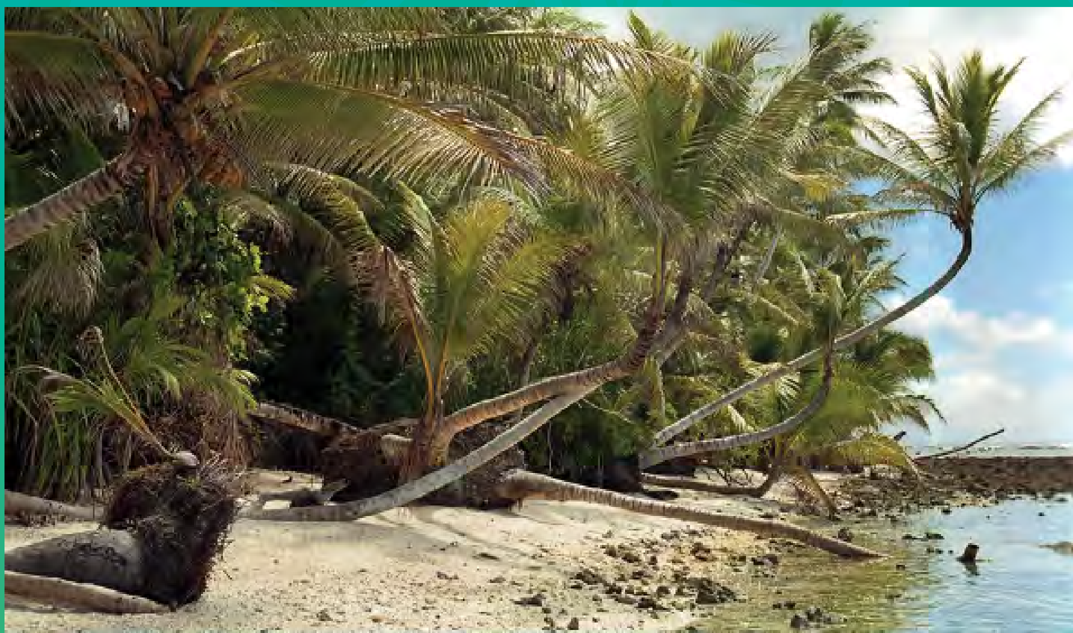
# Coconut Risk Management and Mitigation Manual for the Pacific Region



Compiled by R. Bourdeix, J. M. Sourisseau and J. Lin

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## Disclaimer



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# Coconut Risk Management and Mitigation Manual for the Pacific Region

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# ACKNOWLEDGMENTS

The making of this manual was a passionate adventure. Supported by the participant's interest and enthusiasm, the volume of its text gradually increased to more than double what was originally planned. The three compilers would first like to thank European Union (EU), African Caribbean States (ACP), Pacific Community (SPC), University of Göttingen and the French Agricultural Research for Development (CIRAD), who entrusted them with the realization and writing of this manual.

At the Land Resources Division of SPC, we thank Jan Helsen, Karen Mapusua, Naheed Hussein, Asish Prasad, Roneel Prasad and Stephen Hazelman for the organizational and material support provided in the framework of the Coconut Industry Development for the Pacific (CIDP) project. We also thank Maria Ronna Luna Pastorizo-Sekiguchi of the Greenhouse studio for providing communication support for the Nadi workshop. The meticulous editing work of Mark Ero, Monica Gruber, Emily Legge, and Carmel Pilotti has greatly contributed to improving the quality of the text and images in this manual.

In April 2018, in the framework of a previous CIRAD initiative on seed systems, CIDP organized a meeting during which participants developed 24 technical recommendations and conducted a brainstorming on incentives for boosting the coconut sector. Information and ideas from this first meeting were used in this manual. So, we thank all the participants of this meeting, many of whom became official contributors to the manual.

In December 2018, CIDP organized another meeting, which endeavoured to train participants on risk mitigation in the Pacific's coconut sector and, at the same time, to refine this manual. We are grateful to all participants at this meeting, many of whom have also become official contributors to the manual.

The process for preparing this manual was similar to that used for compiling the 2018-2028 Global Strategy for Conservation and Use of Coconut Resources. Interacting with the 90+ contributors to this strategy was our first training for designing this manual. We are grateful to these contributors and the whole International Coconut Genetic Resources network (COGENT).

The publication of this manual was partially supported by the Australian Centre of Agricultural Research (ACIAR) through their Coconut for Livelihoods Project.

Finally, 52 contributors from 26 countries and territories participated and provided data for this manual. We are grateful to them all. The manual acknowledges the contributors in each of the sections and as an exhaustive list presented in Annex A. We also thank their governments and institutions for allowing them to participate: in the Pacific region, namely Australia, Cook Islands, Federated States of Micronesia, Fiji, French Polynesia, Hawai'i, Kiribati, Republic of Marshall Islands, Nauru, New Zealand, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Timor-Leste, Tonga, Tuvalu and Vanuatu; and out of the Pacific region: Belgium, China, Côte d'Ivoire, France, Germany, Indonesia, and Sri Lanka.

# PREFACE

This manual is the result of a long and important work of compilation and editing, initiated in 2018 under the aegis of The Pacific Community (SPC). This international development organization is owned and governed by its 26 country and territory members. SPC primarily provides technical and scientific advice, and acts as a conduit for funding of development projects from donor agencies. SPC regional development issues include climate change, disaster risk management, fisheries, food security, education, gender equality, human rights, non-communicable diseases, agriculture, forestry and land use, water resources, and youth employment.

The design of the manual was overseen by the Land Resources Division (LRD) of SPC, as part of the project 'Coconut Industry Development for the Pacific' (CIDP), a joint initiative of the Pacific Community (SPC), European Union ( EU) and the African, Caribbean and Pacific Group of States (ACP). LRD's core business is to improve the food and nutritional security of the Pacific Community through the sustainable management and development of land, agriculture and forestry resources.

In the framework of this project, The French Agricultural Research for Development (CIRAD) led and assisted with the design of improved seed production systems and developed a risk analysis for the coconut value chain.

The 40 risks presented in this document cover a wide diversity of themes and recommendations. They are organized in eight sections which explore the following themes: climate change and hazards; pests and diseases; planting material; agricultural practices; organizational and policy issues; post-harvest and processing; economics and marketing, and socio-cultural habits. Each risk is first briefly described; then its occurrence and severity are examined, and the issues associated with its mitigation and adaptation are discussed. Finally, actions to undertake are proposed, and a short bibliography gives key information sources.

Each individual risk assessment is authored by two to five contributors. After the Global Strategy for the Conservation and Use of Coconut Genetic Resources published by the COGENT network in 2018, this manual is the scientific work on the coconut palm which brings together the largest number of contributors, i.e., fifty-two specialists originating mainly from the Pacific region, but also from other continents.

In many countries of the Pacific region, it emerges from numerous discussions with stakeholders that, currently, the major risk is not to find efficient planting material. Sometimes farmers are simply not aware of the existence of improved varieties; or these seednuts are not available, or their availability is too low; waiting lists for seednuts of improved varieties sometimes exceed several years; or the cost of those seednuts remains too high for the farmers' budget. Scientists and policy makers must therefore work on this topic as a priority, without ruling out the possibility of training planters to produce better seeds themselves. Through concepts like Polymotu, planters could learn how to produce hybrids and other types of improved varieties in their own plantations. In addition to government seed-producing structures, there are opportunities for seed production in profitable private enterprises, as already practiced in India for a long time. The public is beginning to appreciate and better value the magnificent genetic diversity of the coconut palm. In Hawaii and French Polynesia, some stakeholders are currently selling seedlings of rare coconut varieties at nearly USD 100 per unit.

In each producing country, there is still room for the creation of one or more coconut Eco museums, which would make the coconut palm and its products better known. According to the concept developed by R. Bourdeix, these Eco museums could house a mini-collection of dwarf coconut palms, helping to conserve the diversity of the species. these museums could combine galleries of ancient, artisanal and artistic objects, sales of seednuts and tendernuts to drink, a store and a restaurant dedicated to all kinds of coconut products. Since the 2000s, the coconut palm sector has been expanding rapidly. However, we believe that this is still only the beginning, and that the economic valuation of the coconut palm and its products will increase considerably over the coming decades.

**Mr Uron Neil Salum,**

Former Executive Director and founder of the International Coconut Community, established under UN-ESCAP & Current Strategic Adviser of the Coconut Industry in Papua New Guinea.

# EPIGRAPHS

***'It is not certain that everything is uncertain.'***

Blaise Pascal (1623- 1662).

***'We risk as much to believe too much than to believe too little.'***

Denis Diderot (1713– 1784).

***'The two great risks are risking too much but also risking too little.'***

Jimmy Chin.

***'Just because you shout: "Beware the wolf!" doesn't mean you won't risk being eaten!'***

Noël Mamère.

***'People who don't take risks generally make about two big mistakes a year. People who do take risks generally make about two big mistakes a year.'***

Peter F. Drucker (1909- 2005).

***'The most elaborate hypothesis cannot prevail over the most wobbly reality.'***

Frédéric Dard (1921- 2000).

# CONTENTS

# SUMMARY

The Coconut Industry Development for the Pacific (CIDP) Project is a joint initiative of the Pacific Community (SPC), European Union (EU) and the African, Caribbean and Pacific Group of States (ACP). CIDP aims to bolster the coconut sector in the region by improving the competitiveness of small producers, and strengthening production and regional integration of related markets. In the framework of this project, French Agricultural Research for Development (CIRAD) led and assisted with the design of improved seed production systems and developed a risk analysis for the coconut value chain. In June 2018, CIRAD launched an online survey on incentives and risks by contacting more than one thousand coconut stakeholders worldwide. The initial results of this survey and meeting output were presented at the 2018 COCOTECH conference, where the risk analysis study was also launched. A meeting was conducted in December 2018 in Fiji, both to train participants in risk mitigation and to improve this manual. Each individual risk assessment is authored by two to five experts and/or participants in the training session. The 40 risks presented in this document cover a wide diversity of themes and recommendations. They are organized in eight sections which explore the following themes: climate change and hazards; pests and diseases; planting material; agricultural practices; organizational and policy issues; post-harvest and processing; economics and marketing, and socio-cultural habits. The introduction to each of these eight sections provides generic perspectives addressing coconut development for the Pacific region. Each risk is first briefly described; then its occurrence and severity are examined, and the issues associated with its mitigation and adaptation are discussed. Finally, actions to undertake are proposed, and a short bibliography gives key information sources. In total, contributors to this manual included 52 experts from 26 countries, of which 19 are located in Oceania, and seven are located in Africa, Asia, and Europe.

# 1. INTRODUCTION

## A. CONTEXT OF COCONUT AGRICULTURE IN THE PACIFIC REGION

*By R. Bourdeix, E. Tamasese, and N. Tuivavalagi*

The coconut industry in the Pacific is one of the foundations of commercial agricultural crops that came into the region with colonialism. It quickly became a major export and dominated the Pacific Island economies up to the 1980s.

In the mid-1980s, the price of coconut oil dropped significantly, causing many producers to discontinue production and diversify to other crops or industries. A contributing factor to the collapse in demand for coconut and coconut products was the potentially flawed assumption that the product's saturated fat[6] content was a contributor to heart disease. However, later scientific studies that showed the health benefits of coconut oil led to changing dietary trends and a change in perception of coconut oil and saturated fats in general. In the early 2000s, demand for virgin organic coconut oil began to significantly increase the production of coconut oil as an edible product.

This event has led to the growing demand for coconut oils and coconut products in general, elevating prices to once again make the coconut a viable investment as a commercial agricultural commodity.

Coconut agriculture is now a two-speed economic phenomenon. Some countries, such as Brazil, India, and Thailand, have started to apply advanced intensive cultivation methods on Dwarf and Hybrids cultivars. For instance, Brazilian farmers often use irrigation, fertigation and high-level mineral fertilization (up to 7 kg/palm/year), together with a leguminous cover crop to fix nitrogen. These farmers often obtain very high yields. Small farmers regularly reach 250 tendernuts/palm/year by using the Brazilian Green Dwarf variety with a planting density of 222 palms per hectare. Many plantations reach 180 mature nuts/palm/year with Dwarf x Tall hybrids, at a density of 180 palms/ha. In these countries, coconut cultivation has become a very profitable business. Some private companies are now investing in the production of advanced planting materials for farmers. In India, for instance, hybrid seedlings are often sold by private companies for more than 5 USD each, and farmers queue to buy and obtain this elite planting material. The cultivation methods applied in these countries are generally neither organic nor environmentally friendly. Much of this activity aimed to increase production due to limited supply of material for the processing stage of the value chain.

The Pacific, however, has a significantly underdeveloped processing sector. Due to this, and despite increasing prices and demand, millions of coconuts are left unharvested on the ground. For example, from the estimated 84 million coconuts per annum produced in Samoa in 2018, only 10% of those are exported after processing. Coconut is also widely self-consumed

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[6] Coconut's fatty-acid profile is dominated by medium-chain triglycerides, especially Lauric Acid (49%), which does not confer the same health risks as longer chain saturated fatty acids. For further information, see risk description n°40.

and used to feed animals. Based on the current going rate for coconuts (approximately 11 cents USD per nut), about 9 million USD per year worth of coconuts are left on the ground.

Some countries, many of them from the Pacific region, continue to plant traditional varieties selected in a very basic manner. Their national average yield is sometimes no more than 40 coconuts per palm per year. The palms are cultivated in a way said to be 'organic', but in most cases, nutrients are generally not available to the palms, which rely only on 'mother nature'. Cover cropping is not practiced. Thus, to reach the production of one hectare as in Brazil, Pacific farmers would need to plant and manage more than four hectares. As most of the work is manual, and with no cover crop installed, farmers injure themselves by weeding very fast-growing wild plants**.** Farmers often abandon the maintenance of their coconut groves: in some countries, up to 30% of the coconuts rot in the bush, no longer being harvested. It would appear from the Samoan example that a significant focus needs to be directed to the reasons for the inability to harvest the yields from the existing plantations, rather than only increase yields from the field.

Experts and economists call for a change in agronomic and commercial practices, in order to enter the large and promising market linked to a modern and globalized coconut industry. But local and regional markets also exist, relying on specific demand and needs, and generate specific risks. In addition, the economic functions of Pacific coconut cultivation and production are embedded in environmental, social, and cultural functions. Depending on the functions considered, the nature of the risks to consider may be common (phytosanitary threats and climatic hazards for instance) or differ; price ruptures or commercial risks are crucial from the industry perspective, and intra-familial or community disputes are part of the 'social' risks.

Sometimes, of course, economic and social functions are linked. For instance, it seems that there is a great willingness of institutional actors to increasingly move towards organic agriculture, to secure the market for Pacific countries. Is this willingness shared by farmers? Are the risks associated with this strategy, from a stronger exposure to markets' instabilities to possible tensions within the communities, if one farmer begins to sell a lot on the international markets?

Another major focus area is assessing the risks that led to the decline of the industry in the 1980s. What were the factors that led to the collapse of a multi-million dollar industry? What interventions or strategies can be implemented to ensure such a collapse can be avoided in the future?

## B. A BRIEF OVERVIEW OF VALUE CHAINS AND STAKEHOLDERS

*By J. Lin and R. K. Myazoe*

The coconut palm is a versatile crop from which a wide variety of products can be prepared or manufactured. The entire nut from the husk, shell, kernel to the water can be used for various products. The value chain is split into multiple levels of processing and for different end products and markets.

Plate 1 provides a graphic overview of the coconut value chain. First, all products are derived from raw coconut materials. In order to produce quality coconuts, additional inputs in breeding, planting, and cultivation are crucial. Since coconut is a perennial crop, it can be harvested all year round, though cyclone season can often threaten the supply of coconuts. In Pacific Island countries, fallen coconuts are collected. This method makes the supply of coconuts inconsistent and unpredictable.

Coconuts at different age levels are used for different purposes. Young coconuts at around seven months after flowering are used to produce coconut water. At around 12 months after flowering, mature coconuts are used for producing coconut oil, desiccated coconuts, and coconut milk/cream.

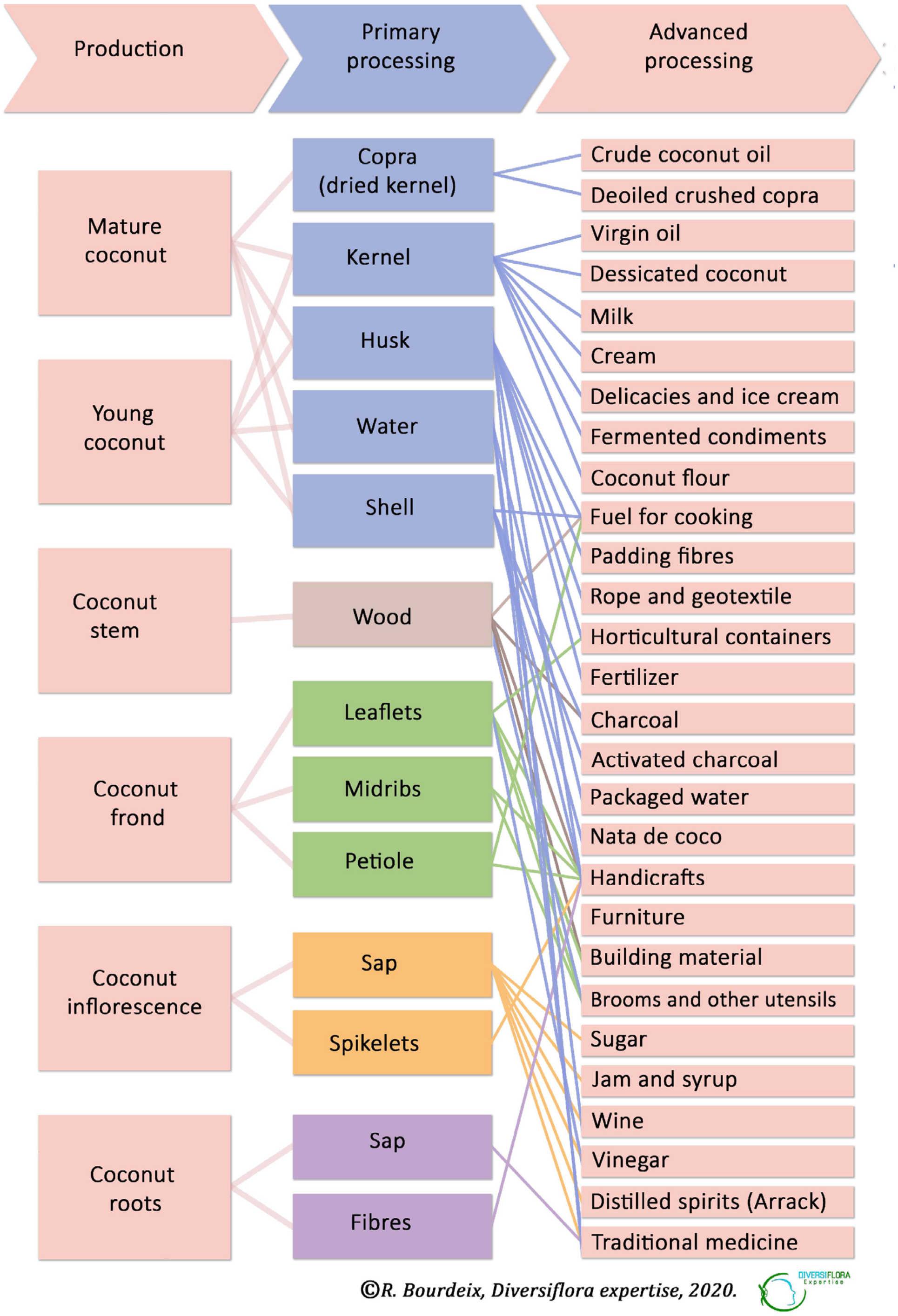


**Plate 1.** Diagram of the coconut value chain showing production, primary and advanced processing activities.

The first level of mature coconut processing involves sorting, dehusking, removing fresh kernels, and drying the kernel into copra. This often is done as an additional on-farm value addition activity by farmers who also collect the coconuts. By-products that emerge from this level of processing are coconut husks, which can be transformed into coir, which can be made into mats, mattresses, hats, etc. and coconut shells, which are often used for handicrafts and charcoal manufacture (including treatment to produce activated charcoal).

The next step comprises further processing copra into crude coconut oil. In the Pacific Islands, farmers transport dehusked coconuts and/or copra to oil millers. Millers or factories press the oil on a larger scale. Plate 2 schematizes the main players in the coconut oil sector in the Pacific region.

Advanced processing of fresh kernels transforms coconuts into virgin coconut oil (VCO), desiccated coconuts, coconut milk and cream, and other products. VCO is processed either on a larger scale in factories, or increasingly commonly, the production of oil at a household level, by hand or with the standard, inexpensive micro-expeller.

The water of young green coconuts is often consumed straight, or after a slight processing which usually involves removing some or all of the husk. Their water is also retrieved for bottling. Then it can be processed and packaged into tetra packs or cans in factories. This level of processing is currently not being done in the Pacific countries because of the high level of capital investment and the need for a consistent supply of quality coconuts.

The sap from coconut flowers can be further processed into coconut sugar, jam, syrup, vinegar, wine and other alcoholic beverage. This requires knowledge on how to tap the sap and for more advanced processing. Currently, there is very little coconut sugar being produced in the Pacific Islands (in Kiribati and Tuvalu), outside of personal or community use. Some countries are transforming senile coconut palms into coconut timber. The logs are sometimes burned as fuel. The timber is used as basic material for construction, or further transformed for manufacture of parquetry, handicrafts, or high-end furniture.

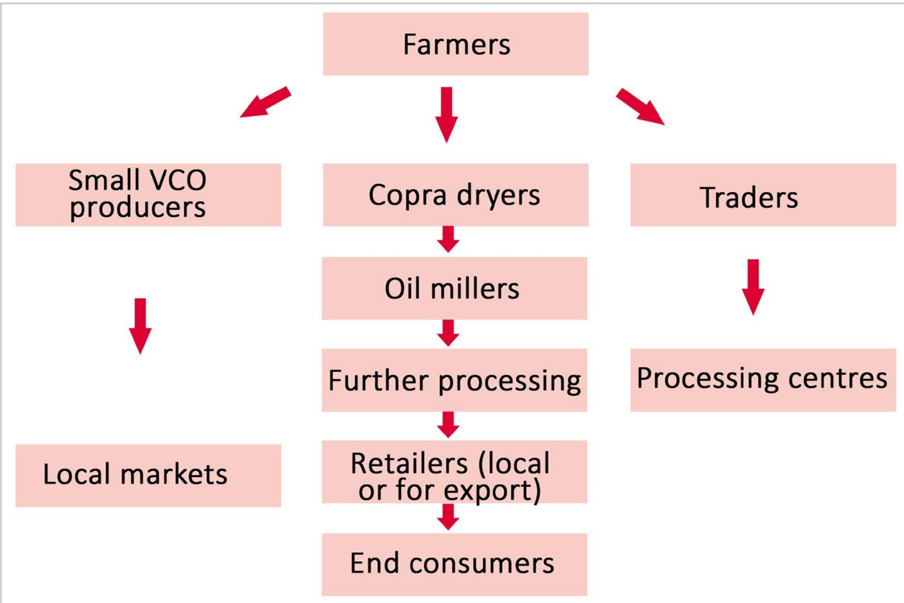


**Plate 2.** Some players in the coconut oil sector.

# C. ABOUT THE NOTIONS OF RISK AND RISK ANALYSIS

*By J. M. Sourisseau and R. Bourdeix*

Conceptually speaking, the notion of risk is based on an unrealized event with a non-zero probability of happening and negatively impacting the activities. A risk becomes proven when it has negatively impacted activities at least once. The negative character of an event, as well as the concept of hazard, depends on cultural habits: risk is in that sense a social and individual construct. This study concerns many island states with very diverse status, and a long tradition in coconut production, where some events or situations have already occurred, with negative impacts on the coconut sector. Therefore, as in many cases of risks analysis in agriculture, we will also consider events already experienced.

Risk results from the combination of four elements of a different nature: a *danger*, its *probability*, its *gravity* and its *acceptability* (Jacquiot, 2010).

The word 'risk' belongs to the vocabulary of everyday life: 'who risks nothing will have nothing'. Most risks result from a possible change in the environment or our relationswith it, which makes inadequate the strategiesdeveloped to reach our objectives, or evenwhich puts these objectives out of reach. Since1921, researchers have distinguished two situations that apply when the future is risky or haphazard: 1) it is possible to calculate or estimate the probability of a negative event occurring, and 2) it is not possible to estimate such probability. In the second case, the stakeholder has to face uncertainty.

These first definitions and warnings suggestadaptations to the agricultural sector. According to Cordier et. al. (2008), there are currently five categories of risk for the farm business, ranked according to the origin of hazards:

1. Climate and plant health risk affects agricultural yield and product quality;
2. Market risk related to price fluctuations of finished products and those of inputs;
3. Institutional risk generated by policy or regulatory changes that affect agriculture;
4. Financial risk related to changes in interest rates and exchange rates that also includes the risk of non-payment and liquidity risk;
5. Human health (sickness, death) and occupational (theft, degradation, destruction of production tools), common to all economic activities.

The specific consequences of risks to the farm business are based on the four essential and interconnected variables of agriculture performances: 1) market value of the production (sales revenue); 2) agricultural yield (quantity produced); 3) the quality produced and; 4) the cost of production. The farmer seeks to manage these variables for the intermediate purpose of controlling the turnover and margin generated by agricultural production. Depending on their integration to market, the farmer's ultimate goals are to feed the family (and beyond the community), and/or to generate a positive economic income from their professional activity.

Farmers' responses depend on how they perceive risks. A few simple characteristics allow classification of agricultural risks:

- The origin of the risk: spontaneous (natural) or induced by people;
- Frequency of appearance;
- Intensity, which is reflected in the magnitude of the damage it causes;
- Type of prevention possible: some risks can be eliminated or mitigated, others can be avoided (or circumvented), others we can only adapt to (or prepare for);
- Level at which an action can be organized: distinguishing the risks that call for a response at the farm level, from those that require the establishment of a collective struggle system.

For managing its plantations, the farmer makes two types of decisions: strategic decisions and tactical decisions. The strategic decisions concern the organization of the plantation, the distribution of species and cultivation systems on and possibly between plots, the choice of varieties, how the crops will be transported and sold, all this to achieve an economic objective. The farmer makes these strategic decisions based on their accumulated experience, those of the relatives, and the available technical information.

During the growing and fruiting period, the farmer reasons tactical decisions based on changes, accidents, opportunities and agricultural work progress. They can, for example, respond to a specific drought by irrigating, respond to parasite attacks by phytosanitary treatments or biological control, or even market fresh nuts instead of mature nuts, because this market has become more profitable.

Some of the risks initially seen as relevant were finally removed from the analysis. Even if some phenomenons strongly jeopardize the coconut sector, they cannot be considered risks because they already occur in most situations. For instance, a significant constraint is the low numbers, volume, and efficiency of coconut breeding programs in the Pacific region; but this cannot be listed as a risk, as it is already occurring in most Pacific countries except perhaps Vanuatu and Fiji. The lack of sufficient and regular national funding of coconut research is another example of risk that was removed, as this situation occurs in many countries of the Pacific region.

Along the value chains, the same five categories of risks are still valid, even if climate and plant health risk relate much more to the production and some specific processing segment of the chain. By analogy to the finance and insurance sector, a risk can be independent or systemic. A systemic risk is defined as a risk that can affect many people simultaneously. A dynamic notion completes this definition, a systemic risk is therefore 'a trigger event, such as an economic shock or institutional failure, that causes a chain of bad economic consequences—sometimes referred to as a domino effect'. In agriculture, systemic risk concerns the three first categories of risk described above (climate and sanitary, institutional, and prices). In contrast, human and occupational risks are mostly independent, affecting only one farm.

Working on incentives and risk analysis are two complementary tasks. Indeed, if the risks linked to a value chain are well assessed and prioritized, it will help to identify the most efficient incentives to mitigate the most important risks.

Risk management may address both the limitation ofthe occurrence of the undesirable event (prevention), and the reparation of the consequences of the adverse unpredictable event. Prevention depends on the nature of the risk and may rely on a wide range of solutions including a combination of those. For example, financial policies can prevent price ruptures and protect the sellers, or chemical applications combined with adapted cultivation techniques can prevent parasite attacks. Still no prevention is available for an extreme climate event. Regarding reparation, insurance can *a priori* solve most of the bad consequences of an unexpected event. But the cost may be prohibitive for fixing a decent price to insurance.

Another challenge is to analyse the possible combination of risks of different nature. The explanation may be highly complex, and a generic and systematic formalization of such a combination is most of the time impossible. For this reason, insurance is hardly a solution for systemic risk related to a domino effect and when damages result from a combination of threats.

Along the value chain, the possibilities for prevention and reparation for the different stakeholders differ; the risk exposure is typically higher for producers because they have fewer options for both risk management types.

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# 2. METHODOLOGY USED FOR BUILDING THE RISK ANALYSIS

*By R. Bourdeix, J. M. Sourisseau, N. Hussein and J. Lin*

## A. SUCCESSIVE STEPS FOR BUILDING THE RISK ANALYSIS

Table 1 (next page) presents the successive steps to build the risk analysis and their level of achievement. Details regarding the participation of other experts in the description of risks are also given in the individual risk description sections.

Although the experts compiling this analysis have a good knowledge and a wide view of coconut value chain, there are not specialists in all the scientific fields required for the implementation of this sequential risk analysis.

Interaction with other experts involved in the CIDP project was necessary to strengthen the scientific accuracy of this risk analysis. We initiated contact with all experts in charge of other CIDP components. Most of them agreed to contribute to this manual voluntarily, and we thank them very much for their support. Their names appear under the heading of each section and in the list of contributors presented in Annex A of this document.

