Dynamics and conservation of the Coconut Palm Cocos nucifera L. in the Pacific region: towards a new conservation approach

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ABSTRACT
Coconut palms, long a symbol of tropical Pacific islands, play an important role in the environment, agriculture, culture and tourism. Through the International Coconut Genetic Resources Network, numerous countries and institutions are collaborating to conserve coconut germplasm and to make coconut a more profitable crop for smallholders. Recent studies, combining both diachronic and interdisciplinary approaches, provide a better understanding of the dynamics of the coconut genetic resources in the Pacific region. Some isolated islands were known by ancient Polynesians as varietal reservoirs for coconut landraces. From 1800 to 1950, the number of coconut palms was multiplied by a 40 to 50 factor. The landraces that have been selected over thousands of years by the Polynesians were gradually diluted in the mass of coconut palms selected only for copra production. Successive cyclones have also severely damaged the coconut groves. The socio-economic changes that affected Polynesia also exacerbated the loss of both traditional knowledge and biological resources. Coconut landraces are now severely under threat from the globalization of trade, cultural leveling, changes in agriculture and climate. These studies lead us 1) to better locate the genetic diversity to be conserved; and 2) to develop a new conservation strategy, based on the use of smallest islands and isolated valleys to conserve coconut, other plants and fauna. One variety per species will be conserved on each islet. The geographical remoteness of smallest islands and isolated valleys can be used as a great advantage in the strategies for conservation and breeding of perennial crops and some other species. This article shows first that this idea was already applied in an empirical manner, by the ancient and modern Polynesians. Then, by combining that ancestral method with the recent progresses made in biological and social sciences, a rational strategy for the conservation of genetic resources and associated traditional knowledge could be implemented.

Keywords
Cocos nucifera L.; crop genetic resources, biological diversity; conservation strategy; governance; Pacific region.

1. INTRODUCTION
Coconut palms play an important role in the culture, environment, agriculture and tourism in the tropical Pacific islands. Coconut is grown worldwide in about 12.2 million ha, of which 88% are located in the Asia Pacific region (FAO, 2002). Island biota are particularly fragile, but also highly productive in term of biodiversity: because of their geographic remoteness, which ensures a reproductive insulation of the organisms living there, islands are home to an extraordinary high proportion of endemic species and crop varieties per unit of surface area (Zedan, 2004). The geographical remoteness of smallest islands and isolated valleys can be used as a great advantage in the strategies for conservation and breeding of perennial crops and some other species. This article shows first that this idea was already applied in an empirical manner, by the ancient and modern Polynesians. Then, by combining that ancestral method with the recent progresses made in biological and social sciences, a rational strategy for the conservation of genetic resources and associated traditional knowledge could be implemented.

2. BOTANY AND HISTORY OF THE COCONUT PALM
Cocos nucifera L. is a tropical palm propagated only by seed. It is the sole species of the genus Cocos. This palm grows in more than 86 countries which can be grouped into eight distinct coastal/oceanic regions on four continents (Harries 2001). It is mostly, though not exclusively, grown along the coasts. The coconut palm grows even in marginal coastal conditions, tolerating drought and poor soils. It is very resilient, able to withstand typhoons and flooding. Small coral islets often continue to exist mainly because the palms’ fibrous root systems prevent coastal erosion. Recent information from the Fakavara Atoll also indicates that the coconut palms are even involved in the creation of some of the coral islets (Tshonfo Ayee Cyrille, pers. Comm.).

There are two main types of coconut palms, the Talls and the Dwarfs. The Talls can grow at a rate of more than 50 cm annually when young and flower at 6-10 years with an economic life span of 60-70 years. The Dwarfs make up less than 5% of the world coconut population, but they can be found all over the intertropical zone (Bourdeix & al., 2005). Apart from their usually short height, most of the Dwarfs show a combination of common
characteristics: autogamic preference (Tallrs are allogamic), small size of organs, precocity, and rapid emission of inflorescences. Dwarfrs can grow at a rate of 15 to 30 cm annually, have a productive life span of 30-40 years but usually start flowering in the third year. Because of the last two characteristics, the Dwarfs play an important role in genetic improvement programs.

