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# The clove tree of Madagascar : a success story with an unpredictable future



**Photo 1.**  
Young clove trees near Tamatave.  
Photograph P. Danthu.

## RÉSUMÉ

### LE GIROFLIER DE MADAGASCAR : UNE INTRODUCTION RÉUSSIE, UN AVENIR À CONSTRUIRE

Introduit à Madagascar au début du 19<sup>e</sup> siècle, le giroflier est originaire des îles Moluques en Indonésie. Malgré la sensibilité de l'essence aux risques météorologiques, tels les cyclones, et aux attaques d'un parasite local, *andretsa*, et malgré la production variable de clous de girofle d'une année sur l'autre, son adaptation aux conditions écologiques de la côte Est de Madagascar, notamment dans la région d'Analanjirifo, est remarquable. Très vite adoptée par les paysans (certains venus s'installer mais la plupart autochtones), ceux-ci l'ont intégrée dans leurs systèmes de culture en complément aux cultures vivrières (riz, surtout) et de rapport (café et vanille). Aujourd'hui, le marché du clou de girofle est une source de revenus réguliers pour les ménages et leur assure la sécurité alimentaire. Le giroflier donne deux produits de grande valeur économique, le clou de girofle, le bouton floral séché, et l'huile essentielle de girofle produite par distillation des feuilles, dont Madagascar est le premier exportateur mondial. Avec la vanille, les produits du giroflier représentent les premiers produits agricoles d'exportation, parfois les deuxièmes, de Madagascar. Les clous de girofle s'exportent surtout en Indonésie, où ils entrent dans la fabrication d'une cigarette locale appelée *kretek*. Un petit volume s'exporte vers les pays du nord sous forme d'épice. L'huile essentielle de girofle est distillée dans une multitude d'alambics rudimentaires dans toute la région de production. La qualité de l'huile essentielle dépend de sa teneur en eugénol, molécule mise en œuvre dans de nombreux secteurs économiques, dont l'industrie des cosmétiques, la pharmacie humaine et vétérinaire et l'industrie alimentaire. Le giroflier de Madagascar semble représenter un exemple d'intégration réussie d'une nouvelle culture dans un système de cultures existant. Cependant, les plantations de girofliers vieillissent et les conditions de leur renouvellement ne sont pas pleinement présentes. Alors que le marché du clou de girofle dépend fortement de la demande indonésienne, les perspectives sont prometteuses sur le marché mondial des épices et des produits contenant de l'eugénol. De ce fait, les pratiques actuelles et les possibilités d'adaptation et de développement du secteur Malgache de la girofle doivent être étudiées de près pour assurer l'équilibre futur entre les marchés et les besoins des paysans en termes de gestion de la ressource et de sa valorisation.

**Mots-clés :** giroflier, *Syzygium aromaticum*, clous de girofle, huile essentielle, systèmes de culture, production, exportation, évolution historique, Madagascar.

## ABSTRACT

### THE CLOVE TREE OF MADAGASCAR: A SUCCESS STORY WITH AN UNPREDICTABLE FUTURE

The clove tree was introduced to Madagascar from the Maluku Islands in Indonesia at the beginning of the 19<sup>th</sup> century. In spite of its sensitivity to hazards such as cyclones, a locally found pest known as *andretsa* and year-on-year variability in the production of cloves, it has adapted surprisingly well to the ecological conditions on Madagascar's East coast, particularly the Analanjirifo Region. The species was adopted very rapidly by farmers (some settlers but mostly native peasant farmers), who integrated it into their cropping systems as a complement to their staple crops (rice, in particular) and cash crops (coffee and vanilla). Currently, the marketability of cloves brings a regular income to households, ensuring them food security. The clove tree bears two products of high economic value, the clove, which is the dried flower bud, and the essential oil, derived from distillation of the leaves, of which Madagascar is the world's number one exporter. Products from the clove tree, along with vanilla, account for the largest (second largest in some years) proportion of Madagascar's agricultural exports. Cloves are exported primarily to Indonesia to be used in the production of the local cigarettes known as *kretek*. There is a small demand from northern countries for exports of the clove spice. Clove essential oil is produced in a plethora of rudimentary stills located throughout the clove growing zone. The quality of the essential oil depends on the content of eugenol, a molecule of interest in a number of commercial sectors including the cosmetic industry, human and veterinary pharmaceuticals and the food industry. The clove tree in Madagascar seems to represent an example of successful adoption and integration of a new crop into existing production systems. However, the clove tree plantations are ageing and the conditions for their renewal are not fully established. Whilst the market for cloves is largely dependent on demand from Indonesia, the future looks promising for the world market in clove spices and eugenol-based products. Consequently, current practices and possible ways of adapting and developing the Malagasy clove sector in new directions need to be investigated and addressed in order to balance the future demands of the markets with the needs of the farmers in terms of resource management and valorization.

**Keywords:** clove tree, *Syzygium aromaticum*, cloves, essential oil, cropping systems, production, exportation, historical evolution, Madagascar.

## RESUMEN

### EL CLAVERO DE MADAGASCAR: UNA INTRODUCCIÓN EXITOSA, UN FUTURO POR CONSTRUIR

El clavero, introducido en Madagascar a principios del s. XIX, es originario de las islas Molucas en Indonesia. A pesar de su sensibilidad a riesgos meteorológicos como los ciclones, a los ataques de un parásito local, *andretsa*, y a la variable producción de clavos de olor de un año para otro, su adaptación a las condiciones ecológicas de la costa este de Madagascar, especialmente en la región de Analanjirifo, es sorprendente. La especie fue adoptada muy rápidamente por los campesinos (autóctonos en su mayoría y algunos foráneos) que la integraron en sus sistemas de cultivo como complemento de los cultivos alimentarios (sobre todo arroz) y comerciales (café y vainilla). Actualmente el mercado del clavo de olor supone una fuente regular de ingresos para los hogares y les garantiza la seguridad alimentaria. El clavero proporciona dos productos de gran valor económico: el clavo de olor —los botones florales secos— y el aceite esencial de clavo, producido mediante destilación de las hojas y del que Madagascar es el primer exportador mundial. Junto con la vainilla, los productos del clavero representan los primeros productos agrícolas de exportación (algunos años los segundos) de Madagascar. Los clavos de olor se exportan sobre todo a Indonesia, en donde se usan para elaborar unos cigarrillos locales denominados *kretek*. Una pequeña parte se exporta hacia los países del norte como especia. El aceite esencial del clavero es destilado en una multitud de rudimentarios alambiques en toda el área de cultivo. La calidad del aceite depende de su contenido de eugenol, compuesto empleado en muchos sectores económicos como la industria cosmética, la farmacéutica humana y veterinaria y la industria alimentaria. El clavero de Madagascar parece representar un ejemplo de integración exitosa de un nuevo cultivo en un sistema agrícola ya existente. Sin embargo, las plantaciones de claveros envejecen y no se reúnen plenamente las condiciones para su renovación. Mientras que el mercado del clavo de olor depende en gran medida de la demanda indonesia, las perspectivas son prometedoras en el mercado mundial de especias y en productos a base de eugenol. Por ello, hay que estudiar detenidamente las prácticas actuales y las posibilidades de adaptación y desarrollo del sector malgache del clavo para garantizar el equilibrio futuro entre mercados y necesidades campesinas en cuanto al manejo del recurso y a su valorización.

**Palabras clave:** clavero, *Syzygium aromaticum*, clavos de olor, aceite esencial, sistemas de cultivo, producción, exportación, evolución histórica, Madagascar.

## Introduction

The clove tree, *Syzygium aromaticum* L., originates from the Maluku Islands in Indonesia and has been used for its spice and aromatic properties for millennia. Whilst products from the clove tree were imported regularly to Europe from as early as the 7<sup>th</sup> century (FRANÇOIS, 1936; MAISTRE, 1964; VAXELAIRE, 2013), its story began more recently with the discovery of the Maluku Islands by the Portuguese, and the expedition organised by Magellan. On returning to Spain in 1522, the *Victoria*, the first boat to circumnavigate the globe, carried in its hold a cargo of spices that included cloves. The first description of the clove tree can be found in Antonio Pigafetta's account of this journey entitled "*Navigation & découverte de l'Inde supérieure & îles de Malucque où naissent les clous de girofle, faite par Antonio Pigafetta, vicentin et chevalier de Rhodes, commençant en l'an 1519*".

The Portuguese held the trading monopoly for cloves until they were driven out of the Maluku Islands by the Dutch at the beginning of the 17<sup>th</sup> century (VAXELAIRE, 2013).

