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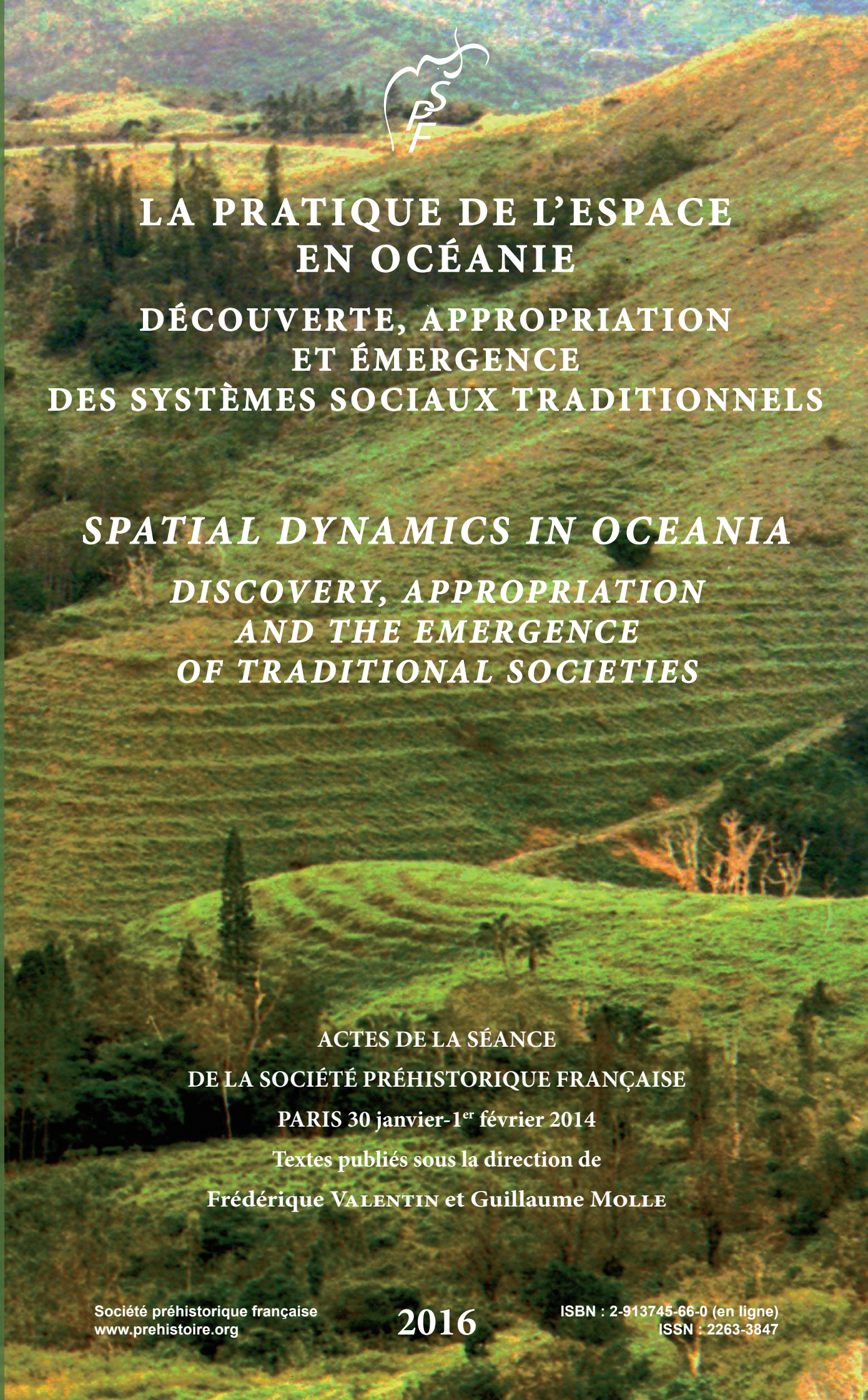

LA PRATIQUE DE L'ESPACE EN OCÉANIE

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SPATIAL DYNAMICS IN OCEANIA

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Siège social : 22, rue Saint-Ambroise, 75011 Paris
Tél. : 01 43 57 16 97 – Fax : 01 43 57 73 95 – Mél. : spf@prehistoire.org
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Tél. : 01 46 69 24 44
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Horticultural Structures on Ultramafic Soils

The Case of Isle of Pines and Other Parts of Southern Grande Terre Island (New Caledonia)

Louis Lagarde and André-John Ouétcho

Abstract: This article addresses questions relating to traditional horticultural practices in some supposedly infertile environments of New Caledonia. It is widely accepted that this southern Melanesia archipelago hosts an extremely elaborate set of horticultural systems, mainly dating to the last millennium and iconic of what is defined as the Traditional Kanak Cultural Complex. These systems are usually distinguished by irrigated terraces dedicated to the production of species which need a constant water supply, such as taro; and also by the construction of elongated earth mounds connected with dryer cultivars such as yam, banana and sugarcane. However, a significant part of New Caledonia's main island, Grande Terre, and the Isle of Pines, is covered by ferralitic soil, derived from the degradation of ultramafic rocks whose origin goes back to a partial, tectonic subduction event which occurred over 37 million years ago. The pedological environment which derived from this phenomenon is particularly acidic, with very low levels of key nutrients (N, K, P, Mg, Ca) but high concentrations of toxic elements, such as metals. These conditions fostered the advent of highly efficient, well-adapted vegetation with extremely high endemism levels and also introduced strong local constraints to the cultivation of species of alimentary importance, introduced by the first Austronesian people who arrived three thousand years ago. It is in these inauspicious settings that important horticultural structures have been archaeologically surveyed in recent years; which, though chronologically linked to other, better-known horticultural structures found on more favorable soils throughout the archipelago, present some clear structural differences. By studying these structures discovered in the south of Grande Terre (in the Yaté and Ouinné regions) and the Isle of Pines, the chemical particularities and the requirements of the soils (to become productive), we were able to form a series of possible interpretations regarding these distinctions. After analysis, it seems reasonable to state that at least some of these specificities were linked to empirical experiences in soil enhancing, and oriented towards productivity. In particular, the deviation of streams in order to irrigate ferralitic plains has long since been demonstrated. The constitution of stone enclosures, usually interpreted as private parcel delimitations, could have been undertaken in order to minimize the evaporation process and the impact of saline conditions in coastal environments. Also, they could have been constructed to enhance the soils key nutrients, through confinement and mulching, in a similar way to that previously observed in the basaltic environments of Polynesia.
The existence of these structures and the care taken in their edification was put into perspective; especially as cultivation in the ferralitic environments of southern New Caledonia still proves difficult today, despite the extensive use of fertilizers. Naturally, it raised the question of intensification in relation to the spatial occupation of the archipelago during the last millennium. Therefore, if one considers that one third of the available surface of Grande Terre and the Isle of Pines is characterized by ultramafic formations, what is one to think of the occupation on the rest of the archipelago where the soils are of better quality? A large amount of archaeological research has been undertaken during the past twenty years on the intensification processes in horticulture implantations throughout the last millennium, leading to the Kanak landscapes as witnessed by the first Westerners. This field has considerably expanded our knowledge of the last thousand years of the archipelago. In particular, the results have demonstrated that the population of the indigenous Kanak, prior to European contact in the late 18th century, was considerably higher than the usual demographic evaluations, which were based solely on missionary accounts and the beginning of French colonial rule in 1853. In conclusion, it seems clear that the existence of the horticultural structures and habitat in marginal zones with poor quality soil provides a supplementary argument in favor of a largely superior pre-European population to that previously recorded.

