M.B. I:151–158, M.B. II:227–233, 1906 M.B. III:75–122). When the limes began to have an economic value Tinomana Ariki either seized the land and took the limes for herself, or demanded a share of the produce (with the result was that the people ceased to make lime juice).

Figure 6 maps the sections contested in these four cases with reference to the productive potential of the soil. Akaoa seaward and the very small claim of Akaoa 48 are entirely located on beach ridge soils, relatively unproductive according to the model, but good lime growing land. The other two claims are on more productive land, in fact part of Akaoa 69 encompasses some highly productive taro swamp. The historically constituted, perceived productive value of the land — based on the economic value of the lime juice — may have no clear relation to the productive potential of the land, as modelled here. A capital investment in the form of lime plantations (or *repotaro*) will have greater weight than the potential for improvement. Moreover the reason for the passionate nature of the hearings for these sections is the perceived injustice of Tinomana's seizure of the limes. This motivates perceptions of value in ways that have little to do with soil type and productivity, and in fact this is a different kind of value than economic value. Though there is a close relation between the two, they should not be conflated — the historically or socially constructed value may in many cases be more strongly perceived than the economic.

Production and potential productivity are not strong factors in determining the likelihood of a land court claim being contested. The potential influence of productivity is counterbalanced by contingent factors. It is not productive capacity that is important, but the form of the productive system, and the social, cultural and historical values associated with it that influence the perceived value of land.

Productivity and Settlement

The final topic to be examined with reference to production and potential productivity is settlement. Considerations such as access to and protection of crops mean that the location of horticultural resources will be a major influence on settlement. Space for both habitation and production is limited on a small mountainous island like Rarotonga, and both are often constrained to occupying the same zone.

The coastal plain, with its rich taro swamps and island bed soils, was the focus of the bulk of production. Most archaeological sites recorded here are high status sites such as *marae* or *paepae*. These survive because they are built of stone. Otherwise modern settlement has destroyed most visible surface remains. Fortunately we have a few clear early historic descriptions of the settlement pattern. Williams, for instance, says

> There is a good road around the island, which the natives call the *ara medua*, or parent path, both sides of which are lined with bananas and mountain plantains… The houses of the inhabitants were situated from ten to thirty yards or more from this pathway … The path leading up to the house was invariably strewed with white and black pebbles … Six or eight stone seats were ranged in front of the premises, by the side of the "parent pathway". (Williams 1837:205)

The Ara Metua was an integral part of the ritual system (Campbell 2002b), with major *marae* located along it. Bellwood (1971:149) pointed out that the Ara Metua runs along the ecotone between the coastal strip and the mountainous interior, thus situating settlement close to all resources and minimising distances travelled. However the coastal plain is at most 1 km wide and distance may not have been a major factor in settlement. Given the narrowness of the coastal plain any road encircling the island will by default mirror the concentric zonation pattern of resources. One environmental factor that may have favoured settlement away from the coast is the incidence of tropical hurricanes. The Ara Metua is generally sheltered from the worst fury of wind and waves, whereas coastal settlements would have been fully exposed.

Lacking visible site remains we are reliant mainly on Williams' description of settlement and on the pattern of surviving *marae* and *paepae* along the Ara Metua in reconstructing lowland settlement. In short settlement seems to have been dispersed across the coastal plain but mainly close to the road, perhaps with some clustering on a small scale within *tapere* boundaries and around the foci of status sites. The highly productive swamp soils would have been unsuitable for habitation, but generally people lived close to their productive holdings. Settlement and road occupied the same location, and while a major infrastructural installation like the road will subsequently influence settlement the road itself is part of the settlement system, and road, settlement, ritual and production would have evolved together.

The situation is somewhat different in the larger valleys where level areas close to streams and suitable for *repotaro* are at a premium. Settlement here is more clustered, with occupation areas constrained to secondary locations above the valley floor or on sloping ground. Four such areas were recorded during the 1997 survey, containing visible surface evidence of domestic sites, including paved *paepae* platforms, house terraces and earth ovens. These were located close, but not directly adjacent, to *repotaro*. Several other isolated domestic sites were recorded including elaborate *paepae* and substantial house platforms, but in neither case was there visible evidence of further platforms or ovens on the nearby sloping ground. The valleys, and the sites in them, remain relatively undisturbed by modern settlement. While they contain numerous visible domestic sites they were not a major focus of settlement.

In contrast the densest valley occupation area observed, in terms of visible surface remains, was in the Kiikii Valley. Here sites were located on the valley floor, which was unsuitable for *repotaro* because the Kiikii is only a small and intermittent stream. This type of settlement pattern may be common, but smaller valleys have yet to be systematically surveyed.

The most extensive and best preserved cluster of sites on Rarotonga is located on the slopes of the Maungaroa Valley, the site of the siege of Tinomana Ariki. Maungaroa is a well prepared defensive position, and numerous *marae* and *paepae* as well as stone faced and unfaced house terraces have been recorded here. These sites were mapped and excavated by Bellwood, and dates range back to the fourteenth century A.D. (Bellwood 1978:206). A number of separate site clusters have been recorded, each with one or more major *marae* serving as a community focus. These are all adjacent to the extensive fernlands already examined, so that the pattern of locating settlement adjacent to productive resources is repeated, but in the case of Maungaroa, emphasised under siege conditions.