In an attempt to keep their hold on the clove trade, the Dutch tried to concentrate the tree's cultivation to Ambon Island, by systematically destroying the trees elsewhere in the archipelago (VAXELAIRE, 2013). This project was destined to fail though, partly due to the tenacity of Pierre Poivre who, more than a century later, organised several expeditions for the French East India Company to pilfer clove and nutmeg plants from the Dutch. The first plants were brought to Mauritius, Ile de France as it was then known, in 1770, where they were acclimatised (VAXELAIRE, 2013). It was from these trees that the first plants on the Reunion Island originated.

According to FRANÇOIS (1936) and DECARY (1937), the first plants were established in Madagascar on the island of Sainte-Marie (off the coast of Grande Terre) in the 1820s, making Sainte-Marie the historical birth place of the Malagasy clove tree (PRUDHOMME, 1901; DE NEMOURS, 1930). Production of cloves at this time remained moderate (15 tonnes in 1880). The crop was only developed on Grande Terre from 1895, at the time of its conquest by the French. This cultivation took off rapidly occupying vast swathes of land, sometimes at the expense of food crops (LEROY, 1946; TOURNEUR, 1947a).

From the 1920-30s, Madagascar became one of the major producers and exporters of cloves. At the same time, a secondary product emerged, clove essential oil, which rapidly elbowed its way onto the world market (MINISTÈRE DES COLONIES, 1917; LEDREUX, 1928, 1932; MAISTRE, 1955, 1936).

Currently, Madagascar is one of the largest producers of cloves and clove essential oil, and since the 1990s, the world's number one exporter (TEUSCHER *et al.*, 2005; FAOSTAT, 2013).

In under a century, the clove tree has been adopted by the small peasant farmers of Madagascar, who have become expert in its cultivation, resulting in a new form of valorization. Cloves and clove oil have become a flagship of Malagasy agriculture.

However, such a success story raises questions. This article investigates how the clove sector has developed over the past century, on the basis of what strategies, and for what uses and which markets. It identifies who has been involved in its development. It looks at how and when essential oil production came into being and how it relates to the initial product, the



**Photo 2.**  
Clove tree foliage (Tamatave).  
Photograph P. Danthu.

clove. It asks what motivates producers in their decisions to favour the production of one product over the other, or alternately to combine the two. How has this complex management led to the sector's current structure? How and in what context has Madagascar become world leader of the clove market?

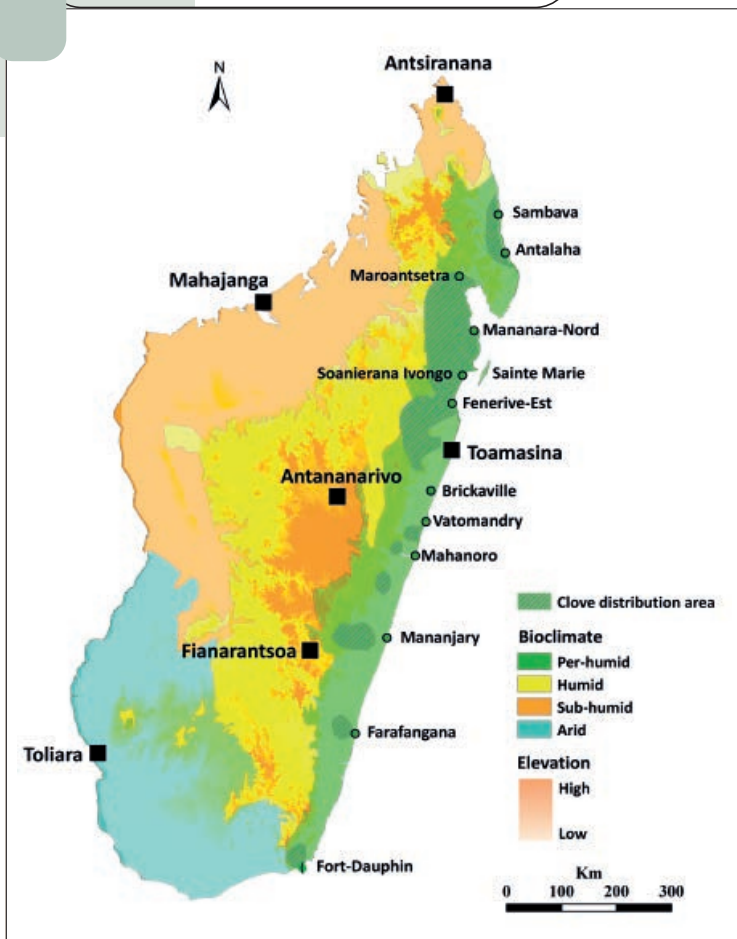
The aim of this article is to describe the present operating dynamic of the clove sector, that is to say the way it is managed and organised around these two products, in a historical perspective in relation to some key background factors in the history of the clove. The article is based on a synthesis of old documents and an analysis of agricultural statistics, and is backed up by field studies carried out in 2012 and 2013 on the island of Sainte-Marie and in the region of Fénérive-Est.

## The Clove Tree: one tree, two products

In comparison to the majority of other spice producing plants, the clove tree distinguishes itself in that it supplies two products of major economic interest, the clove and clove essential oil.

### Biological features of the species

The clove tree, *Syzygium aromaticum* L., is a member of the Myrtaceae family. It is typically found in low lying (below 300m) areas with a humid tropical climate and no noticeable dry season, such as can be found on the West coast of Madagascar (MAISTRE, 1964; DE HAUT DE SIGY, 1968) (figure 1). The clove grows well in poor quality soil (PRUDHOMME, 1909; MAISTRE, 1964; DUFOURNET, 1968). Whilst it is averse to sandy soil, it adapts well to ferralitic tropical soils which, for example, are not suitable for coffee (TOURNEUR, 1947a).



**Figure 1.**  
Coverage of clove growing zone in Madagascar in 1955  
(MAISTRE, 1955).

The tree has a conical crown (photo 1) and measures on average between 10 and 12 metres but can get as tall as 20 metres. It has tough, evergreen leaves (photo 2). The recommended density for plantations is 100 to 150 trees/hectare, ensuring the plants adequate light. However, Malagasy peasants often tend to plant 4 to 5 metres apart (MAISTRE, 1964).

The flowers are clustered in terminal cymes of 20-25 flowers, generally forked into three peduncles, called “stems” (RABECHAULT, 1955; MAISTRE, 1964). The plant flowers for the first time after 8-10 years and trees are fully flowering at around 20 years (FRANÇOIS, 1936; MAISTRE, 1955). The inflorescences bearing the unopened flower buds, “nail-like” spikes called cloves, are handpicked and the cloves are removed from the stems and dried in the sun (photos 3, 4). The peduncles and pedicels from the inflorescences that constitute the clove stems are harvested along with the clove buds (MARTIN, 1991). In Madagascar, the harvest takes place between October and January (TOURNEUR, 1947a; DUCLOS, 2012). If the harvest is left too late (flowering stage), the product is a “headless clove” of lower quality (MAISTRE, 1964). The fruit, called *antofle*, is a lightly-scented, single-seeded drupe.

Clove production varies from one year to another (LEDREUX, 1932; BOITEAU, 1936), without any particular alternating pattern. RAMANANTSOAVINA (1971) estimates the extent of these variations to be between 1 and 7. However, whilst these irregularities have been widely observed, the determining factors have not been established (MAISTRE, 1964; THANKAMANI *et al.* 1994).

The clove tree has few known enemies, despite reported cases of apoplexy (“sudden death”) in Madagascar as well as Zanzibar (HEIM & BOURIQUET, 1937, 1939; BOURIQUET, 1946; FRÈRE, 1955; MAISTRE, 1955). Cases of anthracnose, root rot and sooty mould have been recorded (BOURIQUET 1946). The main pest is *andretra*, the clove leaf miner, lepidoptera *Chrysotypus mabilianum*, of which the first recorded attacks in Madagascar were in 1933 (TOURNEUR, 1947a) (photo 5). Despite widespread damage, which was difficult to estimate, no lasting means of protection or prevention seem to have been put in place (FRAPPA, 1954; DUBOIS & RANAIVOSOA, 1966). The clove tree is noted to be sensitive to wind (FRANÇOIS, 1936), and yet paradoxically, it is the clove growing region of Madagascar (figure 1) which is most susceptible to cyclones (KIRKHAM, 1928; DONQUES, 1975).