Keywords: New Caledonia, Kanak, horticulture, irrigation, ultramafic, ferralitic, soil enhancement, lithic mulching.

Structures horticoles sur sols ultramafiques : le cas de l'île des Pins et d'autres régions du sud de la Grande Terre (Nouvelle-Calédonie)

Résumé : Cet article propose d'aborder les questions d'horticulture traditionnelle sur les milieux *a priori* hostiles de Nouvelle-Calédonie. Cet archipel de Mélanésie du Sud est connu pour abriter des systèmes horticoles très élaborés, datés en général du dernier millénaire de

notre ère, et emblématiques de ce qu'il est convenu d'appeler l'ensemble culturel traditionnel kanak. Ceux-ci sont principalement caractérisés par des aménagements en terrasses irriguées pour les cultures humides (taro d'eau notamment) ainsi que des billons surélevés dédiés aux cultures sèches (igname mais aussi bananier, canne à sucre). Toutefois, une partie du territoire de la Grande Terre et l'île des Pins, qui font partie de cet archipel, est recouverte de sols issus de la dégradation de roches ultramafiques, dont l'origine remonte à une période de subduction partielle qu'a connue l'archipel il y a plus de 37 millions d'années. L'environnement pédologique qui a découlé de ce phénomène est particulièrement acide, pauvre en éléments nutritifs et riche en éléments toxiques comme les métaux, ce qui a à la fois permis le développement d'une végétation performante à très fort taux d'endémicité, et aussi rendu difficile, depuis l'arrivée des premières pirogues il y a trois millénaires, la culture d'espèces introduites à vocation alimentaire. C'est dans ces environnements, peu propices, que des structures horticoles importantes ont été mises en évidence ces dernières années. Si elles s'inscrivent chronologiquement en parallèle des autres aménagements connus ailleurs dans l'archipel, elles restent structurellement différentes. À travers celles découvertes dans le sud de la Grande Terre (régions de Yaté et Ouinné) et à l'île des Pins, nous proposons de dégager leurs principales particularités. La prise en compte des caractéristiques chimiques, et donc des besoins de ces sols, permet également de poser un certain nombre de pistes interprétatives sur les différences structurelles observées d'avec les autres aménagements horticoles connus sur l'archipel, pourtant contemporains. En effet, il semble probable qu'une partie de ces spécificités soient liées à des essais empiriques d'amélioration des substrats. En particulier, le détournement de cours d'eaux entiers afin d'irriguer les zones de plaines est avéré. La constitution d'enclos murés aménageant de petites surfaces de culture, généralement interprétées comme des délimitations de parcellaire horticole, pourraient en réalité avoir été entreprise afin d'au moins diminuer l'évaporation et l'impact des conditions salines littorales, voire pour essayer de concentrer le substrat en éléments nutritifs, comme cela a déjà été mis en évidence dans des environnements basaltiques de Polynésie. Lorsque l'existence même de ces structures et le soin apporté à leur réalisation sont mis en perspective, alors même que les mises en culture dans les zones à substrat ultramafique sont encore problématiques aujourd'hui, malgré l'apport massif d'engrais, alors se pose naturellement la question de la densité d'occupation de l'espace sur l'archipel calédonien durant le dernier millénaire. En effet, si l'on considère que les zones ultramafiques représentent un tiers de la surface de la Grande Terre et de l'île des Pins, alors que penser de l'occupation des zones plus propices à la culture, sur substrats moins acides ? Les recherches archéologiques menées depuis maintenant plus de deux décennies sur les intensifications dans les aménagements horticoles, tendent à démontrer que la population Kanak était plus importante qu'il n'a longtemps été pensé, lors des premiers contacts avec les navigateurs européens. Il semble clair que l'existence même de structures et d'habitats en zones pourtant marginales, défavorables à l'horticulture, corrobore ce propos et apporte des arguments supplémentaires à l'image d'une population pré-européenne largement supérieure à ce qui a été longtemps écrit.

Mots-clés : Nouvelle-Calédonie, Kanak, horticulture, irrigation, ultramafique, ferralithique, amendement des sols, paillage lithique.

Studies of horticultural systems in the Pacific have a long and complex history throughout Polynesia (’Uvea in Kirch, 1978, Futuna and Alofi in Kirch, 1995, the Tuamotu islands in Chazine, 1985, the Cook islands in Allen, 1971 or Hawai’i in Kirch, 1977) and Melanesia (for Aneityum, Vanuatu, see Spriggs, 1981). When one mentions traditional horticultural structures in New Caledonia, one is almost inevitably referring to the famous, massive, field organizations that can be seen throughout the main island. It is through their study that New Caledonian anthropologist and ethnobotanist Jacques Barrau produced a thought-provoking article, ‘L’Humide et le Sec’ (Barrau, 1965), which founded a new way of understanding and studying horticultural systems in the Pacific. Since then, they have been actively surveyed and studied, especially by the local archaeological team of the Institute of Archaeology of New Caledonia and the Pacific (IANCP) over the past few decades (Sand et al., this volume). These structures are connected chronologically to the last millennium and socially to the *ensemble culturel traditionnel kanak* (Sand et al., 2012a). This *ensemble* or ‘complex’ (Sand et al., this volume) is defined by the progressive emergence of knowledge, techniques, skills and material culture, indigenous to the New Caledonian archipelago. This phenomenon took place progressively during the first millennium AD, in response to new constraints: extensive use of slash-and-burn practices during the first part of the chronology by an ever-growing population caused a global pauperization of soils, and probably consequential intensification of social tensions in land ownership (Sand et al., 2012a, p. 103). This triggered a renewed and highly complex set of horticultural structures than can be seen in most environments of mainland New Caledonia, also called Grande Terre Island. These horticultural systems consist of built terraces showing evidence of complex irrigation, for wet crops such as wet taro *(Colocasia esculenta)* and also a series of elongated earth mounds used for dry crops such as yam (*Dioscorea* sp.; see Barrau, 1965). Here, the aim is to highlight the specific horticultural structures that were built on ultramafic soils. This archaeological issue has yet to be fully discussed; partly because of its rarity but mainly because of New Caledonia’s famous archaeological diversity and chronological depth, which spans three millennia of human settlement, presence and adaptation (Sand, 1995).