Maungaroa is an extreme example, and the settlement pattern observed there arises from a unique set of historic circumstances. Fernlands are only indirect evidence of swiddening — fernlands visible today indicate only where soils are depleted, not where a balanced regime of swiddening occurred — and the actual contribution of swiddening to overall productivity is difficult to assess, though it may have been considerable. Two occupation areas in the Avana Valley were only observed after the fernlands covering them were accidentally burnt. This associates domestic sites directly with evidence of swidden horticulture. Most fernlands are on steep slopes quite unsuited to settlement, but many incorporate some relatively level areas. The tuanu‘e ferns themselves are 300–400 mm high and very dense, making surface survey completely impractical. It seems probable that further occupation areas are obscured beneath fernlands, and that much inland settlement was located away from valley floors.

Since swiddens are temporary installations it is possible that much inland settlement was equally temporary, and that evidence for it may be ephemeral. Distances are short, and farmers could commute from the coastal plain to small garden shelters adjacent to inland production sites on a regular basis. More substantial domestic sites recorded in the valleys also indicate some permanent inland settlement, and status sites (*marae* and *paepae*) would have provided a permanent community focus.

Although production worked as a single integrated system it may be broken down into subsystems: the coastal plain centred on the taro swamps; valleys and *repotaro*; and swiddening, of which Maungaroa is an unusual example. Similarly, while there is a general settlement pattern — dispersed close to productive resources — each subsystem of production has an associated variant of the general settlement pattern. Some of the main components of the settlement/production system are becoming clear. Early missionary accounts (Williams 1837, Williams and Barrf 1830) present a picture of mixed crop house gardens and intensive lowland cultivation coupled with settlement spread out along the Ara Metua. Accepting the missionary population estimate of 7000 people, a dispersed settlement pattern, with people living close to their productive resources, was probably a necessity. There would have been a degree of mobility, especially within the *tapere*. The relative location of productive resources would have been of less importance than ownership and access to them. There was perhaps some loose clustering around the community and ritual foci of *marae*. *Tapere* boundaries and the shifting alliances between the various *ariki* and *mata‘iapo* would have been major temporal settlement factors.

Conclusion

In order to examine, in an archaeological context, a Rarotongan production system wider than just the archaeologically visible *repotaro*, a model of potential productivity was constructed. The model was based on an assessment of the productive potential of soil types, and could benefit from a closer attention to factors such as rainfall, elevation or the direction of cyclonic attack, but no matter how fine grained the data and sophisticated that analysis, it will always be flawed. Despite, or perhaps because of, its limitations it becomes valuable as a foil against which to contrast and examine various wider aspects of the actual system of production. It would be naive to take the figures generated by the model at face value, but the reasons why this would be so have turned out to be most instructive. It is important to realise the essential unity of systems of production. Taro horticulture is dependant on soils eroding from swidden systems, and the taro system itself grades almost imperceptibly from *repotaro* to island bed cultivation to swamp taro. Also the cultivation system was, and still is, a mixed crop system, with banana, kape and breadfruit all interplanted among taro beds. Similarly settlement patterns reflect production patterns, with local variants of a general pattern. Settlement mobility and production flexibility are vital on a small island. Maungaroa, where mobility and flexibility are limited, provides the acid test. Even here, though adapted to unique circumstances, the same patterns of production and settlement occur. The Rarotongan production system is not a product of the environment. Certainly it is constrained and channelled by the environment, but in the end, as this analysis has shown, it is a product of history.

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References

Note: References to evidence from the Rarotongan land court records take the form:
Witness, year. *Land section name(s) and number(s)*. Minute book: pages of case (may be discontinuous).

Allen, J., 1991. The role of agriculture in the evolution of the pre-contact Hawaiian state. *Asian Perspectives*, 30(1):117–132.

Bellwood, P., 1969. Archaeology on Rarotonga and Aitutaki, Cook Islands: A preliminary report. *Journal of the Polynesian Society*, 78:517–530.

Bellwood, P., 1971. Varieties of ecological adaptation in the Southern Cook Islands. *Archaeology and Physical Anthropology in Oceania*, 6:145–169.

Bellwood, P., 1978. *Archaeological Research in the Cook Islands*. Pacific Anthropological Records, 27. Bernice P. Bishop Museum, Honolulu.

Buzacott, A., 1985 [1866]. *Mission Life in the Islands of the Pacific*. University of the South Pacific, Suva.

Campbell, M., 2000. Sites and site types in Rarotonga, Cook Islands. *New Zealand Journal of Archaeology*, 22:45–74.

Campbell, M., 2001. Settlement and landscape in late prehistoric Rarotonga, Southern Cook Islands. Unpublished Ph.D. thesis, University of Sydney.

Campbell, M., 2002a. History in prehistory: the oral traditions of the Rarotongan land court records. *Journal of Pacific History*, 37(2):221–238.