## B. THE ONLINE SHORT SURVEY ON RISKS AND INCENTIVES

The online survey was drafted and sent for review to about 10 researchers from CIRAD, Bioversity and SPC. We analysed their replies. Many colleagues favoured extending the questionnaire with additional questions, but we did not choose this option. It seemed preferable to propose a concise questionnaire, and then eventually ask for more information and more participation from those who provided significant answers.

The final survey contained only five questions, available in English, French, and Spanish languages:

1. In your opinion, what are the main risks or constraints in coconut cropping and value-chain? Please cite three and classify them by priority order
2. In your opinion, what could be the most efficient incentives to boost the coconut sector? These incentives can be designed for farmers or any other stakeholders of the coconut value chain. Please cite three and classify them by priority order.
3. In which country are you living?
4. Are you: a farmer, a tropical gardener or landscaper, a local coconut reseller, an agricultural officer, a researcher, a policy maker, a coconut consumer, a craftsman processing coconut, from a small company selling coconut product, from a large one, from a company selling coconut processing equipment, or other?

Your email (optional). It will allow our team to contact you, and you will receive the results of this survey.


" PREPARING FOR UNKNOWN RISKS!"

**Table 1.** Fourteen steps to build
the risk assessment for coconut value chain.

| | Steps | Dates |
|---|---|---|
| 1 | Tender preparation | January 2018 |
| 2 | Online survey on risk and incentives, transmitted by email, Facebook and LinkedIn | June 2018 |
| 3 | Defining a template for analysis of each identified risk. Each individual risk assessment is authored to acknowledge the contribution of external experts | July 2018 |
| 4 | Brainstorming with Jean Michel Sourisseau | August 2018 |
| 5 | Interactions with stakeholders during APCC Cocotech and COGENT meetings in August 2018, presentation of a lecture on incentives | August 2018 |
| 6 | Releasing the inception report and getting advice from CIDP. Categorizing risk in coconut value chain | September 2018 |
| 7 | Fields surveys in Fiji, Tonga, Dominican Republic, and Thailand | August - December 2018 |
| 8 | Third brainstorming incorporating field visit and results of the online survey with Jessie Lin and CIDP staff | December 2018 |
| 9 | Seeking volunteer experts interested in participating (from those who completed the online survey and other stakeholders including CIDP staff). Writing descriptive information associated with each risk | October- December 2018 |
| 10 | Organizing the training course in Nadi, Fiji, and incorporating the opinions and contributions of participants: Two risks added, 10 risks titles reworded, and editing of the text | 11- 14 December 2018 |
| 11 | Second full draft version | 22 December 2018 |
| 12 | Integrating last comments and checking | January 2019 |
| 13 | Release of the final version of the manual | February 2019 |
| 14 | Proofreading, layout and publication of the manual | October 2021 |

The survey presentation and links were included as **a new publication** in the website 'http://replantcoconut.blogspot.com'; to encourage stakeholders to visit the website and boost its audience. We proposed two methods of reply, directly **online via Kobotoolbox**, or by filling an MS **Word version of the questionnaire** and sending it to a dedicated email address (cidp.prag08@gmail.com).

We first composed emails from the expert's list of contacts, from the APCC Directory of Coconut Traders and Equipment Manufacturers and from the COGENT network. From these sources, we created a mailing list containing about 2400 email addresses.

A first message asking stakeholders to reply to the survey was sent via the Google group on 20 June 2018. Then advertisement about the survey was done on LinkedIn (free, using dedicated groups) and Facebook (for a five-day duration and a budget of 50 Euros). On Facebook, the targeted audience was people living in 20 coconut-producing countries and who were interested in agriculture and/or coconut. The same information was sent via the email mailing list on 16 July 2018. We had a reply indicating that the website could not be accessed, so we resent the questionnaire as a MS Word file attached to the email. This was done via the coconut Google group on 31 July 2018.

The results of the survey are presented in Annex B.

## C. THE DOMAR TEMPLATE FOR RISK ANALYSIS

The authorship of individual risk assessments is intended to acknowledge the contribution of external experts and participants in the training session. One of the editors of this manual used a similar participative methodology when compiling the 2018 - 2028 Global Strategy for Conservation and Use of Coconut Genetic Resources organization for the COGENT network. In this document, each section is authored by two to five contributors. Annex A gives the list of all authors involved, their contact details and their institutions.

The first risk description to be written was titled 'Cyclones, tropical storms and tsunamis'. This text served as a reference and example. Each risk description followed the same DOMAR template, and included the following information:

- The risk category: for example, 'Climate change and hazards'.
- The risk name: for example, 'Cyclones, tropical storms and tsunamis".
- The contributors: by R. Bourdeix, T. Sileye, U. Remudu and O. Smus.
- **D**: Description.
- **O**: Occurrence and severity.
- **M**: Mitigation and adaptation.
- **A**: Actions to undertake.
- **R**: References.

# 3. THE FORTY RISKS IDENTIFIED AND THEIR CATEGORIZATION

*By R. Bourdeix, J. M. Sourisseau and J. Lin*

Forty different risks were identified and are listed in Table 2 (next page). Some are rather specific to coconut cultivation, while others are part of a broader approach to agricultural risks. This list has evolved during the research, in interaction with many stakeholders. In the beginning, some socio-economic topics were missing, such as financing and access to credit for farmers, issues related to fair trade and organics, etc. A notation of risk level and gravity from 1 (Low) to 3 (High) is proposed, in accordance with the online survey and the exchanges conducted during the meeting held in December 2018 in Fiji.

During the CIDP meeting held in Nadi, from 11 - 14 December 2018, the participants agreed to add two more risk descriptions and to reword the titles of 10 more descriptions.

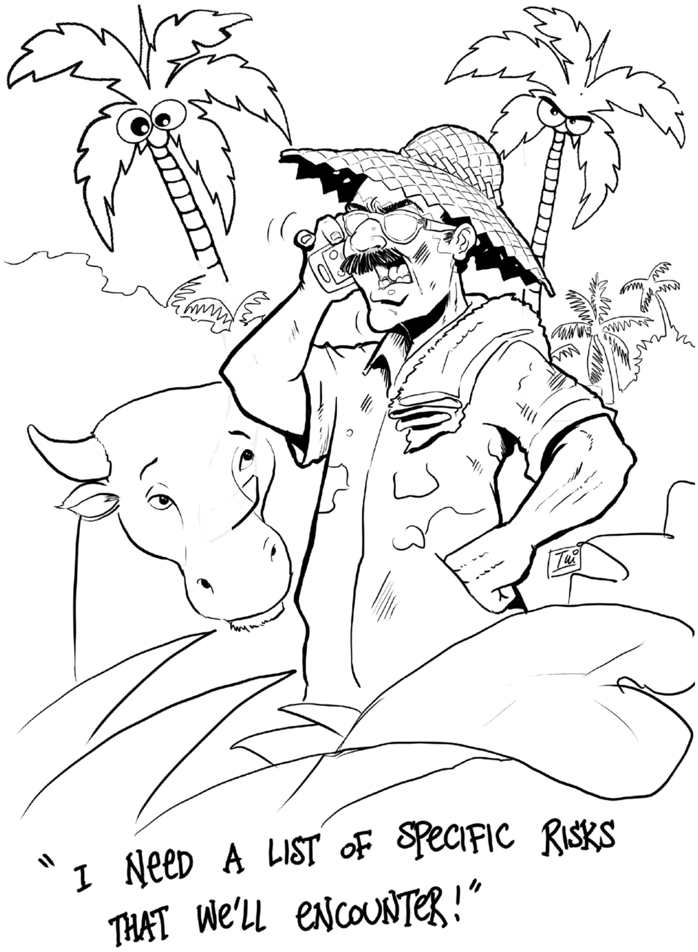

**Table 2.** Categorizing the risks in coconut value chain.

| | Risk | Risk level | Gravity |
|---|---|---|---|
| A | Climate change and hazards | | |
| 1 | Cyclones, tropical storms and tsunamis | 1 | 1 |
| 2 | Drought | 2 | 2 |
| 3 | Flooding, king tides and landslides | 2 | 1 |
| 4 | Temperature and other climate hazards | 3 | 3 |
| B | Pests and diseases | | |
| 5 | Phytoplasmas | 3 | 1 |
| 6 | Viral diseases | 3 | 2 |
| 7 | Oryctes rhinoceros beetle | 1 | 1 |
| 8 | Mites (Aceria guerreronis) | 3 | 2 |
| 9 | Other pests (large animals) | 3 | 3 |
| 10 | Pests and diseases in nurseries | 1 | 1 |
| 11 | International transmission of pests and diseases | 2 | 1 |
| C | Planting material | | |
| 12 | Efficient and diversified planting material | 1 | 1 |
| 13 | Methods for selecting parent palms | 2 | 2 |
| 14 | Traditional varieties | 1 | 2 |
| 15 | Certified organic planting material | 3 | 3 |
| D | Agricultural practices | | |
| 16 | Farming techniques | 2 | 2 |
| 17 | Traditional agricultural knowledge and practices | 2 | 2 |
| 18 | Cover cropping and availability of seeds and cuttings | 2 | 1 |
| 19 | Organic fertilizers | 2 | 3 |
| 20 | Manpower in coconut agriculture and factories | 1 | 2 |

| | Risk (continued) | Risk level | Gravity |
|---|---|---|---|
| E | Organizational and policy issues | | |
| 21 | Investment in coconut research and replanting | **2** | **1** |
| 22 | Regulation on the quality of coconut products | **3** | **2** |
| 23 | Replanting projects and relevant beneficiaries | **1** | **1** |
| 24 | Farmer's organizations | **2** | **3** |
| 25 | Shift to other crops or other forms of land use | **1** | **1** |
| 26 | Making decisions with little information | **1** | **1** |
| F | Post-harvest and processing | | |
| 27 | Harvest and post-harvest handling | **3** | **2** |
| 28 | Aflatoxins, bacteria and chemicals | **2** | **2** |
| 29 | Palatability and practicality of coconut products | **3** | **2** |
| G | Economics and marketing | | |
| 30 | Purchasing price of coconut products | **1** | **1** |
| 31 | Finance and insurance for coconut business | **2** | **2** |
| 32 | The profitable business of aromatic coconut water | **2** | **1** |
| 33 | Cost of organic and fair trade certification | **2** | **3** |
| 34 | Trading accessibility in remote farms or islands | **2** | **3** |
| 35 | Supply of coconut to factories | **3** | **3** |
| H | Socio-cultural habits | | |
| 36 | Stakeholders' beliefs about coconut | **1** | **2** |
| 37 | Reliable information about farming and technology | **2** | **2** |
| 38 | Dietary habits in the Pacific region | **2** | **2** |
| 39 | Adoption of agricultural innovations | **3** | **2** |
| 40 | Consumer interest in coconut products | **3** | **3** |


COULD YOU BRING IN THAT LIST OF RISK FACTORS YOU DOWNLOADED YESTERDAY?
IT'S STILL DOWNLOADING.
INVESTOR

# 4. THE FORTY RISKS ANALYSIS IN A SEQUENTIAL APPROACH

This section is the heart of the project and its main output. It contains descriptions of all identified risks, mobilizing the conceptual and methodological framework defined above. The texts are limited in length (three pages) and authored by 52 specialists or stakeholders who agreed to participate voluntarily.

## A. RISKS LINKED TO CLIMATE CHANGE AND HAZARDS

*By R. Bourdeix, M. Ghanem, U. Vave*

The coconut industry is facing unprecedented threats due to climate change. A main challenge is to sustainably intensify coconut production in Pacific Island Countries and Territories (PICTs) while improving resilience and reducing vulnerability to the impacts of climate change. The consequences of extreme climatic events are devastating for millions of people worldwide as they become increasingly common, more severe, and less predictable. But with the right information and proper planning, it is possible to significantly reduce the related risks and impacts.

The finding that strategies and projects addressing community-based disaster risk reduction (DRR) and climate change adaptation (CCA) often duplicate each other has led some practitioners to develop the concept of integrated disaster risk management (DRM). There is a strong push to integrate the two fields - DRR and CCA - to enhance aid effectiveness and reduce confusion for targeted communities.

Globally, around 180,000 islands enclose a fifth of the world's biodiversity and certainly more than 50% of coconut diversity; coastal zones include at least two-thirds of coconut plantations and most of the coconut growing countries are islands (NareshKumar et al., 2018).

A recent risk assessment estimated that Pacific island countries together suffer 284 million USD (or nearly 2% in regional GDP) in economic losses from natural disasters annually. As shown in Plate 3 (next page) Water - related disasters are the most common and frequent natural hazards constituting 90% of the total disasters in the world.

Cyclones, tropical storms, and tsunamis destroy coconut palms or strongly reduce the yields during at least one year. They can introduce or favour the expansion of new pests and epidemics of human, animal and crop disease. They may also cause trauma from extreme weather events, compromised safety and security of water and food, psychosocial ill-health, population pressures, and health system deficiencies.

Climate change is a major cause of increased floods in some areas and water scarcity and droughts in others. Droughts caused by El Niño/Southern Oscillation (ENSO) episodes were reported in 1978, 1983, 1987, 1992, 1997 - 98, 2001, and 2003. Some stations recorded precipitation drops of up to 87% in the western Pacific, while resulting in unusually high rainfall in the central Pacific.

ReliefWeb is the leading humanitarian information source for global crises and disasters. It is a specialized digital service of the UN Office for the Coordination of Humanitarian Affairs (OCHA). The website provides reliable and timely information, enabling humanitarian workers to make informed decisions and plan effective response. They collect and deliver key information, including the latest reports, maps and infographics from trusted sources. Much information available on the website may be helpful for agricultural purposes.

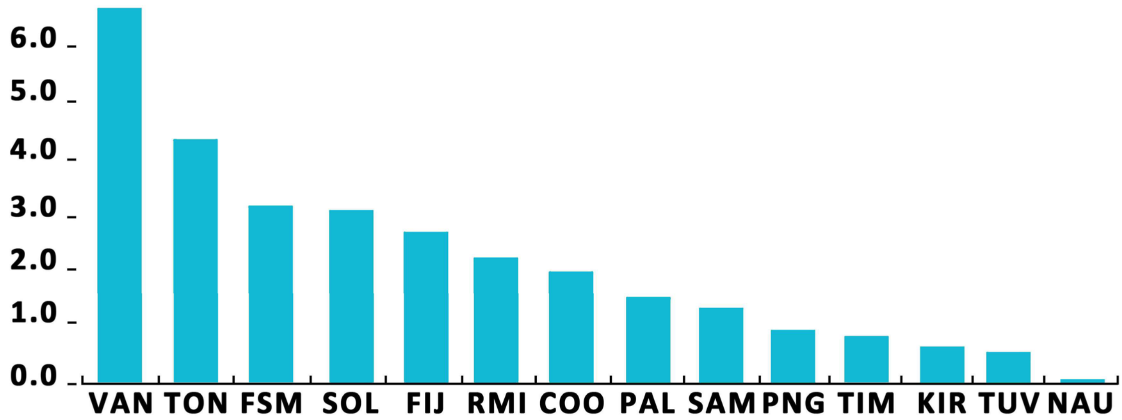


**Plate 3.** Estimated Annual Average Loss Due to Natural Disasters (% of gross domestic product), for the following countries: COO = Cook Islands, FIJ = Fiji, FSAA = Federated States of Micronesia, KI R = Kiribati, PAL = Palau, PNG = Papua New Guinea, RMI = Marshall Islands, SAM = Samoa, SOL = Solomon Islands, TIM =Timor-Leste, TON = Tonga, TUV = Tuvalu, VAN = Vanuatu. Source: Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI), Catastrophe Risk Assessment Methodology, 2013.

A Flood and Drought portal was developed as part of the Flood and Drought Management Tools project funded by the Global Environment Facility (GEF) through the United Nations Environment Programme (UNEP). It responds to a specific need for improved capacity of managers operating in transboundary river basins to recognise and address the implications of changing climatic scenarios and land use on water resource management (see Table 3 next page). Even if such transboundary river basins are rare in the Pacific, it would be useful to develop a similar participative global approach adapted to the Pacific region.

Big Data is expected to have a significant impact on farming and involves the whole supply chain. Smart sensors and devices produce large amounts of data that may provide unprecedented decision-making capabilities. Big Data may cause major shifts in roles and power relations among different players in current food supply chain networks, and not necessary to the advantage of small farmers. It may unravel a continuum of two extreme scenarios: 1) closed, proprietary systems in which the farmer is part of – and highly dependent on an integrated food supply chain; or 2) open, collaborative participatory systems in which the farmer and every other stakeholder in the chain network is flexible in choosing business partners for the technology as well for the food production side.

**Table 3.** Observed and projected changes in the climate of the Pacific region (From Australian Bureau of Meteorology and CSIRO, 2014).

| Variable | Observed Change | Projected Change |
|---|---|---|
| Atmospheric Temperature | Increase of 0.18 °C since 1961 | Increase of 0.5– 1.0 °C and 2.0– 4.0 °C for 2030 and 2090, respectively, under very high emissions scenario |
| Rainfall | SW and NW Pacific – wetter; Central Pacific – drier over past 30 years | Increase in average annual rainfall; fewer droughts; extreme rainfall events will be more common |
| Sea Level | Variable across the region | Increase of 26– 55 cm by 2081 – 2100 relative to 1986 – 2005 (RCP2.6) Increase of 45– 82 cm (RCP8.5) |
| Cyclones | Decrease in total number of cyclones | Less frequent but more severe cyclones |

Ideally, farmers should have interactive maps that can be easily accessed for information on average risks and more timely forecasts, such as for the next three months or the next 24 hours. The farmer would obtain, for their plot, the average probability over the year of experiencing a cyclone or flood, and these probabilities for the three-month or 24-hour periods, considering the meteorological situation at the moment of their request. The ReliefWeb site already offers maps, but they do not have this degree of precision and are rather focussed on events that have already occurred than on the forecasts in the long and short terms.

In many Pacific countries, lack of capacity to address climate change and natural disaster risks remains a central constraint. Building a robust understanding of available tools and resources is essential for planning and responding to future impacts and disaster events. Since 2016, the Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI) has provided Pacific Island states with insurance against tropical cyclones, earthquakes and tsunamis. Vanuatu, Tonga, Marshall Islands, Samoa and Cook Islands were the first policy holders to join PCRAFI in 2016. The World Bank has announced the start of the fifth round, along with the recent establishment of a new Cook Islands-based insurance company, called the PCRAFI Facility, which will deliver this innovative and competitive insurance. It secures Pacific Island countries with a total coverage of 38.2 million USD against tropical cyclones, earthquakes, and tsunamis. World Bank Treasury played an integral role in securing participating Pacific Island countries competitive rates from the international reinsurance market.

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**Plate 4.** Coconut palms in Tuvalu, in the part of a motu most affected by tides and wind. They help in the fight against marine erosion.

## 1. CYCLONES, TROPICAL STORMS AND TSUNAMIS

*By R. Bourdeix, T. Sileye, U. Remudu and O. Smus*

### Description

The risk is for coconut palms to be destroyed, uprooted or broken at the level of the stem by winds or tsunami waters. Cyclones and similar events may cause sharp drops in production even if the damaged coconut trees survive. New diseases or outbreaks of insect pests may follow, brought by the winds or resulting from the poor sanitary conditions induced by a cyclone.

#### Occurrence and severity

Cyclones are occurring, more or less frequently, in most coconut producing Pacific countries. For instance, in the 1990s, extreme weather cost the Pacific region more than 1 billion USD (Asian Development Bank, 2013). Nevertheless, we do not know the real risk for a particular coconut palm to be destroyed by a cyclone (probability per time unit according to countries). From an economic and agricultural point of view, it seems that the damages and loss of production induced by cyclones are more important than the killing of palms, often occurring only close to the cyclone eye.

On Taveuni Island (Fiji) farmers estimate that a category five cyclone hitting their farms cause the loss of about 1.5 to 2 years of production. Such a cyclone is said to occur once every five years, but it generally does not affect all farms in the same way. In the past, the famines resulting from the destruction of harvests could be deadlier than the cyclone itself, because of the island's isolation. Islanders resorted to food of famine.

The way coconut palms are destroyed seems to depend on the nature of the soil: broken stems in rocky and compact soils, uprooting in sandy and soft soils. A new coconut disease seems to have been recently introduced in Fiji following a cyclone (V. Kumar, personal communication, 2018).

Such climate disasters can threaten human and animal lives. One of the worst coconut-related stories was recorded in 1878 on the Kaukura atoll in the Tuamotus, French Polynesia. Copra harvesters were surprised by the storm during the seasonal occupation of a motu. The cyclone killed 117 people.

#### Mitigation and adaptation

- Be aware of and stay continuously informed by the national weather services launching cyclonic and tsunami alerts. Take precautions so that people, animals, vehicles and equipment are as safe as possible when a storm comes. Plans must be already thought out and fully prepared before disruptions. It is safer not to plan to harvest coconut on unpopulated remote islands during cyclone season.
- Manage the plantation so that all the palms are not the same age and be from different varieties. Plant other crops between the palms. If something occurs, such diversity may protect farmers. All palms and crops will not be affected in the same way. Share observations with other farmers and scientists.

- Use coconut varieties tolerant to cyclones. This includes some Tall types, but also Compact Dwarfs and probably their hybrids. There is a need to develop public and/or private coconut breeding programs integrating Compact Dwarf types in crosses and field experiments. Farmers can also produce such varieties and hybrids by themselves. Do not plant Tall-types coconut palms near houses in places where they can damage roofs and vehicles; instead plant slow-growing Dwarfs or Compact Dwarfs.
- Test new planting arrangements where coconut trees are planted in groups of three or four, with greater distances between groups allowing more intercropping. The roots of the coconut trees planted in groups mix and give the whole a greater resilience on soft soils where the risks of uprooting are higher.
- When feasible, cut the largest green leaves off the coconut palms before a cyclone occurs. This can be done with a coconut hook or sickle. It will reduce the leverage effect of the wind force and prevent the coconut tree from being broken, uprooted and damaged. This technique is not easily applicable in large plantations; it can be very useful for palms located close to houses and where vehicles are parked.
- In India, different planting depths were tested, from surface to 90 cm depth. Under cyclone conditions, in the surface, and 30 cm treatments, the percentage of palms uprooted and tilted were 10% and 5% respectively, whereas none of the palms under deeper planting treatments were affected. These results were in accordance with those reported in 1974; planting at 60 cm deep seems the best, it registered significant increase in boll size and number of roots putting forth firm anchorage, thereby enabling the palms to withstand the cyclonic storm. According to Dr Chowdalpa (personal communication), deep planting is mainly practiced on the sandy soils of the west coast of India, not on the East coast where soils are more compact.
- For economic reasons, in the event of serious damage to cash crops, the government may plan official assistance. Farmers need to find out in advance about the agricultural allowances provided in case of a cyclone in their country and try to satisfy the technical and administrative requirements for this aid. *A posteriori* analysis shows that, in the absence of these precautions, only a small percentage of farmers generally benefit from aid following a cyclone.
- Dead trunks remaining after a cyclone can induce proliferation of the *Oryctes* beetle, which can kill many other palms. These trunks need to be cut and removed. In the Philippines, the government distributed chainsaws to farmers after a giant cyclone. Palms affected by the hurricane may need special care, such as organic or chemical fertilization, to help them recover.

**Actions to undertake**

- Study the real risk of coconut palms being destroyed by cyclones and how this risk will evolve with climate change. In each country at risk, farmers must be informed about the real probability of a coconut palm being destroyed by a cyclone within a 20 year period. The experts believe that effects of cyclones are generally localized, and that this probability is less than one in a thousand. The risk of production loss is much higher and should also be more accurately evaluated.
- Field experiments of new planting designs based on palm grouping. In expert opinion, farmers should not wait for the results of the scientific studies (in at least 12 years) before starting to test and use these new designs. Some farmers have already done this in the Dominican Republic.

- In high-risk areas, set up a team to assess the effects of cyclones on agricultural production, early detection, monitoring, and mitigating the development of new pests and diseases. Satellite and aerial remote sensing can help establish a semi-automatic procedure for mapping land instability both in its static aspects (cartography of degraded zones and morpho-dynamic combinations), and its evolution (slope, river and atoll dynamics). Such methods usefully contribute to natural risk assessment.
- It should be acknowledged that the coconut palm remains the most cyclone-tolerant crop, much so that scientists recently created strong synthetic composite material, directly inspired by the molecular structure of the coconut stem.

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## 2. DROUGHT

*By R. Bourdeix, N. Tuivavalagi, M. Cook and M. Ghanem*

### Description

The risk is that severe or extended drought may greatly reduce the yield of coconut plantations, or even kill the coconut palms

Although the Pacific Ocean is by far the largest single body of water globally, water can be a scarce resource in the Pacific Islands. Some small island states in the Pacific have freshwater supply problems that are among the world's most critical. Freshwater resources are often classified as either 'conventional' or 'non-conventional'. The conventional 'naturally occurring water resources' require a relatively low level of technology: rainwater collected and stored, groundwater and surface water, and substitution of water (such as the use of coconuts during droughts). The non-conventional 'water resources involving a higher level of technology' include the use of seawater or brackish groundwater, desalination, water importation by ships or pipelines, treated wastewater, and substitution of water.

The coconut palm generally grows well where annual rainfall is between 1300 and 2500 mm or more. An average monthly precipitation of 150 mm is usually considered ideal in zones where irrigation is not practiced. A prolonged dry season lasting for up to four months may adversely affect the palms.

#### Occurrence and severity

The harvesting and storage of freshwater have numerous constraints, such as small land area, porous atoll geology, pressures of human settlements, conflicts over traditional resource rights, capacity limitations, frequent droughts and inundation by the sea during storms.

Recent droughts associated with El Niño severely impacted both high as well as low islands. They put a lot of strain on agricultural production and depleted rainfall collection supplies and the freshwater lenses and perched aquifers on many atolls in the Pacific. For example, in 1998, Federated states of Micronesia declared a national emergency because 40 atolls ran out of water; Fiji recorded one of the most severe droughts in history, and its sugar cane production declined by more than half. In recent interviews conducted on an island in Kiribati, farmers cited drought as a major cause of the drop in coconut yield.

The coconut needs about 44 months to develop from inflorescence primordia initiation through to fruit maturity. As a result, serious drought affects coconut yield not only during the drought period but also in the following three years by constraining the development of female flowers.

#### Mitigation and adaptation

During severe droughts or natural disasters small islands often rely on coconuts for drinking. Elders breed some coconut varieties specifically for water and water transportation (niu vai). Such varieties are particularly useful in small corals atolls with no fresh water. When elders wanted to colonize such an island, they first went only to plant coconut palms. Six to seven years later, when the coconuts palms start to produce drink and food, they returned to set up the island.

Farmers should manage the plantations so that not all palms are the same age, and include different palm varieties. Plant other crops between the palms. If something occurs, such diversity may protect you. All palms and crops will not be affected in the same way. Share observations with other farmers and scientists.

Apply chlorine (e.g., sodium chloride in the form of sea salt) if the plantation is located more than 500 m from the sea. Whilst chlorine is generally abundant near the coast, there are many sub-coastal and inland areas where the leaching action of intense rainfall has reduced chlorine availability to the point where it limits coconut growth. Chlorine regulates water balance by controlling stomatal closure and improving osmoregulation capacity under water stress. In India and Sri Lanka, when plantations are far from the sea, planters apply sea salt in coconut groves and when planting a new seedling. Such salt application improves the development of inflorescence, the number of female flowers and nut yield.



**Plate 5.** Coconut palms dying from drought in Marquesas Islands.

Use drip irrigation. About 80% of the world's irrigated area is under surface irrigation methods, which have a use efficiency of 30- 50% only. Drip irrigation was introduced in the early 1970s and its use for coconut cultivation has strongly increased in Brazil and India. Drip irrigation is an efficient method of providing water directly to the root zone, minimizing conventional losses such as deep percolation, runoff and soil erosion. Unlike surface irrigation, drip irrigation is more suitable and economical if it is introduced in water scarce areas with undulating topography, shallow and sandy soils and for widely spaced high value crops. It also permits the utilization of fertilizers, pesticides and other water-soluble chemicals (organic or not) along with irrigation water, resulting in higher profit and better yields and quality of product. Irrigated farming results in significant investments to be amortized.

In Kiribati, growers/households utilize local hand pumps (Marakei and Tamana pumps) and solar water pumps to collect ground water for washing, bathing, and some crop watering. In Nauru, water tanks are used to harvest rainwater and help water supply during droughts; brackish water is also used for irrigation.

When feasible, an option is to set up a system of canals like those in Ratchaburi Thailand (Aromatic Green Dwarf cultivation) and Malaysia (Matag hybrids).

Adopting an adapted high density multi cropping planting system and/or adapted cover crop may help retain moisture and increase the profitability of a possible irrigation.

Use mulching or place leaves and husks around the palm trunk. Plant in a flat basin bordered by pineapples, as done in India. In this country, husk and coir pith incorporation into sandy soils increased the yield from 42- 152 nuts per palm per year.

**Actions to undertake**

Reinforce coconut breeding programs. It is feasible to create drought tolerant varieties, as adaptive anatomical and biochemical features are well known. They include leaflets with upper epidermal waxy cuticle two times thicker than the lower epidermis, thicker cuticular edges, xylem tracheids with thick lignification, etc. The stem girth of tall coconut decreases between dawn and midday before increasing again during the afternoon, suggesting stem organized control of water transport, allowing response to drought stress.

Preserve the traditional coconut varieties created by elders for water consumption. Specifically, the best varieties will be recovered from specific locations: the low coral islands without any sweet water available in the soil.

The distribution of access rights to water must be unanimously recognized to not give rise to controversies. Otherwise, quarrels can degenerate into a huge waste of time and effort. The maintenance of perimeters (scrubbing of canals, planning of plots, repair of bunds, etc.) is often a cause of conflicts.