### The Clove: the clove tree’s “historical” product

Cloves have been put to a variety of uses. It is used as a culinary spice in many eastern and western dishes (a staple ingredient in most curried dishes, spicy fruit cakes, sauerkraut) (TEUSCHER *et al.*, 2005). Europe and India are amongst the major importers of high quality cloves (FRANÇOIS, 1934; TOURNEUR, 1947a; FAOSTAT, 2013). It also has a long history of usage in dentistry, cosmetics and perfumery. But the majority of world production goes into the manufacture of *kretek*, a traditional Indonesian cigarette, a mix of tobacco and clove (TEUSCHER *et al.*, 2005; DUCLOS, 2012). According to RUF (2000), around 75% of worldwide clove production was destined in the 1980s for this purpose.

### Clove oil: uses past and present

Clove oil has been used in Europe since the 16<sup>th</sup> century. It is produced essentially by hydrodistillation of the leaves, cloves and stems (LEDREUX, 1932). Higher yields of matter are obtained from the stems (15 to 20% in relation to fresh matter) than the leaves (4 to 5%) (TOURNEUR, 1947b).

Its interest lies in its high eugenol content (BRIAND, 1996; TEUSCHER *et al.*, 2005). It can contain up to 90% eugenol, depending on the organ distilled and mode of distillation (GOPALAKRISHANAN & NARAYANAN, 1988; SRIVASTAVA *et al.*, 2005; RAZAFIMANONJISON *et al.*, 2013). Essential oil from the clove bud and stems give the greatest yields (TOURNEUR, 1947b). Eugenol is reputed for its anti-bacterial, fungicide, antiseptic, antioxidant anaesthetic and analgesic effects, and is widely used in aromatherapy, pharmacy, human and veterinary medicine and dentistry (SURESH *et al.*, 1992; FRANCHOMME *et al.*, 2001; BURT, 2004; TEUSCHER *et al.*, 2005; FU *et al.*, 2007; MILINT & DEEPA, 2011; SHAABAN *et al.*, 2012). Eugenol is also the primary component in the hemi-synthesis of vanillin (TOURNEUR, 1947b; BRIAND, 1996), putting the clove paradoxically in competition with vanilla, Madagascar’s other major export. Clove essential oil is also used widely as a base in perfumery, an ingredient of *Opium* by Yves Saint-Laurent and *l’Air du Temps* by Nina Ricci (BRIAND, 1996), amongst others.



**Photo 3.**  
Freshly picked stems and clove spikes (Sainte-Marie, November 2011).  
Photograph P. Danthu.



**Photo 4.**  
Fresh and dried cloves (Sainte-Marie, November 2011).  
Photograph P. Danthu.

At present, demand for eugenol on the international market is high and on the increase (DUCLOS, 2012). There is a developing sector in the purification of eugenol from clove essential oil, in particular in Indonesia, and the first fractionation plant has just started operating in Tamatave.

Distillation is carried out in stills found in all the villages (*fokontany*) and hamlets throughout the clove growing area. Small farmers wishing to distil will generally hire the still from the owner (photo 6). Whilst the precise number of stills is not known, there are estimated to be between around 1,000 and 2,000 in the region of Fénérive-Est, Vavatenina and Soanierana Ivongo (RAMALANJAONA & JOURDAN, 1961; DANDROY, 1973; P.P.R.R., 2013).

The waste matter from distillation of the leaves can be used as compost for growing taro and bananas. It was used at one time as substrate for growing a very high quality comestible mushroom, *Volvaria volvacea*, (BOURIQUET, 1941, 1942/1943), but this usage seems to have died out.

### Balancing clove and clove oil production: a compromise in the management of trees?

In Madagascar, trees are grown both for clove and clove oil production. Collectors will cut the top 50 cm of the branches for the purpose of distillation (photo 7). Lopping in this way reduces the height of the trees making it easier to harvest the clove buds and protects against wind damage. This is what gives the crown its characteristic platter shape (photos 8 and 9).

Yet, whilst this is poorly documented, it seems that the practice of systematically and drastically reducing the leaf surface has a negative influence on the production of clove buds. Apparently, clove production takes second place to the collection of leaves for distillation. This was observed very early by FRANÇOIS (1934), who claimed that lopping like this was harmful to the trees and that prioritising essential oil production was “the clove industry’s worst competitor”. Likewise, LEROY (1946) described this practice as vandalism and mutilation, compromising for the future of plantations. Furthermore, a regional decree was passed in 2011 to counteract this constraint, forbidding distillation in May and June, when it becomes feasible to assess the quantity of clove flowers and thus selectively direct the collection of leaf biomass destined for oil production. Incidentally, Zanzibar even went as far as to halt the setting up of stills, banning the distillation of fresh leaves, so as to give a better chance to clove production (FRANÇOIS, 1934) and only the lower quality clove spikes and stems were distilled (KIRKHAM, 1928; FRÈRE, 1955). This might explain the higher yields of clove buds from Zanzibari trees (640 kg/ha compared with only 250 kg/ha in Madagascar) (MAISTRE, 1964).



**Photo 5.**  
Caterpillar of *Chrysotypus mabilianum*, responsible for clove tree *andredra*.  
Photograph M. Panco.

## Evolution of the Malagasy clove sector

The history of the clove tree in Madagascar can be approached from two angles; via the evolution of clove and clove oil production, equated here with annual exports, the products being mostly destined for the international market, or alternately by the geographic expansion of the clove sector.

### Historical dynamic of clove and clove oil production

An analysis of the curves (figure 2) shows a wide interannual variation in the production of cloves (as well as essential oil), confirming the irregularities previously highlighted. But aside from these irregularities, it is possible to draft a hypothesis for a periodization in the development of the clove sector in Madagascar since the beginning of 20<sup>th</sup> century.

Before this date, the clove crop remained modest for a long time (15 tonnes in 1880) even if there appear to have been some exports onwards of 1835 (CAMPBELL, 2005). Clove was still considered a secondary crop. Very little consideration was given to clove as a crop of the future by PRUDHOMME, who was Director of Agriculture in Madagascar in 1901, and General GALLIÉNI (1908), the Governor General of Madagascar from 1896 to 1905.

Five distinct periods have been identified, partly inspired by the periodisation suggested by DE HAUT DE SIGY (1968).

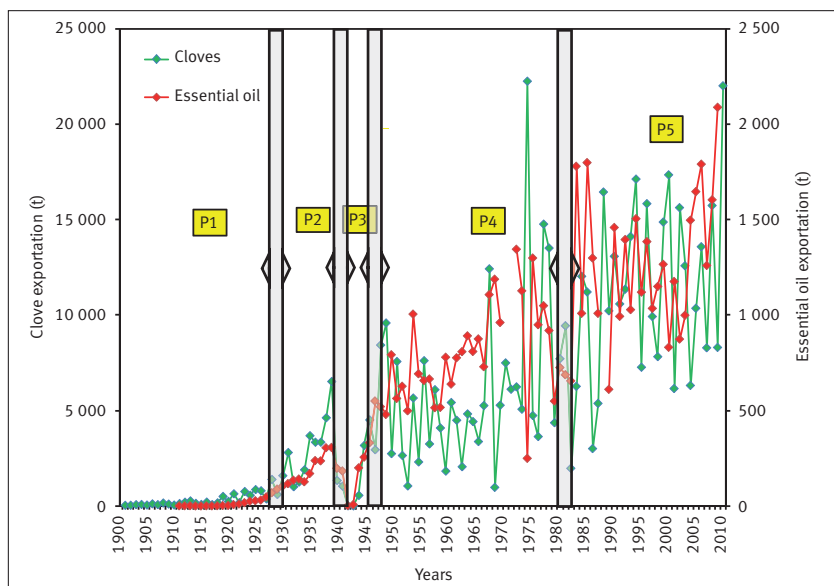
The first period covers the years between 1900 and 1925/1930. This marks the beginning of clove cultivation in Madagascar, firstly on Sainte-Marie, as indicated by PRUDHOMME (1901, 1909). Production at that point was des-

tinued chiefly for the spice trade (FRANÇOIS, 1934). As the plant was considered a secondary crop and the harvest labour intensive, it was not recommended for large scale cultivation (PRUDHOMME, 1909; ROLLOT, 1923), particularly on plantations belonging to European settlers (MINISTÈRE DES COLONIES, 1917). The first wave of plantations, strongly supported by the colonial powers, was organised in the district of Mananara from 1924 to 1926, under the impetus of the Administrator Ballot “who particularly favoured the propagation of native crops” (FRANÇOIS, 1928; BROWN, 2000), in which a million clove trees were planted by local small farmers. ROLLOT (1923) asserts that many clove trees at this time belonged to natives who had planted them around their villages. This development, demanding little upkeep, seems to have been to the detriment of the food crops, especially rain-fed rice. TOURNEUR (1947a) goes as far as to typify it as “a lazy-man’s crop”! Yet, the extent of the clove sector was still quite limited, estimated at 2,800 ha for 1,600 tonnes of clove produced in 1929. It was also during this period, in 1906 or 1911, that the first distillations of clove oil were carried out on stems (MINISTÈRE DES COLONIES, 1917; RAHONINTSOA, 1978). This advance was partly associated with the arrival of the first stills in Madagascar (RAMALANJAONA & JOURDAN, 1961; DUFOURNET, 1968) and partly with the fact that eugenol was found to be a useful additive in the manufacture of the varnish used for the wings of aircraft, for which war had multiplied demand (GATEFOSSÉ, 1921). However, production of clove oil remained modest, with annual output still at less than 100 tonnes (figure 2).

