

Irrigated ethnoagriculture, adaptation and development: a Pacific case study

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ABSTRACT

*The practice of terraced and irrigated creekfield taro (*Colocasia esculenta*) agriculture was once prevalent in the seasonally-dry regions of many Pacific Islands. This ethnoagricultural system has been characterised as technically sophisticated, intensive, highly productive and ecologically sustainable; with links to social stability and enhanced biodiversity. The food output is highly nutritive. However, despite these advantages, a decline in irrigated terracing has been the historic trend over the last century. Given the decline, the question must be asked: how resilient and sustainable is creekfield ethnoagriculture, especially in a changing world? The late Holocene development of irrigated creekfields was probably advanced by superior characteristics of resilience and adaptation in the face of climate change, but evidence is hindered by lack of research. Conversely, creekfield decline appears to have a strong relationship with the influence of extralocal colonial, modern and globalised development during a historically benign climate period of low agricultural risk – now being replaced by a putatively higher-risk period of vulnerability driven by Anthropocene global warming. An ethnoagricultural case study of Fijian irrigated terrace systems (colloquially called vuci), amid other research from the Pacific, indicates enhanced resilience and increased livelihood stability – characteristics that are needed for adaptation to the predicted adverse conditions of the future. The prospects for the revitalization of such systems are discussed. Only some of the reasons for decline are important today, and a developmental reintensification is possible, especially with increased populations and parallel food demands. Innovative technologies can be used to ‘progress with the past’, exemplified by the activities of an NGO which has been reintroducing the ideas and practice of vuci in the Fiji Islands.*

Keywords: Irrigation, agriculture, Navosa, Fiji, Pacific, adaptation, *Colocasia esculenta*, indigenous development, technological change, climate, environment.

INTRODUCTION

One of the features of the relations between people and their environment in the Pacific Islands is the importance of adaptation (Barnett & Campbell, 2010, pp. 15-17), either of people to the environment, or of environment to the impact of people (Bennett, 1976; Fosberg, 1972). Bennett perceived adaptation as part of transformative 'interactive matrices' (Bennett, 1996, p. 5) between humans and environment: together they comprised a historical process he called the 'ecological transition' (Bennett, 1976, pp. 123-155) whereby an increasing (or decreasing) intensity of extraction of 'resources' are used concomitant with changing human population densities in lieu of less (or more) intense ways of using nature. The process of ecological transition in the southwest islands of the Pacific has been a late-starter in historical terms. More controversially, the transition may be proceeding relatively slowly because of the omnipresent force of nature, especially in the form of strong geophysical and climate-related events (see Nunn & Britton, 2001; Nunn, 2007) and the risks they pose to sustainability (Sturman & McGowan, 1999, p. 3). As such, the southwest Pacific region is an ideal field site to study the basic adaptive relationships of people in an environment that is perhaps less predictable and carries more risk than many other regions.

The processes of adaptation¹ are particularly germane in the case of climatic influence and the effects of dramatic weather events such as cyclones for which the South Pacific Convergence Zone is renowned (Field, 2005; Salinger, *et al.*, 1995). These influences, together with periodic El Niño precipitation anomalies, have a pronounced effect upon agricultural risk and related strategies, including the choice of crop cultigens by cultivator-farmers and the type of agricultural intensification (Allen, 2004; Downing, *et al.*, 2002). These effects are likely to be further pronounced by the advent of Anthropocene global warming (Rosenzweig & Hillel, 1998; Rosenzweig & Parry, 1994; Santoso, *et al.*, 2013). In addition to demographic, cultural and political influences towards agricultural intensification (Boserup, 1965; Brookfield, 1972; Leach, 1999; Morrison, 1994), adaptive influences are surmised to be equally important and relevant to the case of irrigation development².

It is reasonable to assume that the development of irrigation was at least partially an attempt to reduce the risks involved in food production by overcoming vulnerabilities in local environments and agricultural methods³. Barrau (1961) posited that the 'deterioration of soils and vegetation' (p. 18) associated with shortened-fallow swidden cultivation led to the need for alternative agricultural strategies including the development of irrigation. Spriggs (1985), on the other hand, has argued that fertility was enhanced by accelerated erosional deposition (resulting from swidden burning) accumulating in colluvial and alluvial sediments subsequently used for agriculture – at least alleviating some of the destructive consequences of erosion. The question of whether either of these processes was a dominant influence on the intensification of irrigated terracing is unresolved – a lack of appropriate data hinders further enquiry. In general, there has been little research on risk and adaptation as they are related to the development of historic or prehistoric irrigation systems despite suggestions of their relevance (Addison, 2008; Brookfield, 1984).

THE DRY AND THE WET OF TRADITIONAL IRRIGATED SYSTEMS IN FIJI AND THE PACIFIC

Gravity-fed, terraced and irrigated agricultural systems growing the food-cultigen taro (*Colocasia esculenta*) are a prehistoric, historic, and in a few places, current feature of the seasonally-dry leeward sides of Pacific Islands with orographic features, an agrobioclimatescape sometimes called ‘the dry’ (the opposite is ‘the wet’ – places that are continuously moist as a result of orographic processes) (Barrau, 1965; Kirch, 1994; Kirch & Lepofsky, 1993; Spriggs, 1981b; 1982; 1990). Taro is unusually adapted to hydroaerobic (moist and aerobic) edaphic conditions – and the humidity that is prevalent in the all-season moist windward areas (the wet) parts of the Pacific Islands. The dominant practice in the wet is unirrigated rainfed cultivation; irrigation has not been necessary and is not common in these windward locations where the bulk of taro production occurs today (Lambert, 1982).

Leaving aside both the gravity-fed, irrigated terrace and the rainfed gardens, there are many other ways of growing taro in the Pacific region, including: non-terraced natural spring-fed, springside (sometimes downstream-side of the spring) wild or semi-wild gardens (called *vure*⁴ in Navosa sub-province, in the west-centre of Viti Levu) (King, 2012b), drained swamp gardens (*sabe* in Navosa), raised-field, island bed, and atoll pit-garden systems. Atoll pit-gardens are somewhat different in that they are predominantly associated with the production of *Cyrtosperma chamissonis*, a larger but less palatable aroid which is more tolerant of anaerobic conditions than taro. I have unconfirmed reports that floating taro gardens existed in the Rewa Delta of Fiji, and Spriggs (1989, p. 6) has observed furrow irrigation on Aneityum, Vanuatu; and documented simple flooded-field and bunded-creek systems for Papua New Guinea (Spriggs, 1989, p. 5). These ethnoagricultural techniques exhibit opportunistic and clever use of natural environments that minimize the loss of biodiversity (Thaman, *et al.*, 1979) and reduce the vulnerability to risks associated with irregular environmental forces. Each of these technological types involving the control of water for agriculture is worthy of research, but in this study the focus will be on gravity-fed systems where fresh flowing water is directed into flooded garden plots or creekfields (conventionally called pondfields⁵) growing taro surrounded by a containment wall (dyke or embankment).

Only a relatively small and scattered number of traditional gravity-fed irrigation systems (usually called *vuci*) exist in the dry regions of Fiji today, despite a substantial area of visible prehistoric and historic landesque capital (Blaikie & Brookfield, 1987b, p. 9; Håkansson & Widgren, 2014) indicating capacious irrigated terrace gardens (Kuhlken, 1994a; 1994b; 2002; Kuhlken & Crosby, 1999; Parry, 1987; 1994; 1997, pp. 129-137). A similar decline is apparent on many other islands with irrigation histories (Thaman, 1984, p. 106)⁶. Notable examples include New Caledonia, Vanuatu, Rarotonga, Mangaia, the Marquesas, the Society Islands, Mangareva, Tubuai, Rapa and Hawaii (Kirch & Lepofsky, 1993). The practice appears to be still vibrant on Futuna (as indicated by satellite photography, local confirmation is needed), and some parts of the Hawaiian Islands (Spriggs, 1989, pp. 14-15) where irrigated production of taro using mechanization and fertilizers is practised commercially as well as for subsistence (de la Pena, 1983). In Vanuatu also, disused irrigation systems have been reactivated, both as an ongoing part of traditional taro

livelihoods (Caillon, 2012; Walter & Tzerikiantz, 2012) and as a consequence of intentional development (Spriggs, 1981a, 1989).