Water control does not protect farmers from all biological hazards. Predatory and devastating animals can also live in irrigated areas. Sometimes the availability of water in a dry zone can attract parasites or cause them to spread.

Concerning environmental effects caused by technical changes, the control of risks, sometimes not easily noticeable in the short term, involves the gradual implementation of forecasting models.

Explore the potential of using organic materials (including mulch, compost and charcoal/biochar) as water storage materials for coconut palm roots. These materials may also capture and store water from mists and dew during a drought.

In India, Government agencies provide significant sums of money in the form of subsidies to farmers for installing micro-irrigation methods including drip irrigation. This kind of policy could be useful in well-chosen places within Pacific countries.

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## 3. FLOODING, KING TIDES AND LANDSLIDES

*By N. Tuivavalagi, V. Mataora, and K. Viliami*

### Description

The risk is that degradation of coconut land could be exacerbated by climate change and hazards such as flooding, king tides, salt intrusion, coastal erosion, sea spray, and increased landslides. Flooding and other hazards may reduce coconut growth and yields. In some extreme situations, palms may be uprooted and killed by erosion and water excess.

Coconut grows on a wide range of light, medium and heavy soils below 600 m; however, it does not tolerate waterlogged clayey soils or laterite soils with a shallow rock layer or hardpan. A soil pH of 5.5 to 7.0 would be ideal for coconut, but it could tolerate acid soils down to pH 4.5 and alkaline soils up to pH 8.2. Coconut also tolerates saline and infertile soil and grows quite well close to beaches, even on shallow soils of coralline atolls.

#### Occurrence and severity

Poorly-drained soil is unsuitable for coconut planting and seedlings in waterlogged condition would invite skipper butterfly attack and root grub incidence. When roots are covered by water for more than two or three days, they start to rot, and the palms die or become unproductive.

Inland erosion and landslides will become severe in areas that will have increased rainfall due to climate change. Inland erosion will be particularly serious where soil and crop management is poor. Landslides occur more often in areas where vulnerable volcanic soils are subjected to increased and prolonged rainfall.

Increased wind forces linked to climate change exacerbate coastal erosion and increased sea spray. In the Cook Islands, islands where the reefs are close to shore increasingly suffer such erosion.

Inland flooding will be more prevalent in areas that will experience more rainfall. More frequent king tides will result more in areas that will experience more coastal flooding. Coastal flooding will also bring in salt to areas that may include coconut plantings. Saltwater intrusion has been observed in atolls in Federated States of Micronesia including a case (Pingelap) in which salt water enters a plantation from underground sources. Experiences in Kiribati tend to show that saltwater intrusion may happen laterally under the soil surface during high tides.

#### Mitigation and adaptation

Coconut palm is one of the most tolerant species to protect coastal areas against flooding, the king tides and tsunamis. The dense root mat of coconuts helps hold the ground surface layers. It can be associated with *Casuarina* trees. In Samoa, for instance, people plant a first rank of *Casuarina* on the beach border, and immediately behind one or two rows of coconut palms. Mangrove also help to mitigate king tides and tsunamis. It is more appropriate than *Casuarina* in areas they are native as mangroves have other benefits (e.g., nurseries for fish and marine invertebrates).

**Inland flooding**: In Ba, Nadi, Rewa and other areas of Fiji, one of the strategies employed is to keep the rivers ‘clean’ by dredging them so that water flows easily and results in less flooding damage. Communities should also ensure that logs are not clogging their rivers and streams.

Those living near rivers and streams should have plans of what to do if nearby rivers or streams flood. They shouldn't be wondering what to do when flooding is happening. Due to climate change, river or stream levels could be much higher than previously experienced.

**Coastal flooding from king tides and tsunamis**: In Federated States of Micronesia, concrete boxes have been constructed for taro production. The concrete structure keeps the taro protected from coastal flooding. For tsunamis, one idea for coral atolls may be to have coconut trees earmarked as shelters and fitted with nailed boards to help people climb them to safety during times of disaster.

**Inland erosion**: In areas under crops including coconuts, we can implement appropriate soil and cropping practices to reduce soil erosion. For example, farmers can grow Vetiver grass along contours to help hold the soil together. An important strategy is to ensure that soil is always covered, especially during land preparation and harvesting where soil is vulnerable to erosion.

**Coastal erosion**: Coconut palms and *Casuarina* and other plants (preferably native trees) can be grown along coastal areas to help hold the soil together and reduce the chances of coastal soil erosion. The Costal Protection Units (CPUs) developed in Cook Islands can be installed along the shoreline to trap and build up sand in eroded areas to counteract coastal erosion. Boulders can also be used instead of concrete seawalls. Maintaining gaps between the boulders helps waves to safely release the huge amount of energy they carry, without causing damage elsewhere. In the case of solid, concrete seawalls, rebuffed waves sometimes damage other parts of the shoreline.

**Sea spray**: plants such as *Casuarina* and native trees and mangroves could be grown along coastal areas as buffers to protect against sea spray.

**Saltwater intrusion**: there is a need to identify coconut varieties that are more tolerant of salt and plant them in areas that are likely to be (more) affected by saltwater intrusion in the future. Scientists from Hainan Island (China) recently conducted advanced genomic studies on coconut tolerance to salt.

Climate risk leads farmers, when feasible, to disperse their agricultural work over large areas. So climatic hazards will not affect all crops and plots in the same way at the same time.

### Actions to undertake

- Hydro-agricultural schemes frequently help to regulate and increase agricultural production by greatly reducing the risks to producers.
- Flood control and drainage should reduce the risk of accidental flooding and excess water. Farmer associations or local communities can achieve medium scale water works, but, if larger, government services must intervene. Mechanical methods such as retardation ponds can be used to protect the communities of lower basins from flooding.

In case of a tsunami, when located in a low coral motu without any way of escape, elders used to apply the following technique; choose a robust coconut palm; climb up; cut off the leaves by removing two-thirds of their length; cut some of the bunches but keep some for food and water; sit in the most comfortable way possible; attach yourself very securely with a rope to the coconut stem; then wait for the tsunami and pray.

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## 4. TEMPERATURE AND OTHER CLIMATE HAZARDS

*By M. Ghanem, C. S. Ranasinghe and R. Bourdeix*

### Description

In addition to cyclones, tsunamis, drought and flooding, countries in the Pacific are affected by frequent natural hazards of smaller magnitude. The risk is that the increasing frequency of extremely hot days, unexpected cold periods, sea-level rise, and king tides may negatively affect coconut production.

#### Occurrence and severity

Climate change is affecting Pacific life in significant and complex ways. Impacts vary across the region, depending on the socio-cultural and economic context and the geology and ecology of islands. The Pacific islands face the highest disaster risk, in per capita terms, globally. Three main sources quantifying risk in the region are: EMDAT, Desinventar, and PCRAFI. A study conducted in 2016 analysed these sources (Noy & Edmonds, 2016). It concluded they all underestimate the risks, especially for atoll nations. This study cited these important trends concerning natural hazards due to climate change: increasing frequency of extremely hot days, sea-level rise, and other oceanic environmental and ecological changes.

Some low-lying atoll islands around the world could disappear due to climate change and sea level rise, leading to mass migration and threatening the existence of several island nations. Countries such as Kiribati and Tuvalu are often positioned as frontline victims of climate change that must anticipate the future uninhabitability of their homelands. Climate change is expected to generate and amplify human mobility. Some Pacific Islands are widely viewed as likely sites of climate-related migration, displacement, and resettlement. For instance, the Fiji government has identified 830 climate vulnerable communities that require relocation, of which 48 are in urgent need of relocation, intending to support their move via government funding and assistance from development partners.

Smaller magnitude climate variation affects crops at different life stages. At adult stages, temperature stress mainly affects fruit setting, causing significant reductions in resulting bunches. Low fruit setting can be due to reduced quality of pollen and button nuts (female flowers), low number of button nuts and /or impaired pollination process. Pollen germination is the most temperature sensitive process of fruit set in coconut. The optimum temperature for pollen germination is 28- 29°C. When the temperatures of coconut growing areas rise above the critical temperature of 33- 34°C or fall below 12°C, pollen germination and the pollination process are impaired, and fruit set reduced.

At the seedling stage, heat stress and high intensity of solar radiation can affect growth or cause seedling mortality due to excessive water evaporation from leaves, leaf yellowing due to reduced photosynthesis or photo-oxidative damage. In the Raiatea nursery, French Polynesia, exposure of the seednuts to strong sunlight in a low wind area resulted in internal rot and low germination rates.

Coconut palms are relatively tolerant to salinity compared to other crops. Pacific farmers point out increasingly frequent phenomena of high tidal swell and saltwater incursions from the ocean on atolls. This phenomenon is not new, but this swell sweep fallen coconuts on the strands and saltwater stays longer on the land and contributes to a high salinization of soils and the fresh-water lens on atolls, inducing a decrease in coconut production.

The cold can wreak havoc if the temperature drops to less than 6°C for a few hours. Semi-lethal temperatures range from 7- 12°C depending on the cultivar. A story was told to Dr R. Bourdeix by a former CIRAD scientist, without exact date and place. In the north of Australia, an investor had set up a large coconut plantation with an area of several tens of hectares. The palms developed very well and even started to produce. One night, a weather phenomenon that occurs only once every 10 years or more occurred. A wave of icy air came from the desert. In one night, it killed all the coconut trees on the plantation. If climate change increases the occurrence of such cold episodes, it may jeopardize larger areas.

Research conducted in Sri Lanka has shown that extremely high rainfall negatively impacts coconut productivity in dry and intermediate zones; that extremely high temperature negatively impacts productivity in dry zones; and that extreme weather does not significantly impact productivity in the wet zone of the country.

**Mitigation and adaptation**

A method was recently proposed to evaluate the susceptibility of islands to climate change, by using four physical and quantifiable variables: island rock-type (lithology), island shape (circularity), maximum elevation and area. These four physical variables were used to determine a dimensionless index for 1779 islands across 26 countries. This approach could help private companies and some farmers select sites for setting up new coconut plantations.

Some recent studies argue that sea level rise does not inevitably lead to coastal areas becoming uninhabitable (Esteban et al., 2019). Humans have an innate and often underestimated capacity to adapt to changes in their environment. Mapping of Funafuti island in Tuvalu from 1897 to 2013 indicates net gain in land, despite a sea level rise among the highest (t∼0.30 ± 0.04 m over the past 60 years). Future reef growth can mitigate the physical impacts of sea-level rise on atoll islands, although reefs may grow too slowly to compensate for rising sea levels.

Manage your plantation so that not all the palms are the same age and grow more than one variety. Plant other crops between the palms. If something occurs, such diversity may protect you. All palms and crops will not be affected in the same way. Sharing your observations with other farmers and scientists will facilitate the emergence of new technical solutions. If the plantation is under irrigation, with correct fertilizer application, soil moisture conservation and good agronomic practices, the palms can tolerate heat stress and perform successful pollination at higher temperatures than critical; i.e., even at about 35-36°C.

**Actions to undertake**

The use of tolerant varieties would be an efficient way to mitigate such temperature hazards. Outside of the Pacific region, breeders have already started to identify criteria for cold tolerance and salinity adaptation. For instance, measurement of coldness on leaves by electrical conductivity; for salinity adaptation, leaf stomatal frequency, leaf gas exchange, the quantum yield of chlorophyll fluorescence, the relative chlorophyll index, etc. Temperature response of pollen germination, female flower production, fruit set, leaf physiological parameters, and pattern of root growth can also be used to select tolerant varieties.

There is a significant potential market for cold-tolerant coconut varieties able to survive in countries with temperate climate. The first cold-hardiness studies in Hainan Island (China) indicated the existence of genetic variability. Māori tried to grow coconut palms in New Zealand many times but never succeeded due to the cold weather. Polynesians living in the Austral Islands (southern French Polynesia) also suffer greatly from scant coconut production. Because it gives any landscape a 'tropical' look, many people attempt to grow coconuts in non-tropical climates. Studies conducted in Florida shows that palms subjected to long periods of low temperature have soft, sunken, reddish areas on the trunk. These cold-damaged trunk areas are often invaded by secondary fungi and/or bacteria that cause trunk-rot and, several months later, the collapse of the entire crown. Fertilization slightly improves cold tolerance.

The possibility of carbon trading in coconut plantations can be explored for the whole coconut growing community. This will mitigate climate change and add value to coconut plantations and growers will get an additional benefit.

Strategies addressing climate change adaptation in the Pacific should include both state-based governance mechanisms combined with customary non-state institutions. Recent negotiations concerning labour mobility, unskilled and skilled, temporary and permanent, do not relate only to climate change adaptation. Mobility helps to balance labour shortages, transfer skills and generate remittances. Successful mobility also helps to adapt to climate risks.

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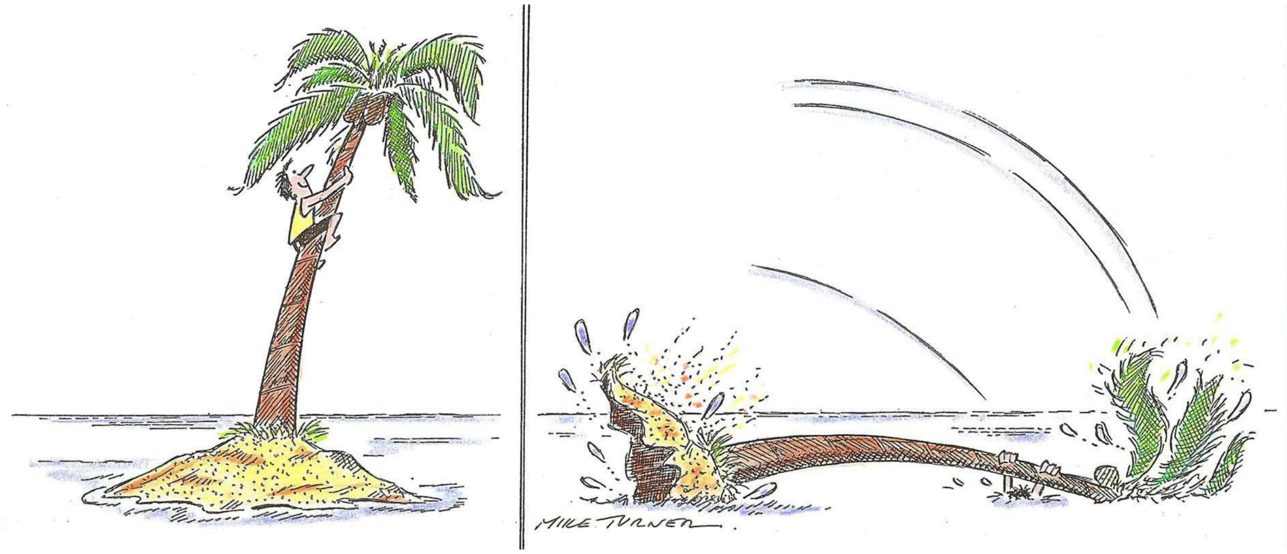
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# B. RISKS LINKED TO PESTS AND DISEASES

*By M. A. M. Gruber, R. Bourdeix, T. McKenzie and S. B. Woruba*

Pests and diseases are challenges for coconut production in almost all tropical countries. Small island developing states (SIDS) in the Pacific are extremely vulnerable to the impacts of invasive species, due to limited resources to combat pests and diseases.

Overall losses are difficult to estimate, but a striking example is the Coconut scale (*Aspidiotus rigidus*) in the Philippines, which has caused the deaths of around 65% of affected trees, with an average loss of about 60% of fruit yield. Regarding diseases, the situation in the Pacific region seems better than in most of the other tropical regions, mainly because of the low extent of phytoplasma diseases when compared to the African continent and the Americas, for instance. A major problem is a new biotype (strain: CRB-G) of the Coconut Rhinoceros Beetle (CRB), *Oryctes rhinoceros* L., which is not susceptible to the *Oryctes rhinoceros* NudiVirus isolate that is used as a classical biological control agent. The new biotype has destroyed thousands of coconut palms in Guam, in parts of the Solomon Islands, Papua New Guinea, Hawai'i and other places where it has spread to. The older biotype of *Oryctes rhinoceros* in the Pacific (CRB-S or CRB-P) seems also to have had a resurgence in some countries, perhaps due to a combination of senescent palms, cyclone damage creating breeding opportunities, coconut planting in locations where the NudiVirus is not present, and renewed interest in coconut cropping.

To help farmers control coconut pests and diseases, sources of knowledge and information have been developed at the national, regional and international levels. For national initiatives, relevant information is often available on the websites of Ministries of Agriculture, Forestry or Quarantine Services. Several initiatives are also being made at a regional level. In the framework of the project **Coconut Industry Development for the Pacific**, funded by the European Union, an **online Coconut Pests and Diseases** toolkit (CPDT: http://coconutpests.org) has been developed in order to aid in basic training for the management of coconut pests and diseases in the Pacific region. Much information presented in this manual comes from CPDT. The website has six main sections:

- **Coconut pests & diseases:** many of the more serious possible pests and diseases affecting coconut. Those causing more severe problems are described in more detail.
- **Identification**: assists to identify possible pests or diseases using the symptoms that are observed.
- **Prevention:** general approaches to prevention (biosecurity).
- **Diversity & resilience:** global change, its effects on coconut production, and ways to minimise these effects.
- **Learning & teaching:** resources for awareness and training
- **Getting help:** as well as the resources in the CPDT, technical experts, regional agencies and NGOs can aid.

CPDT strongly recommends an integrated pest management (IPM) approach to the control of all insects, where possible. This is a combination of methods (pesticides, physical controls such as site hygiene, pheromone trapping, and biological controls) to minimise the use of pesticides and the cost of control. In an agricultural context the Food and Agriculture Organization (FAO) defines IPM as 'the careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations and keep pesticides and other interventions to levels that are economically justified and reduce or minimize risks to human health and the environment'. The goal of IPM is to keep pest populations to a level below which they cause economic harm through the synergistical use of the various management approaches.

Biological control (biocontrol) is often a preferable method of controlling pests such as insects, mites, weeds and plant diseases. Biocontrol of coconut pests is often achieved using predators, parasites, parasitoids, fungal and viral diseases. Biocontrol involves active management in selecting, releasing and maintaining populations of controlling organisms. Over 6000 introductions of more than 2000 insect biological control agents have been carried out worldwide to control insect pests, while over 2000 releases of more than 500 biological control agents have been made against invasive weeds. Biological control can have unintended impacts on biodiversity through attacks on non-target species by any of the same mechanisms. Some biocontrol introductions have gone on to become pests. One of the most dramatic is the cane toad initially introduced to control insects in sugarcane plantations. The main problem is the poisoning of many animals that eat the cane toad which has poison glands and toxic skin. Biological control can sometimes work too efficiently, as described in a famous case from Fiji. A former pest of the coconut palm, the endemic moth *Levuana iridescens*[7], seems extinct because of its biological control by an introduced fly (Bessa remota, see Plate 6). Many lessons have been learned in the best practice for biological control. A sound methodology for new programs of biological control is essential and should include scientists and quarantine officers, in agreement with local farmers.

Biological control has proven to be the most sustainable option to efficiently manage pests and

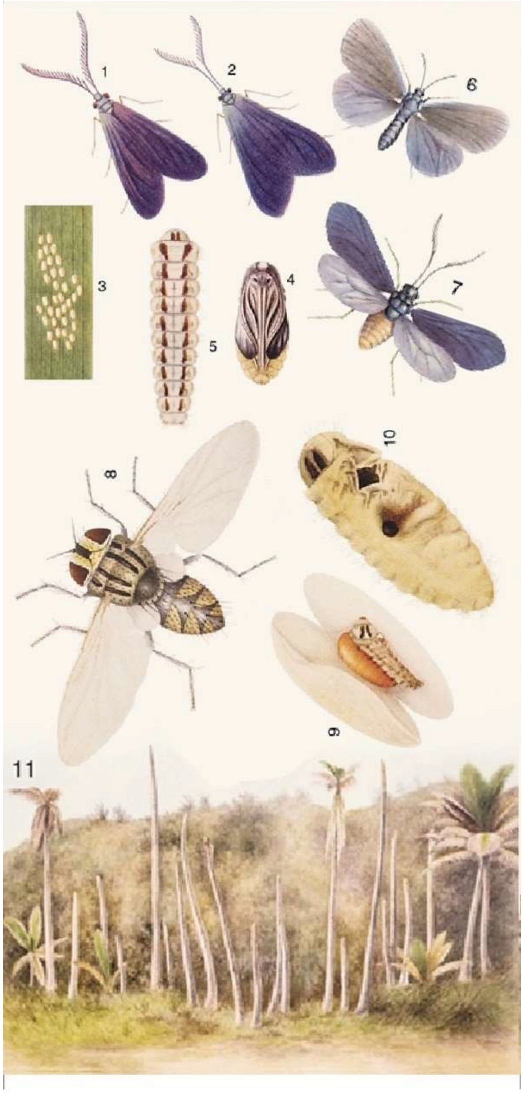


**Plate 6.** (1) L. iridescens, male, resting, (2) L. iridescens, female, resting, (3) L. iridescens egg cluster on coconut palm leaf, (4) L. iridescens, pupa, (5) L. iridescens, fifth instar larva, (6) H. dolens, wings spread, (7) L. iridescens, female, wings spread, (8) B. remota, adult, (9) cocoon of parasitized L. iridescens, opened to show dead larva of L. iridescens and pupa of B. remota, (10) larval corpse of L. iridescens with exit hole for B. remota, (11) death of coconut palms on Ovalau, after successive outbreaks of L. iridescens, prior to control by B. remota. (From Tothill et al. [1930]; paintings of insects by H.W. Simmonds; painting of shoreline by W.J. Belcher.)

[7]*Levuana iridescens* was first recorded as a serious coconut pest around 1877 from a single island, Viti Levu, in the Fijian archipelago. Earlier records on coconut production from 1846 and 1860 do not indicate a severe and widespread pest affecting palms (Simmonds, 1924).

diseases. Sometimes in cases of heavy infestation or epidemic expansion, biological control needs to be assisted using chemical methods (i.e., pesticides). However, establishing the threshold for economic injury levels needs to be established before this decision can be made for efficient and cost-effective management. Potentially it may be better sometimes to lose organic certification but avoid the complete destruction of plantation or harvest. In case of use of pesticides, it must be certain that the products do not contaminate the coconut water and kernel, and that they are fully safe for human and animal consumption. This may enable time for the crop to recover and return later with an improved biological control. A list of the main pesticides used in India is available from the 'References' section. Alternative pesticides may be available in the Pacific. Each Pacific country will have its own regulations on pesticides, and these must be consulted.

Plants have evolved a range of defences that can be actively expressed in response to damage from herbivores, pathogens and parasites at various scales, ranging from microscopic viruses to insect and mammalian herbivores. In any plant–insect and plant–pathogen interaction there is a continuum of possible outcomes, ranging from extreme susceptibility to complete resistance. For pests and disease mitigation, one of the less costly and time-consuming methods is to use resistant or tolerant varieties. This presupposes that consistent breeding programs are set up and succeeded to identify and diffuse such tolerant varieties. Sometimes networks and mutual aid between farmers can also help identify and obtain such varieties directly from farmers' fields.

Manipulating resistance to diseases like lethal yellowing is challenging because of the difficulty in effectively inducing diseases under controlled situations. However, there are many reports confirming genotype variability in resistance to most of the stress factors in coconut, with some varieties carrying exceptionally high level of resistance.

Even in the best case, resistance or tolerance to a pathogen is not likely to be permanent. Plants and animals have been involved in an 'arms race' for millions of years. Over time pathogens can naturally evolve mechanisms to overcome existing genetic tolerance or resistance. For annual crops, it seems that the resistance of a variety to a pathogen has, on average, a lifespan of only 10 to 15 years. After this delay, the variety may be no longer resistant because the pathogen has evolved.

We can extrapolate this situation to coconut. There is good reason to think that if, today, we plant a resistant palm, there is a high probability that 50 years later, before its natural death, this coconut palm will become sensitive to newly emerging forms of pathogens. Therefore, even if good and tolerant varieties are available, research to find the next good variety should never stop**.** This is the only way to mitigate the evolution of the pathogens.

It is also important to note that plant defences evolve over time and the most serious pests and diseases will likely be those that are recently introduced, as the plant has no natural immunity to those organisms. This is one reason why biosecurity is so critical in the Pacific region, which is still not affected by many pests and diseases of coconut, to prevent any potential incursion of exotic pests and diseases.

Biosecurity measures are crucial tools to mitigate pests and disease spread. With increasing global trade, the transportation of pests and diseases has also increased dramatically. The best-known examples are animal and/or human pathogens. However, the same situation also applies to the spread of plant diseases. Unintentional spread through global trade allows pests and diseases to colonise new areas over long distances. Novel areas offer new environmental conditions and novel and 'naive' hosts, enabling pest and pathogen attack. The natural enemies of pests are often absent in new areas away from the native range of pests; these natural enemies can be introduced after conducting a study to ensure that they will not upset the ecological balance.

Climate change may also be conducive to the establishment of pests and diseases in new environments (see related section in this manual). In addition to local quarantine, plant and animal health and biosecurity departments, in the Pacific regional agencies are mandated to assist with preventing (biosecurity and incursion response) and managing invasive species and pests and diseases in the Pacific. The most important of these agencies are the Pacific Community (SPC) and Secretariat of the Pacific Regional Environment Programme (SPREP). Raising community awareness of pests and diseases risks is useful in the prevention of accidental introduction of new threats or early detection and containment of any incursion.

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# 5. PHYTOPLASMA DISEASES

*By R. Davis, F. Pilet, M. A. M. Gruber, S. B. Woruba and T. McKenzie*

## Description

Phytoplasmas are insect-vectored bacteria that cause disease in a wide range of plant species. They are responsible for various forms of Coconut Lethal Yellowing-Like Diseases (LYLDs). Numerous outbreaks of LYLDs of coconut have been recorded in Central America, the Caribbean and Africa since the late nineteenth century and have caused the death of millions of coconut palms. The risk is that these diseases invade the Pacific region and kill many coconut palms.

The only LYLD presently found in the Pacific region is the Bogia Coconut Syndrome (BCS) in Papua New Guinea (PNG). This phytoplasma is not considered as such a worrying problem as the *Oryctes rhinoceros* CRB-G biotype, given its present localized distribution, but rather it does have the potential to become a major disease. In addition, palm death caused by phytoplasmas can provide breeding sites and exacerbate the *Oryctes rhinoceros* problem.

LYLDs are caused by several different, but related, phytoplasmas in different places around the world. Phytoplasmas can survive only inside the plants that host them and the insects that spread them from plant to plant. The LYDL phytoplasmas cannot be cultured *in vitro* and can only be studied using the tools of molecular biology. Because of this they have complex grouping and naming conventions.

Four different, but closely related phytoplasmas are responsible for LYLDs around the world. The phytoplasma in the Caribbean, Central America and Florida, was the first to be found and it is named '*Candidatus* Phytoplasma palmae'. The LYLD phytoplasmas in Africa are '*Candidatus* Phytoplasma palmicola' in West Africa and Mozambique and '*Candidatus* Phytoplasma cocostanzaniae' in Kenya and Tanzania in East Africa. A new phytoplasma recently discovered in PNG is the most immediate threat to the Pacific Islands. It has been given the name '*Candidatus* Phytoplasma noviguineense', Included reference below. Less severe phytoplasma diseases of coconut palms caused by phytoplasmas that are not closely related to the LYLD phytoplasmas occur in Malaysia, Sri Lanka and Indonesia.


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**Plate 8.** Female adult of *Zophiuma pupillata*

Bogia Coconut Syndrome LYLD was identified in 2008 near Madang, in PNG. The causal phytoplasma, '*Candidatus* Phytoplasma noviguineense', is related to but different from those threatening Africa and America. It may be that the BCS phytoplasma was not recently introduced and is endemic to PNG. In studies on BCS in PNG, several sap feeding insects found in the country are very strongly suspected to be vectors of the phytoplasma. One of the most important and widespread is the planthopper *Zophiuma pupillata* (see Plate 8), which breeds on coconut palms

The symptoms of BCS are quite similar to those of other LYLDs and shows a very well-defined sequence that helps identify the disease. The disease progress has five distinct stages, which happen very rapidly (within around four months):

1. The outer fronds of the crown will droop and have a pale to distinctly bright yellow colouring.
2. Premature dropping of nuts of all ages progressively follows, whether they are ripe or not.
3. Fronds then turn brown and hang down the stem, like a skirt.
4. A dry rot develops in the newly expanding spear, progressing downwards to the growing point.
5. Complete necrosis - death of the palm. Finally, all fronds fall, leaving only dead stems.

An early symptom may also include rotting of male and female inflorescences (to see this it is necessary to climb the palm and open the inflorescences manually).

Although each of these symptoms can be caused by other things, the sequence of symptom development, and its rapid speed, is unique to BCS. Similar symptoms have been observed in more than 50 other palm species that suffer from LYLD.

A common mistake is to confuse the symptoms of LYLDs with the damage caused by lightning, which can kill ten or so coconut palms in one fell swoop. In the case of lightning, the trunks of the coconut trees very often bear black elongated marks from burning, with exudates of sap.

**Occurrence and severity**

Bogia Coconut Syndrome is a major concern as coconut is an important food and trade source in PNG. The Bogia Coconut Syndrome phytoplasma also attacks some varieties of cooking bananas, betelnut, and other palms. In the area of PNG affected by BCS many palms have died and plantations have been abandoned. The loss of plantations from the disease can cause serious problems for social and economic security. However, the disease is currently highly localised and subject to strict biosecurity measures to ensure containment

Another phytoplasma was recently found in diseased cooking banana plants, close to the border of PNG (Bougainville, Magusaiai Island). DNA analysis showed it was closely related to the BCS phytoplasma. This phytoplasma, known as Banana Wilt Associated Phytoplasma (BWAP), is found in some areas in PNG. Only bananas are affected but coconuts are not. Unpublished phylogenetic data seems to differentiate the coconut and banana phytoplasmas from Madang Province from banana phytoplasmas from Western Province and the Solomon Islands archipelago. It seems there is genetic variation within the closely related group of phytoplasmas in the Pacific region. This however does not dismiss the potential for a wider spread by BCS given the distribution patterns of other related phytoplasmas in the Pacific.