The second period, from 1930 to 1939, is characterised by a significant increase in the areas planted with clove trees, which increased to 10,000 ha in 1938. The production of cloves increased concurrently to 6,500 tonnes in 1938. Annual output of clove essential oil grew to 400 tons.

The third period was short, corresponding to World War II. Exports of cloves and clove oil (but not production) fell dramatically from 1940 and picked up again in 1944 (DUFOURNET, 1968). These variations are closely linked to the historical conditions, where under Vichy rule, Madagascar was blockaded from 1940 to the end of 1942, and then subsequently seized by the British, then the Free French forces from January 1943, the date when the blockade was lifted. Despite this, trade in cloves remained modest, as did the entire colonial production destined for export and not considered essential to the war effort (FRANÇOIS, 1945; CASTEL, 1947). The exports in 1946 and 1947 corresponded partly to the stocks remaining from the previous years’ harvests (DUFOURNET, 1968).

The fourth period covers the post-war years to 1983, undisrupted by the independence of Madagascar in 1960. The state of Madagascar continued to support the clove sector, whilst research and development of the species flourished, as witnessed by the major studies published at this time by MAISTRE (1955, 1964), RABECHAU (1955), RAMALANJAONA & JOURDAN (1961) and RAMANANTSOAVINA (1971). During this period,



**Figure 2.**

Evolution of Malagasy clove and clove essential oil production since 1900, periodisation of five proposed periods (P1 to P5). Sources: MAISTRE (1964); DUFOURNET (1968); FAOSTAT (2013). Data unavailable for years 1971, 1972 and 1989. Indicated tonnages correspond to exports and account for the fact that the product of year N is generally exported almost entirely in year N+1.



**Photo 6.**  
Still used for clove oil distillation at Sainte-Marie (November 2011).  
Photograph P. Danthu.



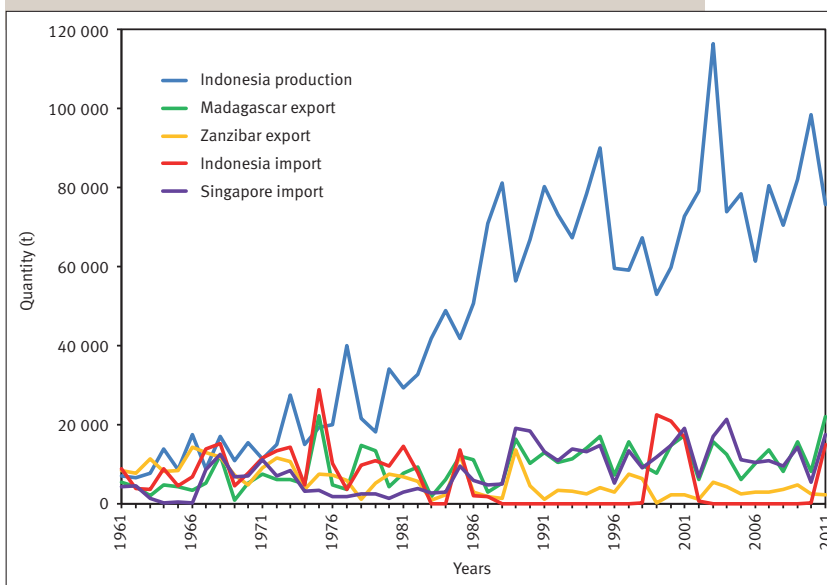
**Photo 7.**  
Transporting bundles of clove leaves in preparation for distillation (Ambatiharanana, around Fénériver-Est, May 2013).  
Photograph P. Danthu.

annual clove exports stagnated, fluctuating between 2,000 and 13,000 tonnes, averaging at around 4,500 tonnes and with extremes of 974 tonnes in 1969 and 22,254 in 1975. The production of clove oil increased regularly rising from 550 tonnes in 1947 to 780 in 1960 and 1,346 in 1973 (figure 2). A drive of plantings took place in the 1960s and 1970s in the region of Mananara (LOCATELLI, 2000). In 1971, RAMANTSOAVINA estimated at three million the number of potentially productive trees. During the years when Madagascar was under socialist rule (1972-1991), the purchase price of the clove bud from farmers was kept low by the government. This strategy was aimed at improving the balance of payments and compensating the deficit associated with the importation of rice, resulting from a drop in production due to keeping the selling price of this basic foodstuff artificially low. This resulted in an illegal trade in Malagasy clove, exporting to the Comoros where the buying price was higher (BROWN, 2000), but this practice did not affect the levels of exportation to any significant degree (figure 2). This period ended in 1983 with the (provisional) halt in exports to Indonesia, which had become self-sufficient for the first time and able to manage without foreign imports, in particular those from Madagascar (FAOSTAT, 2013) (figure 3). This crisis brought about a slump in clove sales for Malagasy producers, some of whom even considered uprooting their clove trees (BLANC-PAMARD & RUF, 1992).

In the fifth period, up to the present day, annual exports fluctuated between 4,000 and 15,000 tonnes, with an average of 11,700 and a few exceptional years (22,000 in 2012). These exports are headed primarily for Singapore from where they are fed into the Indonesian market. Cloves from Madagascar serve as an adjustment to Indonesian production. Annual clove oil exports are around 1,275 tonnes with marked high output in recent years (2010 and 2011), mainly due to the substantial increase in world demand and hence world prices. The sector has been supported during this period by some large scale aid programmes promoting cash crops such as Operation Coffee, Pepper, Clove, Cocoa (*Opération Café Poivre Girofle Cacao* [O.C.P.G.C.]) and the Rural Income Promotion Programme (*Programme de Promotion des Revenus Ruraux*, P.P.R.R.), supported by IFAD (RAHONINTSOA, 1978; P.P.R.R., 2013).

### Geographic extension

The present day clove producing zone extends from Maroanetra in the north to Fort-Dauphin in the south in the areas of Antsinanana, Analanjiforo (meaning “clove forest”), Vatovavy Fitovinany and Atsimo Atsinanana (figure 1). However, 90% of clove production is concentrated around Mananara, Fénériver-Est and Soanierana Ivongo (MAISTRE, 1964). Nowadays, the production on Sainte-Marie is merely token.



**Figure 3.**  
Evolution of Indonesian clove production with exports from Madagascar and Zanzibar and imports from Indonesia and Singapore from 1961 to 2010. Source: FAOSTAT (2013).