Only three examples of traditional irrigated *vuci* growing *dalo* (taro, *Colocasia esculenta*) were observed by the author in the dry season of the relatively traditional, indigenous mixed arable-pastoral-arboriculture farming regions of Navosa and Ba in western Fiji during sustainability research in 1997-1999 (King, 2004). All of these creekfield systems were small and protected from the depredation of free-ranging ungulates (mainly cattle, horses, goats and pigs) by fences or by impenetrable natural forms such as cliffs and precipices. As previously documented (King, 2012a), the exponential increase in ungulate populations during the 20th century, and the lack of fencing, was likely to have severely constrained the development and use of *vuci* during and from this time in the dry of Fiji. Another bulwark, especially for larger historic systems, was the prevalence of (mainly storm-induced) gully erosion in feeder creeks which had restricted the ability of *vuci* cultivators' to form diversion weirs (*vono* in Noikoro dialect, Navosa) at the water intake. There were many other reasons for decline including: a late 19th century invasion of epidemic disease which induced a severe trough in population in the early 20th century (ibid), possibly leaving insufficient labour⁷ to develop and maintain larger *vuci*; and the forced relocation of villages downstream away from their *vuci* during the colonial period. Colonial authorities later promoted plough agriculture and cash cropping to raise tax revenue (Frazer 1964; Knapman 1987) at the expense of traditional exchange and tribute to which the value of taro was strongly linked.

Other changes occurred in local cultural ecologies that may have been detrimental to irrigation. For example, this author theorizes the possibility that the introduction of horses (*Equus caballus*) may have accelerated the decline of *vuci* by facilitating the transport of juvenile taro plants from the <100 m creekside (or riverside) *tanitani* nurseries to elevated 600-900 metre high rainfed growing areas (see Hashimoto (1990) on the vertical distribution of garden types in relation to climate zones in Navosa). These heavy loads would have been carried by people before horses became available (around the turn of the 19th and 20th centuries) and it is likely that the strenuous nature of this work (and danger during war (Field, 2002)) imposed limitations on either or both the number of juvenile plants carried and the distance the cultivators were prepared to travel. The likely effect is that pre-Equus Navosa communities were less inclined to transport taro plants over the riskier, longer (and often very steep) distances required to maintain separate high altitude rainfed gardens than is the case today. In contrast, the alternative of locally-situated *vuci* systems near to their habitations may have been more convenient and involved less social (and possibly, environmental) risk. This theory about a situation-specific effect following the introduction of horse transport, which I call the *Equus*-Enabled Space Compression Theory, is supported by evidence from aerial photography interpretation studies (e.g., Parry, 1987; Field 2002) which indicate that former irrigation terraces are generally at low-medium to medium elevations quite close to the numerous small villages of the time (and their creekside or riverside *tanitani* nursery sites). Some terraces in the upper Sigatoka Valley are at higher elevations where generally moist climates facilitate year-round rainfed cultivation for nearby upland communities. In these places there is usually no necessity for irrigation or vertically-transported replanting but some *vuci* systems existed at quite high altitudes (e.g., on the Tawalese, Wainivau-Lotoloto, Nakaumata and

upper Solikana Creeks), where they were able to exploit high quality water sources, or where good lower-altitude *vuci* sites were lacking (e.g., the Busa-Nadaka Creek).

Taro cultivation has been practised for thousands of years (Chandra & Sivan, 1984; Matthews, 2010), but the origin-dates of Pacific irrigation systems are still largely uncertain. However, it can be confirmed that archaeological evidence across the Pacific situates structured creekfields of substantial size on more than one island about AD. 500 (Kirch & Lepofsky, 1993). It is probable that these systems had a much earlier genesis (Addison, 2008) and developed gradually with increasing populations, although it is possible that a sudden flowering of irrigated terrace construction occurred, synergistic with relatively rapid environmental or sociocultural change, or both. The dating of irrigation features such as terrace walls is highly desired for chronological understanding, but has so far been rarely achieved, probably because archaeological research has been focussed elsewhere. It may be possible to find dateable fossilised charcoal underneath the basal stones of terrace walls, thus allowing inferences about the date when they were constructed. In addition, progress has been made with scientific techniques that allow the dating of fossilised fragments of cultigens (e.g., Ladefoged, 2005).

There has been a long-standing debate about whether the practice of irrigated taro cultivation was ancient and diffused, or innovated independently within island settings (Addison, 2008; Kirch & Lepofsky, 1993, pp. 184-185; Spriggs, 1982, p. 317; 1990). My view, from the perspective of an observant researcher with cultivation experience at the farm scale, is that it would be difficult not to innovate irrigation creekfields for growing taro, and equally but contrarily, that it would be difficult to ignore one's forbearers' knowledge about growing taro. In the first case, the learned praxis or act of transplanting juvenile taro crowns or suckers in new locations (sometimes in moist settings near running water) inevitably involves consideration about hydrologic conditions and the possibility of diverting or draining water to improve these conditions, in part, because of the hydroaerobic sensitivity of the *Colocasia esculenta* cultigen. In my view, all intelligent cultivators are involved in this cognition-action performance (Richards, 1989; 1993) on a day to day basis and technological innovation in these situations is a gradual outcome of trial and error praxis-performance of crop success or failure and the necessity to produce food.

Here are some examples: a taro crown or sucker may be planted in flowing water and the outcome evaluated. A very small ditch may be dug to allow flowing water into a small riparian patch suffering dryness. Floods may come and rearrange the hydrologic conditions of creekside gardens – and the changes observed. Drains are dug to dry a patch where the flowing water has stopped and stagnancy threatens. These are some of the regular experiences and actions of cultivators who adapt their methods to prevailing conditions: some of the outcomes may be conceptualised as innovation, but the extent to which they are truly independent is highly questionable, given the conceptual templates of taro-growing methods as part of indigenous or local knowledge and performance already held within relevant communities and learned from forbearers (also see Yen, 1973).

One point to qualify: today, communities can lose indigenous knowledge quite quickly (after one generation), if they are no longer performing the relevant skill. For example, one of my 1998 guides (an intelligent and skilled young alluvial soil farmer) was not able to recognise prehistoric irrigated

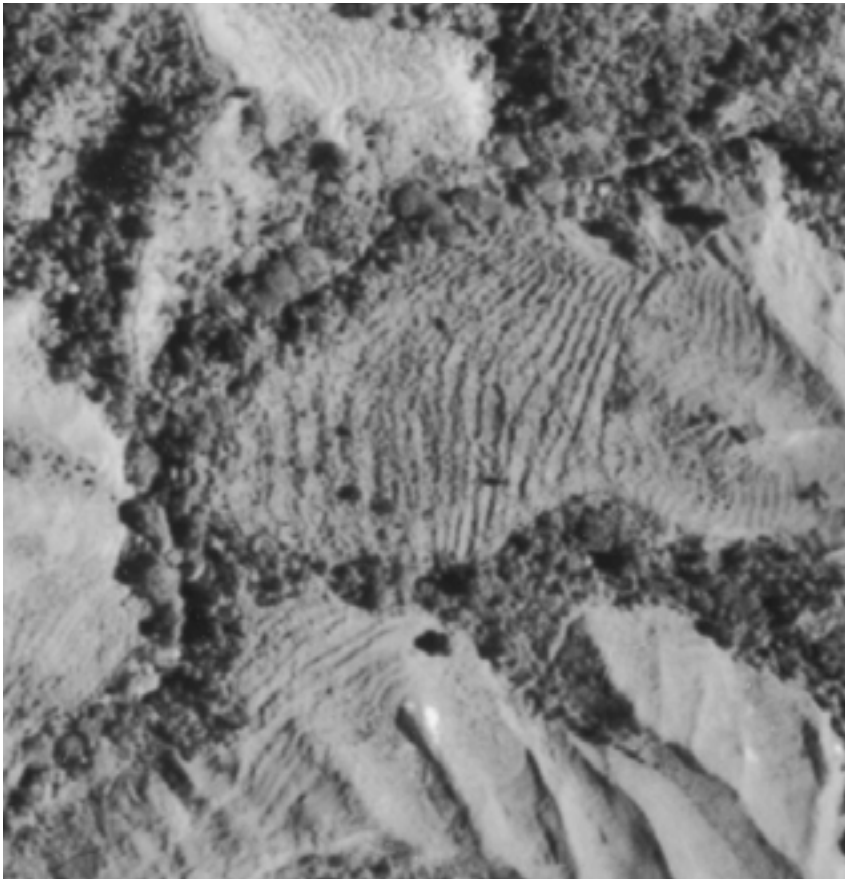
terrace features at first sight. He had not learned about these, although he lived nearby within the region. I have met other (coastally located) Fijian youth from the wet, who did not know how to grow taro at all. In these situations involving the loss of traditional knowledge, where the transfer of knowledge is latent rather than active, communities may effectively become epistemologically independent of each other over time, at least satisfying one aspect of independence and therefore partially justifying a theory of independent origins. More succinctly, the praxis or performance of taro cultivation involves traditional knowledge and skills in a diverse hydro-edaphic context that is situationally-creative, adaptive and conducive to innovation. Both traditional knowledge and the potential for innovative hydro-edaphic intensification coexist at the local scale, and there is no necessity for notions of unilinear evolutionary diffusion or the need for powerful social influence in the incipient stages of irrigation development⁸.