We will focus on the horticultural systems found in the ferralitic and acidic geological environments of southern mainland New Caledonia and the Isle of Pines (located at the southern tip of the main island, fig. 1). Their location and special features, as well as their differences to other nearby horticultural systems are discussed in order to finally address the adaptation process of the Kanak cultural complex to the highly peculiar ferralitic zones of New Caledonia. Therefore, we shall mention the geological, pedological and floral characteristics of these environments as well as their limited tolerance to imported crops. The different kinds of structures that have been discovered here over the years will also be presented, including how they relate to the better-known structures found elsewhere

on the mainland. Finally, we will discuss the presence of these structures and the necessity of a better understanding of their particularities in order to obtain a 'better picture' of human adaptation during the last millennium in New Caledonia.

SOIL AND ENVIRONMENTAL CHARACTERISTICS

Local ultramafic geological and pedological formations in New Caledonia come from the earth's mantle. At the end of the Eocene period, 37 million years ago, during a phase of complete submersion, the deeper layers of the earth's crust covered mainland New Caledonia and the Isle of Pines. This phenomenon was caused by the subduction of tectonic plaques: the Indo-Australian going under the Pacific one (Picard, 1999; L'Huillier et al., 2010). When New Caledonia re-emerged, erosion and fragmentation led to the formation of the complex geology of Grande Terre Island, with different ferralitic environments roughly covering a third of its surface (5,500 km², fig. 1).

In the remainder of New Caledonia, soils are generally considered of medium to good quality, with a large variety of textures, components and abilities. The Caledonian Agronomical Institute (IAC) considers that 2,100 km² are ideal for crops, 9,600 km² are good for forestry exploitation and the remaining, ferralitic 5,500 km² are unfit for modern-day cultivation (L'Huillier et al., 2010). Indeed, these geological formations are known for their high concentrations of metals, a component usually only found as traces in 99% of the surface rocks in the rest of the world (L'Huillier et al., 2010). The soils produced by these geological formations therefore bear some unique pedological characteristics which support a rich, mostly endemic flora. It is in these ferralitic environments that New Caledonia's floral endemism is at its highest with 88.8% of all the vascular plants (Jaffré et al., 2001, p. 32). Therefore, even though chrome and nickel generally have a toxic effect on plants, biologists have discovered that some endemic species found in southern New Caledonia show extreme adaptation abilities to the soils encountered (Jaffré et al., 2013). Known as 'hyperaccumulators', they are able to filter and accumulate nickel, such as *Pycnandra acuminata* (fig. 2) whose blue sap can contain more than 20% of nickel citrate.

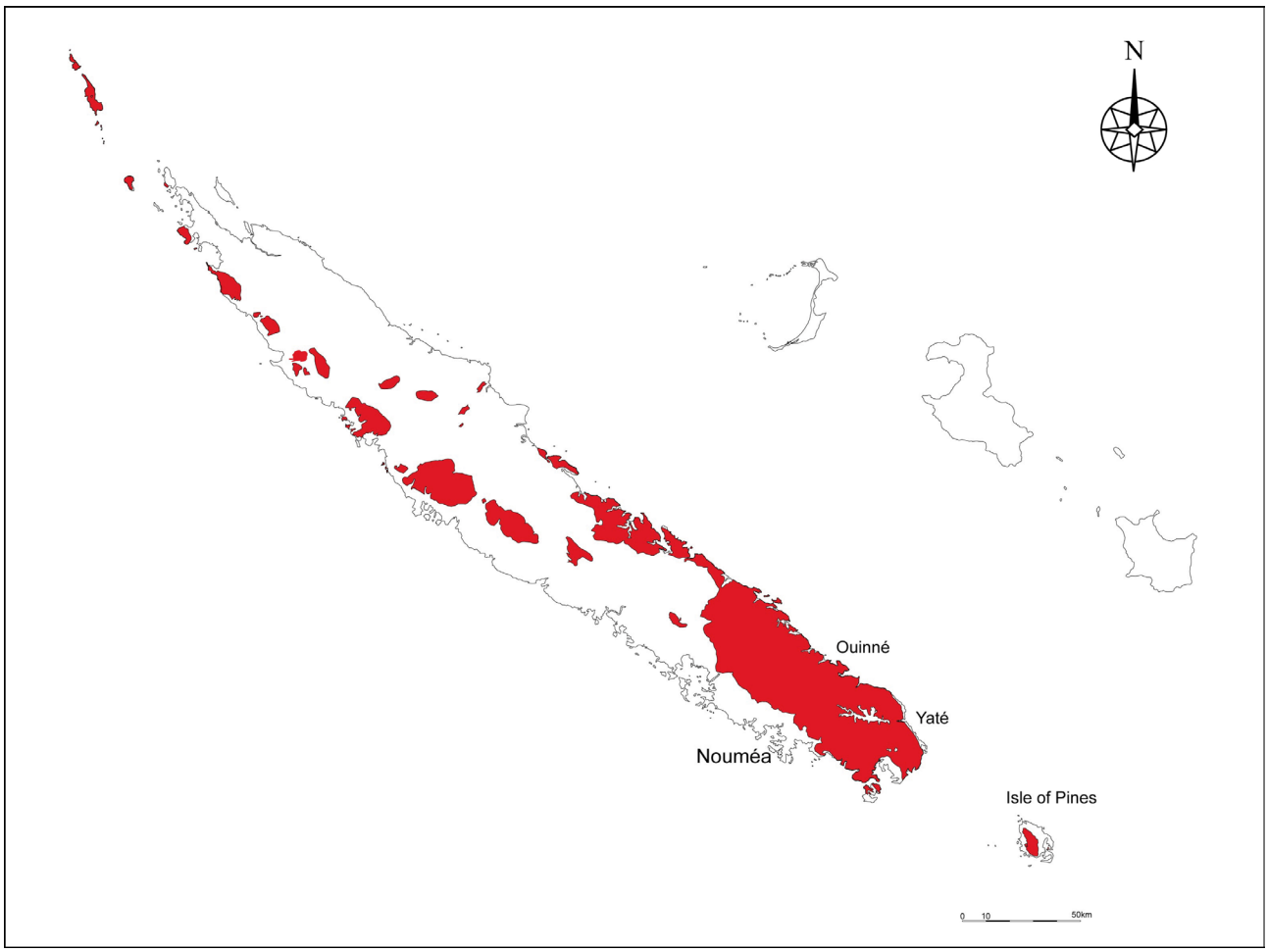

Fig. 1 – Ultramafic formations in New Caledonia.
***Fig. 1** – Formations ultramafiques en Nouvelle-Calédonie.*

There are three main ferralitic soil types to be found in New Caledonia, all of which contain high levels of metal and are therefore toxic to non-indigenous plants. However, they do not all bear the same levels of nutrients, nor do they have exactly the same pH or the same water-retaining characteristics, essential factors for the cultivation of crops.