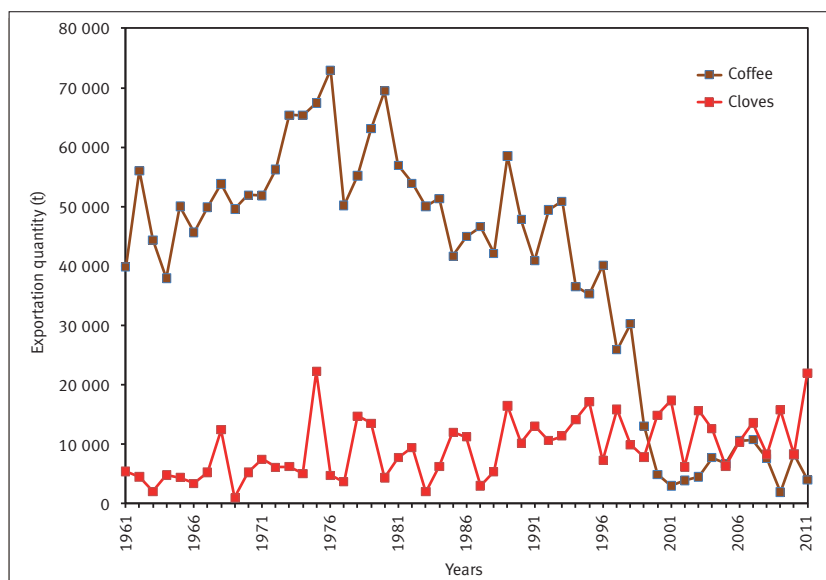
## Evolution in the modes of production and valorization since colonial times

In the region of Analanjirofo, paddy fields are relatively rare and the system of rain-fed rice production gives mediocre yields. This region is therefore under-supplied in rice. Yet, the strategy of peasant farmers when attributing land has always been to ensure that the need for rice is fulfilled (DANDROY 1973; RABEARIMANANA, 1985). Cloves make a significant contribution to household food security by ensuring sufficient income to enable rice to be purchased when there are shortfalls in food production (DANDROY, 1973; ANDRIANIRINA *et al.*, 2010).

### How coffee was overtaken by cloves as number one cash crop

Clove has only recently become the number one cash crop, coffee being the number one agricultural export in the 1980s (RAMILISON, 1985) (table 1, figure 4).

From the 1930s, coffee (mainly the *robusta* varieties) was the main cash crop in Madagascar (DE NEMOURS, 1930). A quarter of Malagasy coffee production came from the Tamatave area and 40% of exports were shipped via the ports of Fénéry and Tamatave (CIOLINA, 1947). Coffee production was seen at that time as a means for buying rice (BLANC-PAMARD & RUF, 1992).



**Figure 4.**  
Evolution of Madagascar's exports of coffee and clove since 1960.  
Source : FAOSTAT (2013).

But from the 1950s, after the Malagasy uprising of 1947 (BROWN, 2000), the colonial administration considered a rice surplus would guarantee social harmony (RABEARIMANANA, 1985). And so, the coffee then occupying the good land in the valley bottoms (CIOLINA, 1947; RAMILISON, 1985) was thought to be a hindrance to the extension of rice paddies (BLANC-PAMARD & RUF, 1992). The administration took account of this contradiction and recommended that cultivation of coffee should take second place to the need to extract full value from the rice fields (RABEARIMANANA, 1985).

**Table 1.**

Ranking of cloves in the value of Madagascar's exports. In the second column, the first figure relates to cloves and the second to clove essential oil. In the third column, the first figure relates to the rank of cloves in exports and the second relates to combined exports of clove and clove oil. Figures taken from *Bulletin économique de Madagascar et dépendances* (July 1901, 3<sup>rd</sup> quarter 1913, 1<sup>st</sup> quarter 1921, March 1931) and CASTEL (1947) and information provided by INSTAT (Institut national de la Statistique) (data covering 1967/1995 unavailable).

Year	Cloves as a percentage of value of total exports (%)	Ranking of cloves amongst exports of natural resources	Main natural resources exported and their percentage of value of Madagascar's exports (%)
1899	0.2 / -	8	gold (31.2%) - raffia (28.9%) - forest rubber (27.4%)
1910	0.2 / -	13	cattle hide (21.6%) - forest rubber (21.3%) - gold (20.5%)
1920	0.8 / 0.1	14 / 14	cattle hide (19.8%) - rice (11.7%) - vanilla (9.9%)
1930	3.7 / 1.5	7 / 7	vanilla (10.6%) - pois du Cap (9.7%) - coffee (9.4%)
1938	4.4 / 1.3	6 / 3	coffee (31.7%) - vanilla (9.0%) - cattle hides (5.2%)
1954*	10.8 / 3.1	2 / 2	coffee (48.7%) - vanilla (5.2%) - rice (4.0%)
1966	2.4 / 1.6	10 / 5	coffee (31.5%) - vanilla (9.2%) - meat extract (6.2%)
2001	9.6 / 0.006	4	vanilla (15.5%) - shellfish (11.0%) - petroleum oil (10.5%)
2007	2.8 / 0.7	4	shellfish (10.1%) - vanilla (4.2%) - petroleum oil (4.2%)
2012	12.5 / 1.0	1	petroleum oil (6.8%) - shellfish (5.7%) - nickel (4.9%)

\*: value for first half-year.



**Photo 8.**  
Old, lopped clove trees (Ambodimanga II).  
Photograph P. Danthu.



**Photo 9.**  
View of a grove of lopped clove trees (Ambatoharanana, area around Fénérive-Est, September 2012). Photograph P. Danthu.

This regressive context for coffee production was aggravated in the 1980s by the world coffee crisis in which supply exceeded demand, bringing about a drop in price for the producers. The value of Malagasy coffee, which came from ageing and poorly maintained coffee plantations, plummeted. Export volumes tumbled (figure 4). Despite the gradual adoption of coffee drinking by the inhabitants (MOREAU, 2013), coffee no longer fulfilled its role as a cash crop, as it was unable to provide a source of income for producers (MINAGRI, 2011; FAO, 2013).

The clove tree was unaffected by this dynamic as it was possible to cultivate it in poor soils. Clove then became, from 1990 onwards, the primary cash crop in Analanjirofo and, along with vanilla, Madagascar's primary agricultural export (table I).

### Evolution in cropping systems

The clove tree developed on the large estates of European settlers, but was also widely adopted by native farmers. In 1918, on Sainte-Marie, 228 hectares were cultivated by the former and 1,200 by the latter (RAHONINTSOA, 1978). From the 1920s onwards, the colonial administration, committed to the promotion of "native crops" (in a bid to generate taxes

and develop exports), launched an extensive campaign to encourage small local farmers in the planting of plots of clove trees (ROLLOT, 1923; FRANÇOIS, 1928; LOCATELLI, 2000). This strategy was pursued until recently by projects such as the O.C.P.G.C. (Operation Coffee, Pepper, Clove, Cocoa), which from 1968 and for a further 20 years or so, was overseeing production (RAHONINTSOA, 1978), as well as the P.P.R.R. (P.P.R.R., 2013). However, not enough is known about the current replanting strategy to ascertain whether it is ensuring the resource's renewal, or whether it is capable of overcoming the cumulative effects of an ageing stock, recurrent cyclone damage and over-collection of leaves.

Currently, plots of monoculture of clove have all but disappeared and the clove trees are included in more or less complex agroforestry systems. These systems, according to the definitions given by TORQUEBIAU (2000), extend from combined agroforestry plotting systems in which the clove tree is associated with annual crops (rice, maize, cassava, sweet potato, etc.) to agro-forests in which they are combined with other trees, forest or fruit (coffee, mango, coconut, etc.) (photos 10, 11, 12, 13, 14). Systems also exist which combine clove trees with cattle, where the cattle graze beneath the trees (DANDOY, 1973; MICHELS *et al.*, 2011).

The situation in Sainte-Marie, where the clove trees are particularly dilapidated, shows that a number of factors have contributed to this evolution. When rights over plots are transferred into a number of different hands over generations, those farming the plots can be dissuaded from investing time in cultivating a crop over which they have no control or from which they are expected to share the profits. Another factor is the myriad of different rights (over the land, the tree, the usage of the cloves and leaves). Moreover, since 2000, a new trend can be observed in the planting of plots previously devoid of clove trees, where the owner concentrates all the rights in order to maintain full long term benefit of his investment (LEVASSEUR, 2012).

### Joint valorisation of the two products, clove and essential oil: complementing household incomes

The clove sector in Madagascar is limited to three leading players: producer, collector, and exporter (SCHWEITZER & RANAIVOSOA, 2007; P.P.R.R., 2013). According to DUAULT (2008), the producers are well paid for the clove; about 58% of the world market price (FOB price) for the clove spikes, which on the whole is a fair price in relation to other cash crops. The collectors and exporters share the remaining 42% equally.

The quality of the products was defined by law in 1930, offering two classifications that differentiate cloves of spice-grade (type 1) from all the others (JO MADAGASCAR ET DÉPENDANCES, 1930). In the 1960s, four grades were distinguished, the highest grade being "prima" consisting of whole cloves (with flower bud, light brown in colour, less than 16% humidity and weighing at least 70g) (MAISTRE, 1964). Currently, cloves are graded according to three categories: CG1 - "Hand pick"; CG2 - "Prima"; CG3 - "Courant", which correspond respectively to spice usage, transformation and non-food usage (SCHWEITZER & RANAIVOSOA, 2007). The greater part of Malagasy exports fall into the third category, destined for the Indonesian *kretek* industry (FRANÇOIS, 1934).