RESILIENCE: FIJIAN AND PACIFIC CASE STUDIES.

In Fiji, irrigated creekfields are generically called *vuci* (but there are many dialect or communalect synonyms associated with particular communities; see King, 2012b, p. 4). Prehistoric remnants have been recorded by Parry (1987; 1994; 1997), Kuhlken (1994a; 1994b; 2002; 2007), Kuhlken & Crosby (1999), and Field (2002). For the historic record, beginning in the mid 19th century, several itinerant observers made note of irrigation (see Perks, 1980), especially in the interior of Viti Levu (see King, 2012a, p. 156) and studies of extant irrigation systems (either in part or *in toto*) have been documented (Hashimoto, 1990; King, 2004; 2012a; 2012b; Kuhlken, 1994a; 1994b; 2002; Sahlins, 1962; Watling, 1984).

Fijian *vuci* systems, especially those of the dry, were primarily contoured on non-alluvial hillslope soils usually above the colluvial zone (*contra* the usually low-lying creekfields in Hawaii and Futuna (Earle, 1980; Kirch, 1994)). One of the larger examples is the disused Drau *vuci* (see Figure 1) on the upper Wainimosi Creek in central Navosa (almost exactly in the centre of Viti Levu). It has about 15 full-length irrigated (some terraces are shorter and narrower) contoured *tavi* (terrace steps) on rich soil. The longest of these, measured on the ground by the author, was Terrace 11 at 209 m long and 4-8 m wide. Terrace 1 (higher up and receiving the intake canal) was 117 m long and 5-14 m wide (unusually, it was flared at one end over a more gradual gradient). There is a further set of unirrigated terraces of about 12 levels (divided by a ridge) above Terrace 1 (making a total hillside count of approximately 27 vertical terrace steps). Informants stated that these topmost unirrigated terraces were planted in rainfed taro; probably only successful in wet years, but possibly valuable for: accommodating excess juvenile plants after the main planting, as a wet season cultivar-exchange reservoir serving (vegetative) propagation, and to lessen risk in case of damage to the *vuci*.

FIGURE 1: *Drau* (means one hundred) *vuci* irrigated taro terrace complex, Wainimosi Creek, Noikoro district, Navosa, Viti Levu, Fiji. Aerial photo courtesy of Lands Department, Government of Fiji, 1990. Disused. The topography is steep and nearly all terraces were built on slopes above the narrow colluvial zone. The longest terrace is 209 m long. The water source is well out of the picture on the top-right but the bottom of the main intake canal can just be discerned. The narrow terraces above the intake canal on the right of the photograph were not irrigated. The terraces on the bottom-left of the photograph to the right of the main creek were fed via aqueducts crossing the gully in the lower-centre of the photograph from the main system.



Only a very few alluvial *vuci* existed but the author is familiar with one: the (about 1 hectare) Nakula creekfield in the Noikoro district of Navosa was functioning up until 1992-1993 when its intake canal adjacent to the Wainivau Creek was destroyed by Cyclone Kina. The author was asked for help in repairing the canal on a visit to Namoli village in 2005, but the request for a bulldozer was beyond development capacities. Today, the Nakula *bila* (alluvial terrace) which includes part of the area previously occupied by the *vuci*, is planted in watermelon, pumpkin, peanuts, cassava and other crops by cultivators mainly associated with Korolevu village.

Some of the larger irrigation systems had very sophisticated hydraulic arrangements where irrigation water descends staircase terraces over multiple levels (4 to 15 levels was typical) and distributed over gullies using aqueducts. Water was sourced from creeks with diversion weirs

(or sometimes springs⁹) and transported via intake canals (typically cut into steep hillsides) sometimes hundreds of metres long (Kuhlken, 1994a; Kuhlken & Crosby, 1999). The intake canal for Drau *vuci* follows the contour on a steeply dissected hillside and is estimated to be 750 m long to the intake weir on the upper Wainimosi Creek. Drau is a large-scale system but lesser-scale systems were more numerous. The smallest are the small springfed systems, maintained by an individual family or subclan (*bito*, *beto*, *tokatoka*) rather than the chiefly *mataqali* (clan) although often serving the clan¹⁰. These small systems were probably important to livelihoods in the past: they were the only type remaining at the time of the author's 1998-1999 research (King, 2004, pp. 185, 361), suggesting that they are more resilient than the larger systems. An agronomic reason for their continuance favoured by the author is that they are more easily protected from ungulates than larger systems. However, reasons associated with sociocultural and politico-economic change are also likely to be important in many cases.

These irrigation systems were developed to be adaptive with Pacific agrobioclimatescapes at their time of construction. The general view is that they are almost universally highly productive (Spriggs, 1989) compared to dryland cropping systems, although there are many variables influencing the yield of corms and other outputs (Spriggs, 1984, pp. 125-126; Caillon, 2012, pp. 202-204), and a scarcity of rigorously-designed comparative studies which are necessary for firm conclusions. In general, there is a paucity of taro studies across many domains (Sunell & Arditti, 1983, p. 34), and most cogently, in the economic, sociocultural, historical and sustainability realms related to the livelihood role of taro (but see the ethnographic studies of: Caillon, 2012; McKnight *et al.*, 1960; Walter & Tzerikiantz, 2012, discussed later). One difficulty in researching *Colocasia*-based livelihood systems is that there are a large number, and more especially, dynamic and varying range of potential research variables (e.g., geographic, climatic, edaphic, floristic, aqua-cultural, agronomic, social, politico-economic and cultural) that influence outcomes and interpretations of outcomes. Most of the studies done so far only consider a very few variables based around the yield of corms, supply of nutrients and less commonly, labour requirements (Bayliss-Smith, 1980, p. 87) as part of the commercial development of taro corm production. More recently, studies have emphasised the role of genetic resources and have incorporated the type of cultivar into this list (Manner & Taylor, 2010; Singh *et al.*, 2010; Taylor *et al.*, 2010). Plant physiologists have begun to study mechanisms that may help explain the adaptation of *Colocasia esculenta* to freshwater wetland environments (e.g., Konnerup, *et al.*, 2011). Research on how taro can be used for the phytoremediation of polluted sites is growing (e.g., Bindu *et al.*, 2010; Madera-Parra *et al.*, 2015). Research on the bioenergy potential of taro has also been initiated (Adelekan, 2012). Further ethnographic studies of existing systems similar to those mentioned above, in Vanuatu and other Pacific islands, may prove especially valuable. However, the interpretation of research requires caution: some variables, e.g., yield, are subject to inconsistency of measurement: many studies do not clearly state the type of scale (i.e., metric or other) that becomes represented as 'tonne' values, and sometimes 'per year' is not calculated, but merely the crop-cycle presented (crop cycles can vary from less than 5 months to 18 months or more). Native soil types and fertility can have a large influence but are often not evaluated. Labour inputs are very difficult to measure accurately and comparisons between studies in different places and cultures may be unreliable. For example, some cultures emphasise group organisation and collective input rather than an individual's input around irrigation (e.g., Östberg,

2014; Sheridan, 2014; Watling 1984), and labour input can be spontaneous and opportunistic in the midst of performing other work. Despite this overall variation, some findings are presented here in an attempt at synopsis.