The three categories are (L'huillier et al., 2010; here: table 1):

– a) Non eroded ferralitic soils located on slopes, highlands and peaks, are the poorest kinds of soils to be encountered in New Caledonia. They show high acidity (a very low pH of 4.6), high levels of toxicity, and few exchangeable chemical nutrients;

– b) Recently eroded ferralitic soils or rejuvenated soils are located on the slopes or peaks, and are extremely poor in exchangeable nutrients; yet, their pH is quite high for an acidic soil (5.9) which is partially due to the presence of high levels of magnesium ions (Mg);

– c) Ferralitic soils connected with alluvial deposits: their higher pH (6.3) is connected with the presence of magnesium and calcium ions (Ca). Even though potassium and nitrogen nutrients are in the same low levels as the two first categories, organic deposit levels in the plains can provide immediate supply and give crops a slightly better chance of survival.

Therefore, plains and lower slopes possess better characteristics for the survival of crops, because of erosion, breakage of the ferralitic elements, and the presence of organic deposits. Overall, though, it remains an extremely harsh environment for non-indigenous, introduced species and cultivars.

Fig. 2 – *Pycnandra acuminata* (© Bernard Suprin).
Fig. 2 – Pycnandra acuminata *(© Bernard Suprin).*

The most important aspect of these soils, other than their metal-induced toxicity, is the scarcity of key nutrients such as nitrogen (N), potassium (K) and phosphorus (P). Used as supplements in mineral or organic fertilizers, these were, in the past, almost impossible to obtain in island societies which did not breed animals for food. On other Pacific islands, the occurrence of chickens *(Gallus gallus)* or pigs *(Sus scrofa)* is due to the early colonizing phase, during which the first settlers voluntarily introduced these species. However, though open to much debate, in New Caledonia evidence of these commensals prior to European contact is unlikely or rare (Sand, 2010): no traces of pig or chicken bones have been found in any Lapita or post-Lapita layers. Pigs were clearly introduced during the 19th century, and chickens appear only later in the chronology, during the last millennium, possibly through Polynesian contact (Lagarde, 2012). With no animal source of organic nutrients, the main source of useful chemicals for horticulture (especially nitrogen) was rainwater. But, for crops to grow in a non-fertilized ferralitic environment, heavy and regular rainfall is essential in order to receive high levels of nitrogen. This happens to be the case on the southeastern mainland of New Caledonia and the Isle of Pines, where the archaeological structures discussed in this paper, were discovered. The global rainfall there is between 1500 and 3500 mm/year, on the higher end of the global New Caledonian spectrum, the average being of 1700 mm/year (L'Huillier et al., 2010).

Another aspect to consider is the water-retaining ability of ferralitic soils: the presence of clay and organic matter plays an important role in the high humidity rate of the alluvial ferralitic soil, almost four times higher than those of the other two ferralitic soil types (on slopes and summits) rising from 7.4 % to 26.8 % (L'Huillier et al., 2010). This, however, is moderated by the evaporation caused by the sun and wind. This, it should be noted, is naturally stronger on the seashore in southeastern mainland New Caledonia, where south-easterly winds clearly dominate.

Here we have a basic contradiction: the best soils in ferralitic environments are located in the alluvial plains close to the coast (higher pH, more nutrients and better water-retaining abilities). However, these areas are generally windy, a condition which favors evaporation, loss of humidity and suffering to crops.

ARCHAEOLOGICAL FEATURES

Large horticultural structures are common all over mainland New Caledonia, and can be roughly separated in two main categories. In the first type, the best soil was gathered in order to form elongated mounds for dry crops, the water being supplied by rainfall. Gener-

	Non-eroded ferralitic soils	Recently eroded ferralitic soils	Alluvial feralitic soils	Common brown soils
pH	4,6	5,96	6;35	6.81
Exchangeable ions (mEq/100 g)				
K^+	0.08	0.06	0.07	0.22
Metals (%)				
Fe	46.5	42.59	36.5	17.3
Ni	0.26	0.94	0.84	0.27
Cr	4.24	2.11	4.62	1.21

Table 1 – Main geological characteristics of New Caledonian ferralitic soils, compared to magnesian brown soils found elsewhere on Grande Terre Island (from L'Huillier et al., 2010).
Tabl. 1 *– Principales caractéristiques des sols ferralitiques de Nouvelle-Calédonie comparées aux sols bruns magnésiens trouvés ailleurs sur la Grande Terre (d'après L'Huillier* et al.*, 2010).*

ally such mounds were dedicated to bananas or sugar cane, but here their main focus was yam *(Dioscorea* sp.*)*: a sacred tuber in Kanak culture, a masculine symbol and a central piece in customary practices and trade. The second type consisted of irrigated terraces, often built on hill slopes dedicated to the cultivation of wet taro *(Colocasia* sp.*)*, another highly praised tuber and feminine counterpart of the yam (Barrau, 1965; Sand et al., 2012a, p. 103). The organization of this new, previously locally unknown, system of horticulture in the New Caledonian archipelago, through the edification of these two main categories of structures has been dated to the last millennium. Therefore, the oldest dates acquired in the southern part of mainland New Caledonia (in the Païta region, close to the ferralitic environments discussed in this article) go back to the last quarter of the first millennium AD (Beta 61956: 1210 ± 70 BP; Sand, 1995, p. 60).

In ferralitic environments, the structures linked to horticultural activities were of four main types:

– a) Terraces on ferralitic slopes showing evidence of water irrigation (fig. 3), as found on the Isle of Pines (Lagarde, 2012). Most notably, a set of twenty-eight terraces, perpendicular to the slopes and measuring between 10 and 50 m, were discovered on the Isle of Pines at site KKR003 in 2010. Each terrace bore masonry of large boulders. Trapped within the masonry was a fragment of *Tridacna* sp. shell which was dated to 704 ± 29 BP (430 cal. BP, 2 σ, Waikato 32924; here: Lagarde, 2012). This is consistent with the attribution of these structures to the emergence of the 'Traditional Kanak Cultural Complex' (Sand, 2012);

– b) Small enclosures on ferralitic slopes which create small walled gardens (fig. 4), as found on the Isle of Pines (Lagarde, 2012). These gardens are generally small, bearing a reduced cultivable surface (from 12 m^2 to around 30 m^2) with separation walls made of piled-up ferralitic boulders, 50 to 80 cm above the ground. These enclosures are generally round or oval-shaped, with some extended ones which usually contained an elongated earth mound similar to those dedicated to yam cultivation found elsewhere on the mainland. Similar small enclosures are also known from places such as the nearby Loyalty Islands (i.e. Sand, 1995, p. 185) and generally throughout the Pacific, in non-ferralitic environments. Usually interpreted as private, nuclear family gardens, they are still seldom seen on the rest of Grande Terre Island;

– c) High circular enclosures along narrow coastal plains, as found in the Ouinné region, southeastern part of Grande Terre Island (fig. 5). Constructed with massive quantities of piled-up boulders, their height ranged from 1.2 m to 2 m, which created a fairly small space for horticulture within (between 5 m^2 and 12 m^2). They have yet to be documented elsewhere in the New Caledonian archipelago. Witnessed from different sites along the 14 km shoreline of the Ouinné zone, surveyed in 2008, they are still considered as indigenous to that location (Lagarde et al., 2008);

– d) Large structures built to divert the course of streams in order to bring water to the coastal plains, as recorded in Yaté (Sand and Ouétcho, 1992; here: fig. 6). Evidence of barrages diverting creeks from their original beds exists elsewhere on the mainland, in non-ferralitic environments, as the irrigation of taro-dedicated terraces needed constant water supply. There are numerous accounts of open air water ducts carved in stone or water-retaining barrages in order to divert stream water for irrigation. Yet, in the Yaté region, these impressive structures can be as wide as 20 m and as long as 70 m, and are not connected to terraces but are created to allow the irrigation of the nearby plains.