The origin of Cocos nucifera L. has been a subject of controversy for years. Various authors have suggested an origin in the western Pacific (Harries, 1978), Asia or Polynesia (Beccari, 1963), Melanesia (Moore, 1973), or the Neotropics (Guppy, 1906; Gunn, 2004). Rigby (1995) reported a Cocos nucifera fossil in Queensland (Australia), of Pliocene age (2 millions of years). This eliminates any action of humans in the original distribution of Cocos nucifera, although the dispersal of it in the Pacific in recent times was partly the responsibility of humans. Before 1000 AD, the Polynesians had settled in central Polynesia (Tahiti and the Society Islands), the Marquesas, Hawaii and Easter Island (Orliac, 2000). Since that time, the coconut palms became an integral part of the Polynesian way of life. The Polynesians have bred coconut palms adapted to different uses, notably by successively planting their coconut palms on new islands. They contributed to the creation of numerous varieties, with spectacular morphological diversity.

The oldest known description of coconut varieties in French Polynesia can be found in the book "Ancient Tahiti" by Teuira Henry, published in 1928 from data collected by her grandfather in 1840. That publication mentions 16 different varieties or forms of the coconut palm.

From 1870 to 1930, following the development of the international copra market, the number of coconut palms planted in Pacific islands was multiplied by a very high factor, probably around 80 to 100. On the coral soils of French Polynesia, coconut plantations were set up at the end of the century and then partly renewed after the severe cyclones in 1903 and 1906. On the high islands, inland valley plantations were set up after World War I. On atolls, the planting technique in most cases consisted in cutting down all vegetation, most probably including the few coconut palms already present, leaving it to dry out, then burning everything before planting coconut palms from another island. Such intensive coconut cultivation harmed the biodiversity of endemic species (Dupon, 1987).

Over the same period, the Polynesian population decreased substantially, leading to a loss of traditional knowledge. The abrupt socio-economic changes that affected Polynesia in the twentieth century subsequently exacerbated that loss of traditional knowledge. As regards the coconut palm, the landraces that had been patiently selected over thousands of years by the Polynesians (Henry, 1928) were gradually diluted in the mass of coconut palms selected and used mainly for copra production. Successive cyclones, particularly in the 1980s, also severely affected the coconut groves (Dupon, 1987). At the present time, it can be estimated that the number of coconut palms in French Polynesia was more than halved between 1930 and 2005. Many of the remaining coconut palms are too old and have stopped bearing. Coconut landraces, which have been passed down from generation to generation of islanders, are now under threat from the globalization of trade, cultural levelling, industrialization and changes in agriculture.

3. TRADITIONAL CONSERVATOIRES OF COCONUT PALMS

In her book, Teuira Henry indicated the existence of particularly enormous coconuts growing the island of Niu-Fou (now known as Niuafo‘ou), a tiny island in the Tonga group, with an area of 52 sq. km. The distance from Niuafo‘ou to the nearest island is 200km. It is a very active volcano that slopes steeply down to the sea floor. There is no safe anchorage for boats. In Tonga, the two only islands where different dialects are spoken are named Niuafo‘ou (New coconut) and Niua Toputapu (Sacred coconut).

Another place famous for its coconuts is Rennell, a raised atoll located in the Solomon archipelago. Its two main features are its lake, now registered as a world heritage, and its Polynesian population, when other Solomon Islands are mainly populated with Melanesians. Except the small island of Bellona, also populated with Polynesians, the distance from Rennell to the nearest island is 170 km. The fruits of the variety known as Rennell Island Tall (RIT) are among the biggest coconuts in the world. Some of the fruits have a long nipple at the bottom, which is very specific to the RIT. M.A. Foale, who visited the Rennell Island in 1964, said that the true-to-type Rennell, with big and pointed fruits, is found only around the volcanic lake on the eastern part of the island. The access from the coast to the volcanic lake is very difficult. It is needed to climb a rocky track with a hard slope, in a forest stuffed with endemic species of poisoning snakes (Laticauda sp.). But in other places, such as the coastal area, there is a mix between the Rennell Island Tall and the ordinary type, known as the Solomon Island Tall, which has smaller oblong fruits. The Rennell Island Tall cultivar (RIT) is now conserved in at least 11 germplasm conservation centres, national and international. RIT is involved as parental material in many coconut breeding programmes.