**Photo 10.**

View of a colonial plantation of clove trees in Madagascar (CASTEL, 1947).  
Photograph Anonymous.

**Photo 11.**

Agroforest of clove trees and a field of rain-fed rice at Sainte-Marie (November 2011).  
Photograph P. Danthu.

**Photo 12.**

Grove of clove trees combined with maize and rice (Ambodimanga II).  
Photograph P. Danthu.

**Photo 13.**

Low land rice and clove trees (Ambodimanga II).  
Photograph P. Danthu.

**Photo 14.**

Young clove trees in an agroforest in Sainte-Marie (November 2011).  
Photograph P. Danthu.

The household income generated by clove production is high but fluctuates from one year to another and contributes considerably to ensuring food security to small farmers and their families (for buying rice and other necessities). Essential oil production is an opportunity for farmers to manage and control their income to respond to one-off or recurrent expenses (lean season, home repairs, healthcare, feast-days, and memorial ceremonies for the dead...). Clove and its two products thus provide a regular income enabling food security and at the same time provide for unforeseeable expenses and investments.

It is nonetheless worth noting that the availability of manpower is a limiting factor in the harvesting of cloves (PRUDHOMME, 1901; DUFOURNET, 1968; RAHONINTSOA, 1978). Collecting and stripping the cloves is a short-lived activity but is highly labour intensive. On Sainte-Marie, beyond utilising the family labour, farmers have resorted to various solutions including forced labour, the quality of which was sloppy; casual labour, which results in poor yields; and *sambiamanana*, which consists of half shares of the harvest for the owner and the picker. Where oil production is concerned, access to a still is the main limiting factor. An agreement is usually struck up between the owner of the cloves used for distilling and the owner of the still; payment is always made in essential oil (DUFOURNET, 1968; RAHONINTSOA, 1978).

## Economic value of clove

Madagascar only recently became the world number one clove exporter. However, the market is unstable and for the most part dependant on Indonesian production. This section deals with the place clove occupies in Malagasy agricultural exports and the place of Madagascar in the worldwide clove trade.

### The place of clove in Madagascar's agricultural exports

Table I shows that Madagascar initially (before WW1) exported mined or collected products (gold, rubber, raffia, wax...). From 1913, the island began exporting agricultural products and cattle (meat, hide, coffee, vanilla) (CASTEL, 1947). Cloves then accounted for a small part of exports. In the years from 1930 to 1960, coffee was by far Madagascar's main agricultural export, followed by vanilla, whilst clove exports were on the increase. From 2000 onwards, clove, vanilla and prawns (with the development of prawn farming) have dominated exports, far exceeding those of lychee, sugar and cocoa. Cloves represented on average 7.3% of the value of exports in the period 2007/2012. In 2012, clove was the number one export.

### Indonesia number one producer and importer of clove, Madagascar number one exporter

Domination of the global clove market by Madagascar and Zanzibar dates back to the beginning of the 20th century with these two world leaders accounting for 90% of the cloves traded (MAISTRE, 1964; MARTIN, 1991).

Until 1960, Zanzibar's exports regularly exceeded Madagascar's (figure 5). Zanzibar's domination can be explained by its far higher output in cloves. There are two reasons: Zanzibar's production concentrates on cloves rather than essential oil and the cloves flower twice a year (a large harvest from July to September and a smaller one from December to January), whilst Madagascar's flower only once (FRÈRE, 1955; DUFOURNET, 1968).

During the period from 1970 to 1990, Madagascar and Zanzibar alternated as the number one exporter. But from 1990, Madagascar's exports increased whilst Zanzibar's were on the decline. Since then, Madagascar has remained the number one world exporter with annual volumes of between 10,000 and 15,000 tonnes (figure 4)

Currently, the majority of exports from Madagascar and Zanzibar (as well as smaller exporters such as Comoros, Kenya and Brazil) are destined for the Asian markets, going almost entirely to Indonesia.

In fact, Indonesia and its *kretek* industry directs the world clove markets. It is by far the largest clove producer (figure 3), whilst not always fulfilling its own requirements. For a long time, Indonesian production (less than 10,000 tonnes until the 1960s) has fallen short of its consumption. The 1980s were the only boom years in Indonesian clove production with volumes exceeding 50,000 tonnes in the leaner years and more than 80,000 tonnes in the good years (1988, 1991, 1995, 2003,

2010) (figure 5). In 1983, Indonesia was self-sufficient for the first time causing a significant fall in exports from Madagascar and Zanzibar (figure 3) (BLANC-PAMARD & RUF, 1992).

Since then, the majority of Madagascar's clove crop is exported to Indonesia, particularly the poorer quality cloves (SCHWEITZER & RANAIVOSOA, 2007). But the volume of exports is still tied to Indonesian production, as can be seen for the period 1999/2001, when a fall in Indonesian output resulted in an increase in its imports (figure 3)... and a subsequent soar in the world clove price.

The 1980s also saw a change to the conditions of the clove trade with Indonesia no longer importing directly but via Singapore (figure 3). Since then, the majority of Madagascar's exports have shipped to Singapore, from where the greater part of the cargo is then re-exported to Indonesia (SCHWEITZER & RANAIVOSOA, 2007).

Volumes of spice-grade cloves exported from Madagascar are small and usually destined for Europe (less than 15% of world market) and India, the second biggest importer of Malagasy cloves (SCHWEITZER & RANAIVOSOA, 2007), apparently despite the superior reputation of cloves from Ambon Island and Zanzibar (TEUSCHER *et al.*, 2005).

Clove oil production from which eugenol is extracted is essentially specific to Madagascar and Indonesia. Indonesian exports of clove oil exceeded 900 t/yr three times between 1979 and 1982, whilst Madagascar's varied between 900 and 1,200 tonnes, peaking twice at 1,800 tonnes in 1984 and 1986 (DUCLOS, 2012). The majority of Madagascar's clove oil is destined for France (300-400 tonnes) and for the USA (300-470 tonnes) whilst the remainder is exported to Indonesia for eugenol extraction and then transited on to Europe and the USA. Indonesia has consequently become the number one importer of clove essential oil and the number one exporter of eugenol. World demand for clove oil is estimated at 5,000 tonnes, far in excess of production, appearing to make this sector one which holds good future potential for Malagasy producers (DUCLOS, 2012).

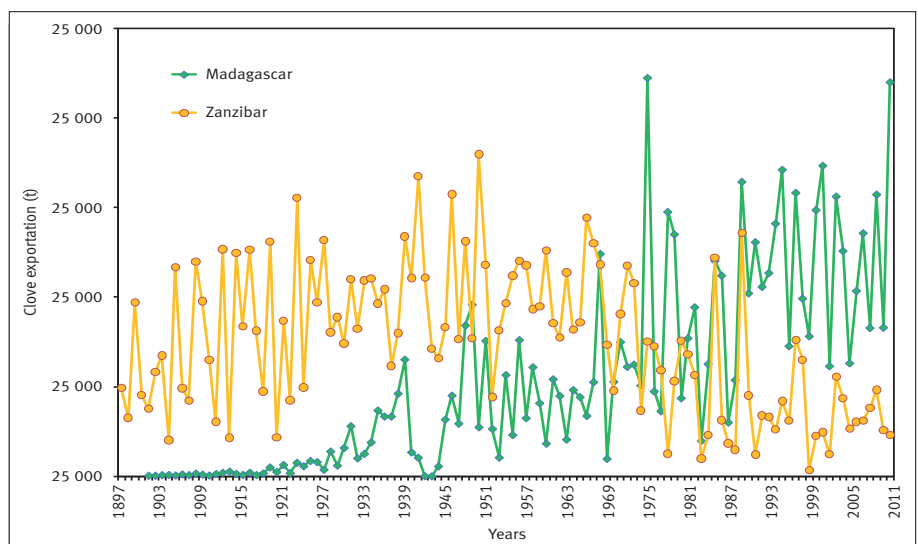


Figure 5.

Comparative annual exports of clove from Madagascar and Zanzibar between 1897 and 2010 (MAISTRE, 1964; MARTIN, 1991; DUAULT, 2008; FAOSTAT, 2013).