INTERPRETATION

To summarize, although these horticultural structures are clearly different, they do bear some common characteristics. The common earth terraces dedicated to wet crops and the elongated yam mounds found on Grande Terre Island are typically carved out or piled-up as previously described. Here, a considerable addition to this practice is that the structures found in ferralitic

Fig. 3 – Built terraces on ferralitic slopes, site KKR003, Isle of Pines (photo L. Lagarde, 2010).
Fig. 3 *– Terrasses construites sur des pentes ferralitiques, site KKR003, île des Pins (cliché L. Lagarde, 2010).*

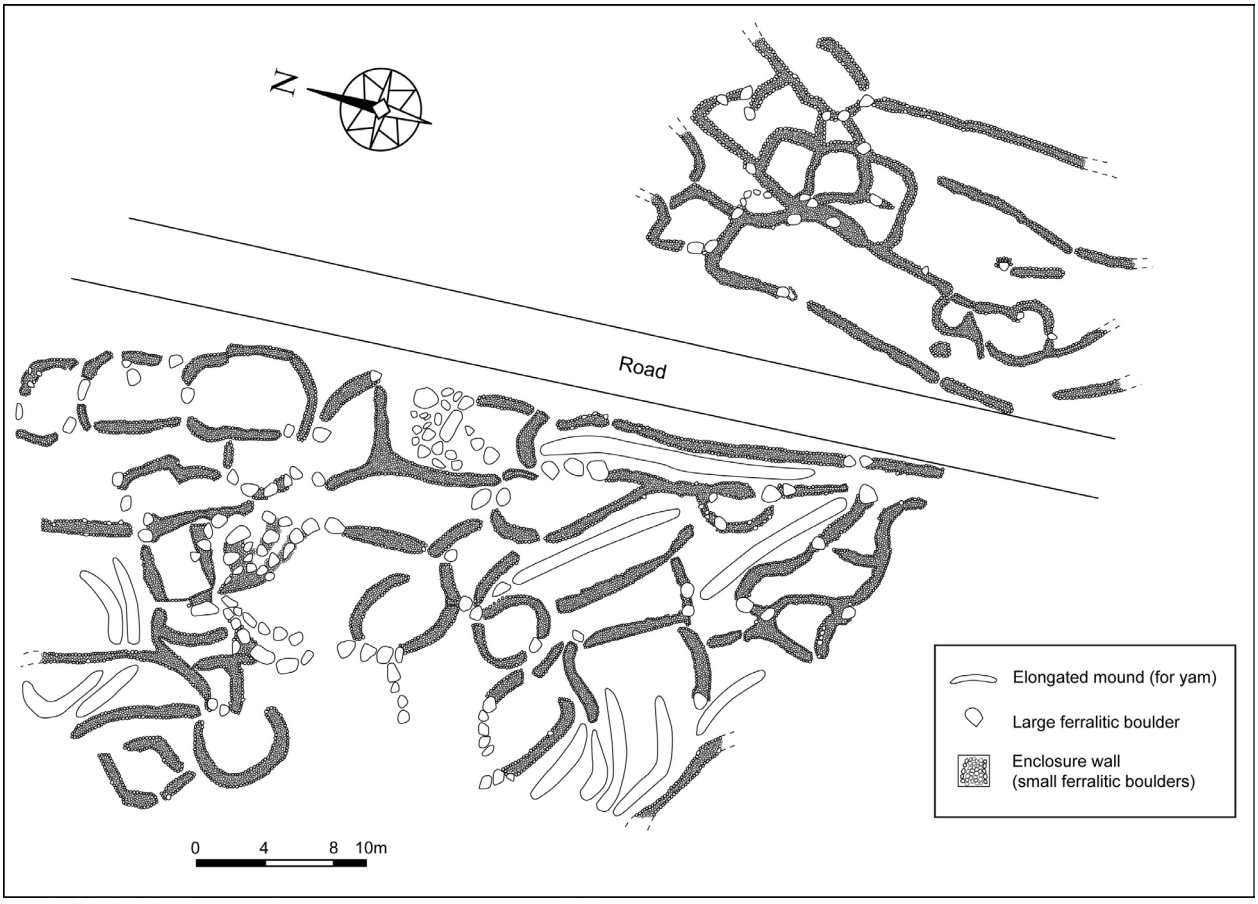

Fig. 4 – Small enclosed gardens on slopes, site KWA001, Isle of Pines (Lagarde, 2012).
Fig. 4 *– Petits jardins enclos aménagés sur des pentes, site KWA001, île des Pins (Lagarde, 2012).*

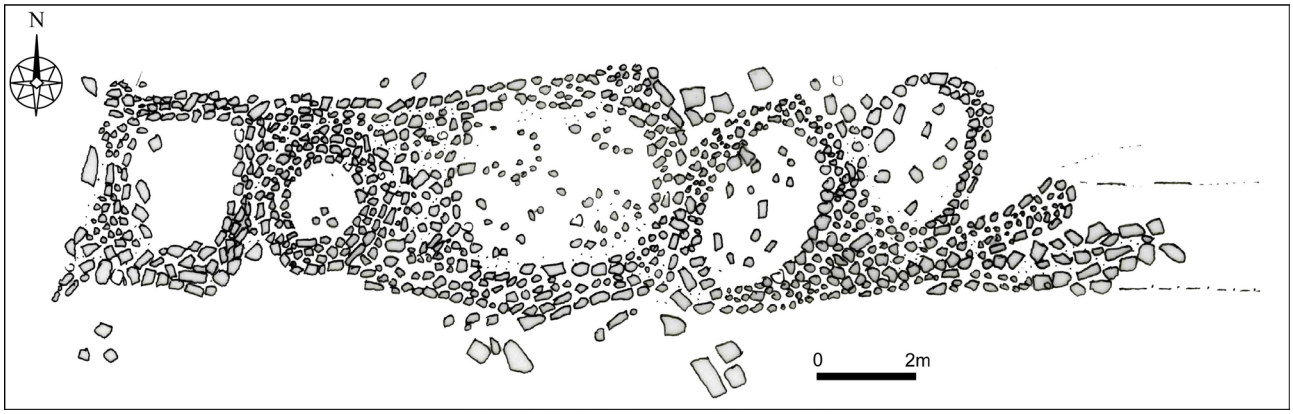

Fig. 5 – High enclosures by the coast, site SOU016, Ouinné (Lagarde et al., 2008).
***Fig. 5** – Enclos hauts dressés le long de la côte, site SOU016, Ouinné (Lagarde* et al.*, 2008).*