**Mitigation and adaptation**

Little is known about how BCS or other LYLDs are spread, and there are limited control methods. There is not economically viable chemical nor organic treatment against LYLDs in the agricultural context. Phytoplasma can be controlled by injection of tetracycline-type antibiotics into the coconut trunk. This requires a bi-weekly systemic treatment on a four-monthly schedule which is not affordable for agricultural production but is sometimes used for ornamental purposes in tourist sites and hotels. The use of antibiotics in agriculture is banned in some countries, and we do not know, for instance, if the coconut water is contaminated by the antibiotic. We do know that misuse of antibiotics can result in antibiotic-resistant pathogens. Such issues will need to consider the ISO standards on safe residue levels of pesticides and other chemical treatments.

Successful integrated pest management (IPM) against LYLD is through:

- Biosecurity measures, which should include, prohibition of movement of palms (and other known hosts such as banana) out of the affected areas, strict quarantine and disease surveillance;
- Prompt detection followed by immediate removal and destruction of LYLD infected trees;
- Proper weeding of alternative plant hosts that may allow the vector to undergo part of its life cycle;
- Replanting with resistant varieties, and;
- Control of the insect vector.

In Ghana, the treatment of infected farms with insecticide by hot fogging followed by felling diseased and contact palms, immediately upon detection, has slowed down the disease and in some cases completely holds the disease in check for few years. Intercropping coconut with other crops has failed to lower the disease incidence but has provided an alternative source of income as insurance against the disease in Ghana.

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**Plate 7.** Coconut plantation destroyed by a Lethal Yellowing Disease caused by a phytoplasma in Ghana.

In Jamaica, the Michael Black farm, totalling 62,000 palms, is in a diseased zone. Thanks to meticulous monitoring of the disease (including culling and systematic early producing hybrid replantation), only 915 palms or 1.5% were lost because of LYLD within the period 2002- 2013.

Some varieties and hybrids of coconut palm are known to be less susceptible to LYLD, but none are completely resistant. Varieties that better tolerate the diseases are different, depending upon which phytoplasma is involved. Information is not yet available about tolerant varieties in the case of BCS, although it is thought that diverse coconut plantations may limit effects of disease. Research conducted in Ghana has revealed that the Sri Lanka Green Dwarf was the most tolerant variety to the local form of LYLD, although LYLD are not present in Sri Lanka. In Jamaica, the most tolerant variety was the Malayan Yellow Dwarf, then the phytoplasma evolved, and also started to kill this variety.

From a research perspective, it is very important to test for tolerance and resistance to BCS of different coconut varieties as this has worked for similar diseases elsewhere in the world and would provide the best control of all. Having diverse coconut plantations may be important to limiting the effects of the disease.

Good biosecurity is the only way to prevent LYLDs from developing in new locations. The BCS phytoplasma has been found in betelnut palms and banana plants. Restricting the movement of live coconut, betelnut and banana planting material out of the Madang Province is vital and this will slow its spread. Young plants, including symptomless banana suckers, can carry the phytoplasma to new places. Whilst the dangers posed by coconuts and betelnuts for planting are not fully understood yet, it would be safest to include these in the restrictions. Research into BCS is identifying other host plants, and as these hosts are found, they will also need to be targeted. Where vector insects are known, their movement should also be tightly controlled.

**Actions to undertake**

- In Papua New Guinea, search for tolerant varieties in local and international coconut germplasm. For instance, it would be useful to introduce the Sri Lanka Green Dwarf, which is tolerant to LYLD in Ghana.
- From 2014 to 2017 Australian Aid funded an ACIAR project in PNG on developing biological knowledge and a risk management strategy for BCS and related phytoplasma syndromes. Results from this and further projects may help to contain or control the disease.
- Maintain strong biosecurity and set up early detection systems. If an outbreak of the disease occurs in the Pacific region, the Ghanaian method should be applied: insecticide treatment by hot fogging (only practical on smaller palms) followed by felling diseased and contact palms.
- Biosecurity should include surveillance for potential host insects. For example, BCS requires the presence of both the phytoplasma and *Zophiuma*, the insect that is one of the vectors of the phytoplasma. It is also important to identify the full range of insects that can transmit the phytoplasma.

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## 6. VIRAL DISEASES

*By R. Bourdeix, T. McKenzie, M. A. M. Gruber, S. Boulekouran*

### Description

The risk is that viral diseases kill many coconut palms and/or greatly reduce their production. The diseases of greatest concern seem for now Vanuatu Foliar Decay and Guam Tinangaja viroid.

Coconut foliar decay (CFD) is a lethal disease of coconuts described only in Vanuatu. It is caused by a very small virus growing in the palm's phloem (where food is transported through the plant). The local cultivar 'Vanuatu Tall' (VTT) is the only cultivar that is fully tolerant to CFD, whereas introduced cultivars and hybrids are affected to different degrees.

As the CFD virus cannot be seen, the only way to identify coconut foliar decay is by symptoms and the presence of vector insects. The only known insect that transmits coconut foliar decay is a small planthopper called *Myndus taffini* (see http://coconutpests.org//pests-and-diseases-of-coconut/coconut-foliar-decay for images). Although the adult planthopper feeds on coconuts, breeding occurs on the roots of *Hibiscus tiliaceous* (hau [Hawai'ian], fau [Samoan], purau [Tahitian], and vau tree). However, *Hibiscus tiliaceou*s and other plants growing near coconuts do not carry the virus.

The first sign of CFD infection is in the mid-section of the crown where fronds have a few yellowing leaflets. Yellowing will begin to spread and the whole frond will bend and be seen hanging through leaves that are still green, due to breakage near the base of the frond. As younger leaves age, they too will go through these stages. At the advanced stage of the disease, the leaves turn yellow with broken mid- leaf section hanging through green fronds and new green fronds emerging from the top of the crown. If palms are not tolerant to the disease, death will occur in infected palms after one to two years.

Tinangaja viroid (CTiVd) causes the lethal Tinangaja disease of coconut palm in Guam. It is related to the viroid (CCCVd) that causes the lethal Cadang-cadang disease of coconut palm in the Philippines, with about 64% DNA sequence identity. Symptoms of CTiVd differ from Cadang-cadang.

From the time of the first symptoms of CTiVd death can take up to 15 years. The first obvious sign are yellow spots on the leaves, and small, thin, scarred nuts without a central kernel. As the disease progresses, leaf, flower and nut production slow down, and there is a general yellowing of the leaves, a tapering of the trunks, and death. Although diseased palms occur in small groups, it is not known how the disease spreads naturally.

### Occurrence and severity

We do not know the exact distribution of the CFD across the 83 islands of Vanuatu. When an island is planted only with the resistant Vanuatu Tall variety, the disease remains completely invisible. Thus, some neighbouring islands, for example in the Solomon archipelago, may also be contaminated by this disease. The only way to check it would be to introduce perfectly healthy Malayan Red Dwarf seednuts on these islands. If these sensitive dwarfs die, it will mean that the disease is present.

The impact of CTiVd in Guam has been considerable. Coconuts in Guam are not used for copra, but are used for drinking, food and oil. Apart from these uses, coconuts play a landscaping role (including the tourist industry), in reducing coastal erosion, as windbreaks, and as shade for many plant species less tolerant to sunlight. Coconuts must be imported. The disease has probably strongly reduced the diversity of coconuts on the island. The related lethal coconut Cadang-cadang disease in the Philippines caused a total loss of 40 million coconut palms.

**Mitigation and adaptation**

For both diseases, the use of cutting tools (such as coconut hooks or sickles) without proper hygiene precautions should be avoided to prevent mechanical transmission of viroid. Tools should preferably be disinfected by wiping with freshly prepared 10% bleach solution plus 1% mineral or vegetable oil between trees.

The removal and destruction of infected trees is recommended, with replacement using healthy seedlings. Seednuts should be collected and selected from areas known to be viroid-free, or have very low incidence of the disease, and not moved internationally. In the past, healthy seednuts of the Vanuatu Tall variety have been sent from Vanuatu to Côte d'Ivoire gene bank (West Africa); then sent from Africa to more than 10 other countries worldwide. In Ghana this variety showed a tolerance to the Lethal Yellowing Disease.

The CFD viroid can be found in the roots, trunk, leaves and the nut including the husk and embryo, but it is unknown whether seeds carry it. Many seednuts are presently produced in Santo Island (where CFD is active) and sent to other Vanuatu islands, and no problem has been reported so far.

In the gene banks and seed gardens of the Vanuatu Agricultural Research Centre (VARTC), the damage caused by the CFD has been overcome by eradication of the host plant of the vector insect. However, *Hibiscus tiliaceous* is often planted as fences and has many traditional uses, so it is almost impossible to eradicate it from coconut farms.

From 1967 to 2008 a conventional breeding program was conducted in Vanuatu with the aim of creating hybrid planting material combining tolerance to CFD with improved copra yield and high copra weight per nut. An improved hybrid, obtained by crossing the Vanuatu Tall and the Rennell Island Tall varieties, was identified with a high degree of tolerance to CFD (less than 1% of trees were affected after 11 years of exposure to high disease pressure). The annual production of this improved hybrid ranged from 21.9- 28.6 kg of copra per tree, depending on the RIT parent, and was, on average, 34% higher than that of 'VTT Elite' an advanced cultivar obtained after four selection cycles of local VTT.

**Actions to undertake**

- Launch a program to determine the full extent of CFD disease in Vanuatu, of CTiVd in Guam and including neighbouring islands, as discussed earlier.
- Many aspects remain unknown about CFD disease in Vanuatu and need further research. The Malayan Red Dwarf (MRD) is the variety most sensitive to CFD. But MRD can be 'vaccinated' in the nursery, by being exposed to the insect vector and the CFD viroid, and then it does not die from the disease. Nobody has planted seednuts from these 'vaccinated' MRD, to see if the progeny is sensitive or not to CFD. Maybe the Vanuatu tall is not resistant to the CFD but is simply 'vaccinated'.

- The Vanuatu Tall is one of the most tolerant variety to Lethal Yellowing Disease in Ghana. Maybe this unusual kind of natural 'vaccination' helps the Vanuatu tall to tolerate the LYD disease. Or maybe there is a unique physiological and genetic reason why Vanuatu tall is tolerant to both LYD and CFD. Therefore, research on CFD is important, not only for Vanuatu and the Pacific region, but because it may help to understand and fight LYLD diseases, that cause much more damage globally than CFD.

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# 7. ORYCTES RHINOCEROS BEETLE

*By M. A. M. Gruber, R. Bourdeix, T. McKenzie, R. Tautua and N. S. Aratchige*

### Description

The main risks are that the new and very aggressive biotype of *Oryctes rhinoceros* beetle (CRB-G), already present in Papua New Guinea, Guam, Solomon Islands, Palau, New Caledonia, Northern Marianas and Hawai'i continues to kill many coconut palms; and that it invades more islands in the Pacific region. The most common CRB-S/CRB-P biotype also cause damage in many coconut producing countries.

*Oryctes rhinoceros* (commonly called Coconut Rhinoceros Beetle or CRB) is an important pest of coconut palms, and currently causes more concern than other pests and diseases in the Pacific. The adults bore into the heart of the palm to feed on sap, damaging immature fronds which emerge subsequently showing typical V-shaped cuts with reduced photosynthetic area. When the flag leaf is damaged, it will be hanging from the top of the palm. Crooked leaf bud with retarded growth of the seedling occurs when the young seedling of less than a year is damaged and repeated attacks destroy the growing point and kill the palm. Beetle exit holes can often be seen at the crown base. Young oil palms are also attacked and more easily killed. While it is endemic in Asia, the pest was accidentally introduced into the South Pacific in the early 20$^{th}$ century, and then spread and become established in several South Pacific countries.

*Oryctes rhinoceros* has two different 'biotypes' in the Pacific, known as CRB-S (biotype susceptible to known virus isolates) and CRB-G ('Guam' biotype, tolerant to the virus infection). Sometimes people use the term CRB-P instead of CRB-S. CRB-G is not affected by the viral biocontrol isolates that have been used to control CRB-S. This means CRB-G can reach very high numbers, as adults live up to nine months, that cause severe damage in palm plantations and become very difficult to control.

### Occurrence and severity

Where pest populations are generally under control, the damage CRB causes to palms results in reduced leaf area, early death of flowers and early nut fall, consequently reducing coconut yields. However, CRB-G resistance to the biocontrol virus has allowed this biotype to grow in numbers and move to new areas where there are fewer natural predators. It has been nicknamed the 'Palm Killer' as it can cause devastating damage and within one year destroy entire palm populations. It has been estimated the CRB-G has killed 50% or more of palms on some islands. Damage from CRB increases the risk of secondary infections and infestations e.g., by bacteria, fungi, viroids, viruses and weevils, in the crown.

In many Pacific countries, people living in the outer islands are still reliant on coconut/copra for income. Therefore, the introduction of CRB into countries such as Republic of the Marshall Islands or Kiribati will significantly harm the country's economy, culture, livelihoods and well-being of the people. As stated in the CIDP meeting held in Nadi 17- 20$^{th}$ April 2018, destruction of coconuts by beetles may also have significant impact on tourism and handicraft, with significant economic flow-on effects.

**Mitigation and adaptation**

Integrated pest management (IPM) based strategies including removal of breeding sites, extracting beetles using metal hooks, application of coal tar or burnt engine oil on innermost leaf bases to repel the adult beetles, placing naphthalene balls at the leaf bases, insecticides and biological control, are practised worldwide to control CRB.

Coconut rhinoceros beetles have general natural enemies such as birds, pigs, rats, insects including ants and scoliid wasp parasites. Although rats are invasive in the Pacific, especially on islands, they can be important predators of both CRB larvae and adults. However, the most useful biological control has been isolates of the *Oryctes rhinoceros* NudiVirus. Adults are infected with the virus and then released to spread infection to larvae in breeding sites, and to other adults within palms. Unfortunately, the CRB G-biotype is apparently resistant to the strains of *Oryctes rhinoceros* NudiVirus used for control.

*Metarhizium majus* (formerly *Metarhizium anisopliae*, green muscardine fungus) has also been an effective biocontrol. Spores can be applied to known breeding sites, or adult beetles dusted with the fungus spores and released to infect larvae and adults in natural breeding sites or artificial impregnation boxes of 1 m x 1 m x 0.5 m which is filled with breeding medium (typically a mixture of coir/saw dust and cow dung). *Metarhizium* is easily mass-produced on-farm using maize grits. It is important that the impregnation boxes are kept moist for survival and longevity of the fungus. The fungus can also be purchased from the supplier FGV AGRI SERVICES SDN BHD in Malaysia, and in bulk online at websites such as alibaba.com (subject to local biosecurity requirements). Samoan farmers cut trunks into logs and bulk it up, then add the virus and fungus portion, then cover the mass with coconut leaves. When the beetle encounters this bulk to lay eggs, they can be infected with virus and fungus.

Removal or reduction of plant waste (fallen palms, organic manure) is needed to reduce the breeding sites for CRB. Sanitation of plant materials is currently the main tool for control and is therefore very important. It is much easier to control the beetle life-stages that take place in the ground (eggs and larvae), rather than in the trees (adults) - i.e., control of breeding sites. The removal of fallen palm trunks and dead standing palms is essential to reduce breeding substrates. If possible, cut or break up the trunks into smaller pieces, dry them and then burn. Fine chipping will help rot down the wood faster. Breaking up the palms into smaller chunks (30 to 40 cm) that rot down quickly will also reduce breeding habitat. Note that it is not always feasible to burn, especially in wet tropical climates. Burning can also be an environmentally unfriendly action in and adjacent to urban areas. If the logs cannot be burned that should be used for something, rather than left to rot in the plantation. It is also possible to allow cover crops to grow over the felled trunks to provide less access for adult beetles to reach the decaying trunks for egg laying. Organic materials should be composted and turned regularly, so the larvae can be completely removed. Organic manure and coir dust heaps should be properly disposed of or should be well earthed up with the soil or maintained as a thin layer of less than 1 inch, if using as manure.

In the Andaman Islands of India traditionally people made a fig fire by night at the centre of their villages. Many beetles were attracted by the fire light and burned.

Biosecurity awareness material should include advice to all Pacific countries about activities being undertaken in countries where the new CRB-G strain is already present. Inter-island shipping biosecurity is critical e.g., farmers transporting compost or plant materials between islands. In high risk countries, biosecurity/quarantine services issue trap surveillance kits, and have prepared emergency response plan and control intervention measures such as: short/long term responses, eradication and containment plans.

Mass trapping using the aggregation pheromone, ethyl-4-methyl octanoate which attracts both male and female beetles is an effective way to reduce the rhinoceros beetle population. However, care should be taken in using pheromone traps. Firstly, pheromone traps are only a component in the IPM of CRB. From the experiences of other countries such as Sri Lanka, it is evident that the pheromone traps alone will not be enough to manage the pest, but can reduce the damage by more than 50%. Secondly, the traps should be continuously maintained with timely replacement of the pheromone. Thirdly, experience in coconut and oil palm plantations in Sri Lanka reveals that the pheromone traps are more effective if used in large plantations (>1ha). If small scale growers opt for the use of the pheromone traps, they should be installed community-wide i.e., to install the traps in a village or by a few growers installing traps simultaneously. It is also advised to preferably install the traps along the periphery of the plantation or in non-coconut areas. However, placing pheromone traps at the border of the plantation has found to be effective only in blocks without infested breeding sites.



**Plate 9.** Dr Visoni Timote of SPC demonstrates how to use a CRB trap with PVC pipe.

One pheromone trap per hectare is recommended, but it can be reduced to one per two hectares in moderately damaged areas. Two types of traps can be used. The first one, 'PVC tube or Pitfall trap' is made of 1.5 m long and 10-15 cm diameter PVC pipe (see Plate 9). Two windows, 10 x 10 $cm^2$ each are made on either side at 0.5 m and 0.75 m from one end. Close to the other end, a few holes are made to drain excess rainwater. This end is closed with an end-cap or any other closely fitting lid and fixed to the ground vertically with the aid of a pole or may be attached to a trunk of an adult palm. The pheromone sachet is fixed on one window using a wire. The beetles attracted to the pheromone fall into the pipe and are killed manually or using an insecticide/soap solution. The beetles cannot escape the trap so will eventually die anyway.

The second type of trap (cross vane trap) is made of a plastic bucket of 10 litters and two metal sheets of the diameter of the bucket and a height of 0.5 m, arranged at an angle of $90^0$ by making a slit on each sheet halfway. Cross vanes are pushed into the opening of the bucket and made to stand erect by removing a triangular portion of the metal. A few holes on the bottom of the bucket are made to drain excess water. A soap-water solution is filled up to the level of the holes. The pheromone sachet/vial is hung on the middle of the vanes. The beetles attracted to the pheromone hit the metal vanes and drop into the soap-water solution and die.

*Oryctes* pheromones are available at ChemTica Internacional, S.A. Apodo. 640-3100, Heredia, Costa Rica (www.chemtica.com., info@pheroshop.com., sales@pheroshop.com) and Pest Control (India) Pvt. Ltd. Mumbai, India (www.pestcontrolindia.com. solutions@pcil.in). Other sources may be available but have not been tested.

**Actions to undertake**

- Biosecurity rules and International Guidelines for transfer of coconut germplasm should be strictly followed to prevent pests and diseases being moved to new locations.
- Scientists should strengthen the search and evaluation of virus strains effective against the CRB-G biotype.
- More investigation into the tolerance of diverse coconut varieties, the role of adequate plant nutrition, and other factors such as general phyto-sanitation must be part of the solution. As it is easier to manage short palms than tall ones against *Oryctes*, the many Compact Dwarf varieties and their hybrids with local varieties should be tested and distributed, together with local Tall varieties. A consistent program of collecting Compact Dwarf varieties and testing them for *Oryctes* resistance should be developed in several Pacific countries. Farmers can start to plant and test some Compact Dwarfs by themselves.
- In the Solomon Islands, seek the coconut palms remaining in the old Yandina Research Centre and try to recover the existing varieties. Old documents and offices were burned, but the coconut palms remain. When visited in 2018, evidence was found that some red or yellow Compacts Dwarfs are still alive and could be cultivated.
- Investigate ways to obtain value from the huge quantity of *Oryctes* larva and adults presently harvested (up to 15 tons per month in some oil palm plantations).
- Scientists in the Pacific region to test the method recently developed in Pakistan with other bio-control agents.

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# 8. MITES (ACERIA GUERRERONIS)

*By N. S. Aratchige, L. C. P. Fernando and R. Bourdeix*

## Description

The risk is for this mite *Aceria guerreronis* Keifer to reach the Pacific region, to become epidemic and to reduce the size of the fruits and yields by as much as 15- 20%.

Over the past 50 years, the coconut mite, *Aceria guerreronis* Keifer has emerged as one of the most important invasive pests of coconut in many coconut growing countries in the Americas, Africa and Asia. Although not properly documented yet, symptoms like coconut mite damage were observed in coconut fruits in Thailand. The coconut mite has not been recorded yet in the Indo-Pacific region, the area of origin of coconut, suggesting that it has infested coconut only recently. Recent studies suggest an American origin of the coconut mite and lend evidence to a previous hypothesis that the original host of the mite is not a coconut palm.

The adult coconut mite is tiny, only 0.20- 0.25 mm long by 0.03– 0.05 mm wide, yellowish white in colour and worm-like. Eggs are small, white and round to oval. Mean length of the life cycle from egg to adult is about 10 days. Their small size, worm-like body and high reproductive performance make the coconut mites one of the most intractable pests in the world. They colonize the bract-protected region under the coconut perianth, the so-called meristematic region of the fruit. The coconut mites avoid predation by using habitats that are difficult for predators to access. The coconut bracts apparently also provide protection against the direct action of many of the acaricides sometimes used against the coconut mite. The coconut mites are dispersed into new areas mainly through wind currents and possibly by infested fruits. However, the possibility of initiation of new infestations through dispersing on insects such as honeybees that visit coconut inflorescences has also been suggested. Once introduced into new areas, the coconut mite tends to establish permanent infestations, mostly in population outbursts in a short time.

The coconut mite is found in Asia, Africa and America (Central, North, South and the Caribbean), but not yet in the Pacific region. Apart from coconut, it has been reported only from three other palm species. Two of them, (*Lytocaryum weddellianum* (H. Wendl., cited as *Cocos weddelliana* H. Wendl. and *Syagrus romanzoffiana* Cham.) are palms of South American origin and are used as ornamentals. In the Indo-ocean region, the coconut mite was reported on palmyra palm, also called wine palm or ice apple (*Borassus flabellife*r) and in Areca palm in India and Sri Lanka.

The coconut mite can colonize fruits of any age, but peak populations have been observed on 3-6 month old young fruits (i.e., fruits 3- 6 months after fertilization). The coconut mites are not evenly distributed among the coconut bunches in a palm and within the coconut palms in the field.

### Occurrence and severity

Early damage caused by the coconut mite is progressively visible as a triangular white patch arising from the margin of the perianth, which is specific to *A. guerreronis*. As the infested fruits grow, the damaged tissue turns necrotic, brown colour and corklike, sometimes with deep fissures and gummy exudates. Infested fruits later become distorted with stunted growth. Coconut mite infestations can also cause extensive premature fruit drop, reduction in coconut fibre length and tensile strength and the reduction in husk availability for the coir industry.

Symptoms of the coconut mite infestation on coconut fruits differ from those of other phytophagous mites that are found on coconuts, such as *Dolichotetranychus* sp., *Amrineus cocofolius* Flechtmann, *Colomerus novahebridensis* Keifer, *Steneotarsonemus concavuscutum* Lofego & Gondim Jr. and *S. furcatus* De Leon. Usually, the other herbivorous mites that have been reported on coconut fruits are reported to produce symptoms that are characterized by a necrotic transverse strip whose proximal margin is not in contact with the perianth or the strips that encircle the whole fruit (commonly referred to as 'ring spot') or a rectangular patch extending from the margin of the perianth, but never typically triangular.

In Sri Lanka, the yield loss in affected areas varies from 2- 15%. The value of de-husked fruits also could be reduced by 30- 40%. In some countries, losses vary according to seasons, with higher attacks during dry periods.

**Mitigation and adaptation**

If the mite infestation is reported in few palms in an area for the first time, cut and burn all bunches in the infested palms, and possibly spray with 2% sulphur 80WP to wet the crown region of infested and surrounding palms.

More than 50 chemicals and mixtures have been tested worldwide to control this pest, but only a handful of chemicals have been reported to be at least partially effective. Systemic insecticides were more persistent, but the residues have been observed in fruits. See the paper 'The coconut mite: Current global scenario' in the 'References' section for details.

For biological control, pulverization of coconut, babassu, oil palm or degummed soybean oils are used in Brazil and India to control the mite. These oils have side effects on the predatory mite *Neoseiulus baraki*, a key natural enemy of the coconut mite, but they are more toxic for the mite than for its predator. In Sri Lanka, the predatory mite, *N. baraki* is recommended to control the coconut mite. Release of laboratory reared *N. baraki* at the rate of approximately 5000 mites brought to the plantation on one in four palms, at 3- 4 month intervals during the seasons without rainfall, results in lower percentage of small fruits and increased kernel thickness in the harvest.

An emulsion of 20% palm oil and 0.5% sulphur 80WP (palm oil 200 ml, water 200 ml, soap powder 12 g (2 tablespoons), aqueous sulphur 80% 5 g (1 tablespoon) was found to be effective in controlling the coconut mite in Sri Lanka. The spraying of this emulsion on to the crown of affected palms with a modified knapsack sprayer at six month intervals significantly increased the undamaged fruits and decreased the damaged, small-sized fruits in the harvest. Application of this emulsion not greatly affect *N baraki*, the predatory mite of the coconut mite. The modified sprayer can be operated on the ground with an extended output tube tied on to the top end of a bamboo stick at the required height. With this sprayer two people can spray palms up to the height of 12 m. Application of this mixture once in every six months (or 3- 4 months in drier areas) reduces the mite damage up to 90%.

In India, commercial formulations of *Hirsutella thompsoni* Fisher such as 'MYCOHIT' are available. A holistic approach to control the coconut mite by incorporating cultural practices (correct fertilizer application, moisture conservation and irrigation during drought, use of organic manure) that improve palm vigour can also be recommended.

In Sri Lanka, screening of coconut varieties with different susceptibility levels of coconut fruits to coconut mite damage has revealed that the varieties that are less susceptible to coconut mite damage are more roundish in shape and they show differences in plant volatiles and epicuticular waxes. These volatiles and waxes are either absent or produced in low amounts in susceptible varieties such as the Sri Lankan Green Dwarf.

**Actions to undertake**

- Variation among coconut varieties in response to coconut mite damage needs to be further studied. Perianth in smaller fruits is less firmly attached to the fruit enabling mites to access interspace between the fruit and the lower perianth lobes for colonization, whereas in larger fruits this gap is mostly impenetrable. Further, it was observed that on infestation, some palms resist damage by increasing the perianth-fruit gap that makes the coconut mites uncomfortable to settle, while exposing them to predators.
- Quarantine aspects need further study. The coconut mite can survive for 3 weeks on a dry coconut. Therefore, trans-boundary movement of coconut needs strict quarantine supervision. We met mariners who, 20 years ago, took back coconut seednuts from America and planted it in Fakarava atoll, French Polynesia.
- Biological control needs further study. Given the fact that the coconut mite is either absent or occur in very low populations in the Pacific region, some efforts should be dedicated to study the natural enemies in that region. Predator performance of the mite may be impaired by the presence of a second prey species.
- In Moorea Island, damage observed by R. Bourdeix and on nuts of the Compact Red Dwarf Variety looked similar to mite attacks. This needs further observation by a qualified entomologist.

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## 9. OTHER PESTS (LARGE ANIMALS)

*By R. Bourdeix, T. McKenzie, M. A. M. Gruber, O. Smus and S. Ratu*

### Description

The risk is that large animals (bigger than insects) destroy the harvest and/or compromise replanting by destroying seedlings.

Rats, crabs, squirrels and more rarely bats, are known to destroy coconuts when still on bunches, and sometimes also when fallen on the soil (crabs). The old coconut pierced by the animals remain on the ground. Some of them fill with rainwater and provide perfect breeding places for mosquitoes that can transmit diseases to animals and humans.

Rats are a major mammalian pest that damage coconut and other important crops. Three species are found in the Pacific: Pacific or Polynesian rat (kimoa, kiore), Black rat or ship rat, Brown rat or Norwegian rat. They are mainly nocturnal, but overpopulation may drive them to be active during the daytime also. Gnawing damage by rats can often be seen on young nuts but sometimes also on the trunks and on inflorescences, opening ways for disease or insect attacks. Mature nuts are fed on when they have fallen to the ground.

Wild or semi-wild pigs and goats often eat coconut seedlings planted by farmers, and sometimes ruin almost all replanting efforts. Cattle sometimes feed on the young coconut leaves, causing damage as long as the leaves remain within their reach.

In two places it has been observed by Dr R. Bourdeix that overgrowth of birds (seen in Motu One, Tetiaroa Atoll, French Polynesia) and bats (seen near Madang in Papua New Guinea) may induce an infestation by PHYTOPHTHORA. This water mold causes immature nuts to fall and sometimes the death of the coconut tree by bud rotting. One hypothesis is that the droppings of these animals constitute natural culture media for the fungus. This needs to be verified by scientific studies and more farmers observations.