As far as coconut varieties are concerned, Niuafo‘ou and Rennell are the most famous islands in the Pacific region. Similarities between these two islands are huge. They are both very isolated small islands, at a distance of 170-200 km from the nearest big island ; They have both additional and successive factors of insolation : difficulties to access by boat, harsh slope to climb to reach the place where grow the coconut palms, risks linked to high volcanic activity or endemic poisoning snakes.

In the 2000’s, Dr R. Bourdeix, one of the authors of this papers, visited numerous Pacific island in the framework of surveys organized by Bioversity International. L. M. Fili and T.H. Hoponoa, from the Ministry of Agriculture and Forestry of Tonga, told him about the traditional coconut variety called «Niu ʻutongau ». This variety belongs to rare forms of coconut, highly threatened, and known as « Sweet husk ». In most coconut, this husk is harsh and not edible. But sometimes, the whole husk of the young fruit is sweet and can be chewed like sugar cane. Its taste resembles that of coconut heart. Once the fruits are ripe, the husk fibres are white and particularly slender. There exist various names and various types, in which husk characteristics are more or less accentuated. Those varieties have yet to be scientifically described. The «Niu ʻutongau » coconut variety can be found in quantity only on the small coral islet of Onoiki in the Ha‘apai group. Tongians are still sometimes taking seedlings from that islet, which is so small that it does not appear on most maps.
4.1 Historical background

If the first hand pollinations were done in India in 1920, the first hybridization between coconut varieties has been attributed to Marechal: in the Fiji islands as early as 1926 (Marechal, 1926). Unfortunately, his work did not survive the 1929 economic crisis and the pedigree of the hybrids was lost (Child, 1974). From 1930 to 1990, the JCSC (joint coconut research scheme) in Solomon Islands, and later the VARTC (Vanuatu Agronomic Research and Training Centre) have played important regional roles in the field of coconut research (Friend, 1977; Labouisse et al., 2004).

The International Coconut Genetic Resources Network (COGENT) has been coordinating the collection, description and conservation of coconut varieties during the last 17 years. COGENT is a global research network organized by Bioversity International. It presently gathers 38 coconut producing countries. To provide double security for conserved germplasm in national gene banks and to promote effective access and safe germplasm movement, the COGENT Steering Committee decided to establish a multi-site International Coconut Genebank (ICG) in 1995, consisting of five regional gene banks located in Brazil, Côte d’Ivoire, India, Indonesia and, for the South-Pacific region, Papua New Guinea. The International Coconut Genebank for the South Pacific (ICG-SP), located at the Stewart Research Station in Madang, is managed by the Cocoa and Coconut Institute. National coconut field gene banks are located in Tonga, Vanuatu, Fiji, Samoa and the Solomon Islands, as shown in Table 1. The column “with passport data” and “with evaluation data” refers to accessions with more than 25% of completion for the standard descriptors for the coconut (IPGRI, 1995).

Table 1. Summary information of conserved germplasm in the South Pacific region (Coconut Genetic Resources Database, 2003)