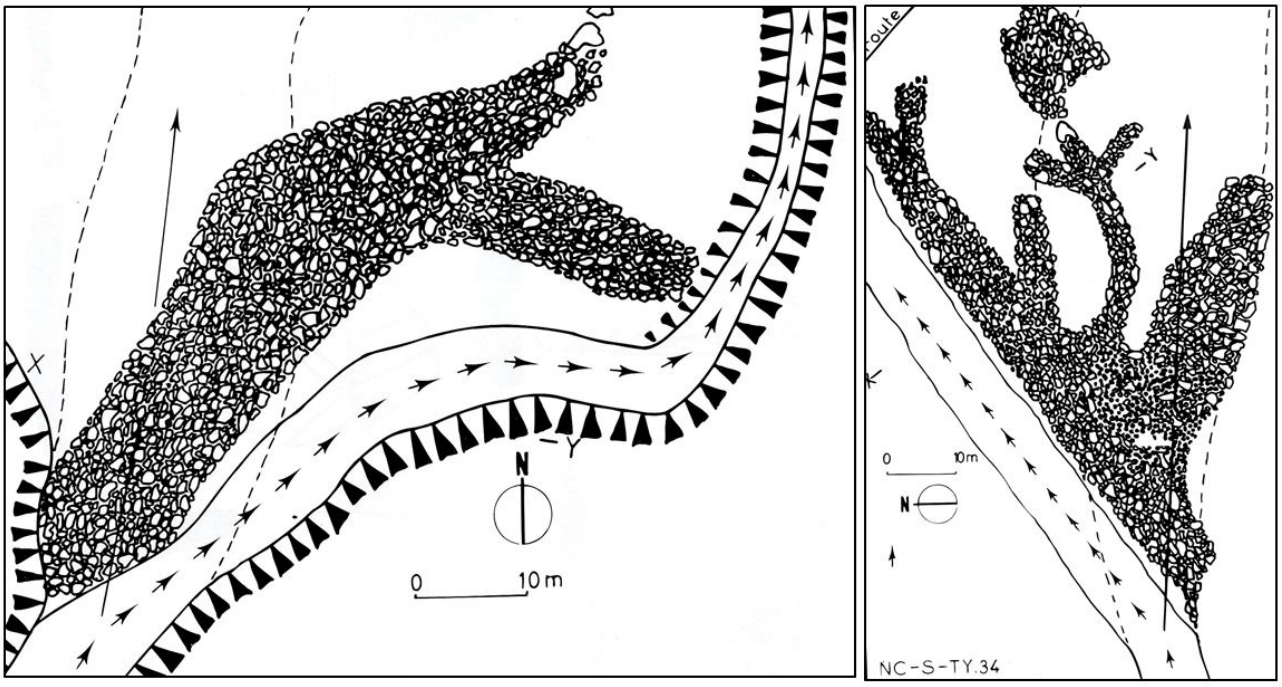

Fig. 6 – Anthropic structures diverting the course of rivers, sites STY024 and STY047, Yaté (Sand and Ouétcho, 1992).
***Fig. 6** – Structures anthropiques modifiant le cours des rivières, sites STY024 et STY047, Yaté (Sand et Ouétcho, 1992).*

environments were also built (fig. 7). The large ferralitic boulders coming from the fragmentation of the available top geological layers, outcropping nearby, became the material used to build the terraces, the enclosure walls and barrages. The terraces were then reinforced with blocks and the yam mounds were encircled with enclosure walls. Furthermore, even though the structures on ferralitic soils are less common than on the rest of the mainland, they show clear evidence of more extra effort having been taken in their construction.

These characteristics might have been aimed at enhancing the soil, or at least increasing productivity. In the case of the stream diverting structures, for example, allowing irrigation of the plains is obviously productive for crops. In the case of small enclosures, it is possible that the edification of small walls around crops was a way to diminish the evaporation process. This hypothesis can be verified on the Isle of Pines because two different geological environments coexist (fig. 8):

– a) A flat plateau, dating to the Eocene period, of ferralitic origin and located in the center of the island. Its general altitude is around 80 m above sea level, and it is linked to a small mountainous range in the south of the island culminating at 262 m (N'Ga peak). On the top of the plateau, the soil is very poor (of the non-eroded ferralitic category), and there are no known horticultural structures. However, on the slopes the soil is slightly richer, and this allowed a number of different sets of enclosed gardens and terraces to be surveyed (Lagarde, 2012);

– b) Surrounding the plateau, only slightly higher than sea level, is a recently uplifted coral limestone plain. In this non-acidic environment, with deep rich soil and ever-

Fig. 7 – Retaining wall constructed as part of a horticultural terrace, site KKR003, Isle of Pines (photo L. Lagarde, 2010).
***Fig. 7** – Mur de soutènement faisant partie de la construction d'une terrasse horticole, site KKR003, île des Pins (cliché L. Lagarde, 2010).*

green forests, similar enclosures were not found, even though coral boulders are frequent (Cherrier, 1986).

These structures are difficult to analyze, as formal Melanesian or Polynesian equivalents are not always used in the same way. Similar stone walls exist elsewhere in Oceania, but are not necessarily linked together: their function or functionality differing from island to island or archipelago to archipelago. They are often referred to as 'gardens' or 'horticultural parcels' (in New Caledonia, see Sand, 1995, p. 186), which indicates a relation of property and limits to the walls encountered. If traditionally some walls were built in order to physically determine land ownership, the small enclosures found on the Isle of Pines do not necessarily fall in this category.

Thus, throughout the Polynesian triangle, similar enclosures have been used since ancient times in order to enhance soils and productivity (Ladefoged et al., 2010, p. 84–85), as in the Easter Island *manavai* (McCoy, 1976; Hunt and Lipo, 2007, p. 96). There, small enclosures are known to significantly increase the level of key nutrients (i.e. K, P, Ca, Mg) within the soil, particularly potassium (K) and phosphorus (P).