The coconut crab (*Birgus latro*) is a species of terrestrial crab, also known as the robber crab or palm thief. It is the largest land-living arthropod in the world, with a weight up to 4.1 kg (9.0 lb). Coconut crabs cannot open fresh coconuts when still on the palm. In 1981, the crab was listed on the IUCN Red List as a vulnerable species, but a lack of biological data caused its assessment to be amended in 1996. Conservation management strategies have been put in place in some regions. So, it is better to keep crabs and let them eat some of the coconuts.

#### Occurrence and severity

Damage by rats and other mammals is difficult to quantify, but rats can affect production of coconut and other crops, with the most damage being done by the black rat.

In the 2010's in Marquesas Islands, most young coconut palms were destroyed by semi-wild pigs that circulate freely in plantations without being supervised or circumscribed by their owners. All attempts to replant coconut palms have failed. The village mayor has published local edicts threatening the owners of these pigs with fines, but this measure has remained mostly ineffective. Goats also eat young seedlings. Wild pigs sometimes eat mature coconut fallen on the ground.

**Mitigation and adaptation**

In case of damage by animals, the first step is to identify which animal caused the destruction of the nuts. This can often be identified by the way the fibres of the husk have been cut. Once identified, some specific actions can help control these pests.



**Plate 10.** Damage caused by squirrels on Green Dwarf coconuts in Thailand. It is rare to observe such significant damage.

Preventing rats from invading new areas is very important as it can be difficult to eradicate them later. Rats are frequently found on boats, ships and aircraft as stowaways. Rats can also swim considerable distances. Therefore, biosecurity at possible entrances must be managed. The import of rats is prohibited into and out of most Pacific island countries, including New Zealand and Australia. Some countries, such as New Zealand, use dogs specifically trained to detect rats.

Rats are commonly introduced by and found around human populations. Therefore, keeping environments clean and tidy and storing food resources securely can help reduce rat populations. Rat-proofing storage places can help reduce products being destroyed. Putting metal trunk banding or plastic sheets around the coconut palm trunk can help deter rats and stop them from reaching the crown. When using such bands, be careful: if the leaves from one palm touch another, and if rats can climb neighbouring trees, then they will reach all the coconut trees and continue to damage fruits. Electric fences (lethal and non-lethal) and other enclosures have been successful, but are expensive.

Trapping is a great option to catch all species of rats and help with identifying what species is present. Snap traps and live traps can be used. Rats may become 'trap-shy' (i.e., they avoid traps), and then are able to repopulate areas.

Baiting with pesticides is commonly used as a control or eradication tool. Commercial baits can be brought from most stores to eradicate rats within small areas (homes and storage). For wide ranges, bait stations (spaced at 50- 200 m) are used or spread along the ground. Aerial distribution is also used to dispense poisons in large and hard to reach areas. Rodenticides should be used with caution. Poisoning of non-target species may occur. Rats sometimes become 'bait-shy' to these poisons. Always follow guidelines and instructions on the use of pesticides. There may be **restrictions** on their use within your country.

Plant-derived pesticides are used within the Pacific and can be less toxic than commercial pesticides (more needs to be consumed). The young leaves of legume shade tree, *Gliricidia* are pounded and mixed with cooked rice, maize or other food as a lure. The bark can be used as well. Chemicals in the leaves, once converted with bacteria, are similar to the brodifacoum in commercial baits. In the Solomon Islands *Barringtonia asiatica* fruits' white inner flesh has been used as part of a rat poison. The scraped fruit is added to cooked rice or shredded coconut. However, this may be dangerous, as the concentration of the toxin is unknown. Be aware that some organic products can be as dangerous as modern chemicals for humans and other domesticated animals or wildlife.

Semi-wild and wild pigs can be controlled by trapping or shooting. A Marquesan farmer made the decision to install traps in his plantation, to catch, kill and eat all the pigs that roam. This type of solution may lead to conflicts with neighbours. In addition, it must be ensured that the traps used are absolutely safe for humans, and especially children. At the community level, there are often hunting campaigns that can help control wild pigs, which sometimes become dangerous for humans (seen in Atiu, Cook Island, motorcycles knocked out). In addition, the meat of these pigs is delicious and canned food well prepared according to traditional recipes could be sold at a premium price. Wild pigs should never be consumed if rat control has been undertaken in the area as the rat poison can accumulate in the tissues of pigs, particularly the liver. In Sri Lanka, protecting seedlings from pigs is carried out by enclosing the seedling with a large plastic or metal barrel having both sides open.

**Actions to undertake**

- Interactions can exist between pests. Some observations made in Thailand indicate that squirrels and/or rats, even if destroying some coconuts, may help to protect against other insect pests: it seems that they eat the *Oryctes* beetle, and could help to control it. This could indicate that we should not attempt to completely destroy these pest populations, but rather maintain them in a state of equilibrium that reduces damage to plantations. We strongly recommend an integrated pest management (IPM) approach to the control of all pests, where possible.
- Monitoring of rat populations is recommended. This can be done by rat traps, tracking tunnels or tiles and rodenticide bait blocks. They are a relatively cheap method for surveillance of populations in known areas and possible areas of concern.

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**Plate 11.** Coconut crab (*Birgus latro*) on a coconut palm  in Tuvalu.

## 10. PESTS AND DISEASES IN NURSERIES

*By R. Bourdeix and S. Boulekouran*

### Description

The risk is that diseases in nurseries may reduce the quality of seedlings delivered to farmers, and diseases may be transmitted from the infested nurseries to the farms.

#### Occurrence and severity

In the Solomon Islands, in 1979, an outbreak of disease in the Yandina commercial nursery was found to be associated with the presence of *Marasmiellus cocophilus (*Foale, 1987). This fungal organism was previously unrecognised in the Pacific and known only in Kenya and Tanzania. Seeds of the hybrid MRD x RIT (cross between the Malayan Red Dwarf and the Rennell Island Tall), which were produced in large quantities in Yandina, were banned from export after a recommendation from the SPC in Suva. In 1986 another recommendation to lift this ban was made after a period of 7 years during which the disease did not recur.

The coconut groves of French Polynesia are attacked by the *Brontispa longissima*, an insect pest attacking the very young coconut leaves. Biological control is ensured by the mass rearing of *Tetrastichus brontispae* (a parasitoid of Brontispa) which allows the release of coconut palms. In Tuamotu and Australes archipelagos, many farmers think that the beetle was introduced to their island because of the release of seedlings from the coconut nursery located in Raiatea Island. Most of these farmers no longer accept seednuts and seedlings from this nursery. We cannot confirm this disease transmission story but in 2006, when we visited the Raiatea nursery, it was full of brontispa. The beetle hides among very young leaves and may escape insecticide treatments.

In Samoa, serious seed germination problems arose due to the presence of *Marasmiellus inoderma* in the fruit husk. This fungus causes the death of the germinating seedling, often before the shoot emerges from the husk. The disease is known as coconut embryo rot, coconut pre-emergence shoot rot, banana sheath rot, taro corm rot or sheath rot of maize. Coconuts can be contaminated while still attached to bunches on coconut palms. According to Foale (1987), the plant pathologist E.H.C. McKenzie reported several findings about this disease: (1) No *Marasmiellus* is detectable in the husk of MRD X RIT hybrid seed when first harvested from the mother palms; (2) After 3 months in the nursery, up to 40% of nuts have *Marasmiellus* in the husk; (3) Seedling losses are variable depending on the variety, with greater sensitivity of the MRD x RIT hybrid compared to Samoa Local Tall.

In 2018 in Fiji, the nursery of Koronivia Research Station was contaminated by a disease, identified as leaf blight disease (*Cytospora palmarum*) by Dr Chowdappa, the Director of CPCRI, India. In some areas, the little fire ant (LFA*), Wasmania auropunctata* can colonize nurseries, care must be taken not to spread it during the distribution of seedlings.

#### Mitigation and adaptation

When installing a coconut nursery on a soil where other plants were previously growing, and especially on land previously covered by forest, old papers recommended a strong chemical disinfection of the soil before starting a nursery. This has environmental consequences and prevents the seednuts produced to be labelled as organic for at least three years.

All information related to nurseries is highly sensitive. A regular periodic report (per month or per semester) regarding the pest and disease status of national nurseries should be published online. This report must be signed by a designed service and a designed officer who will fully assume its contents. The report should also indicate, for each nursery and each crop, if the seednuts are organic or not.

A movie on coconut nursery was delivered by the CIDP project. The best technique, regularly resulting in a high germination rate, seems the one presently used in Côte d'Ivoire. In this country, the CNRA Agricultural Centre recommends that for a sandy soil the seeds are partially buried, watered regularly to efficiently control their hydration. Thus, for other countries, a solution for inland plantations could be to delimit the seedbed space with a concrete border, bring one or two trucks of sea sand, and filling the seedbed with a sand thickness of about 20 cm. Coconut was naturally selected to grow on sea sand!

From an island to the other, even in the same country, it is preferable to move seednuts rather than seedlings, and when feasible apply the same rules as in the case of international transfers.



**Plate 12.** Preparation of transportation of coconuts from one island to another in Tuvalu. Even if in this case the transfer was well prepared (non-sprouted seednuts), there is a risk of disease or insect transmission from one island to another.

**Actions to undertake**

Collaborations between farmer groups and experts working on planting material and those working on coconut pests and diseases should be strengthened. Public awareness on the management of coconut pests and diseases should include recommendations on selecting good planting material, nursery management and planting.

The use of salt or brackish waters in the coconut nursery has been tested in Brazil on the Green Dwarf coconut variety. Using such salty water could help to reduce nursery diseases. This needs to be confirmed by further studies, devoted to how to disinfect seednuts and seedlings in an organic way.

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# 11. INTERNATIONAL TRANSMISSION OF PESTS AND DISEASES

*By V. Johnson and R. Bourdeix*

### Description

The key risk is that even traces of insects or pathogens such as viruses, bacteria or fungi, when accidentally introduced into a country, may trigger epidemics and cause economic or social disasters, linked to sectors in agriculture, food, and animal and human health.

The term 'biosecurity' was first used by the agricultural and environmental communities. It related first to a set of preventive measures designed to reduce the risk of transmission of infectious diseases and pests in crops and livestock, invasive alien species, and even living modified organisms.

The National Agricultural Quarantine Services, Biosecurity teams (or equivalent organizations) play a critical role in protecting agriculture and the environment from invasive plant and animal species, pests and diseases. The Services' tasks include pest risk assessment and analysis, pest identification, pest treatment and mitigation protocols development, invasive pest management policy development, and administration. They also include routine inspections of international passengers, commercial vessels, trucks, aircraft and railcars. They work to ensure reciprocal market access – export and import of biological products - and to maintain high efficiency in any emergency response.

Pest risk analysis (PRA) and import risk analysis (IRA) are the processes that are used to technically establish phytosanitary measures regulating plants and plant products imports and exports. Although these processes are primarily used to determine import and export requirements for commercial quantities of traded commodities, they apply also to importing small quantities of germplasm that are internationally transferred as planting material or for breeding purposes. Rules for commercial products and germplasm introduction may slightly differ, where those for germplasm movements are more stringent.

### Occurrence and severity

This is an extremely important risk. Several scenarios can be quoted as illustrations: 1) imports of plants other than coconut palms but which have transmitted coconut pests; 2) introductions of coconut plant material that have transmitted coconut diseases and 3) Introduction via machinery and equipment unrelated to agriculture, such as brightly lit warships on which *Oryctes* beetles have been found attracted to light. Another case is coconut products transmitting pests and diseases to organisms other than coconut, but this will not be described here.

Two examples of such introductions are: 1) the coconut rhinoceros beetle (*Oryctes rhinoceros*) was introduced into Samoa by a large boat transporting hundreds of thousands of rubber seedlings in the early nineteenth century, and introduced elsewhere in the Pacific Islands over subsequent decades. Some Dwarf seednuts transferred in 2018 from Costa Rica to Dominican Republic were infested with nematodes (*Bursaphelenchus cocophilus*- causing red ring disease) and they were destroyed. When species are transmitted to areas beyond their natural range, there is also a risk that they will spread rapidly in the absence of natural predators which normally co-evolve in the natural habitats. Insect and other vectors are often responsible for transmitting pathogens, so these also need to be considered in any quarantine and pest mitigation strategy.

**Mitigation and adaptation**

The first step is to identify the range of pests that are likely to be infesting commodity flows, carried by coconut food and non-food products, seednuts, seedlings, pollen or embryos (cultivated *in vitro*). For each of these pests, technical data are compiled in a datasheet that include information on pest biology and transmission, and when available, their economic importance.

Coconut should be internationally moved only as processed products (including copra), seednuts, cultured embryos/ plantlets and pollen. Importing coconut seedlings is banned in most countries. Whole mature coconut and green coconut for drinking, when exported from Pacific countries are very often fumigated with methyl bromide, to destroy all insects and arthropod pests that may have casually moved with the fruits. This treatment is incompatible with organic certification. Alternatives are available, but as of 2019 these are also pesticides, and jeopardize the development of an organic market for mature and drinking coconuts in these countries.

In the case of coconut germplasm transfer, the material destined for export should be collected in a zone free of disease, and especially free from phytoplasma, viruses and viroids. A manual (Cueto et al., 2012) provides information and guidance on movement and duplication of coconut (*Cocos nucifera L.*) germplasm using embryo culture transfer protocols. Coconut embryos are extracted from the coconut and cultivated *in vitro*. Plantlets are then obtained that can be transferred to the field and grown on to become adult coconut palms. This is feasible only by well-trained scientific teams. Embryo transfer was considered as the safest technique for moving germplasm, until a team from Mexico found the lethal yellowing disease (LYD) can be transmitted through the embryo onto plantlets. Cadang-cadang has been detected in the embryo and pollen but is not proven to be seed- and pollen-transmitted. Phytosanitary measures to ensure effective hygiene must be implemented according to national and international standards when sharing material.

**Actions needed**

- **Biosecurity services** assist millions of travellers, goods, vessels and aircraft to move in and out of Pacific states and other countries at the same time, minimising adverse effects on environment, and human, animal and plant health. Public awareness and inspection programs are a crucial component of this task, and some of them should target specifically farmers. Coconut products should not be moved abroad without quarantine inspection. Developing and implementing national **by-laws** and **border controls** can also assist in successful biosecurity.
- As mentioned above, ensuring compliance with effective **phytosanitary protocols**, or introducing these where they are not currently implemented, are critical to preventing international transmissions of pests and diseases. Pacific island countries, including Australia and New Zealand, should strengthen their collaborations to have more harmonized quarantine and biosecurity policies.
- To supplement biosecurity services, countries should develop and enforce policies based on sound **epidemiological knowledge** and contingency plans to anticipate threats from key invasive species (see also separate sections on pests and diseases risks). Once a pest

invasion has been recorded, governments should be prepared to control spread and eradicate, using measures already developed in national disease management plans. This will include forecasting, surveillance, vector control and using new pest diagnostic protocols, all based on sound epidemiological knowledge. In many cases, governments may need to embark on capacity building programs.

- **Pollen** is sometimes exchanged for breeding purposes. Treatment of coconut pollen is not possible, other than sieving out the larger contaminating pests, so all consignments should be carefully, visually inspected using a low power microscope, before dispatch and again at point of entry. Use preferably pollen from bagged inflorescences where insecticide and nematicide have been added before the natural opening of the spathe.
- Using **seednuts** can reduce risks of introduction. In this case, the bracts protecting the perianth should be systematically removed, as mites breed there, and the seednuts must be treated with appropriate insecticide and fungicide. Sometimes seednuts can be partially de-husked to increase the efficiency of chemical treatment.
- **Coconut variety diversity** on farms provides some protection against epidemics. If several varieties are present in the agricultural landscape, this increases the chances that some will be more tolerant, and pest or disease spread may be constrained.

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# C. RISKS LINKED TO PLANTING MATERIAL

*By R. Bourdeix, V. Kumar and L. Perera*

In the framework of this manual, planting material refers to the type of living material used to establish an agricultural field or replace it. This chapter focus mainly on coconut planting material, even if multicropping is widely practiced in the Pacific region. Another section of the manual discusses planting material and techniques for cover crops that help maintain soil fertility.

The types of planting material generally fall into one of two groups: conventional planting material and tissue-culture plantlets.

Conventional coconut planting material includes seednuts and seedlings. Seednuts can be planted directly in the fields. In this case, as shown in a recent movie produced by the CIDP project in the Cook Islands, farmers sometimes conduct selection by removing part of the palms, generally before they start to produce, but sometimes after. Seedlings are raised in a nursery that allows good care of the young palms and enables useful comparison and selection in a homogenized environment. To date, this is the only method for obtaining organic planting material.

Tissue culture is relatively new in the case of the coconut palm. Plant tissue culture is a collection of techniques used to maintain or grow plant cells, tissues or organs under sterile conditions on a nutrient culture medium of known composition. Plant tissue culture is widely used to produce clones of a plant in a method known as micropropagation. Growing plantlets in sterile containers allows them to be moved with reduced chances of transmitting diseases, pests, and pathogens. The success of tissue-culture plantlets on a commercial scale depends on the ability to transfer plants out of culture on a large scale, at low cost and with high survival rates.

For planting material, the main risks are linked to diversity and genetic value. Farmers may be advised or forced to use a planting material with low genetic value and/or lack of diversity. The large-scale planting of a unique variety may result in the disappearance of many traditional varieties and an increased risk of major epidemics that can destroy the harvests or even the whole plantations.

Under the framework of the CIDP project, thirty participants from fifteen countries and territories in the Pacific region joined a dedicated meeting held from 17- 20th April 2018 in Nadi, Fiji. Participants agreed that the situation in Pacific countries regarding planting material is highly variable. This ranges from situations where: 1) no seedlings are provided to farmers by any institution; 2) seednuts are provided free to farmers with or without financial incentives for replanting; 3) international import of Dwarf x Tall hybrids seedlings are cultivated in vitro at 10 USD per unit (Solomon Islands); to 4) selling of special Dwarf at 100 USD per seedling (Hawai'i). All participants agreed on the 24 regional technical recommendations, of which some concern planting material.

Given the emerging risks to the coconut industry and need for large scale replanting, the group recommended that more dedicated resources be focused on coconut planting material, seed systems, and plantation management. In small island developing states, at least one research and one extension officer should be dedicated to coconuts. Larger countries should consider the establishment of separate coconut units within their Ministries with a team focussed on coconuts. Recognising both the disparities and the commonalities between these situations, the group agreed on the following six recommendations.

1. National Agricultural Services should allow farmers a primary role in making their own varietal choices and consider advising against farmers growing only a single coconut variety (Tall, Dwarf, Hybrid, or other). At the national level, agricultural services and other stakeholders should provide farmers with a range of at least six different coconut varieties, including **Tall, Dwarf, Compact Dwarf, Hybrid**, and eventually composite varieties; and explain to farmers the specificity of each variety regarding environmental adaptation and cultural practices. To reduce overall risk, farmers should be encouraged to plant more than one variety. Local stakeholders (men and women farmers, private enterprises, NGOs and CSOs) should be encouraged to become more involved in **supplying quality germplasm**. Farmers and other stakeholders **should be taught** how to **autonomously produce quality seedlings** of hybrids and other varieties, using the **Polymotu concept** or any other acceptedmethod.
2. In order to better assess and to boost the coconut value chain, the group recommends agricultural services create and/or strengthen national coconut farmer's databases and create well-documented coconut parent palm databases using **the method and datasheets** recently developed by R. Bourdeix, V. Kumar and V. Mataora. These databases should be conceived and implemented to link with other existing farmer's databases. They should also integrate with Geographical Information Systems.
3. The meeting noted that nothing can replace well-designed, regular and sustainable **breeding programs** conducted by well-trained professionals. Expertise is needed to assess the coconut breeding programs and gene banks presently existing in the Pacific region; to help developing local skills; to create new programs and to facilitate international collaboration between these programs. SPC could play a crucial role in the process by ensuring safe germplasm exchanges between countries.
4. The suggestion of organizing a **coconut variety contest** should be encouraged at local, national and regional level, in order to increase awareness of the diversity existing within the countries and the region. Such contests could be integrated in yearly cultural events organized in most PICTs (such as **Aloha festival** in Hawai'i of **Teuila festival** in Samoa).
5. The new concept of **delocalized community-based coconut collection** should be tested in the Cook Islands as a CIDP-funded activity, and should be extended to other countries. Each coconut palm planted in a public place should be from a variety perfectly identified; its identity and its localization (latitude and longitude, date of planting) should be recorded in a database available online. If the Ministry applies this advice, after ten years Cook Islands will probably have the largest coconut gene bank in the world – without devoting any dedicated land to this activity.
6. **Vanuatu** should play a leading regional role as a training centre for technical activities related to coconut breeding and germplasm conservation. Fiji could also develop a good regional breeding research centre.

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# 12. EFFICIENT AND DIVERSIFIED PLANTING MATERIAL

*By R. Bourdeix, V. Johnson, V. Kumar and L. Heimuli*

### Description

The risk is that state services, private companies and NGOs do not invest in the production of coconut material, and advise all farmers to use the same variety, or the same kind of varieties. Farmers will find themselves unduly influenced and constrained to use planting material that is genetically limited or not adapted to local conditions. A uniform variety can harbour a pathogen, if disease-susceptible, or even disease-tolerant, and thus can accelerate epidemics in the case of new or existing diseases. Yields and harvest uses may also be limited using a single varietal type that is either unproductive or not suitable for all uses.

### Occurrence and severity

As explained in the risk sections related to loss of traditional varieties and agricultural knowledge, coconut landraces (mainly Tall-types) that were created over millennia by the Pacific islanders were progressively diluted in the mass of coconut palms selected only to produce copra. We estimate that at least 50% of the coconut varieties created by Pacific Islanders over centuries are already lost, and the extent of loss for traditional agricultural knowledge is certainly much higher.

Nowadays, traditional coconut plantations in the Pacific region show a high level of variability, especially for fruit shape, weight, kernel and water contents. In the middle of a copra coconut plantation, a few palms of traditional Polynesian varieties survive, or a mix of these varieties. Some palms produce long coconuts with a thick husk that were used for making ropes, some produce large shells with flat bottoms that were used as containers, some have soft and/or sweet kernels or husks, some produce sweet and tasty coconut milk. At least half of the Polynesian coconut varieties conserved in *ex situ* gene banks were collected from such mixed populations.

A recent trend is to promote 'local Tall varieties'. But in many cases, what is called 'local variety' by farmers and agricultural officers is no longer a variety, but an uncontrolled mixture of various traditional varieties and sometimes modern hybrids. The 'best palms' harvested for seednuts are often natural hybrids between traditional varieties or progenies of these hybrids. Seednuts are harvested on palms close to Dwarf x Tall Hybrids, and sometimes directly on the Dwarf x Tall hybrids considered as traditional varieties. Such a situation was encountered in Avatoru village, Rangiroa Atoll, Tuamotu, French Polynesia. Here grew a mix of some local Tall varieties, Malayan Yellow and Red Dwarfs, a dwarf called 'Tahitian Red Dwarf' (but originating from Papua New Guinea), Compact Dwarfs from the Cook Islands, the Brazilian Green Dwarf, the hybrid Brazilian Green Dwarf x Rangiroa Tall, the Hybrid Malayan Yellow Dwarf x West African Tall, and progenies F2 and F3 from these hybrids. This mixture of varieties, many of which being imported less than 50 years ago, was already called 'the variety of our ancestors' by many villagers.

### Mitigation and adaptation

Do you want to plant Tall-type coconut? Sometimes seednuts are harvested by agricultural officers on Dwarf x Tall hybrids instead of Tall-type palms. It is not always easy to make the distinction. Hybrids may be confused with very productive Tall types. Most Tall populations are only brown or green coloured. When, in a nursery, or in the progeny of a parent palm, more than 10% of yellow or red sprout is observed, part of the seedlings is probably harvested on a hybrid instead of a Tall-type.

Because of their rapid vertical growth, Tall-types are associated with more risks than other coconut varieties. From 6 to 12 years, their vertical growth generally ranges from 60 to 120 cm per year. Even if their growth strongly reduces with age, they generally reach a stem length of about 15 m at 25 years old. Fruits and leaves fall on people, house-roofs and cars and cause damage. People, and especially children, fall when climbing palms and are often severely injured. When planted closed to houses and when a cyclone occurs, uprooted stems damage roofs and cars. A study was conducted at the hospital of Kirakira, a small community in Solomon Islands. Within a 3-year period, 142 of the trauma admissions involved children. Among them, 49 (34%) were coconut palm trauma including 35 from falls, 12 from falling branches and two from falling coconuts. Coconut palm trauma involved mainly males (80%) and the median age of those injured was 13.

Hybrids need to be demystified and promoted at all levels: Farmers, agricultural officers, processors and policy makers. A coconut hybrid is just the cross between two coconut varieties, be they local or not local. Farmers can produce hybrids by themselves as long they understand the reproductive biology of the palm. For instance, in Fiji, farmers can create a hybrid by crossing the Fijian Tall and the Rotuman Tall (bigger fruits). They are systems based on the recognition of the colour of the sprouts at nursery stage that allows to produce hybrids quite simply. For selecting the best hybrids, field genetic experiments occupying about 8-10 hectares for 12 years are needed in the framework of a regular breeding program. Such experiments can be conceived as a profitable plantation in collaboration with private partners.

### Actions to undertake

Agronomists who select varieties, determine optimum fertilizer rates or compare the effects of cropping techniques should not consider only agronomic characteristics: the criterion of yield of raw product per hectare should be replaced by yield efficiency. The selected varieties and the proposed cultivation techniques should result in products whose characteristics are compatible with traditional technologies; or, in collaboration with food scientists, new technologies adapted to the products should be developed and widely diffused.

Because of the lack of sustainable and efficient coconut breeding programs in the Pacific region, the few hybrids presently diffused were created and dates back at least 35 years. For instance, the hybrid Malayan Red Dwarf x Rennell Island Tall was first planted in 1979. It would be good to act now and to start to prepare for the future. It would be better to avoid that, in fifteen years, the hybrids planted in the Pacific region will date back 50 years.

A short movie (5- 10 minutes) is needed to explain Pacific farmers how they can produce hybrids by themselves. This will be more efficient than written guidelines. Such movie could be also useful for mother palm selection, nursery techniques and seedlings selection. Applications accessible by smartphones and paper brochure are also to be considered.

To date only two countries have started to improve hybrids: Côte d'Ivoire and Vanuatu. No Seednuts can be exported from Vanuatu because of the Coconut Foliar Decay Disease. The Lethal Yellowing Disease in Côte d'Ivoire remains quite far from the place where the parent palms are located. Pollen from the best Rennell Tall or Polynesian Tall parents would need to be imported. Such pollen will allow production of local hybrids yielding about 20% more. Further studies are needed to check disease transmission by pollen.

*In vitro* cultured coconut clones may be available in the near future, but still planting materials developed by *in vitro* technique would be expensive. In the long run, it may be cost effective. The cost of *in vitro* cultured coconut planting materials is yet to be determined and depends on the multiplication rate. Clones are far from being a panacea, as their value depends on the value of the palm that is cloned, and on the value of the fertilizing pollen, if clones are obtained from embryo plumules. Field evaluation trials are also needed to select the best clones, if not produced from known and recommended cultivars. It may become possible to import advanced clones from Vanuatu, because the cloning technique, together with molecular tests, will give the certainty of not transmitting the Coconut Foliar Decay disease.

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## 13. METHODS FOR SELECTING PARENT PALMS

*By R. Bourdeix, V. Kumar, V. Mataora, U. Remudu and J. L. Konan Konan*

### Description

The method consisting of simply harvesting seednuts on 'best' palms is what scientists are calling '*mass selection using open pollination*'. Although this method has been practiced by thousands of farmers for millennia, its efficiency over the short term remains very limited. Coconut is a perennial crop and yields of individual palms fluctuate unpredictably within the year and between years. It can be improved slightly by using best selection criteria but, even in this case, for each generation of palms in farmer's fields, the yields' improvement will be very limited, probably no more than 5 to 10%.

So, there is a risk that the planting material used by farmers will remain the same, with limited genetic improvement, only shaped by the forces of nature, from generation to generation. Such low yields may lead to poverty, economic vulnerability and the difficulty of responding to shocks. Even if some Pacific farmers have developed better techniques, as illustrated by our movie from the Cook Islands, their knowledge may not be transmitted and disappears because of globalization.

### Occurrence and severity

In the expert's opinion, up until 2018, the processes of parent palm selection conducted by agricultural officers in farmer's fields in most Pacific countries has not provided significant improvement of the existing varieties. In many cases, selection is only visual: within a plantation, 50 to 80% of the existing palms are often selected as parent palms for seednuts production.

In some cases – selecting only the largest fruits without taking account their composition, using the small germinated seednuts forgotten in the farms - these practices may even reduce the yields. The intensity of selection (selection pressure) is low so that this risk remains limited.

Thus, in the expert's opinions, most of the selection processes used so far in the Pacific region are only conservative, meaning that the progeny of the parent palms generally has the same genetic value as the population from which they are selected.

### Mitigation and adaptation

An alternative method conceived by R. Bourdeix and V. Kumar was proposed in the CIDP website and used to design proposals for implementation of better seed production systems. This method is based on: 1) a higher selection rate, only 10% of the existing palms; 2) not only on visual appraisal but also on fruit analysis conducted directly in farmer's fields; and 3) on securing all the data in a comprehensive geo-referenced database.

We created seven data sheets or forms for recording all the requested information: first about farmers and farms; 2) palm localization; 3) Palm characterization; 4) and 5) two methods for mature fruit analysis; 6) tendernut analysis; and 7) Nursery test for discarding hybrids.