<table>
<thead>
<tr>
<th>Sites</th>
<th>Number of accessions</th>
<th>With passport data</th>
<th>With evaluation data</th>
<th>With molecular data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cocoa and Coconut Research Institute, Rabaul, PNG</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Ministry of Agriculture, Nuku’alofa, Tonga</td>
<td>7</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Saranotou Research Station, Santo, Vanuatu</td>
<td>79</td>
<td>71</td>
<td>11</td>
<td>53</td>
</tr>
<tr>
<td>Stewart Research Station, Madang, PNG</td>
<td>54</td>
<td>31</td>
<td>54</td>
<td>30</td>
</tr>
<tr>
<td>Taveuni Coconut Centre, Taveuni, Fiji</td>
<td>11</td>
<td>8</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>Research Station, Apia, Samoa</td>
<td>9</td>
<td>0</td>
<td>9</td>
<td>3</td>
</tr>
<tr>
<td>Research Station, Yandina, Solomon Islands</td>
<td>21</td>
<td>4</td>
<td>21</td>
<td>11</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>184</strong></td>
<td><strong>114</strong></td>
<td><strong>106</strong></td>
<td><strong>106</strong></td>
</tr>
</tbody>
</table>

French research institutes CIRAD, IRD, CEF (and now CIRIOBE) are helping the COGENT network to develop numerous research methodologies: varietal identification techniques using standardized morphological descriptors (IPGRI, 1995); molecular marker analysis kits (Lebrun et al., 2001; 2003); creation and development of the International Coconut Genetic Resources Database and other dedicated software (Hamelin et al. 2005); strategies for germplasm survey and conservation (Bourdeix et al., 2005a); and the publication of catalogues of coconut varieties (Bourdeix et al., 2005b).

4.2 Limiting factors to coconut conservation and breeding

In a perennial plant such as the coconut palm, the constraints connected with its biology increase the cost of the scientific progress and aggravate the consequences of possible errors. For instance, a genetic experiment frequently covers an area of eight hectares for a minimum period of twelve years. Consequently, coconut research not only needs high investments but also a great functional stability. For obtaining the first results, a coconut research station should be operational for at least twenty years. The coconut palm is a cumbrous plant, both in terms of space and time. Planting densities generally range between 100 to 250 trees
per hectare, according to varieties and cultural practices. One year is necessary to get mature seeds from female flowers; and again one more year for raising the seednuts in the nursery before planting. The time between planting and flowering varies from one year, for most precocious dwarfs, to height years for certain tall ecotypes.

In conventional field genebanks, coconut accessions are planted close the one to each other. Most of tall coconut varieties are allogamous. In order to avoid mix between accessions, the regeneration and the duplication of these accessions is done by using the technique of controlled pollination. In the case of coconut, this technique is very costly. It requires a well equipped laboratory, well-trained technicians able to climb the palms and a huge amount of manpower.

Imagine a farmer wants to plant one hectare with a special coconut variety conserved in a conventional field genebank. She/he will ask the genebank for a lot 200 seednuts. For producing these seednuts by controlled pollination, the genebank requires a delay of one year and half; and the cost of pollination only is more than 3000 USD. Most of the farmers can not afford it.

If the same variety is planted in an islet or an insulated valley, as proposed in the Polymotu concept, this geographical remoteness will ensure the reproductive insulation needed for true to type breeding through natural pollination. In this case, seednuts will be immediately available, and pollination will be free of charge.

4.3 Cultivar characterization using Microsatellite markers

Coconut is cultivated worldwide under the tropics, and many varieties have been described, although rarely in a very precise manner. The difficulties result from the bulkiness of the tree, its long life cycle from its giant seed. All these factor make it particularly difficult to compare the varieties in similar environments, which would be necessary to show that two varieties are effectively distinct. Molecular markers are thus especially useful in coconut to characterize varieties, to assess their relationships and to identify possible introgressions of one variety into another. Microsatellites were chosen to develop a kit for identifying coconut cultivars. Their codominant nature and the large number of alleles make it possible to reveal a large spectrum of diversity in coconut. Moreover, such markers are revealed through the PCR technique, which is relatively inexpensive and less demanding in terms of DNA quality than others. A 14 marker kit (Lebrun et al., 2002) was developed. More than 2000 trees, representing about 100 cultivars or hybrids from the whole cultivation area have been analysed with this marker set and Bayesian software was developed to assign individuals (or groups of individuals) to their population of origin (Baudouin et al., 2004; Piry et al., 2004) Recently, a further set of 17 markers was developed in a Generation Challenge Programme (GCP) project and analyzed in 1225 individuals. Figures 1 and 2, taken from Batugal et al. 2009, are convenient to describe the distribution of coconut diversity at a global level and the relationships of the Pacific cultivars with the other genetic groups.