## Perspectives

The current state of the clove sector in Madagascar has arisen from a number of favourable convergent factors. First, it can be considered the compatibility between the ecological requirements of the species and the environmental context on Madagascar's East coast, even if its sensitivity to cyclones might be a hindrance to its development. The second factor was the rapid uptake of the species by small farmers who integrated it into their cropping systems, sometimes even at the expense of their food crops. This was mainly because of the small manual outlay required to maintain the clove tree, and the ease of harvest and preparation of the cloves relative to the substantial income generated by its sale. A third favourable factor has been the soaring global demand (especially Indonesian) for cloves making it a high return cash crop. The fourth factor is associated with the innovation represented by the development of essential oil production and the strong interest for eugenol from different high value-added industrial sectors.

Thus, from the beginning of the 20<sup>th</sup> century, clove cultivation took an increasingly important place in the cropping systems and incomes of peasant farmers in the area of Analanjirofo. Madagascar subsequently became a major player on the world clove and clove oil market.

Can Madagascar's clove production then be described as a success story? Or is this where the story takes a downturn?

Possible developments in the world market could determine the future of Madagascar's clove sector. Whilst the market for eugenol (and hence clove oil) looks promising, there are doubts about the clove market. Effectively, competition from the major multinational tobacco companies who are trying to penetrate the enormous Indonesian market at the expense of the *kretek*, could in the medium term be responsible for a drop in demand (and thus imports) from Indonesia (HANUSZ, 2002; LAWRENCE & COLLIN, 2004; ARNEZ, 2009).

At the producing end of the sector, resource management is giving way to an economy of gathering from an ageing and seemingly insufficiently renewed resource, despite world demand which seems to be steadily increasing (at least for clove oil). The resilience of plantations, especially in the face of damage from cyclone and pests has enabled this resource (considered adequate as it stands) to be maintained. However, the division of plots into smaller parcels over the generations has rapidly led inheriting farmers to incur a shortfall of trees and lower output per farm.

If Madagascar's clove sector is to continue growing and performing at its optimum, a market evaluation is required which, together together with a better definition of the quality of products and a clearer understanding of farmers' strategies, will provide a basis on which to construct tomorrow's clove.

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## Bibliographical references

- ANDRIANIRINA N., BENOIT-CATTIN M., DAVID- BENZ H., 2010. Diversité, diversification et inégalités chez les ménages ruraux. Le cas de l'observatoire rural de Fénérive-Est à Madagascar. Actes des 4<sup>es</sup> journées INRA-SFER-CIRAD de recherches en sciences sociales. [En ligne] <http://www.sfer.asso.fr>. Accessed 30<sup>th</sup> November, 2013.
- ARNEZ M., 2009. Tobacco and *kretek*: Indonesian drugs in historical change. Aktuelle Südostasienforschung / Current Research on South-East Asia, 2: 49-69.
- BLANC-PAMARD C., RUF F., 1992. La transition caféière. Côte Est de Madagascar. CIRAD et Centre d'Etudes Africaines Editeurs, Collection « Documents Systèmes Agraires », 16, 248 p.
- BOITEAU G., 1936. Le girofle. La Revue de Madagascar, 13 : 107-116.
- BOURIQUET G., 1941. Les Champignons de Madagascar. La Revue de Madagascar, 28 : 117-137.
- BOURIQUET G., 1942-1943. Notes de mycologie malgaches. Bulletin de l'Académie malgache, 25 : 12-24.
- BOURIQUET G., 1946. Les maladies du giroflier. In : Les maladies des plantes cultivées à Madagascar. Encyclopédie mycologique Paul Lechevalier Editeur, France, 237-252.
- BRIAND C., 1996. L'essence de feuille de girofle, précurseur de nombreuses molécules indispensables aux créateurs de parfums et d'arômes alimentaires. Les Cahiers du CITE, 4 : 61-62.
- BROWN M., 2000. A history of Madagascar. Damien Tunnacliffe Editor, Cambridge, 408 p.
- BURT S., 2004. Essential oils: their antibacterial properties and potential applications in foods- A review. International Journal of Food Microbiology, 94: 223-253.
- CAMPBELL G., 2005. An economic history of imperial Madagascar, 1750-1895. Cambridge University Press, Cambridge, 413 p.
- CASTEL R., 1947. Commerce extérieur de Madagascar. M. de Coppet (Éd.), Madagascar et Réunion, tome deuxième. Encyclopédie de l'Empire français, France, 101-114.
- CIOLINA F., 1947. Le café. M. de Coppet (Éd.), Madagascar et Réunion, tome premier. Encyclopédie de l'Empire français, France, 299-308.
- CORNET A., 1974. Essai de cartographie bioclimatique à Madagascar. Notice explicative 55, Office de la Recherche scientifique et technique outre-mer (ORSTOM), France, 28 p. + appendices.
- DANDROY G., 1973. Terroir et économie villageoise de la région de Vavatenina (Côte orientale malgache). In : G. Dandroy (Éd.), Atlas des structures agraires à Madagascar, Maison des Sciences de l'Homme et ORSTOM, France, 94 p.
- DECARY E., 1937. Les débuts de la colonisation agricole à l'île de Sainte-Marie de Madagascar. Revue de Botanique appliquée et d'Agriculture coloniale, 17 : 610-618.
- DE HAUT DE SIGY G., 1968. Contribution à l'étude de la production de clous de girofle à Madagascar en rapport avec la pluviométrie. Institut de Recherches Agronomiques à Madagascar, Document n° 151, 11 p. + annexes.