Purseglove (1972) reported that: ‘In Melanesia, crops grown without irrigation are said to yield 7.5 ton/ha, but double this amount when irrigated’ (p. 64). Spriggs (1984) adjudged: ‘For taro the yield per hectare with irrigation is considerably higher than in rain-fed dryland conditions in a similar environment’ (p. 123), a view supported by Onwueme (1999): ‘the corm yields are much higher (about double)’ (p. 12). The controlled-moisture characteristics of irrigation systems have the potential to allow year-round and out of season production, aided by the relative absence of weeds (following flooding and suffocation) with protection from some pests such as the taro beetle (*Papuana spp.*). The reduction of weed and pest competition contributes towards high planting densities and higher corm yields. Higher planting densities, and the greater density of foliage produced from the increased production of suckers associated with submerged conditions¹¹, in turn, reduces weed competition. Research carried out at Maewo in Vanuatu realised irrigated corm yields of between 25.1 t/ha/yr and 58.1 t/ha/yr (Spriggs, 1984, p. 126). Caillon (2012) has reported an average yield (partially drought-affected) of 18.3 t/ha (pp.202- 203) for taro water-gardens in Vanua Lava, Vanuatu; that use a sequential (rather than continuous) flood irrigation technique. Futuna creekfields, established many generations ago, yielded between 13.3 and 20 tonnes/ha/yr of *cooked* corms (Kirch, 1994, p. 154) together with crayfish, mud fish (*Tilapia spp.*), and eels. Hawaiian pondfield farmers (using heavy fertilizer and weedicide inputs) produced yields between 22.4 t/ha/yr and 49.4 t/ha/yr (Bayliss-Smith, 1980, p. 89)¹². According to the Queensland Government Department of Agriculture and Fisheries, dryland (rainfed) taro: ‘yields vary from 4 to 30 t/ha. Yields up to 70 t/ha have been recorded in Hawaii with heavy fertilisation. Commonly, yields of 10 – 25 t/ha are achieved’ (QGDAF, 2015). The studies of ‘dryland’ taro reported by Lebot (2009) indicate yields from 14.85 t/ha to 33.55 t/ha (p.332), but ‘dryland’ yields can be increased with intercropping (p. 333). As alluded to before, a number of studies on yield have been conducted in Hawaii, some of them on irrigated ‘wetland’ (meaning creekfield) cultivations including larger creekfield complexes of many hectares (Plucknett & de la Pena, 1971). In 1992, taro creekfields in Hawaii covered 123.43 ha (Fleming, 1994)¹³. An analysis of an irrigated taro cropping cycle of 15 to 16 months showed yields (after metric conversion) of 19.36 kg/ha/yr of corms (*ibid*).

To summarize, it appears, very broadly, that the upper margin of the average of rainfed yields is about the same as the lower margin of the average of irrigated creekfield yields. It is possible that agricultural development, focused mainly on rainfed systems and cultivars, has increased non-irrigated taro yield at the expense of irrigated yield, leading to a reduction in the yield difference between these production types that Purseglove, Spriggs and Onwueme reported at an earlier time.¹⁴ The production of taro corms is only part of the yield, however, because cultivators can also selectively harvest eels, prawns, fish (and following a special transplanting technique, shellfish) from creekfields and aqueducts. Also, similar to intercropping in rainfed systems, tree crops, fruits and green vegetables (including watercress, taro leaves and edible ferns) can be harvested from different parts of the irrigation infrastructure (field observations, VNV-FOSLE). This diversity of productive outputs is highly variable, often temporally intermittent and harvested

by different persons or households, making these outputs very difficult to measure. Overall, they are probably of minor importance on average, but they can become valuable in times of stress or shock (e.g., in droughts and after floods or cyclones) when they serve to enhance livelihood resilience.

As alluded to above, there have been very few specific studies of taro livelihood systems in the Pacific. Perhaps, the ethnographic work of Caillon in Vanuatu (e.g., Caillon, 2012) has been the most detailed and revealing in the way it focuses on the historically fluid, but strongly-linked social and cultural relationships between Vanua Lava communities and their sequentially-flooded intensive taro water-gardens in a region of relatively low but increasing population intensity. In that place: ‘Taro is good to eat and think’ (Caillon, 2012, p. 189), and according to Caillon, amounts to a taro civilisation where ‘they live to cultivate and eat taro every day’ (p. 189). In these ‘social and sustainable’ (p. 204) places taro is the dominant food (each person consumes 1.09 kg fresh taro daily (p. 203)) and cash income comes from the sale of copra. Walter and Tzerikiantz (2012) argue that the apparent stability of traditional taro production in Western Santo, Vanuatu, is actually a product of processes of constant renegotiation, migration and change. Gardens tend to die with the person who initially established them, only for descendants to re-establish gardens elsewhere, sometimes in places already endowed with landesque capital in the form of ‘great horticultural complexes’ (p. 209) (terraces, walls and water conveyancing) and agroarboricultural gardens that were once utilised in historic or prehistoric times: ‘in a sense, nothing is abandoned, rather, the existence of a large complex allows a rotation of pondfields in use, which benefits productivity and provides strategic flexibility’ (*ibid*, p. 216).

Articles by Kuhlken (2002) and Watling (1984), and to some extent, Hashimoto (1990), describe some of the social, livelihood and adaptation factors around extant irrigated systems in Fiji. Kuhlken’s contribution describes the livelihood value of the then existing irrigated terracing (*vuci*) at Ravitaki on the island of Kadavu in some detail. He comments: ‘wetland taro was probably never a required cropping strategy, only a relatively fail-safe one.’ (2002, p. 168). Thus, risk-reduction around food scarcity is a benefit. Further:

‘Villagers there persist in cultivating taro in a pondfield environment for a number of reasons. They speak of drought and cyclone hazards, of higher yields and preferred taste, but also tell of perpetuating the obligatory custom of serving irrigated taro for feasts.’ (p.176).

Feasts are understood as enjoyable events but the villagers also ‘cite advantages of the communal labor required for maintenance of the terraces and associated infrastructure’ (p. 177). These findings are largely in accord with my own observations and interview records from Navosa, where the *solesolevaki* (communal work group) was highly valued as a means to perpetuate clan, religious or village solidarity in the face of socioeconomic changes leading to altered identities, individualism, and fragmentation. The onerous work component of *solesolevaki* is often relieved by joking banter and social sharing, with the outcome that participants may perceive the day’s work (or performance) as enjoyable and rewarding in itself. Kuhlken also comments on the decline of *vuci*:

The persistence of irrigated taro cultivation on terraced pondfields in Fiji may be viewed as a deviation from the normal path of agricultural disintensification. In the face of overwhelming reasons not to practice such intensive methods, its perpetuation is surprising, though understandable within the context of cultural forces supporting the esteemed position of wetland taro in ceremonial and social gatherings (p. 186).

In other words, for Kuhlken, (traditional) culture is the ‘preserving factor’ that perpetuates *vuci* in history around the dusk of the 20th century.