Campbell, M., 2002b. Ritual landscape in late pre-contact Rarotonga: a brief reading. *Journal of the Polynesian Society*, 111(2)147–170.

Cheesman, T., 1903. The flora of Rarotonga, the chief Island of the Cook Group. *The Transactions of the Linnaean Society of London, 2nd Series Botany*, 6(6):261–313.

Clement, H. and L. Bourget, 1992. Outline scheme for water development and management. Report to Cook Islands Water Department, Rarotonga.

Crocombe, R., 1964. *Land Tenure in the Cook Islands*. Oxford University Press, Melbourne.

Hather, J. and P. Kirch, 1991. Prehistoric sweet potato (*Ipomoea batatas*) from Mangaia Island, Central Polynesia. *Antiquity*, 65:887–893.

Io, 1906. *Vaireva 90I*. M.B. II:240–252.

Kerr, I., 1976. Tropical storms and hurricanes in the Southwest Pacific, November 1939 to April 1969. *New Zealand Meteorological Service*, 148. Wellington.

Kirch, P., 1994. *The Wet and the Dry: Irrigation and Agricultural Intensification in Polynesia*. The University of Chicago Press, Chicago.

Kirch, P. and D. Yen, 1982. *Tikopia: The Prehistory and Ecology of a Polynesian Outlier*. Bernice P. Bishop Museum Bulletin, 238.

Lange, R., 1982. *A history of health and ill-health in the Cook Islands*. Unpublished Ph.D. thesis, University of Otago.

Leach, H., 1997. The terminology of agricultural origins and food production systems — a horticultural perspective. *Antiquity*, 71:135–148.

Lepofsky, D., 1994. Prehistoric agricultural intensification in the Society Islands, French Polynesia. Unpublished Ph.D. thesis, University of California, Berkeley.

Leslie, D., 1980. Soils of Rarotonga, Cook Islands. *New Zealand Soil Survey Report*, 49. Department of Scientific and Industrial Research, Wellington.

Manarangi, A., 1984. Important taro varieties in the Cook Islands. In, S. Chandra (ed.) *Edible Aroids*, 24–27. Clarendon Press, Oxford.

Maoate, 1916. *Taapake 9*. M.B. VI:370–379, M.B. VIII:26–40, 59–62.

Massal, E. and J. Barrau, 1956. Food plants of the South Sea Islands. *South Pacific Commission Technical Paper*, 94. Noumea.

McCormack, G. and J. Künzlé, 1995. *Rarotonga's Mountain Tracks and Plants: A Field Guide*. Cook Islands Natural Heritage Project, Rarotonga.

Pitman, C., 1827–1845. *Journal*. Ms., 6 volumes, State Library of New South Wales, Sydney.

Revell, C., 1981. Tropical cyclones in the Southwest Pacific, November 1969 to April 1971. *New Zealand Meteorological Service, Miscellaneous Publication*, 170. Wellington.

Savage, S., 1980. *A Dictionary of the Maori Language of Rarotonga*. Institute of Pacific Studies, University of the South Pacific, Suva.

Simmonds, N., 1966. *Bananas. Second Edition*. Longmans, London.

Spriggs, M., 1981. Vegetable kingdoms: taro irrigation and Pacific prehistory. Unpublished Ph.D. thesis, Australian National University.

Spriggs, M., 1984. Taro irrigation techniques in the Pacific. In, S. Chandra (ed.) *Edible Aroids*, 123–135. Clarendon Press, Oxford.

Spriggs, M., 1997. Landscape catastrophe and landscape enhancement: are either or both true in the Pacific. In, P. Kirch and T. Hunt (eds.), *Historical Ecology in the Pacific Islands: Prehistoric Environmental and Landscape Change*, 80–104. Yale University Press, New Haven.

Te Rei, S., 1904. *Avaavaroa 17*. M.B. I:107–139.

Thaman, R., 1984. Intensification of edible aroid cultivation in the Pacific Islands. In, S. Chandra (ed.) *Edible Aroids*, 102–122. Clarendon Press, Oxford.

Tomlin, C., 1990. *Geographic Information Systems and Cartographic Modelling*. Prentice Hall, Englewood Cliffs, New Jersey.

Various witnesses, 1903. *Akaoa seaward*. M.B. I:47–61.

Various witnesses, 1904. *Akaoa 48*. M.B. I:151–158.

Various witnesses, 1904. *Arerenga 90K*. M.B. II:227–233.

Various witnesses, 1906. *Akaoa 69*. M.B. III:75–122.

Walter, R., 1996. Settlement pattern archaeology in the Southern Cook Islands: a review. *Journal of the Polynesian Society*, 105(1):63–99.

Williams, J., 1837. *A Narrative of Missionary Enterprises in the South Sea Islands: With Remarks upon the Natural History of the Islands, Origin, Languages, Traditions, and Usages of the Inhabitants*. J. Snow & J. R. Leifchild, London.

Williams, J. and C. Barrf, 1830. Raiatea to Huahine via Cook Islands &c. Microfilm, State Library of New South Wales, Sydney.

Wittfogel, K., 1957. *Oriental Despotism*. Yale University Press, New Haven.