Implementing such a process needs preferably a team of two or three workers, of which one is an agricultural officer and a coconut climber/harvester. The total working time is probably between one and two hours per selected palms, including the nursery test. Agricultural officers should ask for temporary recruitments of workers when needed.

The numbering of the palms is crucial. The experts strongly recommend buying sets of already numbered aluminium tags (from 1 to 1000) that will be placed with nail on the east side of the palm at about 1.80 meter above the soil, in addition to band painting. By using these tags, if another agricultural officer comes back 15 years later, he/she be able to find the palm again.

When collecting seednuts on farms, there is a way for farmers to avoid selfing (self pollination) of palms and inbreeding depression: select green palms for harvesting seednuts; germinate the seednuts and look at the colour of the sprout; keep only the brown sprouts for planting (this means green father, brown mother, so sure that the mother is not also the father). Such a method could increase the yield of 5 to 10%.

Selection of seedlings in the nursery, based on germination speed and the vigour of seedlings have proven to increase yield of a coconut population by 10- 12%. Thus, after nursery laying, selection on non-germinators in the nursery after 80% germination should be culled. Then after 7 months, seedlings should be selected based on vigour and that selection step culls another about 10% seedlings leaving only 70% seedlings for releasing to farmers from a well managed nursery. Currently in the Pacific region, this is not practiced. This concept should be introduced to all nurseries and also to farmers who are raising their own seedlings.

**Actions to undertake**

- Recover the maximum information about coconut breeding and research programs conducted in the past. This is particularly preoccupying in Tonga, the Solomon and French Polynesia. Management of information systems should be improved in ministries and research centre, and technical information effectively archived in the long run.
- Revive coconut breeding programs in the Pacific region. The examples of Côte d'Ivoire and Vanuatu show that a yield increase of 10- 20% - up to best existing hybrids – can be obtained in one generation by testing combining ability of individual male parents.
- Conduct more studies about removing the worst palms in a plantation, and planting with palms grouping, as explained in the CIDP website. Selection criteria for removing the less productive palms are to be improved: see for instance the video describing the traditional technique applied by an old farmer from Atiu, Cook Islands.

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# 14. TRADITIONAL VARIETIES

*By R. Bourdeix, F. Haikuo and M. Cook*

## Description

The risk is that the traditional varieties, which elders have taken thousands of years to breed, might rapidly disappear or dilute whereas they are vital for developing new products and markets, and for the prevention of emerging pests and diseases.

A major challenge is the existing conflict between the dissemination of agricultural technologies (intensification of agriculture) and maintaining agro-biodiversity. Adoption of more uniform, improved crop varieties may narrow down crop varietal diversity on-farm. Two polarized visions oppose each other: the 'genetic erosion model' blames globalization and the Green Revolution for most of the loss of agro-biodiversity. A less common school of thought sees improved varieties as having an important role in maintaining and even enriching genetic diversity of the local gene pool and indigenous cropping systems.

In the risk description n°12 (Lack of good and diversified varieties), we provided an example of syncretism leading to mixing and dilution of traditional and modern varieties. We also show, in the sections n°12 and n°35, how seednuts can be harvested wrongly on hybrids, either consciously or by mistake (Hybrids mistaken for productive Tall-types).

### Occurrence and severity

A study conducted on Bellona (Solomon Islands) has shown that only five coconut varieties could be found in 2004, to be compared to the nine varieties recorded forty years ago. As experts, we estimate that a quarter to half of the coconut varieties are lost every 50 years, from 1850 onwards in the Pacific region. When surveying coconut varieties, asking questions of farmers and gardeners, the reply is often 'I don't know, but I know the one who knows'. Unfortunately, in many situations, it happens that 'the one who knows' has retired or passed away and will no longer able to transmit her/his knowledge. Because of cultural and social changes linked to globalization, the agricultural knowledge of elders is often lost.

In the 2000s, L. M. Fili and T. H. Hoponoa, from the Ministry of Agriculture and Forestry of Tonga, told us about the traditional coconut variety called 'Niu 'utongau'. This variety belongs to rare forms of coconut, highly threatened, known as 'Sweet husk'. The 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 thin and sometimes can be removed with bare hands. The 'Niu 'utongau' coconut variety was said to be found in quantity only on the small coral islet of Onoiki in the Ha'apai group. In 2018, when returning to Tonga, the key officers in the Ministry of Agriculture did not know 'Niu 'utongau' and had no idea about the traditional conservation work by elders in Onoiki motu.

During a survey conducted in Moorea Island, we interviewed a farmer about the same kind of rare and disappearing *sweet husk* varieties (see above). He replied: ‘I had one *kaipoa* coconut palm in my farm, but I cut it two years ago. Why? Over 10 years, I was unable to harvest a single fruit: all were stolen and eaten by children from the neighbourhood.’ This example is emblematic of the dynamics that occurred in Polynesia in the 2000s: a traditional variety remains appreciated by the child, the next generation; the farmer is not aware of the rarity and of the cultural value of the resource; because of various reasons – in this case overuse due to rarity- the farmer neglects or destroys the resource.

Crop diversity is central to food security. Article 9 of the International Treaty on Plant Genetic Resources for Food and Agriculture emphasizes the enormous contribution that local and indigenous communities and farmers have made and will continue to make for the conservation and development of plant genetic resources. With respect to national legislations, this article encourages protection and promotion of Farmers’ Rights regarding plant genetic resources for food and agriculture. This includes: a) protection of relevant traditional knowledge; b) the right to equitably participate in sharing benefits arising from germplasm use; and c) the right to participate in making decisions, at the national level, on related matters. Thus, national laws that restrict access to plant genetic resources have emerged in many Pacific countries, while most of these countries do not have coconut gene banks to preserve their traditional varieties. The recognition of national sovereignty and restrictions to access genetic resources, combined with a lack of interest about traditional varieties, have made the availability of genetic diversity in recent years much more difficult. We estimate that complicating the management of genetic resources in such situation creates a strong risk of increasing the losses of traditional varieties.



**Plate 14**. Whitish sweet husk variety (left) compared to normal coconut husk (right).

**Mitigation and adaptation**

The coconut industry is facing an important revival linked to the diversification of coconut products. Both traditional varieties and associated knowledge should be preserved, because of their high cultural value and their economic interest.

Governments to support agricultural services in collecting, characterization and perseveration traditional coconut varieties. This may remain difficult in the Pacific countries that do not have coconut gene banks. The new concept of delocalized community-based coconut collections developed in the Cook Islands may help in such situation.

Agricultural officers, when selecting mother palms for national coconut replanting programs, should record data on palms in farmers' field as recommended in the method developed by Bourdeix et al. (2018); and carefully keep these data in a standardized and easy-access format. Create, share and maintain databases of traditional varieties conserved *in situ* by farmers, and produce catalogues of traditional varieties, following the template created for the catalogue of conserved germplasm.

Farmers' perception is the key determinant of their actions. Thus, communication with farmers is crucial. Farmers can pay more attention to conservation of their traditional varieties, and act by themselves, as individual or through NGOs or associations.

In the highly competitive context of the tourism industry, it is becoming increasingly important to stand out by offering less standardized travel offers. Many tourists are no longer satisfied with the exotic golden beaches fringed by anonymous coconut palms. Those who are satisfied of it will choose the cheapest destinations. According to Bourdeix et al. (2013): 'Coconut palms should no longer serve as symbols of anonymous and counterfeit exoticism: they tell true stories, specifically related to island cultures in the framework of an ecotourism approach.'

**Actions to undertake**

Ministries of Agriculture, in coordination with important cultural events, should organize varietal contests at the national or regional level. CIRAD launched a reflection on how to organize such a contest. Its multiple benefits would be to: 1) strengthen local interactions between coconut farmers; 2) encourage farmers to develop private initiative in coconut seed production; 3) strengthen interactions between farmers and national services in charge of extension and research; 4) locate coconut germplasm, assess its diversity and facilitate the collecting process; 5) help farmers preserve disappearing traditional varieties; and 6) boost global communication of the coconut value-chain in the Pacific region.

On-farm conservation strategies may target some specific farmers who better understand the occurrence of replacement and loss and those who better appreciate the role of traditional varieties to their livelihoods. Organizing contests will help to locate such farmers.

Record the elders' knowledge before it disappears. A century of colonial, capitalistic and industrial coconut cultivation should not wipe out the traditional varieties and associated knowledge that Pacific islanders have patiently bred and developed over millennia.

Educational programs are needed for farmers to understand the importance of traditional varieties and the need to conserve them, highlighting that they may be important varieties in the future, particularly for climate resilience. Mass media advertising such as radio programs may help people learn about genetic diversity and importance of conserving it. Farmers should be encouraged to provide their most diverse traditional varieties to the National *ex situ* coconut collection. Even if not perfect, transfer to the *ex situ* gene bank will increase the probability for those varieties to be conserved.

An imported question remains: imagine I am a farmer, I am afraid of losing a traditional variety, and want to deposit it in the national field gene bank (if it exists - in the Pacific region, only Fiji and Vanuatu presently have credible and efficient coconut gene banks); but I want this variety to be recognized as a property of myself or my local community. How to proceed?

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**Plate 13**. An amazing Compact Green dwarf with 'Kaipoa' characteristics: the husk of young fruits is tender, sweet and edible in its upper part. This palm was photographed on the Katiu atoll, Tuamotu, French Polynesia. It is the only one of its kind observed so far.

# 15. CERTIFIED ORGANIC PLANTING MATERIAL

*By R. Bourdeix and S. Hazelman*

### Description

The risk is the shortage of good value organic coconut planting material. It may result in the farmer choosing organic planting material with low genetic value, so the yield of their farm will be limited; or the farmer choosing non-organic seedlings with high genetic value, so the farm could not be certified as organic during a certain period – or loose it's certification and related markets.

Organic production is a way to get better access to market and to sell farm products at better prices. The delay between un-organic management and certified organic management is 3 years. So, in theory, farmers can plant non-organic coconut seedlings with mineral fertilization and chemicals. Three years later (or 1.5 years later according to the Pacific organic standards) when or before the palms will start to produce, it will be organic if no unwanted products are used during the delay.

Another point is that, if a farm is not organic, all the surroundings farms will have to consider a buffer zone. Size of buffer zones may differ according to standards, the physical configuration of the land, and the risk of contamination. On flat land, the distance is generally 20 m or less.

#### Occurrence and severity

In many places, mixed cropping is used. Not all the coconut palms are replanted at the same time. Other crops are often grown while the coconut palms are growing and not yet producing. Even in this case, the use of non-organic coconut seednuts will not remove the organic certification of the whole farm, for the other crops grown, such as banana, cocoa, etc. Thus, having a good source of organic coconut seedlings is not a major priority.

The countries where advanced coconut seednuts and seedlings are produced are Papua New Guinea, Fiji and Vanuatu (Hybrids and Dwarf varieties). All these seedlings are presently produced in an inorganic way, using mineral fertilizers to boost parent palm production. So, organic farmers who want organic seednuts can only plant traditional Tall-type varieties.

In many Pacific countries, seednuts and seedlings are taken mainly from uncertified farmers fields and there is no recording whether these producing farmers use organic cultivation or not.

#### Mitigation and adaptation

Convince leading countries, policy makers and heads of research centres that the first government sites to be organic certified should be the places where seednuts are produced.

Local stakeholders (men and women farmers, private enterprises, NGOs and CSOs) should be encouraged to become more involved in supplying organic and good quality planting material. Farmers and other stakeholders should be taught how to autonomously produce organic seedlings of hybrids and other varieties, using the Polymotu concept or any other accepted method.

### Actions to undertake

Over the next decade, coconut cloning will develop. By growing little pieces of coconut tissues (from embryo or leaf explants) in glass tubes, scientists can obtain callus from which hundreds of plantlets can be regenerated. These plantlets are grown as seedlings in the nursery. Can such a coconut seedling that grew in a tube be considered organic?

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## D. RISKS LINKED TO AGRICULTURAL PRACTICES

*By R. Bourdeix and J. Ollivier*

There is a kind of balance to be found between the time and resources devoted to a plantation, and the benefits that this plantation will bring. For a farmer, finding that balance requires experience. This equilibrium indeed depends on many factors: the cost of labour, the economic opportunities of selling the production, the availability of land, etc. If agricultural land is widely available, it seems that a fairly extensive farming method would be more profitable in terms of quantity produced per unit of work. The yields are then low, but the work devoted to agriculture is small.

The existence of agricultural risk may rise to a preference for extensive cultivation practices that need a relatively small amount of inputs, labour and investment per unit area. This is due to the lack of a secure and guaranteed link between investment - in agricultural labour and purchase of inputs - and the return on investment (which is very often not immediate) - the volume and value of the yields. For many farmers, low incomes and lack of capital prevent good control of their agricultural environment: irrigation, fertilizers, pesticides are not widely used. Insufficient mechanization and motorization do not facilitate timely interventions over significant areas. The means of transport, storage and conservation are too rudimentary and do not help enough to even out in space and time the annual variations of an agricultural production often subject to the vagaries of nature and markets.

But when the value of land increases, when the land becomes scarce, or when the farmer wants to raise his standard of living, shifting to more intensive farming methods may require more labour and inputs.

Land degradation in many Pacific Island Countries and Territories (PICTs) has become an emerging concern in recent years. The causes of land degradation in PICTs include: deforestation; 2$^{nd}$ or 3$^{rd}$ cycle of coconut monocropping; inappropriate agricultural practices; overgrazing; mining; population pressure; land tenure issues and changing climate. Deforestation and inappropriate agricultural practices especially on sloping lands often lead to soil erosion. A recent study conducted in Africa may also apply to the Pacific region. This study suggests that smallholder farmers are unable to benefit from the current yield gains offered by plant genetic improvement. Continued cropping without sufficient inputs of nutrients and organic matter leads to localised but extensive soil degradation and renders many soils in a non-responsive state. The lack of immediate response to increased inputs of fertiliser and labour in such soils constitutes a chronic poverty trap for many smallholder farmers.

The following is an unhealthy example from Europe. As nitrogen is the main limiting factor for wheat yield in Europe, farmers have always tended to provide more fertilizer than needed, thus running the tangible risk of lodging and thus a decline in yield. This wheat lodging played an effective role of regulation. The introduction of growth regulators (anti-lodging substances) and dwarf varieties made this risk negligible. As the cost of these regulators and nitrogen was low compared to the selling price of wheat, much of this spontaneous regulation has disappeared. This led to an unreasonable increase in fertilizer doses, with significant pollution of aquifers by nitrates.

In the past, agricultural intensification has developed mainly through breeding, associated with increases in the use of inputs such as chemical fertilizers, herbicides, pesticides, irrigation and mechanization. Such a model has shown adverse effects on the environment. Today, by contrast, 'agricultural ecological intensification' has been proposed, defined as the 'maximization of primary production per unit area without compromising the system's ability to maintain its productive capacity' or as 'producing more food from the same area of land while reducing the environmental impacts'. The contribution of the Pacific region, as developed here under, may integrate in this definition an optimization of agricultural labour.

The intensification pursued to its end implies an artificialization of the environment (irrigation, for example), that should in principle reduce the agricultural risk much more than could the extensive cultivation practices. The control of water often appears as a preferred way to allow farmers to intensify production without the fear of seeing their efforts brutally reduced to nothing. Many governments are willing to invest large budgets in hydro-agricultural development. It is expected that irrigation can make up for the irregularity of the rains and provide the water necessary for the growth and development of cultivated plants when periods of water deficit are more or less predictable. Water control and drainage help to reduce the risk of inadvertent floods and excess water, even if this control seems more difficult than in the case of drought.

Consumers appreciate organic certification for several reasons: preservation of the environment, health concerns (based on the perception that organic products are better), preservation of biodiversity, real or supposed risks related to the cultivation of genetically modified organisms. To these main reasons, there is also a search for foods with better taste qualities; and reflections of a more ethical nature, which go beyond the boundaries of organic farming. These last ones concern the compensations of the producers, the relations of power and domination between stakeholders in food market, and possibility of forging direct links between producers and consumers.

In Europe, the public authorities have committed themselves to organic production. Farmers' organizations follow this movement, but with an attitude sometimes timid and circumspect. For example, in France, from 2007 to 2012, an action plan provided for the tripling of areas dedicated to organic farming (from 2% to 6% of French agricultural area). The plan was divided into 5 areas: structuring studies; research, development and training; adaptation of regulations for collective catering; encouraging the conversion and sustainability of organic farms. Some European peasant organizations were reluctant to put forward arguments in favour of organic production, which at the same time implies criticism of the conventional agriculture practiced by most of their members.

In the Pacific, the situation appears to be reversed - a much larger portion of land is traditionally managed organically. Farmers and their organizations are driving organic farming, with support from regional or global organizations like SPC and ICC. Governments took time to become supportive.

Organic farming in the Pacific region has significant advantages: environmental protection and a higher resilience to environmental changes, increasing farmers' income and reducing external input costs, enhancing social capacity and increasing employment opportunities. However, the main challenges of this production system include lower yields in comparison to conventional systems, difficulties with soil nutrient management, certification and market barriers, the educational and research needs of small-holders, and the effective support of policy makers.

In many situations, intercropping of coconut palms with food crops and self-consumption should be favoured. Outside of the Pacific region, an African study comparing farm families living in the same geographical area (Rwanda) has shown that those who practice a cash crop (tea) have a more modern lifestyle; but these so called ‘modern’ families eat less well than those who do not grow tea, even though the modern families spend more to buy their food.

Crop substitution may also be a risk - or an opportunity - for the coconut value chain. For instance, in some Pacific countries plenty of land presently or previously used for sugarcane production could be turned into coconut cultivation. In the case of stimulating an industry of bottled coconut water in the Pacific region, it would become much more profitable to cultivate coconut than sugarcane.

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## 16. FARMING TECHNIQUES

*By R. Bourdeix and V. Kumar*

### Description

In the Pacific region, most farmers are not achieving the full potential of their coconut plantation. Caricaturing slightly, here is the Western, pessimistic and stressed representation of a scenario:

> Farmers will take low genetic value seednuts: those germinated naturally in the fields from forgotten small coconuts; or large seednuts coming from a heap and selected only based on large size. They will plant the seedlings without any fertilizer, be it organic or not. Many seedlings will be destroyed by wild animals, such as pigs and goats. So, farmers will plant again and again. Maybe they will finally succeed in achieving an appropriate density of palms; maybe they will plant too densely. In this last case, the palms will grow vertically very fast with a low production of fruits. Farmers who do not use any cover crops, will have to control fast growing useless weed species by more labour-intensive ways. When, after 6 to 8 years instead of 4, the young palms start to produce, the average fruit production will be no more than 50 fruits/palm/year. Farmers will leave the husk and leaves in big heap in the plantation, without distributing them and restoring them to the soil. Agricultural manpower is lacking, and the farmer will not regularly weed by themselves. So, the soil fertility will progressively decrease, or the land will return to bush.

#### Occurrence and severity

Unfortunately, whatever we do, this scenario will continue to occur, at least in some places, in the Pacific region. Lack of machinery may result in labour intensity, which restricts production, especially for the elderly, and women who are burdened with extensive caring obligations. In developing countries, where a relatively low level of technology is frequently adopted in farming, there is typically a high level of labour intensity.

#### Mitigation and adaptation

We presented a first vision as 'Western, pessimistic and stressed'. Here is again almost the same scenario, but this time on another representation that we could call 'Pacific, optimistic and relaxed'.

> The soil, enriched with volcanic ash, is rich and fertile. The land is available in large quantities, because we are still quite few on the island. The climate is mild, watered and conducive. Just plant for it to grow. The plantation includes many cultivated species: coconut, banana, breadfruit, taro, sweet potato, medicinal plants. Maintenance is far from optimal, there are also wild species. The whole gives an impression of disorder close to nature. While the yield may be higher, it does not matter to us. For us, the important thing is to have enough income and food while working as little as possible. It is appropriate for us to make the most of each hour devoted to fieldwork.

When comparing these two representations, one could almost say there are two different worldviews that clash. Is there a true representation and a fake one? Probably no. There is a part of truth in each of these representations, which express different points of view.

In the introduction to this chapter, one of the definitions of 'agricultural ecological intensification' was 'producing more food from the same area of environmental impacts'. We could propose a new 'Pacific orientated' definition of such intensification, which also considers the labour aspect: 'producing more food from the same area of the environment, while improving the productivity of agricultural labour'.

There are already technical solutions that allow greater production while working less. We can cite the use of more productive varieties; taking special care of young coconut trees to produce well over the next fifty years, using cover crops that naturally enrich the soil and reduce weeding.

**Actions to undertake**

- Technical changes must be considered in terms of productivity of labour. It seems urgent to popularize, in full agreement with the farmers, technical changes that will preserve or even increase productivity of labour, and not only increase yields. This dynamic has already begun but needs to be reinforced and integrated into all communications with farmers: 'we (agricultural officers) do not want you (farmers) only to produce more; we want you to produce more while working less'.
- Carry out training for farmers and educate them in appropriate management techniques.
- Carry out demonstrations/research on various management practices such as cover crops, fertilizer application (organic/inorganic), breeding techniques, Integrated Pest Management, water conservation etc.
- Carry out soil and plant nutrient analysis to determine the nutrient status of coconut palms in the Pacific and formulate fertilizer recommendations (either organic or inorganic).
- Study the cost benefit of optional management practices.
- Explore other special management techniques available in other countries and the possibility of adopting them into the Pacific farmers conditions, if possible (for example: Thailand uses canals to support transportation and avoid drought).

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## 17. TRADITIONAL AGRICULTURAL KNOWLEDGE AND PRACTICES

*By R. Bourdeix, S. Ratu and P. Visintainer*

### Description

The risk is that, if traditional agricultural knowledge disappears, techniques perfectly adapted to local conditions will be lost, replaced by modern and standardized ones. The most efficient agriculture would be obtained by studying, understanding and recording traditional knowledge in its local context, and merge it with modern techniques when needed.

Traditional knowledge has been slowly developed by farmers over millennia. Such knowledge is generally adapted to local contexts but tends to be replaced by modern and standardized agricultural methods. There is a risk that the useful traditional knowledge and practices will be lost because of cultural changes and globalization. In fact, this is already happening but, as it is happening increasingly, it remains a risk.

This risk is concerning not only knowledge but also practices, which are even more challenging to record. When observing traditional farmers, agricultural officers and scientists often find that they undertake very specific agricultural actions. When the farmer is asked why they are doing this, they often reply that they do not know, that they are only repeating what their parents have taught them, or that the reason is mystical or religious. Technicians sometimes ask the farmer to modify this action. This sometimes triggers disasters. It is only when things go wrong that, sometimes, scientists start to understand the reason for farmer's traditional practices.

The sharing of knowledge within a society is a crucial social and cultural fact, positively impacting cultural richness and reinforcing social structures. In traditional societies, vertical (parent to child) transmission of knowledge is by far the most important mechanism, generally accounting for more than 80% in the cases studied.

#### Occurrence and severity

Regarding preservation of local agricultural knowledge in the Pacific region, an early approach was to better understand the biological, social and historical dynamics which shape coconut biodiversity and its uses. A diachronic historical approach was developed. In many islands, the same kind of dynamics seem to have occurred. In the 1800s, Pacific families had each a limited number of coconut palms, but there existed many coconut landraces serving widely differing purposes including: food and drink; making ropes and containers; medicine; building houses, and braiding. Between 1800 and 1950, coconut and copra became a huge colonial business. The number of coconut palms in the Pacific region multiplied 60 to 100 times. During this period, the agricultural landscapes and practices were profoundly and brutally modified. Many islanders were forced to work in coconut plantations and in the copra drying ovens. On many islands, the population was decimated by diseases imported by Europeans, such as measles. Let's imagine living in a village, with no book and no computer, and that more than 90% of the villagers die within a short period. How much traditional knowledge will survive?

Nowadays, societies are quickly evolving and standardizing. Urbanized citizens have plenty of electronic appliances, vehicles, clothes etc., but most of them no longer take care of living beings, except their families, their friends and perhaps a few pets. People are saturated with too much information. They know hundreds of varieties of cars, cell phones, clothes and music. A few farmers and some gardeners may continue to pay attention to crop varieties. Traditional agricultural knowledge continues to disappear.

Sharing knowledge is sometimes perceived as losing both identity and prerogatives. When researching in French Polynesia, it appeared clearly that, in the present situation, some ethnic groups in Tuamotu would prefer the traditional knowledge to be lost than to be shared with strangers.

Conflict and incompatibility with scientific knowledge may lead to the disappearance of traditional knowledge. For instance, in French Polynesia, farmers apply three distinct classifications as 'male and female' to their coconut palms and seednuts (Bourdeix et al., 2013). From a scientific point of view, the coconut inflorescences all include both male and female flowers but more than 80% of the interviewed farmers did not know this. Although the farmer's representation does not fit the scientific knowledge, there are good reasons to think that farmer's classification is useful from a pragmatic point of view and serves them to efficiently select and breed their crop. In this situation, imposing the scientific knowledge on farmers without care may have a destructive effect on some of their useful traditional practices. On the other hand, acquiring scientific botanical knowledge may help farmers produce better varieties by themselves.

**Mitigation and adaptation**

Saving traditional knowledge in books is useful. But it sometimes leads to a kind of mummification and a loss of 'traditional flavour'. Here is a surprising story on taro varieties in Vanuatu. An ethnologist visited a farm and observed that the farmer was using a very large number of taro varieties. No agronomic reason could justify this very high number. Five or six varieties would have been sufficient to cover all the needs. When questioning the farmer, the ethnologist discovered that the reason for conservation was cultural. Each variety of taro was associated with a legend or the history of a clan. Happy with her discovery, the researcher decided to interview all the farmers. She carefully collected all the legends related to taro varieties. She published a book in local language and offered it to all clan leaders, who were happy with it. A few years later, she returned to visit the first farmer. She observed that his number of Taro varieties had strongly declined. 'Why don't you conserve these anymore?' The farmer replied: 'There is no need, as all the stories are now written in your book'.

'Knowledge must be accessible to all' is a belief and a will held by Western societies, and not shared by all ethnic groups. Scientists should not impose their scientific knowledge, or cultural assumptions, without first studying the traditional knowledge their actions may destroy.

Video is the medium closest to the traditional oral transmission of information, as you listen to and see the people. Video thus creates a useful link between tradition and modernity. The best way to record the traditional knowledge of old people is video. Good video cameras are available for 200-300 USD. Simple free software is available that allows video editing. A good example of such an approach is the movie prepared in 2018 by the CIDP in the Cook Islands (see below).

**Actions to undertake**

- Educate farmers on the importance of collecting and preserving traditional knowledge for the benefit of community and for the future generations.
- Encourage farmers to share traditional knowledge with other farming communities.

- Collect and publish traditional knowledge available in the Pacific.
- Promote selected important traditional knowledge.
- When conducting surveys on traditional knowledge and varieties, focus on individual interviews and never use as the first approach the fast 'participatory mapping method' based on group interviews. This can potentially destroy the social division of knowledge in the group. Some village people would refuse to share or might even lie.
- Systematically include in development projects the purchase of video cameras and one-day training on basic filming and video editing.
- Release videos online in a way they will remain available even if the video maker dies. Currently YouTube is a very useful medium for sharing such videos.

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## 18. COVER CROPPING AND AVAILABILITY OF SEEDS AND CUTTINGS

*By R. Bourdeix, J. Ollivier*

### Description

The risk is that many farmers have little or no knowledge about cover crops and its advantages. Even if they are aware and interested in using a cover crop, there are difficulties finding the planting material adapted in quantity and quality to their needs. Farmers could then give up the use of cover crop, losing the benefit of the nitrogen naturally brought to the soil, and of reducing the working time devoted to weeding.

Documents in the 'References' section below show that a large diversity of species that can be used as a cover crop. These plants have various advantages:

- Some naturally enrich the soil with nitrogen, and a multitude of beneficial bacteria and fungi.
- They contribute to the maintenance of the soil and limit its erosion.
- Vegetation cover, if properly managed, may reduce time spent on weed control.
- Cover crops reduce grasses, whose fast growth is in competition with that of coconut trees, and can harbour disease-carrying insects, which are especially dangerous at a young age.

### Occurrence and severity

Pacific farmers use little cover plants. They are not informed, or they are not convinced of the benefits of these plants. In cases where they practice intercropping, they do not know which species are best adapted to their situation. Last, but not least, even if they are interested, they can not easily find seeds or cuttings to grow on their plantation. They may renounce this innovation for lack of means to implement it.

This often leads to a risky 'obsession with fire'. The modern fanatical way of cleanliness in coconut groves is to compulsively use matches instead of machete, so what is thoroughly cleaned away is fertility. At the same time, dioxins are spread because of burning empty plastic bottles forgotten in the fields.

In managed coconut plantations, the most common cover crops are *Pueraria javanica* and *Mucuna prurens*. The opinions concerning these two plants are divided. Some (in Solomon Islands) argue that the *Mucuna* is too aggressive at a young age, that it can cover and smother young coconut and oil palms; those prefer *Pueraria*. Others say that once the palms have grown and make a lot of shade, the *Mucuna* is the only plant that can maintain good vegetation cover. *Pueraria* often collapses in this situation. For both species, when rains are abundant and regular, it is difficult to obtain seeds.

*Pueraria phaseoloides* is a plant species within the pea family, its largest and more robust variety being *Pueraria javanica*. It is known as puero in Australia and kudzu in many tropical regions. The reproduction can be vegetative or generative. Its main advantages as a cover crop are the high nitrogen accumulation and the improvement of the soil structure due to its deep rooting system, and its ability to overcome the invasive grass *Imperata cylindrica* and local graminea. It can be used as a grazed forage crop and as green manure in crop rotations. Furthermore, it can be used to prevent soil erosion on sloping terrain.