The global diversity is represented in figure 1 along the first two axes of a Factorial Analysis of Correspondences (FAC). The Two groups appear clearly: Indo-Atlantic Tall (Groups B1, red and B2, orange) predominate in the Western hemisphere and are opposed to the coconuts of the Pacific region, to the right. Diversity in the Pacific group is larger and includes both Tall and Dwarf cultivars.

The FAC of figure 2 concentrates on the Pacific Tall cultivars.
In figure 2, cultivars from Melanesia (group A4, dark green) appear to be central and close to those from South-East Asia (group A3, pale green). The pre-Columbian populations from Panama and Peru (group A7 purple) are a very special group, with affinities with South-Asia (Baudouin and Lebrun 2009). The Micronesian populations (A5, pale brown) are close to the South-East Asian ones, while the Polynesian ones (A6, blue) are close to Melanesia.

4.4 Towards an international networked virtual gene bank?

The global coconut conservation strategy (GCCS), developed by the International Coconut Genetic Resources Network and the Global Crop Diversity Trust, is mainly based on ex situ conservation in five large regional field gene banks. The implementation of a network collection could move this system towards the involvement of more countries, sites and stakeholders. A Networked collection, also called a virtual collection, is located at more than one geographical/institutional site, spans the genetic diversity of a given species and gathers stakeholders having a mutual interest for rationally conserving and exchanging germplasm. In the extreme application of this concept, each accession could be conserved at a distinct site. All intermediate strategies are thus conceivable.

The “Polymotu” concept was also integrated as a new experimental approach in the GCCS. Several accessions of coconut palm could be planted each in a distinct isolated site. This geographical remoteness will ensure the reproductive insulation needed for true to type breeding of the crop varieties through natural pollination.

The criteria for an accession to be included in the Networked collection need to be further refined: uniqueness of the germplasm, genetic representativeness, ability to reproduce it true-to-typeness and policy considerations.

5. CONCLUSION

Although considerable work has been achieved during the past 20 years, safeguarding and characterizing Polynesian coconut germplasm, especially the disappearing traditional varieties, remain a pressing need. This is made more urgent with the impact of climate change, where rising sea levels threaten the permanent loss of important diversity.

We therefore propose bringing back into fashion a traditional practice of the ancient Polynesians, which consisted in planting each coconut variety separately on small islands or insulated valleys. By combining that ancestral practice with the recent progress made in biological and social sciences, a better strategy for the conservation of genetic resources of the coconut palm will be implemented.

The Polymotu Concept can not substitute to conventional field genebanks; anyway Polymotu complements efficiently these genebanks. One of main interests of Polymotu concept is to maintain, to increase – sometimes to create – strong links between germplasm, people and places. It facilitates the germplasm access to people. Conventional field genebanks are mostly used by scientists, the main limiting factor being the prohibitive cost of reproduction of the accessions.

The concept of Networked/virtual genebanks needs further examinations. It could lead to the disappearance of the classical delineation between in situ and ex situ conservation. In the future, one of our dreams is to gather in the same network: small Polynesian islets, each planted with a unique coconut variety; and coconut accessions conserved in international germplasm banks. Polymotu concept could also be extended to other species, be they cultivated or wild plants such as Noni (Morinda citrifolia) or kohai (Sesbania coccinea). It could also be extended to animal species, such as the Coconut crab (Birgus latro) or some birds. This extension could be done in the same islets or insulated valleys, for an economy of scale.

6. ACKNOWLEDGMENTS

Thanks to Ifrecor and Cribeo Cnrs Ephe for funding our research activities in French Polynesia. Thanks to all the people of the Fakarava Atoll, Tuamotu Archipelago for their patience towards scientists and their kind and essential cooperation.

7. REFERENCES