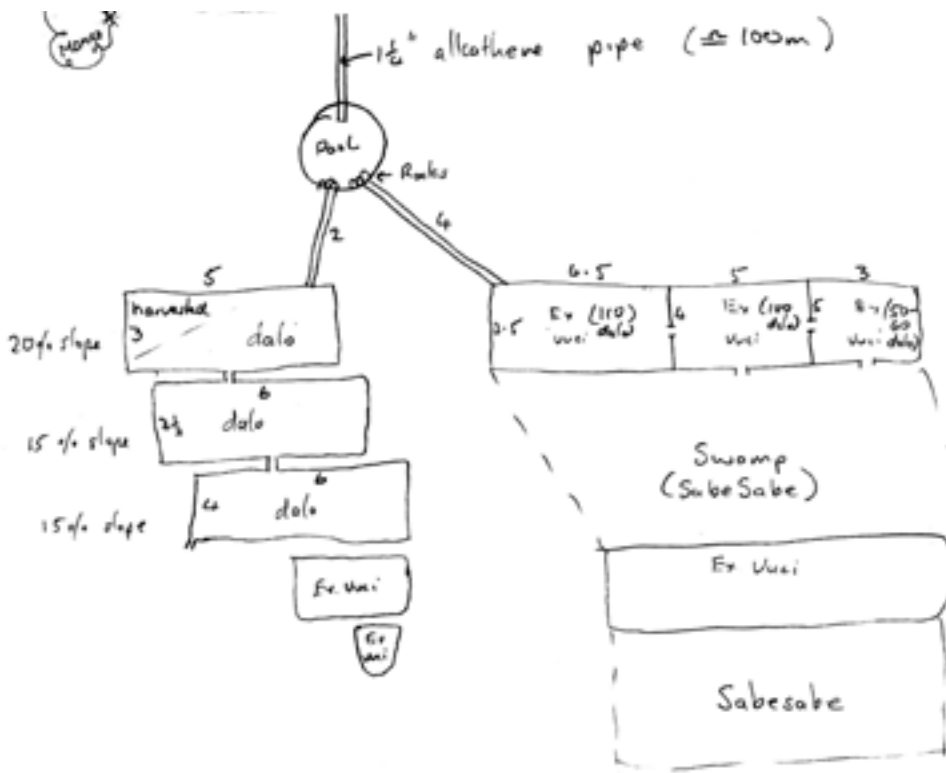
Watling’s (1984) article presents a Fijian history of irrigated creekfields and a study of the *vuci* at Vatukurukuru, Gau Island, describing the technical features of the traditional irrigation system. Polyvinylchloride (PVC) pipes were used here in addition to traditional bamboo piping. Similar to my observations elsewhere in Fiji, there was a preference to plant from January to April in order to harvest near Christmas in December. The advantages of irrigated terrace cultivation that Watling recorded were: (a) especially tasty taro (excellent for *vakalolo* pudding, served at feasts), (b) greater numbers of suckers are produced, facilitating replanting, and (c) less weeding (p. 134). One of the disadvantages mentioned that accords with observations elsewhere in Fiji by the author is the need for ‘continuous supervision’ (p. 134). This is a significant detraction where cultivators have several gardens dispersed over a landscape (a common practice in Navosa today, see Hashimoto (1990)), growing a much greater range of crops (and animals: see King, 2012a) compared to traditional times when yams and *vuci* were ‘king’. Consequently, less time is available to monitor any one crop, *vuci* included, adding to the challenges of *vuci* revitalization projects.

Nevertheless, *vuci* are relatively (compared to yams and cassava) resilient in the face of cyclone shock – *Colocasia esculenta* and its relatives withstand severe winds better than many competing crops, especially when the plants are small. Evidence for this comes from the author’s 1998-1999 research data (previously unpublished) from Nasauvakarua and Nawairabe villages, Navosa, where every household in each village (both had a total of 34 households) was interviewed. Cassava was the main food crop with a total planting across both village communities of 231 square chains (sq ch.), whereas taro was the second most planted food cultigen covering 161 sq ch., substantially more than the third most common (*Xanthosoma taro*, 41.5 sq ch.) and other food cultigens. *Yaqona* (*kava*, *Piper methysticum*) was most widely planted occupying 276 sq ch., but was a drink, not a food crop. The participants were asked: which food was best after a cyclone? *Xanthosoma taro* (*dalo ni tana*) ranked the highest (2.57 av. rank), before cassava (2.83) and then taro (2.85) followed by several other food crops and purchased commodities. The high ranking for *Xanthosoma taro* is partly because it is usually planted in sheltered, semi-shade locations (often part of intercropped agroarboriculture) and has side-tubers that tend to escape damage. The high score for cassava is explained by its usefulness immediately after a cyclone before the damaged tubers begin to deteriorate, but taro was consistently rated highly despite being planted in typically open, sunlit and exposed situations. The participants were also asked: which food is best during a drought? Cassava rated highest (av. rank 1.23) followed by sweet potato (2.68) and *Alocasia* (*via*, or giant) taro (2.8), while

(rainfed) taro was not ranked highly, a consequence of its lack of resilience under dry conditions. Thus, it is apparent that taro is valuable for avoiding food scarcity following cyclonic storms in the wet season, but unirrigated taro has little value during long droughts. This result is expected given that the cyclone season overlaps with the main wet season taro-growing period and very little (rainfed) taro is available during drought-prone dry seasons. Unfortunately, there was virtually no irrigated *vuci* taro (except for one very small streamside creekfield of about 1.5 m x 1.5 m in Nawairabe) to build a comparison with the rainfed technique.

Flooding will damage taro planted in running water at riversides and larger creeksides, but the practice in Navosa is to transplant such taro (usually juvenile plants, called *tanitani*) to rainfed fields at higher elevations, either on the alluvial terraces (a lesser flood risk) or to secure upland agroarboriculture gardens (*teitei*), in the months preceding the beginning of the cyclone season (about September to November). In the past, they were probably also transplanted to *vuci*. Some *vuci* systems are resistant to drought stress, in particular those fortunate enough to have consistently reliable sources of cool water (Addison, 2008). However, those *vuci* subject to a severe decline in the supply of water during drought are less resilient. Taro rot (*Pythium spp.*) can invade the corms if the water supply slows and becomes hot and stagnant or where a *vuci* dries-out and the mud becomes hot. It is posited here that those creekfield systems with secure and reliable water supplies, *ceteris paribus*, are most likely to be both the oldest and the most sustainable. They were also places that are likely to have attracted nearby settlement in the prehistoric past. Creekfielding supports agrobiodiversity by distributing water over larger areas, utilizing dampness efficiently and protecting nearby biodiverse forests. In this way *vuci* can be an adjunct to the agroarboricultural systems common in the Pacific (Clark & Thaman, 1993). Several other advantages of taro irrigation systems are already documented (Spriggs, 1984, 1989; Thaman, 1984) and there is insufficient space to cover all of the reasons here, but I will finish with a description of a small extant *vuci* located at a high altitude (690m asl.) settlement at Natoka in Navosa, Fiji (see Figure 2).

FIGURE 2: The author's 1998 hand diagram of the small *vuci* at Natoka (690 m asl.) in upland Navosa, Viti Levu, Fiji, referred to in the text. It was one of two *vuci* observed as being used in Navosa in 1998. The other, at Nawairabe (which used a traditional tula (bamboo pipe)), no longer exists. *Dalo* is the Fijian word for taro, and the numerals refer to metre length (except the 1¼ inch (32 mm) polythene pipe). This pipe, from the water source, enters at the top of the diagram and empties into a small (about 1 m diameter) pool before being distributed to the two sections of the *vuci* below through rock filters, and further down to the *sabesabe* (drained swamp taro beds) which receive the outflow from the *vuci*. The slope for the section on the right was about 10%. This place was situated near the chief's house - helpful for security purposes. It has been observed elsewhere that relatives or other community members have harvested taro leaves from *vuci* gardens for *bote* or *rourou* (Fijian spinach) without asking the cultivator. Although this serves community livelihoods in general (and is part of Fijian egalitarianism), it compromises the production of the especially tasty *vuci* taro corms and the special efforts of the cultivator for this end.



The interview with the senior *dau ni vuci* (expert *vuci* cultivator, who was also the hereditary chief) was conducted in the drought of 1998. In his view, any soil can be used for *vuci* (most of the surrounding soil was heavy and of good fertility). He installed the 32 mm diameter PVC pipe of about 100 m length to bring water from a small upland spring to his *vuci* (costing him \$100 in 1971). The water flow, which he considered to be ample, was about 36 litres/minute equally divided between his two small sections totalling 117.75 square metres of active *vuci*. He outlined some *vuci* advantages: labour requirements for the *vuci* are mainly in the dry season which complements the labour requirements of wet-season *yaqona* (the dominant cash crop). *Vuci* taro

also has better taste and obtains a good price. A disadvantage is that it requires more digging to prepare the bed of the *vuci*, compared to rainfed taro.