The variety of *Mucuna pruriens* used as cover crop is named *utilis* and has similar properties to *P. Javanica* but grows faster. Beware than in some other *Mucuna* varieties, the hairs lining the seed pods cause severe itching when touched. The calyx below the flowers is also a source of itchy spicules and the stinging hairs on the outside of the seed pods are used in some brands of itching powder.

**Mitigation and adaptation**

*Mucuna* seeds will grow in roughly prepared land, provided the seed is covered or rain falls soon after seeding. About 1000 seeds weigh 1 kg. Collect fresh seeds and soak them in water for 24 hours. It can be sown in furrows or dibbled in at 1 x 1 m spacings with two seeds per hill. Seed is sown at the beginning of the rainy season at 22 kg seed/ha. Better results are obtained by sowing into a prepared seed bed. Sow them in raised beds in polybags in the nursery to a half a finger-depth. Maintain two feet between them. In about 4 to 12 days 90% of the seeds germinate. Seedlings are transplanted to the field two months after planting.

Try to find the *Mucuna* cultivar best adapted to your local conditions among the numerous that are in use. The Mauritius bean is a black-seeded type used in green manuring, while the Australian velvet bean has a large, mottled seed. In Tanzania variety J52 yielded 1980 kg dry matter/ha in Tanzania, and 'Somerset' yielded 1780 kg. /ha. Other cultivars include 'Stringless', 'Osceola', and 'Bunch' (Queensland), J54, J77, 'Local White' and 'Local Black' in Tanzania.

*Mucuna* may be able to be reproduced by cuttings. For another species closely related to *Mucuna* (*Bractea*), the technique is as follows: Select cuttings having three nodes, apply a slanting cut about 5cm below the bottom node. Above the top node leave as much length as possible. Plant in bags filled with potting mixture. The bags are kept in partial shade until the buds open from top node. A decay may start from the tip of the top internode and proceed downwards. The dormant buds will have to sprout before it reaches the middle node. Cuttings can be dipped in water mixed with ascorbic acid (50 mg per litre) to avoid such a decay.

*Pueraria javanica* seeds should be scarified before being broadcast sown or drilled onto a well prepared, weed-free seedbed. Seed growth is relatively slow, and seed must be sown on weed-free soil. The seeds are sown by the fly or in rows, 15- 20 seeds every three meters, one meter between the lines, and 2.5 cm deep. There are 80,000 to 90,000 seeds per kg. A good seeding rate is 0.5-1 kg seeds/ha, planted at the beginning of the rainy season. In new planting locations the seeds should preferably be inoculated with an appropriate strain of the bacterium that fixes nitrogen (*Bradyrhizobium*). The first months of establishment are somewhat difficult and require weeding. After that, it becomes more aggressive and effectively smothers weeds. When seeds are not available, vegetative propagation can be done by planting rooted stolons at 1-2 m distance. Long cuttings of 70 cm to 1 m can be used, distributed at a rate of two per hole every 2x1 m.

Cuttings of cover crops can be grown in a nursery or in farmer’s field, but if moved, the same precautions as those presented in risk n°10 (transmission of pests and diseases through nurseries) apply. It is important to avoid transmission of pests and diseases when releasing seeds or cuttings to farmers.

Choice of cover plants must be tailored to the local ecological conditions. Some are better for coral soils, such as *Vigna marina*. In case of association with livestock, the edibility and digestibility of these plants also need to be considered.

The tropical nitrogen-fixing tree *Gliricidia sepium* can be used at the border of the farm as living fences, which have the advantage of reducing large animals wandering. Stakes of wood are planted close together (30 to 50 cm), these take root, become a tree, and form a fence difficult to cross.

**Actions to undertake**

- Make aware farmers about cover crops and their advantages in coconut growing fields (moisture conservation, preventing soil erosion, weed control etc.).
- Establish cover crop field demonstrations with different varieties for the farmers to observe and convince them through observation which will trigger promotion of cover crops.

It seems that the most important consideration for small farmers is not at all to enrich their soil, but to reduce the time devoted to weeding, especially for the elderly, and women who are additionally burdened with extensive caring obligations. If people do not agree on the best cover crop, maybe the best option is not to use only one cover crop, but a mix of different species. Here again, good scientific studies are missing. *Mucuna* and *Pueraria* are imported, may be there are some local plants that are also useful? Research in different Pacific islands should identify and list local alternatives to *Mucuna* and *Pueraria*.

Because of its vigorous fast-growing habit, *Pueraria* was listed as an invasive plant in Costa Rica, Ecuador, Puerto Rico and some Pacific Islands (Hawai'i, French Polynesia, Niue and New Caledonia). This is not the case with *Mucuna* because it does not have stolons that re-root.

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## 19. ORGANIC FERTILIZERS

*By S. Hazelman, R. Bourdeix, and N. Tuivavalagi*

### Description

The risk is that coconut farmers will not have access to adequate and affordable organic fertilizers. Organic coconut farmers should be able to achieve yields attained by conventional farmers without depleting the fertility of their soil.

Organic farming includes returning microbial, plant or animal material to the soil to increase or at least maintain soil fertility and biological activity. The need to maintain optimal levels of fertility to strengthen the health of plants and enhance their resistance to pests and diseases is well recognised.

### Occurrence and severity

Presently, many coconut by-products are used for organic cultivation of other crops, but not for cultivation of the coconut palms. For instance, in Rarotonga, Cook Islands, farmers traditionally use coconut leaves to manage soil in Taro plantation, but this is now sometimes replaced by a plastic cover. In most Pacific Islands, coconuts also contribute to feed for tasty organic chicken and pigs.

Most farmers do not use organic fertilization in coconut plantations. Even if part of the husk and leaves are left on the coconut plantation, they remain in a big heap and are not effectively distributed among palms.

Cultivating coconut palms without any fertilization, without cover crop and by removing all by-products will deplete the soil and reduce the yields by more than half. There are examples in other countries. In many coconut plantations located close to the sea in Côte d'Ivoire, West Africa, farmers did not provide any fertilization. Soil was over pastured by cows. All by-products were taken out: husks for burning and fish drying, leaves for braiding fences and roofs, nut for selling. Within a 20 year-period, the soil declined from good fertility with plant cover to infertile white sand with almost no plants growing under the palms. Together with ageing palms, the yield was reduced to less of than 30% of its initial value.

### Mitigation and adaptation

Feed the coconut during its first five years, it will feed you during the next fifty years. The first years are crucial for establishing the palms well. Before buying any expensive fertilizers, the following practices help to enhance soil fertility in organic farms:

- Planting green manure crops such as *Mucuna* spp., *Arachis pintoi*, and *Desmodium*.
- Using animal manure; however, this should be composted rather than being applied directly to plants; raise livestock under coconut while avoiding antibiotics as treatment for animals.
- Growing tree legumes such as *Gliricidia* or *Calliandra* in fallow fields and planting climbing beans in taro fields.
- Applying locally sourced fertiliser inputs, such as wood ash and seaweed, to sustain the soil – isolated areas are especially dependent on this practice.

At the nursery and planting stages, encourage the use of organic fertilizers for coconut cultivation. For container planting, husks, manure and biochar or charcoal could be added to the container when filling it with soil. When planting bare-rooted seedlings, both coconut husks, dried and green leaves, manure and biochar/charcoal can be placed in the planting hole. Modifications depend on the nature of the soils, and the atoll soils need special attention regarding micro-nutrients (such as iron); there may be some advantage in inverting the A and B soil horizon so that more fertile soil is immediately available to the emerging roots.

Coconut husks are rich in potassium and retain moisture and coconut leaves make good ground cover to protect soil. Do not let the coconut husks lie in a large useless heap in the farm. It is preferable, instead to use them for compost, to surround the base of the coconut palm with a first layer of coconut husk and a second layer of coconut leaves; this will both feed the palms and reduce weed growth.

The Pacific Organic Standard (POS) has provided a guideline of allowable inputs for organic cultivation in the Pacific (No. P1/2013). See the section 'References' below for details.

Organic Certified inputs like fertilizers and other products are progressively becoming available in the Pacific region. For instance, in Fiji, the company Ag Chem is selling organic inputs certified by ACO of Australia. However, it is uncertain if they are presently used in Organic Coconut production. Producing organic fertilizers can become a good business for farmers: some may benefit from coconut cultivation both by using the coconut by-products for fertilization of their own crops (including coconut) and/or by selling these by-products for preparation of organic fertilizers and substrates. There are now examples of large-scale compost production in Samoa, Fiji, New Caledonia, Cook Islands and Tuvalu.

**Actions to undertake**

In some cases of heavy infestation or epidemic expansion of pathogens, biological control may lose effectiveness. Thus, it may be useful to set intervention thresholds at which farmers would be better off foregoing the organic approach and biological control and using chemical methods as a temporary measure. It seems better sometimes to lose the organic certification but avoid the complete destruction of the plantation or the harvest. In case of chemical use, it must be certain that the products do not contaminate the coconut water and kernel, and that they are fully safe for human and animal consumption. This will give time to come back later to an improved biological control.

Study the possibility of taking soil samples from the best coconut plantations and burying them around coconut palms in places where production is lower. This can add useful micro-organisms where they are missing. In the past, more than 150 years ago, priests brought full boatloads of soil from Tahiti to the Tuamotu Atolls. There are also new commercial micro-organism preparations that could be useful to improve soil properties.

Study the possibility of preparing mulch from coconut stems and store it in confined spaces where the *Oryctes* beetles can enter but cannot leave, and feed chicken and young pigs with the beetle.

In theory, organic certified farmers must have organic management plans that outline how they will improve fertility and management of their coconut plantations. This rule, not really applied nowadays, should be implemented and strengthened in future.

Coconut exported from Pacific countries are often fumigated with methyl bromide, in order to destroy all insects and other arthropod pests that may be transported with the coconut fruits. For instance, all the containers of mature nuts leaving Tonga are systematically fumigated, so they lose their organic certification. A treatment able to destroy pests while keeping organic certification should be developed.

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## 20. MANPOWER IN COCONUT AGRICULTURE AND FACTORIES

*By J. Poihega and R. Bourdeix*

### Description

A scarcity of labour power may drive some farmers to neglect their coconut plantation: insufficient weeding resulting in turn of plantation to bush; heavy competition between plants reducing yields; difficulty in harvesting and loss of a significant part of the coconut hidden by weeds; irregular and late harvests leading to a deterioration in coconut quality. Lack of manpower may also jeopardize the economic viability of processing factories.

In agricultural planning, competition between crops is sometimes combined with extensive management of areas, without a decisive improvement in labour productivity.

**Occurrence and severity**

The conjunction of three phenomena may cause causes a scarcity of labour power: extension of surfaces, low productivity evolution, lack of adjustment of crop calendars.

In the Savai'i Island (Samoa) according to the Ministry of Agriculture and Fisheries, 20 to 30% of the coconut are not harvested; according to other stakeholders (Savai'i coconut growers association), it could be as high as 40%. Reasons are as follows: 1) Price offered is too low for the work as small growers obtain only 0.25 Tala (0.1 USD) per coconut. 2) Lack of labourers: young generation move to Apia or overseas and do not stay in the farms. Only old people often remain in the farms.

The hard work is probably a third reason. The fields are typically grass covered and the coconuts are transported on the backs of people. At certain times of the year, the situation may be worsened by labour supply bottlenecks, which are unsatisfactorily resolved by neglecting certain operations, including weeding.

In June 2017, the ' Pacific Agreement on Closer Economic Relations Plus ' (PACER) was signed and included a side-arrangement on labour mobility. The Pacific wanted an agreement that went beyond the Australian SWP and the New Zealand Recognized Seasonal Employer (RSE) scheme. Although low-skilled labour mobility is facilitated under these labour mobility programs, the Pacific wanted more binding commitments in the PACER Plus Agreement that would ensure that the region's gains from labour mobility are safeguarded. While this agreement has several cultural and economical advantages, it can also strongly affect labour supply.

**Mitigation and adaptation**

- Although the complete mechanization of coconut cultivation appears complex and not necessarily desirable, simple and affordable machines could be introduced into coconut cultivation and processing that reduce the labour demand. Such machines are well developed and affordable in India and Sri Lanka.
- Use cover crop to reduce weeding work.
- Use more modern means of harvesting and transporting nuts than carrying on a person's shoulders. See for instance the CIDP movie: coconuts are harvested with horses and collected in huge plastic bags that are mechanically dumped into trucks, minimizing the

manual labour of transportation.

- Pay the workers better, so more stay in the country instead of going abroad for work.
- Allow temporary or permanent immigration of workers from poorer countries (as presently done by Australia, New Zealand and Cook Islands in the Pacific region).

**Actions to undertake**

Labour cost is usually a major component of the capital outlay and operating cost of smallholder tree crop projects. It is therefore important to have reasonably reliable estimates of the time taken (per tree or per unit of products) for silvicultural activities (e.g., planting, weed control, thinning and pruning), harvesting and postharvest processing.

Find ways to convince the youth to stay working in agriculture.

In coconut factories too much menial and repetitive physical production line work is undertaken. While it is not good to systematically replace the work of humans with that of machines, solutions must be found. Agricultural work, even if it is repetitive, does not look like production line work. It is outside and not in a confined space; the actions are less strictly repetitive. The term production line is defined by an organization in which:

- the complex work is broken down into elementary and hierarchical tasks that execute successively and repetitively;
- each jobholder is assigned a physically fixed position (or with very few movements);
- the objects to be produced or transformed are made mobile by a suitable conveying process: They are brought and removed from each station without the operators having to worry about their handling.

Despite its obvious success in the field of production, and the wage increases obtained, many workers have denounced the inhumanity of such production line work.

Research should find ways to reduce the painstaking work in coconut plantations. In fact, many technical solutions are already available, the question is to convince farmers to use them.

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## E. RISKS LINKED TO ORGANIZATIONAL AND POLICY ISSUES

*By J. Lin, J. P. Alasia and J. Helsen*

Agriculture plays crucial role both for the livelihoods of farmers and for the economy. In addition to providing incentives towards food and nutrition security, agriculture remains the engine for economic growth. It is therefore paramount that governments invest in the agriculture sector and put in place mechanisms for regulation. Such government interventions, together with international guidelines, are needed to regulate input and commodity markets and determine best agriculture production processes. Domestic government policies and international regulations could either assist the industry to flourish or create obstacles during the process. Often, public officials try to protect society against the risks of potential food shortages, hazards such as climate change and cyclones, or excessive foreign investments.

An agricultural crisis can create problems for the society as a whole. For example, a break in agri-food supplies, rising or decreasing prices, rural migration, increased unemployment, social unrest, import - export policies among others. To mitigate the potential impacts that may arise from such a crisis, governments often try to ease political risks by intervening with various sets of policies and put in place potential conducive mechanisms towards their effective implementation.

Nowadays, countries import and export staple crops and other exotic commodities in order to cover the shortfalls or to create better revenues for the country. At the same time, transportation has proven to create many negative environmental effects, especially for countries in the Pacific, since they are remote to most dominant economies in the world.

Strict international regulations for product imports often create challenges for producers in the Pacific. They may cause an adverse effect on local production systems giving preference to the importation of cheap food, often of lesser quality. In-country biosecurity and quarantine regulations within Pacific Island countries is also a challenge. Coconut products have entered niche markets in many developed markets such as the United States, the European Union, and East Asian countries. However, to protect their consumers, importing countries set up specific regulations for food items. These can often vary from country to country. Since coconuts are made into many end-products, exporters in the Pacific must comply and be up to date on the changing regulations.

Smallholder farmers in developing Pacific countries face additional constraints in terms of limited access to credit and capital to further develop their farms and processing units. The establishment of small mutual agricultural credit unions for small farmers may be effective, so that farmers are not completely dependent public funding.

Many countries have set up coconut funds and projects in the hope of developing their coconut industry and integrating into the global market. However, the effectiveness of these programs is sometimes questionable. Replanting programs need ex-ante and ex-post monitoring and surveying to see whether the programs have achieved their goals. Extension systems need to be in place and effective, and extension officers need to follow-up with farmers and see what their needs and constraints are. There is often a discrepancy between decision-makers and farmers. Governments need to target and address the needs of farmers for projects to be successful.

Some governments might not have the capacity, nor all the information systems, to provide assistance throughout the coconut value chain. In this case, private investments in research and development programs are needed. For example, products such as coconut water and organic VCO in countries such as the Philippines and Sri Lanka are invested in by large foreign corporations.

Land tenure systems, such as indivisible lands in Pacific countries, can create obstacles to agricultural intensification and the optimal utilization of land assets. While customary land tenure systems may hamper productive investments, they have social advantages to prevent foreigners from buying excessive amounts of land. In some Pacific countries, without this traditional barrier of undivided ownership, most small islands (*motu*) would have been bought by foreign investors.

This section provides an overview of risks that are linked to policies in the coconut value chain.

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## 21. INVESTMENT IN COCONUT RESEARCH AND REPLANTING

*By J. Lin, R. Bourdeix and J. P. Alasia*

### Description

So far, in the Pacific region, major companies are not investing in coconut replanting and research. The risk is that this investment starts and generates negative effects for the most fragile actors of the sector: the small farmers. However, if the intervention of large companies is well managed, it could be beneficial to the whole coconut industry. These companies, by investing in coconut in the Pacific region, would also take risks.

There is a model of private players developing a large plantation, with a factory producing value added products. These private companies may collaborate with small farmers by training them with better cultivation and processing methods and directly buying their products. Such a win-win collaboration seems beneficial. However, creating large private farms may create competition with small farmers, reduce total market price. In the worst cases, it could even force small farms out of the competition.

One of the most impressive complex plantation/factories is in Brazil. Coconuts with husk are harvested with horses and collected in huge plastic bags that are mechanically dumped into trucks, minimizing the manual labour of transportation. CIDP published a movie on how horses are used to facilitate the harvest; a similar method using donkey existed about 100 years ago in Samoa. In the Brazilian factory, all is used to prepare high value products: husk, shell, meat, water, shell. The few that is not used is burned to provide energy to the factory. The ashes go back to the fields as fertilisers.

Private investment in trainings and technology could assist farmers to produce high value-added coconut products and to diversify from reliance on only copra and coconut oil. On the other hand, results of the research undertaken with private partners is not always publicly available and sometimes do not benefit all relevant players. Private companies use results of public research as a starting point. Then, they conduct independent research for improvements, but do not always share the results as a public good. Private research often focuses on the needs of large-scale farms in developed countries, and not enough on small farming.

Research in science and technology is crucial in improving both the quantity and quality of agricultural commodities and products such as coconut. The lack of sufficient and regular national funding of coconut research is a major challenge faced by many Pacific Islands countries. The involvement of private companies may help to complement this lack of government funding.

Private companies also run a risk when investing in coconut replanting, value-addition and research. Like farmers, they must also account for natural disasters such as cyclones and pests. Local, political and commercial constraints can reduce their profits and sometimes ruin their projects. In the Solomon Islands, about fifty years ago, Unilever invested heavily in coconut plantations and research; finally, they lost everything because of political instability. Even if the coconut industry is currently booming, there is never a guarantee that the end business will be profitable.

Long-term investment in the research and development of coconuts is crucial to ensure the sustainability and growth of the industry. Many private companies are hesitant due to the long-term time investment in fields of the coconut research. For instance, genetic experiments that test new varieties usually last 12 years or more. One solution is to invest this experiment from the beginning as a profitable plantation.

**Occurrence and severity**

In the Philippines, around 18 percent of the total agricultural research and development involved the private sector. Currently no data exists, but it appears that the prevalence is much lower in the Pacific region.

In the Dominican Republic, within the last 3 years, private companies have replanted large areas with coconut palm. A company has replanted 100,000 Brazilian Green Dwarf palms by using advanced non-organic cultivation methods. Another company planted 35,000 hybrid coconut palms imported from Mexico. These companies succeeded to obtain importation permits from Costa Rica, Brazil and Mexico (although LYD is active in this country). They paid two US dollars per dwarf seednut and between five to seven USD per hybrid seednut. Currently, Dominican Republic is exporting 300,000 mature coconut fruit to USD and Canada market and importing 25 million of coconut per year for its industry. The large new plantings by private companies are expected to produce at least 25 million more coconuts locally. This could reduce coconut imports from India and Indonesia.

As far as we know, such initiatives of large replanting programs by private companies do not yet exist in the Pacific region. Edible coconut products are often perishable; therefore, technological research and advancements are crucial in extending the storage life of products such as coconut milk and coconut water. Out of the Pacific region, some coconut research programs already involve the private sector. In Sri Lanka for instance, the production and processing of high-value added products, such as coconut water and activated carbon, involve private partners.

**Mitigation and adaptation**

If well conducted, involvement of private companies in coconut research, replanting, and value addition could be highly profitable to all partners in the Pacific region. Large private companies have the means and power. There should be a mechanism in place that could protect the interests of smallholders such as inclusion approach (smallholders are included in decision making and initiatives) and empowering a sustainable business model, while reassuring companies that they will benefit from political and commercial support.

Governments should encourage foreign investment by removing barriers, such as unnecessary red-tape procedures, while protecting small farmers and local private enterprises from overly aggressive business practices, unequal competition and land grabbing. There should be a national regulatory body, restricted to coconut or not, to monitor such investment in small countries. Land protection policies may also contribute to ensure smallholders are protected from land grab. Smallholders depends on their land for survival.

In 1996, the 'relational risk' was defined as the concern that firms may not work towards the mutual interests of the partners; hence, they may not cooperate as expected, the motives of such behaviour being either rational or irrational. 'Relational risk' seems not limited to private companies, which sometimes arouse but also undergo such situation.

### Actions to undertake

Public private partnership is a possible option to encourage farmers to produce high quality products for exports. In the Philippines, the companies Cargill, BASF, and Proctor and Gamble, have teamed up with the German development organization GIZ and the Philippine government to train farmers with the possibilities to obtain the Rainforest Alliance certification for coconut oil.

Serendi Coco, a joint venture between local and US, is the first large company which recently invested in coconut replanting in Samoa and the Pacific region. The progress of this endeavour must be followed to retrieve lessons for preparing further similar investments.

To launch a large coconut water business in the Pacific region, an economic feasibility study should be conducted, preferably with private partners already involved in the business. In Fiji, there is a special opportunity linked to a special Green Dwarf variety with pink coloured coconut water, which could be marketed as medicinal and would become a Fiji distinctive product.

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## 22. REGULATION ON THE QUALITY OF COCONUT PRODUCTS

*By J. Lin and A. Pirmansah*

### Description

The risk is that changes in coconut products quality standards required by importing countries or international bodies may complicate production and processing and may reduce exported volumes or profit margins. On the other hand, lack of regulation can lead to poor quality products being placed on the market, which will ultimately threaten or offend consumers and reduce overall consumption.

Coconut producing countries are exporting more than one hundred food and non-food types of coconut products to international markets in Europe, Americas, Asia, and Australia. Such exports are subjected to legal regulations in importing countries and specific requirements from buying companies.

The main non-food coconut products include coconut shell based products (activated carbon, briquette and coconut shell charcoal), coir fibre and coir pith/dust, and crude coconut oil used for cosmetic products. Main coconut food products are copra and its oil, virgin coconut oil, coconut milk and cream, desiccated coconut, mature (husked) and immature whole coconuts, coconut sugar, nata de coco, coconut water, as plain or a mix with other liquids.

Often, each country or region has its set of regulations when importing coconuts. Since the coconut industry is evolving rapidly, these requirements are subject to change soon. This is a major challenge for small producers who want to export their products, especially for those in the Pacific Islands due to the lack of standards in many of these countries, and their remote locations.

Anticipating this fast-changing phenomenon may help mitigate possible constraints for farmers and other stakeholders of the coconut value chain in producing countries.

To gain access and to become competitive in the international market, countries and stakeholders must ensure that they are up to date on the most recent regulations and able to adapt if regulations change.

Firms exporting to the U.S. will soon face increasingly more stringent public standards spurred by the U.S. FDA's Food Safety Modernization Act (FSMA), signed into law in 2011. FSMA requires supplier verification, food safety certification, and traceability for all food imports to the U.S.

A full study for all coconut products would is outside the framework of this risk manual. Our analysis focuses on four products for which we estimate regulations will likely evolve: bottled coconut water, whole mature coconut, immature coconut fruits, and virgin coconut oil.

### Occurrence and severity

In the U.S., according to the FSMA website, about 48 million people (1 in 6) get sick, 128,000 are hospitalized, and 3,000 die each year from foodborne diseases. Because of such problems, many developed western nations require standards or certifications when importing coconut products. Achieving certification to these standards is a difficult process for smallholders and can often jeopardize their access to markets. This is presently the case for bottled coconut water. The absence of quality standards may result in poor products that buyers will reject, reducing the market for producing countries. This is presently occurring for mature coconut fruits exported to Europe.

Coconut water is now one of the fastest growing beverages in the world. The global coconut water market size was estimated at 4.27 billion USD in 2019. The growth of coconut water internationally is projected at 8.3 billion USD in 2023.

Presently, some brands are producing water from young coconut fruits. Others are producing water from mature coconut, or a mix from mature and immature fruits, without informing the consumers. Water from mature coconut has a lower organoleptic and taste value. Thus, driven by consumers requirements and competition between brands, regulations are likely to evolve to discriminate between these two different kinds of water. This will have consequences on the whole coconut water business.

Exported mature coconuts need to comply with standards like other fresh fruits. They are expected to be ‘brown, uniform and without excessive fibres; free from cracks, pests or fungus; without sunken or wet mouldy eyes’. Some buyers in the EU may require certification, such as the GLOBAL GAP, to ensure food safety. Many fresh coconuts exported to overseas supermarkets end up rotten. This low quality, in addition to difficulty to open mature coconuts, limits potential customers. It is therefore evident that the current standards are insufficient and an improvement to address the issues will benefit the entire value chain. It is predictable that regulation will change, and requirements may vary from country to country

Almost all virgin coconut products exported to the EU, United States and Canada have organic certification. Although much of VCO production in the Pacific Islands can be considered ‘organic’, obtaining this certification proves to be difficult and costly for producers. Additionally, countries in the Pacific are developing standards for what is considered VCO. The standards for VCO production that producers adopt are those set by the ICC. These are generally accepted standards that buyers also accept. Oil in general is typically assessed against quality standards for free fatty acid content, moisture and iodine values. Some customers will also request biological assays.

Coconut water exported to countries in the European Union (EU) must meet the legal requirements of the EU and are subject to official controls. Coconut water is very sensitive to biological and chemical contamination. The EU requires that the colour of coconut water be clear and transparent. The longer the coconut is stored after harvest the opaquer the water becomes. There is currently no minimum requirement for the brix level of either natural or concentrated coconut water.

There are requirements within various food laws, including the fruit juices directive, the maximum residue levels, microbiological contamination, general product safety, additives, hygiene, and health claims. There have been some recent changes regarding certain specifications. As of 2015, the maximum lead level in fruit juices reduced from 0.05 to 0.03 mg/kg. Packaging requirements could pose a challenge for smaller producers. The package must protect the colour and taste of coconut water. New labelling requirements in late 2014 forbid any efforts that would mislead consumers, such as claims of prevention, treatment, and nutritional values. The new change also requires potential allergens to be labelled in the list of ingredients.

Additionally, the product must be free from bacteria and other contaminants, from moisture loss and dehydration. Beyond legal requirements, some firms require additional regulations for environmental and social purposes.

All coconut beverage items imported into the US must comply with the juice HACCP regulations. These regulations are updated from time to time, with the most recent in August of 2017 with the FDA Food Safety Modernization Act. In 2015, a well-known coconut water company in the US warned of not complying with HACCP standards.

Countries in the Pacific Islands have been slow to take part in the global coconut water market due to the high monetary investment needed to meet the taste and colour requirements demanded by international regulations. Other prohibitive elements include:

- Import duties in Japan of coconut import products.
- Products into Australia must pass through biosecurity. A large share of Pacific coconut products is exported to Australia.

As more and more coconut products become available and demanded in western countries, the regulations will become more stringent, and may include non-legal additional requirements by individual firms. Changes in international regulations have already taken place and are likely to continue in the future.

**Mitigation and adaptation**

Countries in the Pacific Islands have been slow to adapt to the standards and requirements of importing countries due to the cost of technology to meet the various standards, cost of the certification itself and human resource capacity to implement the various management systems that the certification requires In order to meet demand of importing nations, The first steps would be to identify the various standards and their implications on local industry, and to help farmers and producers obtain certifications most required for market access. Then, adaptation would be to have a monitoring system to react to standard's evolution, either by a change in practices or by a change in the regulations. Certification, Food Safety and Standard, Organic are all costly exercise and currently the main risk is associated with capital for smallholders.

Information on international regulations is usually published online, especially for exports to large economies like the United States, The EU, and Australia. Available links are:

- https://www.fda.gov/Food/GuidanceRegulation/HACCP/ucm2006803.htm
- https://www.fda.gov/food/guidanceregulation/fsma/
- https://www.cbi.eu/market-information/processed-fruit-vegetables-edible-nuts/coconut-water/europe/
- http://www.acp.int/sites/acpsec.waw.be/files/acpdoc/public-documents/NL%203%20EN.pdf

The regional organization 'Pacific Trade and Investment', has an office in Sydney which assist companies in meeting the requirements when exporting to Australia[8]. Local authorities are suggested to subsidise the cost for small enterprises to meet such standards and certification.

[8] See the URL: https://pacifictradeinvest.com/

### Actions to undertake

- Companies should ensure they obtain the most up-to-date information on current international regulations. Access to relevant information should be facilitated by dedicated government services.
- Trainings and understandings on regulations, such as food safety, should be provided for those who want to enter the international markets. Capacity building relating to certification and preparation is needed at national level to reduce cost and assist small enterprises.
- Those who want to enter specific niche markets for coconut water, such as organic or fair trade labels, should be informed about the necessary requirements for each country for they might differ. See the dedicated risk descriptions in this manual.
- Establish a formal information platform through either government ministries or a regional organization that specifically lists the requirements for coconut products and the access requirements to enter the various markets.
- Adopt or develop quality standards for the Pacific such as those provided by ICC, and possibly in collaboration with ICC. Based on this information, local regulations and standards should be put in place to facilitate access to the international market.