- DE NEMOURS C. P. (DUC), 1930. Madagascar et ses richesses. Collection Les Pays Modernes, Pierre Roger Éditeur, France, 294 p.
- DONQUES G., 1975. Les cyclones tropicaux des mers malgaches. Mise au point. Madagascar, Revue de Géographie, 27 : 9-63.
- DUAULT Y., 2008. Analyse financière et économique du programme d'intensification et de structuration des principales filières d'exportations. Rapport pour le Centre Technique Horticole de Tamatave, Tamatave, Madagascar, 134 p.
- DUBOIS J., RANAIVOSOA H., 1966. *Chrysopypus mabilianum* Viette, chenille mineuse du giroflier (*Andretia*). Biologie et lutte mécanique. L'Agronomie tropicale, 21 : 822-836.
- DUCLOS T., 2012. Le girofle de Madagascar : l'exotisme par excellence ! Expression cosmétique, 13 : 208-213.
- DUFOURNET R., 1968. Le giroflier et sa culture. Bulletin de Madagascar, 262 : 216-279.
- FAO, 2013. La crise du café et ses conséquences. [En ligne] <http://www.fao.org>. Accessed December 1<sup>st</sup>, 2013.
- FAOSTAT, 2013. Production. Trade. [On line] <http://faostat3.fao.org>. Accessed august 31<sup>st</sup>, 2013.
- FRANCHOMME P., JOLLOIS R., PÉNOËL D., 2001. L'aromathérapie exactement. Éditions Roger Jollois, Limoges, 510 p.
- FRANÇOIS E., 1928. La culture du giroflier à Madagascar. Revue de Botanique appliquée et d'Agriculture coloniale, 8 : 693-696.
- FRANÇOIS E., 1934. Pour l'organisation de notre production de girofle et d'essence de girofle. Bulletin économique de Madagascar, août 1934, 732-736.
- FRANÇOIS E., 1936. Giroflier et girofle. Revue de Botanique appliquée et d'Agriculture coloniale, 16 : 589-608, 892-907.
- FRANÇOIS E., 1945. Le commerce extérieur de Madagascar en 1944. Revue de Madagascar, Numéro spécial, 26-30.
- FRAPPA C., 1954. Sur la chenille de *Thyrididæ* du genre *Chrysotypus* nuisible au giroflier sur la côte est de Madagascar. Bulletin de Madagascar, 95 : 280-287.
- FRÈRE J., 1955. Le Girofle à Zanzibar. L'Agronomie tropicale, 10 : 485-498.
- FU Y. J., ZU Y. G., CHEN L. Y., SHI X. G., WANG Z., SUN, S., EFFERTH T., 2007. Antimicrobial activity of clove and rosemary essential oils alone and in combination. Phytotherapy Research, 21: 989-994.
- GALLIENI J., 1908. Neuf ans à Madagascar. Librairie Hachette et Cie, France, 361 p.
- GATEFOSSÉ J., 1921. Les végétaux aromatiques de Madagascar. L'Agronomie tropicale, 6 : 113-121.
- GOPALAKRISHANAN N., NARAYANAN C. S., 1988. Composition of clove leaf oil during leaf growth. Indian Perfumer, 32: 130-132.
- HANUSZ M., 2002. *Kretek*: the culture and heritage of Indonesia's clove cigarettes. Equinox Publishing (Asia), Jakarta, Indonésie, 220 p.
- HEIM R., BOURIQUET G., 1937. La maladie de l'apoplexie du giroflier à Madagascar. Comptes rendus hebdomadaires des Séances de l'Académie d'Agriculture de France, 23 : 25-29.
- HEIM R., BOURIQUET G., 1939. Maladies et champignons du giroflier. Revue de Pathologie végétale et d'Entomologie agricole de France, 26 : 35 p.
- JOURNAL OFFICIEL DE MADAGASCAR ET DÉPENDANCES, 1930. Arrêté réglementant les conditions de circulation, de mise en vente et d'exportation de certains produits naturels de Madagascar et Dépendances. November 15<sup>th</sup>, 1930, 1016-1024.
- KIRKHAM M., 1928. Rapport sur l'industrie du girofle à Madagascar. Bulletin économique de Madagascar, 28 : 76-80.
- LAWRENCE S., COLLIN J., 2004. Competing with *kreteks*: transnational tobacco companies, globalisation, and Indonesia. Tobacco Control, 13 (Suppl. II): 96-103.
- LEDREUX A., 1928. Le giroflier dans les régions de Fénériver, Soanierana et Sainte-Marie. Bulletin économique de Madagascar, 1: 38-45.
- LEDREUX A., 1932. Le giroflier à Sainte-Marie et Madagascar. Bulletin mensuel de l'Institut National d'Agronomie Coloniale, 175/176 : 1-22 + appendices.
- LEROY J. F., 1946. Le giroflier et les plantes à parfum. Revue internationale de Botanique Appliquée et d'Agriculture Tropicale, 26 : 425-429.
- LEVASSEUR S., 2012. Analyse des systèmes agricoles à base de girofliers à Sainte-Marie, Madagascar : entre héritage colonial et innovations paysannes. Mémoire de fin d'étude, RESAD, Institut des Régions Chaudes, Montpellier, France, 74 p.
- LOCATELLI B., 2000. Pression démographique et construction du paysage rural des tropiques humides : l'exemple de Mananara (Madagascar). Thèse de doctorat, École Nationale du Génie Rural, des Eaux et des Forêts, Centre de Montpellier, France, 441 p.
- MAISTRE J., 1955. Le giroflier à Madagascar et Zanzibar. L'Agronomie tropicale, 10 : 413-448.
- MAISTRE J., 1964. Le clou de Girofle. In : Les plantes à épices. G.-P. Maisonneuve, Larose Éditeur, France, 77-124.
- MARTIN P. J., 1991. The Zanzibar clove industry. Economic Botany, 45 : 450-459.
- MICHEL S., BISSON A., RALAIKOVY V., RABEMANANJAR H., JAHIEL M., MALÉZIEUX E., 2011. Horticultural agroforestry systems in the humid tropics: analysis of clove tree-based systems in Madagascar. Acta Horticulturae, 894: 161-168.
- MILINT P., DEEPA K., 2011. Clove: a champion spice. International Journal of Research in Ayurveda & Pharmacy, 2: 47-54.
- MINAGRI (Ministère de l'Agriculture de Madagascar), 2011. Relance de la filière café à Madagascar. [En ligne] <http://www.agriculture.gov.mg>. Accessed October 17<sup>th</sup>, 2013.
- MINISTÈRE DES COLONIES, 1917. Rapport sur la situation économique de la colonie de Madagascar et dépendances en 1915. Bulletin de l'office colonial, France, 657 p. [En ligne] <http://gallica.bnf.fr>

- MOREAU S., 2013. Construction et déconstruction de patrimoines alimentaires à Madagascar : le cas du café. *In* : M.-C. Cormier-Salem, P. De Robert, D. Juhé-Beaulaton, B. Roussel (Éds.), Effervescence patrimoniale au Sud : entre nature et société. Éditions de l'IRD, Collection Latitudes 23, France, 313-335.
- P.P.R.R. (Programme de Promotion des Revenus Ruraux), 2013. [En ligne] <http://www.ppr.rg>. Accessed November 22<sup>nd</sup>, 2013.
- PRUDHOMME E., 1901. L'agriculture sur la côte Est de Madagascar. Comité de Madagascar, Tananarive, 118 p. + appendices.
- PRUDHOMME E., 1909. Ressources agricoles de Madagascar. Bibliothèque d'Agriculture coloniale, Augustin Challamel Éditeur, France, 68 p.
- RABEARIMANANA L., 1985. La politique économique coloniale sur la côte est (Madagascar) dans les années 1950. *Omalysy Anio*, 21-22 : 307-337.
- RABECHAULT H., 1955. Sur l'anatomie du giroflier [*Syzygium aromaticum* (L.) Merrill et Perry]. *L'Agronomie Tropicale*, 10 : 449-484.
- RAHONINTSOA E., 1978. Sainte-Marie de Madagascar : insularité et économie du girofle. Mémoire de maîtrise de géographie, Université d'Antananarivo, 166 p.
- RAMALANJAONA C., JOURDAN E., 1961. L'essence de girofle de Madagascar. Technologie-Distillation-Emballage. Institut de Recherches Agronomiques à Madagascar, Tananarive, 66 p.
- RAMANANTSOAVINA G., 1971. Aperçu sur quelques produits agricoles malgaches (café, vanille, girofle, coton). *Terre Malgache - Tany malagasy*, 10 : 199-230.
- RAMILISON A., 1985. La production caféière à Madagascar. *Omalysy Anio*, 21-22 : 339-359.
- RAZAFIMAMONJISON G., JAHIEL M., RAMANOELINA P., FAWBUSH F., DANTHU P., 2013. Effects of phenological stages on yield and composition of essential oil of *Syzygium aromaticum* buds from Madagascar. *International Journal of Basics and Applied Sciences*, 2: 312-318.
- ROLLOT C., 1923. Les productions agricoles de Madagascar. *In* : Madagascar économique - La foire commerciale de Tananarive. Les Impressions de l'Imerina, Tananarive, 143-182.
- RUF F., 2000. L'avenir des cultures pérennes en Indonésie. Cacao et clou de girofle après la tempête monétaire. *Tiers-Monde*, 41 : 431-452.
- SCHWEITZER C., RANAIVOSOA L., 2007. Étude de marchés internationaux pour le piment et le girofle. Rapport final. Ministère de l'Agriculture, de l'Élevage et de la Pêche, Programme de Promotion des Revenus Ruraux (P.P.R.R.), Antananarivo, Madagascar, 118 p.
- SHAABAN H. E. A., EL-GHORAB A. H., SHIBAMOTO T., 2012. Bioactivity of essential oils and their volatile aroma components: Review. *The Journal of Essential Oil Research*, 24: 203-212.
- SRIVASTAVA A. K., SRIVASTAVA S. K., SYAMSUNDAR K. V., 2005. Bud and leaf essential oil composition of *Syzygium aromaticum* from India and Madagascar. *Flavour and Fragrance Journal*, 20: 51-53.
- SURESH P., INGLE V. K., VIJAYALAKSHMI V., 1992. Antibacterial activity of eugenol in comparison with other antibiotics. *Journal of Food Science and Technology*, 29: 254-256.
- TEUSCHER E., ANTON R., LOBSTEIN A., 2005. Girofle. *In*: Plantes aromatiques. Collection TEC & DOC, Éditions Lavoisier, Cachan, 266-272.
- THANKAMANI C. K., SIVARAMAN K., KANDIANNAN K., PETER K. V., 1994. Agronomy of tree spices (Clove, nutmeg, cinnamon and allspice). A review. *Journal of Spices and Aromatic Crops*, 3: 105-123.
- TORQUEBIAU E. F., 2000. A renewed perspective on agroforestry concepts and classification. *Comptes-rendus de l'Académie des Sciences de Paris, Sciences de la Vie/Life Sciences*, 323 : 1009-1017.
- TOURNEUR M., 1947a. Épices et aromates. M. de Coppet (Éd.), Madagascar et Réunion, tome premier. *Encyclopédie de l'Empire français*, France, 310-321.
- TOURNEUR M., 1947b. Plantes à parfum. *In*: M. de Coppet (Éd.), Madagascar et Réunion, tome premier. *Encyclopédie de l'Empire français*, France, 322-327.
- VAXELAIRE D., 2013. Les chasseurs d'épices. Éditions Orphie, Chevagny-sur-Guyon, 359 p.