His *vuci* (which was situated next to his house) was divided into two sections (south and north). The south section was comprised of three active beds (*vuci* fields, from top to bottom, west to east, each draining into the next: 5 m x 3 m, 6 m x 3.5 m, 6 m x 4 m) plus two smaller retired beds below these (slope gradient varied from 20% at the top to 15% below). The north section consisted of 3 beds (from top to bottom, south to north, each draining into the next: 6.5 m x 3.5 m, 5 m x 4 m, 5 m x 3 m). It had been used for 2 or 3 years and some of the area on the slope below (gradient about 10%) was now in the *sabesabe* (drained swamp) style without creekfields. The 6.5 x 3.5 bed contained about 110 plants, the 5 x 4 bed contained 100 plants, and about 50-60 plants occupied the north section 5 x 3 bed. All beds were densely packed with taro plants: it was not ascertained at the time, but it is assumed that a considerable degree of suckering had occurred. There were scattered straggling weeds in the *vuci* and a weeding task was probably imminent. Both suckers and crowns (tops) are used for replanting.

The plants take a full 12 months to mature compared to the 6 to 12 month maturity period for the rainfed traditional Vavai and Toga cultivars planted on other slopes nearby. He uses two traditional cultivars in the *vuci*: Lewa ni vuya and Vudra. Both have the advantage of staying sound in over-maturity, but Lewa ni vuya was better in this respect. They are used for local consumption, but were also sold to the Ba market for \$15 a bundle of 5-6 (approx. \$2.00 - \$3.00 kg). When the taro is mature he dries the *vuci*, which makes harvesting easy (the roots die and leaves wilt and the corms can be pulled in half a day). Planting can be done anytime, but is more difficult than harvesting – it takes a whole day: the soil must be moist and digging deep is necessary to allow full root development (the soil type was heavy). Weeding is necessary every three months, which he considered fairly hard work: a half to one day each time for each of the three terraces. *Noko ni kisi* (otherwise unidentified) was one of the most annoying weeds.

The tendency for extant *vuci* to be operated by clan chiefs or their senior relatives was noted throughout Navosa, although this was not an interview question. Chiefs are expected to contribute well at local gatherings and ceremonies and contributions of *vuci* taro are highly esteemed, reflecting positively on the donor's social status. This association of *vuci* taro with social status is deeply embedded in local culture today¹⁵. Unfortunately, this has a negative side in that it may tend to restrict *vuci* development to chiefly families: commoners may not want to be seen to be upstaging the chief by presenting *vuci* taro at a ceremony, or even by growing it without the chief's permission.

Were these *vuci* systems otherwise resilient and sustainable? The question has both physical and sociocultural-politico-economic aspects. From a physical perspective, prehistoric terracing is still quite visible, especially in inland Viti Levu, today. Some terrace remnants appear relatively undamaged, especially when the many decades since the beginnings of disuse and the exponential increase in ungulate animals are considered. It appears that the maintenance of terraces was not too difficult and was a sustainable practice. The (usually riparian) water transport systems, however, are seldom visible, especially on aerial photographs, although the remains are often visible upon investigation at ground level. What has become apparent for most of the old *vuci* sites visited by the author is that floods have damaged access to the water intake. The creek

beds have been down-cut making impractical the rebuilding of the rock diversion weir¹⁶ (*vono*, Noikoro dialect) in the original location and forcing either a new weir upstream or abandonment. In recent decades it is the latter option that has been taken. Aqueducts, traditionally, were made from the hollowed trunks of tree fern (*balabala*, *Cyathea lunulata*) and bamboo (*bitu*, *Schizostachyum glaucifolium*) but these have not persisted, except for a very few in current usage that are protected with fences. The relatively recent prevalence of ungulate animals (largely absent prior to AD. 1900), especially in the dry western region where cattle inhabit the shade of gullies, has had a major effect on fragile infrastructure such as riparian water supply systems which traditionally were not protected with fences. It is this ungulate-impact that the author believes to be a hidden reason (a consequence of colonial policy (King, 2004, pp. 86-89)) for the frequent abandonment of *vuci* from about the mid-20th century (King, 2012a).

The reference to colonial policy introduces the sociocultural-politico-economic element of resilience and sustainability. Agricultural systems adapt not only to geophysical forces but also to sociopolitical (Blaikie & Brookfield, 1987b; Thrupp, 1993), developmental (Brookfield, 1984) and economic ones (Earle, 1980). Many of the reasons for *vuci* decline can be attributed to sociopolitical and economic influences (Durutalo, 1985; King, 2012a, p. 157; Kirch, 1994; Perks, 1980, p. 70) that shape development, influence ecological transitions (Baines, 1989; Bennett, 1976) and alter the risk characteristics of agriculture and livelihood systems (Berkes & Folke, 1998). The type of technological change in agriculture within Fiji has been consistently over-determined by top-down forces associated with the history of British imperialism (McNeill, 2003) and more recently influenced by the political economy of trade and aid remittances from temperate countries (Belshaw, 1964; King, 2004, p. 351-353). There has been a long history of plans and putative improvements suggested by extralocal developers with very low adoption rates among local farmers, especially in recent decades¹⁷. At the centre of this 'adoptive conservatism' is risk. In general, extralocal developers are naive about the environmental and economic risks that Fijian farmers are very aware of, especially the risk of cyclone and flood damage.

CLIMATE CHANGE, ADAPTATION, RESILIENCE AND SUSTAINABILITY

There is some suggestion that irrigation may go through periods of adaptive decline and renewal (King, 2012a; Walter & Tzerikiantz, 2012). An important question is: to what extent has traditional irrigation been influenced by environmental influences and especially by climatic factors? Is there a link between climate change and the indigenous development of irrigated terracing?

Nunn (2007) has argued that there are strong links between past climates, environment and society in the Pacific, especially in the prehistorically more recent late Holocene period. In particular, he has focussed attention on a period of climate change around AD. 1300 when there is evidence for increased precipitation and storminess (Nunn & Britton, 2001, p. 9). This period is associated with a Pacific-wide decrease in temperature of 1.4°C to 3.2°C within 100 years (ibid, p.120) between the Medieval Warm Period and the Little Ice Age. This time coincides with a likely development period¹⁸ of irrigated terracing in Fiji (Kumar, *et al.*, 2006) and other places throughout the Pacific, and leads to the question: did the AD. 1300 'event' stimulate irrigated

agricultural terracing¹⁹? This question is more complex than it seems because there may have been many events and not just one associated with AD. 1300 phenomenon. For example, recent studies based on sulphate deposition at Law Dome in Antarctica indicate separate major volcanic eruptions just before and during the AD. 1300 period (Plummer, *et al.*, 2012). These eruptive events are likely to have caused a dramatic reduction in solar irradiance as well as lowering surface temperatures. My suggestion is that such conditions could have severely affected the culturally-preferred (Perks, 1980, p. 46) sunlight and temperature-sensitive yam (*Dioscorea spp.*) crops of the dry in the Sigatoka Valley, especially if combined with wet and stormy conditions (which penalise yams and favour taro); and forced a greater reliance on taro production at a time when population was increasing rapidly and putting pressure on carrying capacity and social boundaries. At this time, social conflict may have limited local access to the high-elevation moist, rainfed taro growing areas defended by the forerunners of highland clans such as Emalu²⁰ (Brewster, 1920), or more distant access to taro from the wet windward regions, thus forcing the construction of taro terraces at drier lower elevations closer to downstream settlements.

The development of larger-scale irrigation systems may also have been an adaptive response to erosion and land degradation occasioned by the regular burning of the landscape as Barrau (1961) suggested, and as King (2004) observed during the severe drought of 1998. However, the lack of site-specific evidence about chronological differences in land fertility make this claim hard to substantiate, despite the evidence for sudden onset of erosion in the sedimentary record after the date of initial settlement (Dickinson, *et al.*, 1998). Spriggs' (1985) suggestion, that early colonizers practised a type of landscape enhancement by cultivating on alluvium or colluvium washed from (intentionally) degraded hillsides, is subject to a similar criticism: there is a general lack of evidence about the fertility of soils before and after. The current observed tendency of cultivators in the dry of Fiji to plant on higher slopes rather than lower slopes also suggests that the assumption that lower strata sedimentary soils are more fertile is limited in applicability, and bears investigation. An important factor to consider here is the role of crop diseases such as *anthracnose* which tend to accumulate around and in the compacted and less-aerated colluvial soils at the base of lower slopes – limiting the cultivation of yams and other crops on these sites.