This process, known as lithic mulching, has proven to be efficient in basaltic environments and has taken many different aspects in Polynesia (Kirch et al., 2005, p. 255; Palmer et al., 2009; p. 1450). It is clearly difficult to state, at this stage of research, that the structures found on the Isle of Pines could have been built (and been effective) to enhance poor ferralitic soils. To confirm this, further comparative chemical analyses would be required. Yet, what is certain is that the forefathers of the present-day islanders had no precise knowledge of chemicals and nutrients necessary to ensure crop production. Empiric observation of leaves and their growing rates is what must have fostered either the search for innovative restructuration of horticultural land, or the local adaptation of traditional techniques brought from elsewhere in Oceania. Furthermore, it is clear that even if the enclosure technique did not significantly enhance the poor ferralitic soils it inevitably reduced evaporation and maintained a higher internal humidity, an essential factor for the growth of crops. This was probably of importance on the Isle of Pines, especially during the two dry periods of the year (March-April and July-September, fig. 98). Maintaining a constant water supply in ferralitic soils with high drainage ability seems to have been an important issue, as several freshwater sumps were found close to horticultural structures during the survey of the plateau slopes (Lagarde, 2012).

The soil enhancement-related interpretation of these structures can be further confirmed on the Isle of Pines, as these structures are only be found on the slopes of the ferralitic plateau. On the surrounding calcareous forest plains, where classic Kanak horticultural structures are

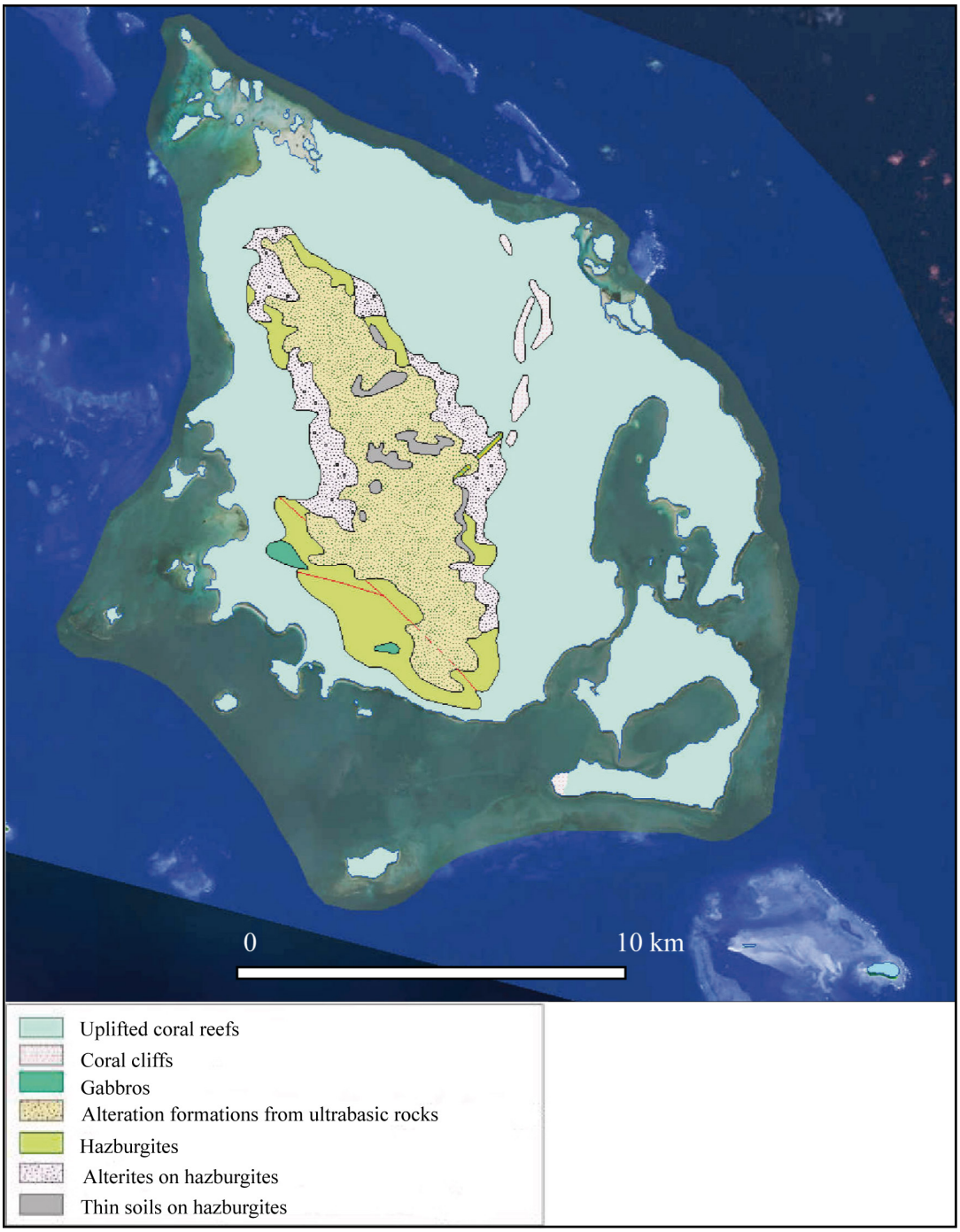

Fig. 8 – Geological map of the Isle of Pines (GIS GEOREP, New Caledonia).
Fig. 8 *– Carte géologique de l'île des Pins (SIG GEOREP, Nouvelle-Calédonie).*

located and oral traditions relating to the production of tubers have been recorded, there are no such enclosures. This does not mean that a limestone setting is ideal for cultivation, as on small uplifted island environments in Melanesia, similar stone enclosures are known. Some were discovered on Tiga Island (Sand et al., 2010), where the locals believe they were built in order to facilitate the growth of tubers by protecting them from saline air (C. Sand, personal communication, 2012). On the Isle of Pines, however, the width of the coastal plains (several kilometers) has allowed crop production, on rich brown rendzine soils, without any kind of protective measures. Lastly, soil enhancing techniques, such as the concentration of useful nutrients, reduction of the evaporation process, or the impact of saline air are not necessarily in contradiction with the interpretation of private gardens or parcels. The appropriation of land for gardening by a family or clan is fully compatible with technical innovation. These smaller structures could be related to cultivation within a kinship relation of different, more fragile species or cultivars which necessitated alternative traditional practices, for instance mulching within the enclosures.