In summary, it is likely that irrigation has to a substantial extent been the result of adaptive processes between local communities and especially the climatic and physical environment but with differential levels of change over time, and that the development of irrigation maintained the resilience and sustainability of dry zone Fijian communities in times of duress.

The reasons given for decline of terracing (see King, 2012a) in many ways also reflect the role of adaptive processes including those having sociocultural and political origins. Change is ongoing: only some of the reasons for irrigation decline are relevant today and new reasons for irrigation expansion are appearing. There is no space to elaborate further upon the many social factors here, but I will point out that sociocultural-politico-economic influences, *contra* geophysical forces, can be reversed or modified to allow new adaptation possibilities to occur, for example, to support the adaptation of Pacific agriculture to climate change *via* the revitalization of irrigated terrace agriculture.

DEVELOPMENTAL POSSIBILITIES AND PROGRESSING WITH THE PAST

In 2005, the author responded to a request for help to restore a traditional irrigated creekfield system damaged by flooding in the inland sub-province of Navosa on the island of Viti Levu, Fiji. The Ministry of Agriculture (MAFF) had been approached without success: unsurprising because the ministry was still partly a relic of its colonial foundation, informed by and practising strategies symptomatic of Eurocentric diffusionism (Blaut 1993), like many others elsewhere (Blaikie and Brookfield, 1987a); and subject to the whims of trade and aid deals which stifle locally-adapted innovation (Belshaw, 1964; Gupta 1989; Richards, 1985). For example, the Nacocolevu Agricultural Research Station in the lower Sigatoka Valley of Fiji has for decades hosted a stream of small vegetable-growing projects funded and managed by overseas donor partners introducing new agronomic technologies but without much interest from Fijian farmers (who pass by the research fields on every trip to Sigatoka town) or obvious signs of widespread adoption (new Papaya cultivars may be a partial exception). The suitability and economics of the experimental crops and technologies are, by and large, a poor fit for local farmers and it is easy (if a trite rhetorical) to conclude that the experimental research is of more benefit for the host nation than Fiji. By contrast, taro continues as one of the staple foods for Fijians and other Pacific Islanders (Wilson, 1984, p. 590), not just because of its locus with cultural identity (Pollock, 1992, p. 235) but because the taro cultigen (together with breadfruit, plantain and others) has a long history of successful agricultural adaptation which lowers the risk of food scarcity (as Pollock recognizes, *ibid*, p.231) to communities in the region.

As a response to a just and unfulfilled need, the author decided to develop a non-government organization (NGO) based on a model of 'progressing with the past' (Clarke, 1978), in order to satisfy the request for a restorative *vuci* canal project and to minimize land degradation through a focus on a developmental model based on sustainable livelihoods and environmental conservation. The justification was as follows. In Fiji, as in many other Pacific places, many rural communities are expanding (despite rural to urban migration) and village leaders are keen to find work for burgeoning youth populations. The prospect of refurbishing old terrace systems with secure water supplies and providing irrigation is attractive to village leaders, especially those villages with elders who remember growing irrigated taro in their own youth²¹. Other important factors include: the high market price of taro which provides an incentive for production, strong demand for irrigated taro corms for weddings and other ceremony (the taste of *vuci* taro is locally highly esteemed), irrigated taro is affected minimally by the taro beetle (*Papuana spp.*) pest if the corms are submerged under 5 cm of water, pesticides are not necessary and production is generally higher than rainfed cultivation and can be maintained throughout the year; all of which invokes the criteria of sustainable agricultural development.

The author has observed that gullies in the upper reaches of the Sigatoka Valley where valuable cash crops (typically *yaqona* (kava, *Piper methysticum*) and taro) grew together with agroarboricultural species were seldom burned by fire in droughts, unlike valleys without cash crops or agroarboriculture and where dominated by the introduced and invasive fire-climax *Pennisetum polystachyon* pasture. The author theorized that if similar agronomic practice was introduced at lower altitudes, aided by fences and irrigation, then some control on excessive

burning and land degradation could begin. This was the concept that suggested the renewal of traditional irrigation systems in valley locations and justified the development of the NGO *Vitokoni ni Vuci* – Friends of Sustainable Livelihoods and Environment (VNV-FOSLE), where *Vitokoni ni Vuci* means ‘friends of taro creekfields’, in Navosa dialect.

The author had observed two key things in 1998 about the extant irrigation systems. The first was that protection from ungulates was necessary, and the second was that water conveyancing needed to be robust and easy to maintain. About the first, protective fencing in Navosa is insufficient. Although three-wire fences are now fairly common, farmers’ complain that the high cost of materials is a bulwark to more secure enclosure. The existing fences mainly serve to keep free-ranging ungulate animals out, rather than keeping domestic ungulates in. In most cases the vulnerable valleys and old irrigated terraces are located at some distance from modern villages on, or adjacent to, steep land areas where free-ranging ungulates roam, thus necessitating the construction of strong fences in areas of challenging topography and where the cost of fencing is high. About the second point on water conduits, in 1998 the author observed the innovative use of polythene pipe as a gravity-fed aqueduct at an upland Navosa settlement, previously described, which allowed water to be conveyed in a reliable manner to a *vuci*, needing little maintenance and robust against the penetration of ungulate hoofs. It was an indigenous development (Maiava & King, 2007), and therefore already accepted and adapted to the agricultural system of which it was part, and thus highly suitable as a technological centrepiece together with protective fencing for development projects: an example of ‘progressing with the past’ (Clarke 1978). This model involves adapting a traditional practice to current conditions with the aid of labour-saving new technologies and is a more efficient way to develop livelihoods or attempt conservation than by using alien and poorly-adapted techniques driven by coercive politics and external control.

To date, VNV-FOSLE has completed some projects in the Navosa region in the period 2007-2012 (see Figure 3). The results of monitoring, evaluation and later assessments²² indicate that projects have been most successful: (a) in communities with a purely farming mode of production, (b) where renewal of old terrace systems was undertaken, (c) where elders of the village previously practised the method in their youth, and (d) where a hereditary chief with uncompromised power supported the project. There are many hindrances: increasing evidence of social change and community fragmentation, inadequate assessments of water supply, contested village leadership, land tenure disputes, and instances of miscommunication and misunderstanding have been obstacles in addition to the logistical difficulties imposed by remote locations with difficult access and the usual set of financial and organizational problems associated with development projects.

It is hoped that the initiatives will help reinvigorate irrigated terrace agriculture in Fiji and lead to preservation of the indigenous knowledge and skills. The author has observed one case where *vuci* have been developed independently by a village farmer influenced by VNV-FOSLE project activities and it is hoped that the *vuci* learning workshops previously conducted together with the publication of *The Vuci Manual* (King, 2012b) will lead other farmers and communities to take-up and experiment with this locally-adapted method.

FIGURE 3: First planting of dalo (taro) in refurbished terraced vuci creekfield, Nakoro, Noikoro district, Navosa, Viti Levu, Fiji, 2012. VNV-FOSLE project. The clan chief in the lower-right, who planted this way when he was young, instructs the others. Note use of polythene pipe to reduce risk associated with the water supply, part of 'progressing with the past'. The taro beetle (*Papuana* spp.) cannot live 5 cm below water in creekfields like this and few weeds grow allowing high production despite vuci dalo taking longer to mature than rainfed dalo. This terrace, constructed on a steep slope during prehistory, has rich soil and was previously used continuously for decades with no fallow.



CONCLUSION

The evidence suggests that the prehistoric expansion of irrigated creekfield ethnoagriculture of *Colocasia esculenta* in the Pacific Islands was an adaptation intended to account for changing environmental and social circumstances in the region. The advent of global warming-induced climate change impels us to consider a new era of environmental volatility in the Pacific. Agriculture must learn to adapt to changing environments and it is suggested that ethnoagriculture methods that were developed to enhance resilience during periods of past volatility will have a renewed importance in the future. The idea of progressing with the past, whereby the sustainable base of indigenous and local knowledge surrounding ethnoagriculture is amended with new technologies to further enhance adaptation to changed circumstances, is advised as a general strategy to develop production and more resilient livelihood systems in the Pacific Islands. The refurbishment and enhancement of disused creekfield systems minimizes risk while facilitating livelihood resilience, land conservation, agrobiodiversity and security.

Today, village populations, despite urban migration in some areas, are tending to increase across the Pacific. An important question is: will the type of agricultural development that has been practised in recent decades across many parts of the Pacific be resilient and sustainable in the future? Instead of relying on extralocal or imported ideas which frequently fail to be adopted

because of their poor adaptability in local conditions, it is suggested that we progress with the past using ethnoagriculture amended with technological refinements that reduce risk, enhance resilience and maintain sustainability.

ENDNOTES

- ¹ *In the refined sense of 'adjustments to reduce vulnerability' (Barnett & Campbell, 2010, p. 16).*
- ² *A commonsense (or naïve realist) view would argue that there is ample documented evidence of indigenous irrigation strategies in niche communities that unequivocally indicate adaptation (e.g., see evidence in Spriggs, Addison & Matthews (2012)). Nevertheless, the question must be asked: are there alternative explanations about the origins of niche irrigation?*
- ³ *Alternative explanations include: attempts to gain tributary advantage and political power by being dominant in rituals involving the customary exchange of food resources, and attempts to increase gross agricultural production for financial profit.*
- ⁴ *Vure are distinct from the taro nursery beds (tanitani in Navosa) which can be observed alongside creeks and rivers (often near villages) in Fiji, especially where a dry season is manifest and before the beginning of transplanting to rainfed gardens at the start of the wet season.*
- ⁵ *Creekfield is the preferred term, instead of pondfield. Creekfield more accurately describes the need for a well-aerated water supply to grow taro (*Colocasia esculenta*) in submersed hydromorphic conditions.*
- ⁶ *An detailed list of islands with past irrigation systems is in Thaman (1984, pp. 105-106) together with references and other valuable information. Thaman, however, similar to other researchers of the time, tended to focus on the more visible larger systems and under-reported the small and scattered (often streamside) niche systems still in use in hilly or mountainous zones of the Pacific.*
- ⁷ *Perks (1980, p. 90) in Footnote 33 adds that the high extralocal demand for Fijian wage labour in the mid 20th century was also a factor. There is debate about the relative importance of labour requirements for vuci compared to rainfed cultivation. The general consensus is that extra (workgroup) labour is initially required to build the terraces and water conduits (the landesque capital) but thereafter labour requirements are less (e.g. less weeding and pest control is needed in flooded creekfields) (also see King, 2012b, p. 21) but local circumstances and techniques are variable and more research is needed.*
- ⁸ *Despite his overall focus on social-political influence in large-scale hydraulic societies, Wittfogel (1957) recognized that incipient and small-scale irrigation communities were exempt, at least initially, from these processes: he used the term 'hydroagriculture' (p. 3) to describe their innovation.*
- ⁹ *Robert Kuhlken produced an excellent video-recording featuring a local indigenous narrator with their vanua workgroup demonstrating the planting of taro in an irrigated creekfield at Ravitaki on Kadavu island of Fiji. The water source was a spring. The recording is called 'Laua ni Ravitaki: Terrace Farming in Kadavu, Fiji, 1992', University of the South Pacific, Suva.*
- ¹⁰ *The vuci at Natoka (690 m asl.) was maintained by the high clan (yavusa) chief himself with the help of his subclan. The vuci at Nawairabe (68 m asl.) was maintained by an elderly relative of the son of a former chief, until his passing about 2005.*
- ¹¹ *Generally, there will be more suckers produced under irrigated cultivation compared to rainfed cultivation; but different cultivars vary in their production of suckers. VNV-FOSLE's experience suggests that traditional Fijian cultivars produce more suckers than the current hybrids and thus traditional cultivars are more suited to irrigated production because of their increased propagation potential – a very important agronomic factor where vegetative reproduction is necessary and local climate is limiting.*

- ¹² Bayliss-Smith (1980) analysed several studies that researched 'wetland' taro in Hawaii and elsewhere and is worth further reading for more detail. Some of the Hawaii figures are from moderately large-scale studies reported by Plucknett and de la Pena (1971) and others.
- ¹³ Manner and Taylor (2010, p. 9) provide numerical estimates of the cultivated area of taro in various countries. I advise caution in the use of these statistics given the unreliable means of collection in many countries (Wang, 1983, p. 5). For example, in Fiji during 1998-1999, MAFF did not collect accurate production data from the hilly and difficult-to-access part of the Sigatoka watershed where I did my research, and limited their efforts to the downstream alluvial farms of the main Sigatoka Valley. There are many other factors that compromise accuracy including substantial (sometimes dominant) amounts of taro exchanged for livelihood and ceremonial purposes between community members that is not recorded because it does not go for sale to the market.
- ¹⁴ This stands as only a hypothesis, however, as the necessary historical and comparative research has not been done as far as I am aware.
- ¹⁵ Given the evidence for the prevalence of prehistoric irrigated terraces in the Navosa region, it is likely that the current elevated status of vuci taro, and its value as a social gift, is associated with its increased scarcity compared to a past abundance when vuci taro was commonplace.
- ¹⁶ Fijians do not traditionally build permanent 'vertical' dams, especially downstream, because of the risk of destruction in floods – a common occurrence in Fijian catchments. Instead, they build diversion weirs made from river stones, branches and other vegetation including rot-resistant ivi tree (*Inocarpus fagifer*) leaves and mud. These weirs are located at a wide, flat part of the creek and are easily reformed by a village work party after a damaging flood as long as down-cutting of the creek does not occur. Today, small irrigation dams (1-2 m from base) can be constructed in narrow creeks with the aid of modern materials (cement and piping); a common practice in providing potable water for villages. It can be noted that an invasive large tree, *Samanea saman* (originally promoted as an agroforestry tree and used for firewood), produces voluminous amounts of heavy debris that have been particularly damaging to large downstream culverts and bridges during floods of recent decades.
- ¹⁷ Some qualifications are needed. Iron tools were keenly adopted during contact with the first Europeans. There was a period in the early-mid 20th century when animal-drawn ploughs and other implements were introduced and adopted in areas of flat topography. However, in many upland communities today manual digging with iron spades is favoured over use of the plough because of the land-degrading slope erosion the latter causes. Various new cultigens have been adopted and add to the diversity of food crops grown today.
- ¹⁸ A difficulty is the lack of accurate dates to pinpoint terrace construction, as previously alluded to. Research is badly needed here.
- ¹⁹ Unfortunately, there are few proxy indicators to help with assessments of prehistoric climate variables for western Fiji.
- ²⁰ Agricultural terraces have recently been discovered underneath previously-assumed undisturbed forest by survey research teams on the high-elevation Nadrau Plateau in Emalu territory of central Viti Levu (anonymous personal communication).
- ²¹ The time was the mid 20th century when many of the Navosa creekfield systems were retired (a post-apocalyptic time of low community populations and when taro had little market value). It coincided with the adoption of plough agriculture and new edible cash crops including cassava (*Manihot esculenta*).
- ²² In general, the process of monitoring and evaluation was very a discontinuous process, where data was gathered somewhat opportunistically and with less participatory monitoring than initially planned. There was a lack of funds for fully diagnostic and follow-up evaluations, partly because of the difficulty and expense of travel to remote project sites subject to the vagaries of weather and without all-year road access. A process involving adaptation to local conditions has figured highly in implementing this type of project work, and carrying-

out a conventional synchronic social and environmental impact assessment could be viewed as intrusive and disturbing given the arrangement of diachronic power-knowledge and social structure in remote Fijian villages where the local chief is also the caretaker of the vanua (land-people nexus). Instead, a less-direct indigenous Fijian 'conversational' style of evaluation and assessment with different community members was carried-out when opportunities arose. A follow-up assessment was completed recently at the author's expense. The outcome indicated a frequent demand for the construction of small dams to aid the irrigation water supply.

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