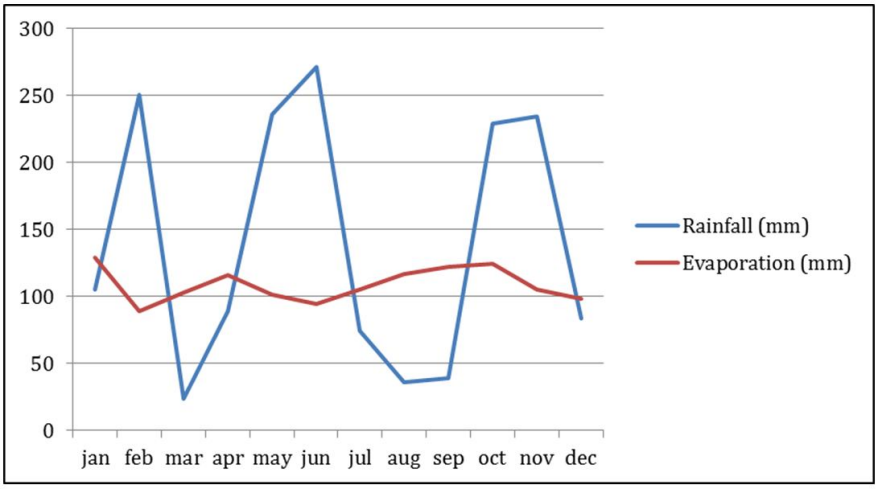

Fig. 9 – Comparison of rainfall and evaporation in soil over the course of a year (here 1984, in Cherrier, 1986).
Fig. 9 *– Comparaison des précipitations et des évaporations des sols au cours d'une année (ici 1984, in Cherrier, 1986).*

The techniques used also seem to be different to those used on the larger irrigated terraces, as much as they seem to be related to different social uses.

It appears, therefore, that these enclosures, discovered on the slopes of the plateau, were connected with a strategy to enhance the soil. Similarly, in the Ouinné region, the large, high enclosures found on the narrow coastal plains seem to be linked to mulching processes: the poor soil is put under the stress of nearby saltwater in a windy environment. Protection of crops has to be obtained through the construction of high and thick walls, thus preventing high levels of toxic chlorine (through salt), and also preventing wind-induced evaporation.

If the soil-enhancing hypothesis seems like a reasonable explanation for the characteristics of these layouts, evidence is difficult to obtain. Whether or not these structures and their characteristics can be interpreted as systematic experiments in soil enhancing is a difficult debate, especially as too few dates and too little analyses have been made on the structures themselves. None of this can be proven until a considerable amount of further research has been undertaken and experimental data acquired on the topic.

However, a series of important questions remains: why are there horticultural systems in place in such poor environments? Why would traditional societies bother with unfertile soils, and build, with such a high degree of care and attention, complex systems in order to grow crops where they knew the soil was not good enough? Indeed, if 70% of the global surface of the Grande Terre Island is covered in medium-to-good soil why bother at all?

Generally speaking, archaeological remains in harsh ferralitic environments are quite rare: on the summits and higher slopes, where the soil is extremely poor, there is generally no trace of perennial human settlements or horticulture. These results were obtained recently by the IANCP, after a large number of archaeological surveys were completed at the demand of mining corporations. The only traces of human presence are cairns, some occasional hearths, ancient Kanak pathways, meeting places for traditional exchange rituals and funerary deposits (Sand et al., 2012b; Lagarde et al., 2008). The same can be said for the top of the Isle of Pines' plateau, where only the mysterious tumuli are to be found. However, the lower slopes and alluvial plains are archaeologically richer because they were easier to access, they have slightly better soil, and the proximity of the sea allowed fishing and a better food intake for those living there. Yet these environments are far from ideal in a society where the main nutrients of the diet are acquired through the consumption of tubers. Therefore, if these horticultural structures and the nearby habitats are linked to the last millennium, as appears to be the case, then it probably means that most of the cultivable land must have been in use during this period. The intensification of archaeological remains found in ferralitic environments dating to the second millennium AD has already been noted. This intensification is visible through the growth in the use of these landscapes as customary landmarks. Specific zones defined as locations for traditional exchange ceremonies and/or meeting places, as well as being spiritually important, are linked with the imaginary origin of kinship ensembles (Sand et al., 2012b). All of this supports the idea that during this period, the archipelago was under strong demographic pressure. This is indeed consistent with general remarks that have been made since the 1990s (Sand, 1995), regarding the intensification of landscape occupation during that period, eventually leading to this comment by Captain James Cook upon his discovery of southern New Caledonia: "…Smoke was seen at the first place all the day, we also saw smokes daily on several parts of the coast, a sure sign the whole was inhabited…" (cited in Sand, 1995). This once again forces us to reconsider the size of the Kanak population prior to European contact, and the effects of the introduction of disease to local populations in the eighty years between the first contact (1774) and the beginning of the French colonial administration (1853).

CONCLUSION

The study of horticultural intensification processes in Pacific island environments has proven a difficult task. The adequation between intensification and demographic growth, long believed solely relevant, has been threatened by other causes so that nowadays it is generally considered as the result of multiple factors. If demographic and social variables played an important role in the emergence of the intensification processes, then so did ecological variability and its interdependent technological developments (Kirch, 1995, p. 18). The aim of this paper was to bring attention to the peculiar horticultural systems documented on the ferralitic soils of New Caledonia, which can hopefully help us understand the global processes at stake during the last millennium. We believe they hold fundamental information which could help refine our understanding of the traditional Kanak adaptation mechanisms to their landscape. We hope that this article will inspire further research on the soils themselves, from an anthropic, archaeological and horticultural perspective. New Caledonia has the double privilege of having a unique geological environment in the Pacific and a rather long anthropogenic chronology spanning three millennia. Global population growth throughout this length of time seems to have eventually led its indigenous inhabitants towards more inhospitable sites, at least as far as horticultural practices were concerned. The traditional soil enhancement techniques uncovered may not have been very helpful in the past, however, future research could use the structures specific measurements to show how or if empiric solutions to local problems helped the natural growth processes of crops.

P. V. Kirch wrote that "…the contrast of wet and dry environments, crops and agricultural technologies holds a key to understanding the history of Polynesian agriculture…" (Kirch, 1995, p. 10). This statement can be further addressed by the geology of New Caledonia's unique and complex pedology. However, the lack of archaeological dates on these structures still remains a problem. It is partially due to the limited archaeological work undertaken in these environments, and also the general paucity of relevant datable archaeological material. Furthermore, the lack of available ethnographic information from most of the horticultural structures discovered in ferralitic environments is an issue, partially due to some of these unfertile areas being currently deserted (like the Ouinné region). In other populated areas like the Isle of Pines, traditional horticulture is still an important part of the Kanak socio-economical system, but the ferralitic zones are no longer used for cultivation. Once again, if favorable soils are available, the effort of cultivation does not need to be placed on ferralitic zones.

More broadly, the generalized collapse of the Kanak population throughout the 19th century (and in some areas, its relocation) led to an abandonment of these environments as fields.

However, a few of these ferralitic areas are currently used to produce crops, like in the Mouirange region (20 km south of Noumea), with the extensive use of fertilizers. Hopefully, with more intensive research, some effective traditional methods can be rediscovered, and maybe even reused?

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Louis Lagarde
Université de Nouvelle-Calédonie,
BP R4
98851 Nouméa, Nouvelle-Calédonie
louis.lagarde@univ-nc.nc

André-John Ouétcho
Institut d'archéologie
de Nouvelle-Calédonie et du Pacifique
65, rue Teyssandier-de-Laubarède,
98800 Nouméa, Nouvelle-Calédonie
andre-john.ouetcho@iancp.nc