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## 23. REPLANTING PROJECTS AND RELEVANT BENEFICIARIES

*By R. Bourdeix, D. F. Koelau and A. Nongkas*

### Description

What are the risks of replanting projects? In many Pacific countries there remains a huge gap between the national objectives in terms of coconut replanting and what is really achieved. Governments sometimes devote important budget to coconut replanting programs, but this does not have the expected results.

### Occurrence and severity: *The 'bad' list.*

According to Fink (2002): '*Corruption in agricultural production poses problems for large and small landholders around the globe. Corruption issues affect land title and tenure, credit availability, quality of supplies, water allocation, marketing, and the development of agribusinesses*'. Rural societies depending on survival agriculture are affected proportionally more by corruption as the bribes paid by stakeholders generally impact a higher percentage of their income.

When considering the global cost of the whole development program and the final number of coconut palms, the average cost is often more than 10 USD per palm remaining alive in the fields. This situation can result from different types of malfunctions. What follows is a kind of 'bad list' of all that should be avoided.

In the research station, a large block of old selected coconut palms remains, but nobody remembers where they came from, who planted them, how and why. These palms produce plenty of coconuts that are taken or stolen by workers or other people. So, these coconuts are not available as seednuts, which are instead bought from farmer's fields. The choice of farms that provide the seeds is dubious. No studies are conducted to estimate the real value of their seednuts. The criteria for choosing seednuts suppliers are mainly social or relational; or the farms closest to the nursery are simply chosen.

The selection of seednuts in the farms is inefficient, or even counterproductive: seedlings already sprouted from too small nuts are forgotten in the plantation; too many selected mother palms (50 to 100% of the existing) jeopardize selection efficiency; choice of Dwarf x Tall hybrid as parent palms, mistaken for highly productive Tall-type coconut palms; choice of the largest nuts taken from the harvest heaps, which will give progenies producing a small number of large fruits and low yield.

Seednuts harvested and sold by farmers are not picked up in time: some germinate, others dry out or rot before they are transferred to the nursery.

The methods used for nurseries are obsolete or unsuitable: Only 25 to 40% of seeds germinate instead of the expected 70% standard. The watering of the nursery is irregular or non-existent. The plants develop in a rickety way. They sometimes catch diseases, which are transmitted to the estates of farmers who come for picking seednuts.

The only type of seed offered is a Tall-type variety, certainly resilient but whose yield is genetically limited. Farmers, however, are also asking for seeds of hybrid or dwarf varieties. When they ask for hybrids, instead of giving them true ones, the nursery gives seednuts harvested from hybrids. These seeds will give a heterogeneous mixture less productive than true hybrids. The false belief that hybrids are bad varieties is reinforced by this practice.

Seednuts or seedlings are given to farmers free of charge, without recipients being registered in a database, which would allow them to be found and re-contacted. No monitoring of the plantation will be carried out. Farmers who received these seeds and seedlings for free will not take care of them. More than half of the donated seeds and seedlings will rot without being planted or get overgrown where they were placed after obtaining them from the nurseries. In the end, less than one-fifth of the seeds purchased from farmers will yield new live coconut trees on farms.

Well-established coconut farmers do not take seeds from this nursery because they do not trust it. Only new farmers, or some farmers cultivating other crops, come to take coconut seednuts. They will use nuts only to feed their families and animals. Their harvest will not benefit the local coconut industry.

Hopefully, there is a not a country where all these factors occur together. But, during the visit conducted in 2018 for CIDP project in the Pacific region, at least one element of this bad list was observed in almost all visited countries.

**Mitigation and adaptation**

Observations made in Fiji and Solomon Islands seem to indicate that the process runs better when an already installed private company is involved in seednuts distribution. In this case, seednuts and seedlings are provided as a priority to the suppliers of the company. This strongly increases the probability that the new planting will benefit the coconut industry.

Other farmers should not be neglected, and in particular the youth. A recent paper tried to explore possible incentives to boost coconut production, but a lot remains to be done in this area. As discussed in another section of this manual, ppromoting joint private and public sector partnership on these replanting activities can help to enhance their sustainability.

There is an example from Fiji where coconut seednuts were distributed only to sugarcane growers, who use it mainly to plant all around their sugarcane fields. Those farmers presently use the coconuts only for self consumption and feeding their animals.

Setting financial incentives and distributing seedlings to farmers who do not want to plant coconut might be useless. There is a high risk that those farmers will take the incentive given for planting, take the incentive give for palms remaining alive 6 or 12 months later, but will not care anymore about these plantations when all incentives have been received.

Given the emerging risks to the coconut industry and need for large scale replanting, the group at the first Nadi meeting recommended that more dedicated resources be focused on coconut planting material, seed systems, and plantation management. In small island developing states, at least one research and one extension officer should be dedicated only to coconuts. Larger countries should consider the establishment of separate units within their Ministries with a team focused on coconuts.

Corruption in agriculture can be mitigated through careful project selection and good project implementation procedures. Fink (2002) proposed a methodological framework to fight corruption, which he referred to by the letters TAAPE, which stands for: Transparency, Awareness, Accountability, Prevention, and Enforcement.

### Actions to undertake

Although not very encouraging, the example (given above) of sugarcane growers in Fiji may require further reflection. Indeed, these farmers do not feed the coconut industry. On the other hand, even if it takes time, maybe some of these sugarcane growers will be more and more interested by coconut; and maybe some will shift, at least partially, from sugarcane to coconut cultivation.

A better method to convince these farmers would be to establish coconut demonstration plots and manage them the way it is done in Brazil, Thailand and Sri Lanka (see description in the section devoted to coconut cultivation). Old, irrigated sugarcane plots are the best place to install such demonstration fields. Communication campaigns to promote coconut as a high value crop will also help to convince farmers.

As an example, the National Coconut Replanting program in PNG will revolve around the regional resource centres and model farms, using a model conceived on cocoa that worked well. Each model farm will serve a group of farmers with a minimum membership of 25 female and male farmers. Elite farmers or group leaders will be owners and managers of the model farm. Coconut nurseries and demonstration plots will be established at the regional resource centres as well as at the model farms. Establishment of nurseries will go hand in hand with awareness on the coconut replanting program which will include both block rehabilitation and new block development. During the awareness campaign data on interested female and male farmers will be collected and this will determine the number of seedlings to be raised at the nurseries. In some provinces, seednuts will be given free while in others, where coconut development is well established, the seedlings will be sold at about 0.5 Euros. The supply of seedlings at the model farms will first target their own members. Other interested farmers outside of the groups will be given second priority.

An index of efficiency of coconut replanting projects could be created. As a first step, this index could be calculated by dividing the number of palms planted and standing in the fields to the total amount invested in the project. A standard value of this index should be established; in first estimation, all included, a good project should not spend more than USD 8 per coconut palm planted and alive at the end of the campaign.

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## 24. FARMER'S ORGANIZATIONS

*By J. M. Sourisseau, K. Bennett, E. Tamasese, I. Bororoa and N. Hussein*

### Description

Referring to systemic risk, a failure in the functionality of farmer's organizations (FOs) can impact the farmer's access to seeds, to pesticides, to value markets, etc. When the FO is dysfunctional, it cannot protect its members from hazardous events and it restricts the ability of individuals to access markets and the required expensive common equipment.

Each human organization needs to learn and innovate to adapt to its environment. Those who make inappropriate choices collapse and disappear. As with other kinds of organizations, farmer's organizations evolve over time, with cycles comprising different phases: birth, growth, maturity, crisis, and recovery or disappearance.

Farmer's organizations (FOs) are extremely diverse. A rough typology suggests to distinguishing (Mercoiret, 1994):

- FOs driven and created by national or international institutions, to implement specific global policies.
- FOs linked to local development programs, with specific and generally specialized tasks, their potential is very high if they survive to the initial program (which is quite rare).
- Endogenous FOs, linked to civil society movements, with diverse functions, from technical and financial supports to advocacy and lobbying.
- Endogenous FOs coming from an adaptation of traditional organizations, with a deep territorial and cultural anchorage.
- Endogenous and spontaneous FOs, targeting a specific activity (economic, social or environmental) and generally built around leaders with high skills and experience.

Their longevity, and therefore the risk of institutional rupture with negative impacts for producers, is closely related to their origin.

FOs can also be characterized by multiple parameters, of which there are four:

1. The resources available to them, in particular the quantity and nature of material, financial and human resources (members of the board, employees, etc.).
2. The technical system of the FO, depending on the characteristics of the marketed product, the technologies used, the investments made, the agricultural and/or non-agricultural activities developed, and the material and/or intangible services provided to the members.
3. The forms of internal coordination that govern collective action and cover all the formal and informal rules defining the relationships between the members and the management structure of the FO.
4. The forms of external coordination that cover different modalities (contract, networks, etc.) to define relations with external actors (customers and suppliers, community, support services, or political network).

Several external factors influence their functioning and their characteristics, namely:

- The requirements of market demand that influence the way goods or services are produced, through standards and norms, and the margins of maneuver of producers in terms of selling prices and production costs;
- Sectoral or territorial public policies that drive directions in the choice of production, goods or services and define an institutional framework that facilitates or limits the initiatives of producers and FOs.

The central key to any organization is that it is coordinated to address value chain gaps that would otherwise severely restrict the ability of individuals to access the market. Successful farmer organizations are those that are formed under such conditions. Examples of these are Krissy in Samoa which coordinated a Fairtrade farmer cluster to supply fair trade certified coconut cream and similar products for their markets in New Zealand, Australia and the USA. Another example is Natures Way in Fiji which supplies Heat Treatment services permitting products such as papaya, breadfruit, eggplant among others to have export access.

**Occurrence and severity**

There are several challenges that farmer collectives or cluster groups face. These can be in the form of the following:

a. The capacity of the FOs to provide essential support and services to their members in terms of agronomy support, provision of technology or assistance for harvesting, planting materials or liaison with Government to ensure an effective policy framework is in place
b. When the FO oversees post harvest processing, its capacity to purchase the entire crop from the ICS. In many cases the collective will not have the processing ability to utilize the entire crop or vice versa
c. Intermediation between traders and their members, to maximize the products' prices.
d. Issues of monopolization of the Internal Control Systems (ICs) by the commercial processor putting restrictions on farmers within the collective seeking to maximise revenue from their crops. Cost of certification and its maintenance.

From a value chain perspective there are several risks therefore that can occur that can create chaos in farmer associations or groupings putting the value chain at risk or causing losses to the value chain or collapsing it completely.

Some FOs may become politically involved. Their role turns more to facilitate a political agenda rather than serve the agricultural interests of their members. Collapse or absence of FOs may lead to the exploitation of farmers by unfair intermediaries.

Nevertheless, estimating the occurrence and the severity of the FO's dysfunctions for farmers, as we face systemic risks, is very difficult.

**Mitigation and adaptation**

The first field of action is the prevention of FOs failure, i.e., to work for their longevity and resilience.

Such efforts can come from national support policies. A range of measures can mitigate/manage FO dysfunctions at a government level. It may be a careful approach that organizational structures are stipulated by Government to ensure that any groups have both management and legal frameworks. Those allows them to manage the various risks, and to have an independent body to which they can seek advise or enforcement of fair and equal standards as set by Government policy.

Specific attention can be paid to a permanent support of FOs actions. In case of a market failure or an extreme climate event, supporting FOs can mitigate the consequences for producers. Some FOs, when they have financial reserves, can assist farmers in case of a cyclone.

But mitigation and adaptation can also rely on internal mechanisms and strategies. A valuable lesson learnt in the above two examples demonstrates that associations should rely on a clear requirement to work collectively. The list below gives some examples of possible clear requirements:

1. Enabling certifications to international standards such as fair trade, Organic, HACCP etc that members individually could not afford or do not have the human resource skills or time to implement
2. Enabling collective purchasing of expensive technology that would be well beyond the capacity of the individual members. From the coconut perspective, this takes the form of centralized oil manufacturers
3. Provision of a unified platform that validates communication with Government or international donors to enable access to development funds or programs. Such organizations often must deal with conflicts: members compete for funding; conflicts of interest, fraud and theft of funds may occur.
4. Collective production to ensure sufficient volumes of quality produce are available to meet the demand of customers

Another valuable lesson is the success of organizations that have a strong commercial founding membership sitting at the processing and or exporting position of the value chain structure. There is a strong financial motivation for these members to ensure a 'win win' arrangement as success of members of the collective or cluster translate to success at the processing/exporting stage.

### Actions to undertake

Such requirements may not be sufficient. FOs need good governance practises to achieve them. There is unfortunately no rule to ensure good governance, as far as the human and cultural aspects are determinant. But fine-tuned strategic objectives and clear management plans are indeed keys. FOs with relatively homogenous membership and with close links to the market (which helps both to set quality standards and to generate money for the organization itself) are generally better able to get involved in technology than their larger, more political counterparts.

The second field of action is to play on the other stakeholders (of the value chain and of the territories concerned), in order to reinforce, indirectly collective actions in the benefit of all. Here again there is no recipe, as the complexity of interactions between the stakeholders makes it difficult to anticipate the impact of a policy. But the idea is to consider the importance of collective action through FOs within the VC and the territories, to facilitate their functioning.

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**Plate 15.** Free distribution of seedlings after a general assembly of a farmers' association in Samoa. The plants distributed were the rare traditional Niu Kafa variety. This action made it possible to increase by fifty percent the total number of coconut palms of this variety existing on the island of Upolu.

## 25. SHIFT TO OTHER CROPS OR OTHER FORMS OF LAND USE

*By R. Bourdeix, N. Tuivavalagi and J. M. Sourisseau*

### Description

The middle term risk here is that land devoted to coconut cultivation, research or conservation (gene banks) may be progressively cleared of coconut palms and used for other activities; This reduction in coconut area could impact the coconut value chain and its stakeholders at several levels, in medium and long term.

#### Occurrence and severity

Between 1800 and 1950, as already discussed in risk description n°17, the number of coconut palms in the Pacific region multiplied by 60 to 100 times. A lot of senile plantations are now slowly returning to bush. From the 1980s, following the fall of the copra price, many coconut plantations in Papua New Guinea were converted to oil palm, as the land was sold to large companies and the price of copra collapsed. In Madang province (PNG), three coconut plantations were recently turned to a Tuna factory. Similar situations are encountered in many Pacific countries.

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**Plate 16.** A modern oil palm nursery in the Solomon Islands. If the large companies succeed to manage such modern nurseries for oil palm, they can also do it for the coconut palm.

Where large-scale farms are concerned, the choice to shift from coconut to another crop is not a risk for them, rather an economic choice. But doing so, the eventual providers of the plantation and the actors downstream in the value chain are affected and for them, the industrial choice is a risk for their activity and livelihood.

When it concerns small scale agriculture, negotiated and accepted by farmers and previous landowners, this shift can be seen as a positive opportunity for them, but once again the consequences for the other stakeholders in the value chain may be negative. Therefore, it could be seen as a medium and long term risk. When the transformation in land use is not negotiated or can be assimilated to forced land grabbing, it's obviously a short-term risk for the farmers and their communities.

In Samoa, the Olomanu Seed Garden and gene bank, located in the West part of Upolu Island, was the place where coconut germplasm was conserved and where coconut hybrid seednuts were produced. In 2010 the Samoan government turned it to a Juvenile Rehabilitation Centre, under the Samoan Ministry of Police and Prisons, with no more link to the Ministry of Agriculture. Most of the accessions of the coconut gene bank have been partially cut off since from this time. Samoa is now trying to create a new coconut gene bank close to the old Olomanu site. Several coconut gene banks around the world, including some with international status, have encountered or are currently experiencing this problem.

**Mitigation and adaptation**

The way to reverse the trend against coconut is to demonstrate the value chain can be more profitable and environment friendly than other cash crops. This goes with a vision all along the value chain. Coconut may not be competitive regarding only short-term economic indicators, but life cycle analysis can prove its global performances are better

Connected with the industrial global transformation of the coconut value chain, the modernization of breeding and nursery techniques and processes can allow replantation and mitigate the risk of abandonment. In addition, for the actors up and downstream from production, reorganization of the value chain playing on better prices for the products or developing exchanges with other areas still producing are ways to adapt while maintaining activities around coconut production.

*Ex situ* gene banks and agricultural research centres are crucial for conserving and testing the planting material used for creating new coconut varieties. Be they Field, *Cryo* or *In Vitro*, the gene banks should be from the beginning conceived as multifunctional. Creating a new *ex situ* field gene bank for conserving only coconut, as presently envisioned in Samoa and PNG, seems not viable. The patrimonial value of this gene bank will not be sufficient to ensure its durability. One of these days, be it in 15 or 30 years, a local policy maker will decide to recover the land for other purposes and will destroy the gene bank. Some experts are of the opinion that such 'pure coconut' field gene banks are already dead even before being planted.

The case of Olomanu in Samoa needs more attention. Olomanu could have become a Juvenile Rehabilitation Centre and, in the same time, could have remained a coconut gene bank. Young prisoners could have been trained to the technical tasks required for gene bank and research activities, and to pay more attention to biodiversity and the importance of conserving traditional varieties. The media image of the Ministry of Police would have benefited from such a situation. But this kind of organization needs multifunctional flexibility and harmonious relationships among departments that remains rarely found in the Pacific region.

**Actions to undertake**

A wide set of actions is needed to make coconut more profitable and to allow coconut plantation to remain viable in the medium and long term. As described all throughout the present manual, this set comprises incentives to maintain and enhance production means, better production techniques (including the strategic issue of tree and fruit protection), incentives to improve the quality and the diversity and therefore the price of coconut products and the income for farmers and traders, and finally to gain more rewarding markets.

Convince growers of other crops of the profitability of growing coconut for high value products; encourage these growers (large companies) to make coconut demonstration plots using modern and elaborate techniques that they already use (especially for nursery and beetle control);



**Plate 17.** A modern coconut nursery in Brazil.

Land tenure systems, such as indivisible lands, in the Pacific countries create obstacles to agricultural intensification and the optimal utilization of land assets. Nevertheless, this system has a social advantage: it prevents foreigners from buying excessive amounts of land. In some Pacific countries, without this traditional barrier of undivided ownership, most of small islands (*motu*) would have bought by foreign investors.

Land Protection Policy may ensure smallholders are protected and ensure that larger companies not to grab all the land. Smallholders depends on their land for survival.

Government and non-government bodies aiming at assisting economic development in the Pacific islands should support local individuals and companies involved in buying, value-adding, selling, and exporting coconuts and coconut-products. Import substitution should also be promoted as there are numerous imported items e.g., body and hair lotions that could be substituted by local, coconut-based items.

Education and training on the various dimensions of the performance of the ‘coconut tree’ sector should be strengthened. With a thriving local, coconut industry, there will be little or no desire by coconut farmers to explore other forms of land use.

Considering some adverse experiences with certain coconut gene banks, we recommend the construction of new research stations, or the installation of new field gene banks should only be established where the land on which these facilities will be located is legally recognized as being of public utility by the host government, prior to any project.

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## 26. MAKING DECISIONS WITH LITTLE INFORMATION

*By N. Tuivavalagi, J. Lin and R. Bourdeix*

### Description

The risk is that policy- or decision-makers may make inappropriate policies or decisions based on incomplete, obsolete, or erroneous information. This has led to the failure of large and expensive projects. On the other hand, faulty or erroneous information may unintentionally or deliberately mislead consumers regarding coconuts and/or coconut products.

This risk description was added on request of participants of the CDIP meeting on risk mitigation in December 2018. The participants agreed that several agricultural and development projects have failed because the information, premises and assumptions that underpinned these initiatives were false. Both technical and economic information and decisions are to be considered in this risk description even if, from the result of our online survey, the economic and market seem the most concerned and sensitive issues.

#### Occurrence and severity

At the above-mentioned meeting, one of the participants, recently appointed as the new and only coconut Officer for his country, indicated that he took over the position without receiving any single page of information or data on the coconut industry in his country from his predecessor. While some Pacific Island countries are better off, we should realize that Pacific islanders are generally not good in recording. As such, some countries lack accurate data on basic information such as number of coconut farmers, areas under coconut, number of coconut palms, etc. Even when we hire foreign experts with PhDs, they will still need local data. If data they are given is 'weak' the maxim 'garbage in, garbage out' will apply, leading to faulty conclusions.

In Pohnpei there has been an effort to award farmers with good records to encourage the practice. However, inadequate data affects other aspects of the coconut industry apart from production. A fluctuating market for coconuts and coconut products has been quoted as a major cause of problem for the coconut industry in the Pacific islands. However, looking at this issue from a broader perspective, we can say that the issue has to do with weaknesses in our capacity to study, predict, and respond appropriately to data relating to market trends. The recent (2018) fall in the price of copra and coconut oil may illustrate this situation. Some local and international experts thought the recent coconut boom - particularly the production of coconut water and virgin oil - would result in securing and stabilizing the market for copra and oil. Recent events prove that this hope was not accurate. It seems that big players organize the speculations and cause fluctuations to benefit from them - but even this last hypothesis does not rest on a solid knowledge basis.

Regarding coconut cultivation in the Pacific region, there is an example of new data which completely changes the perspective of the coconut sector. In most publications, it is written that, in the Pacific region and many other places, coconut plantations are owned or managed mainly by poor smallholders, who deal with cultivated areas of 1 to 3 hectares in average.

Recent data from a Samoan farmer organization indicates a total area of 37,933 hectares shared by only 796 farmers, so an average size of the farm of 48 hectares. If this data is confirmed, some big Samoan players own or are managing very large coconut plantations.

Strategies recommended by some visiting coconut experts would have been different if they had this information on sizes of coconut farms.

Processors need to know if some coconut products are getting more popular or if interest in some products is dying out. We should be better prepared for future events. Unfortunately, there are stories of equipment and facilities that were ordered and paid for, but never used as they arrived when the product was no longer desired by the market.

In the Pacific islands, we also have a serious problem with predicting human behavior. A sad example experienced in many Pacific islands is where coconut replanting was promoted by paying farmers to plant coconut seedlings or paying them to weed and clean up their newly established coconut plantations. This initiative was based on the false assumption that the payment would make farmers develop a long-term interest in their coconut plantations. In many cases, farmers were just interested in receiving the payment. It was later found that plantings were not made according to agreed procedures and specifications, and care of planted coconut palms did not continue after payments were received, leaving the palms to be smothered and killed by weedy vines.

Another sad thing happening is people, including scientists, willingly writing erroneous information to uplift or downgrade certain products, in a context of merciless economic competition between agricultural and commercial sectors.

A recent study conducted in Africa listed the possible consequences of failure of research and development projects, and this can also apply to inefficient policies. It slows down economic growth, loss of revenue by state, unemployment, creates a bad image for government or implementing bodies, collapse of local businesses, cost escalation, government sector underdevelopment, loss of foreign aid/grants, discourages investment, stricter donor regulations, loss of election, financial institutions lose confidence in the state, loss of revenue by the citizens, lack of capacity, substandard infrastructure; it slow down citizens' human empowerment, loss of worker hours, pollution, armed robbery and theft, relocation of services, denial of citizens' basic rights, loss of properties, emotional stress on citizens, accidents and deaths, imprisonment, and abandonment of homes.

**Mitigation and adaptation**

The risk is not the ‘decision making’ itself, but that a wrong and negatively impacting decision is taken, due to incomplete information. Therefore, mitigation means to improve information quality and relevance, adaptation means to minimize the incidence of such a wrong decision.

Data on coconut agriculture and production remains limited. As more coconut products get widely traded, countries would have more incentives to track the production process and trade of specific products. Coconut stakeholders can also put some pressure on governments to collect individual household data on coconut farmers.

Nevertheless, some production and trade data are available and accessible for everyone. The Food and Agricultural Organization of the United Nations (FAO) publishes statistics on crops and commodities on their Statistics webpage. To gather data on the type of coconut products that each country exports and the partners they trade with, UN Comtrade seems the most reliable source. However, it does take some time to become familiarized with how to obtain the appropriate information. A limitation is that not all coconut products are represented in the database, and sometimes more specific products are generalised, such as Virgin Coconut Oil, which is clustered under 'Coconut Oil'.

Indexmundi publishes monthly updated prices data on coconut oil. It is also possible to compare different oilseed prices.

Lastly, the International Coconut Community (ICC) gathers from its member countries and publishes monthly newsletters and statistical yearbooks for a fee.

Who are the Pacific coconut farmers? Are they mainly smallholders cultivating one or two hectares or, as indicated by recent data in Samoa, large areas are cultivated by big players? At the farm level, an important step to confident decision making is recognizing there is monetary value and environmental impact in every decision made by coconut growers. As margins tighten due to fluctuation of crop price, the importance of good decision-making grows. Today's modern farmers are using data to make decisions. They must focus on improving their position on the 'big five': planting material, chemicals, fertilizer (these two may be organic), manpower and machinery. No good decision can be made using bad data.

**Actions to undertake**

Regional bodies such as SPC and USP should assist Pacific Island countries in the collection and storage of accurate and useful data and information. About the false alarm about dangers of coconut products, a Samoan Country Report of an FAO Consultation in 2013 advised (under Scientific Research and Promotional Strategies): 'There needs to be sound scientific research into the positive benefits (health) from coconut products and published under an internationally recognized research facility.'
There is no good development project without side research. Some research needs to be conducted prior the project, during the project, and even after.

Better information on prices and margins at each stage of the coconut value chain is needed. This information should first be produced; second validated according to the various national situations; third, widely diffused through social and professional networks; and fourth, stored with an appropriate conservation strategy to be able to assess its future evolution.

In the 1990s, a study analyzed experience with project evaluation for a sample of more than one thousand World Bank projects. It appeared that the project's analysis and evaluation needed to cope with a large degree of uncertainty, which the traditional methods of project evaluation and selection have not been able to reduce. Thus, the risk of incomplete, erroneous or subjective data do not concern only project conception and selection, it also relates to project evaluation. To mitigate this risk, it must be ensured that the teams chosen for project evaluations are sufficiently diverse, in profession as in opinion.

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# F. RISKS LINKED TO POST-HARVEST AND PROCESSING

*By R. Bourdeix and R. Beyer*

Risks linked to post harvest processing are varied across the region and are specific to the products and processing methods that each participant in the value chain is producing. This variation across the wide diversity of actors makes the specific identification of post harvest issues challenging.

Food quality and safety are central issues in today's consumer-driven societies. Recent health issues and crises have directed consumer attention to food safety issues. Theses concerns have been integrated in the political agendas of many countries: for instance, the European Food Safety Agency was set up set up in 2002 following a series of food crises in the late 1990s. Consumers started to pay more attention on the way food is produced, from farms to factories. Organic production, animal welfare, the use of genetically modified organisms, trans fatty acids and saturated fats provided some of the most prominent debates. Many consumers became more demanding and specific in their food choices, leading to situations where quality has become one of the most important criteria for buying.

The products from the coconut tree are very diverse but only some of them will be discussed below, focusing mainly on food and cosmetics. Coconut kernel contains about 35% fat and 50% moisture (wet basis). For preparing copra, moisture content is reduced to less than 7% by drying. This reduces the transportation weight and cost, preventing microbiological deterioration and increasing oil content. Traditional methods for preparing copra include solar drying, smoke drying and drying using kilns.

Coconut oil has a long shelf life and a melting point of about 76 °F (24°C). Commercially, oil from copra is expelled using rotary ghanis (a traditional method of oil processing in India), hydraulic presses or expellers. This 'crude' coconut oil may not be suitable for direct consumption as it may contain contaminants and must be refined with further heating and filtering. Refined, bleached, and deodorized (RBD) coconut oil is widely available and used for cooking, commercial food processing, and cosmetic, industrial, and pharmaceutical purposes. Different types of coconut oil (edible) are available, namely: coconut oil from copra, with different grades, such as refined, unrefined, ' white copra', solvent extraction method from coconut expeller cake; and coconut oil from wet coconuts, obtained by extraction with heating or without heating (virgin).

Copra cake or copra meal is the coconut flesh residue after oil expelling (cake) or after additional solvent extraction (meal). It can be conserved for up to 12 months at 12% moisture content. It is used for feeding cattle and, in some cases, human nutrition.

Coconut milk and cream are generic terms for the aqueous emulsion expelled from wet solid coconut endosperm. They play an important role in the cuisines of the Pacific region and Southeast Asia. Coconut butter and creamed coconut are also made from the kernel, pulverized and formed into solid blocks that can be broken up into chunks and added to sauces or curries toward the end of cooking. Some traditional products are obtained by fermentation, for example the sauce called *mitihue* in French Polynesia, made with soft coconut kernel, mixed with shrimp heads, fermented and cooked.

Desiccated coconut is unsweetened, finely ground coconut with most of the moisture removed. Coconut dietary fibre is made from finely ground, dried and defatted coconut kernel. Coconut flour has a finer grind and almost all the fat removed. Frozen fresh grated coconut is a developing product.

The tender coconut water is the liquid endosperm present in young green coconut (7-8 months old). As the coconut matures, the solid endosperm thickens while the amount of liquid endosperm reduces. At the age of 10-12 months, when the coconut is cracked open, this sweet liquid can be collected and consumed directly as it is sterile and contains sugars and vitamins. Mature coconut water was a by-product of the copra and desiccated coconut industry. In the past it was used to feed pigs and cattle when fresh, or went to waste, but it is now sold and used for preparing beverages.

The unopened flower of the coconut tree is the source of a sweet sap. A sharp knife is used to make a very fine slice in the bud. Several incisions twice a day result in the continuous flow of nectar, that is used to produce syrup, a kind of vegetal honey, sugar, vinegar and alcoholic beverages. Tuvalu and Kiribati are the Pacific hubs of such production.

With the world moving towards standardised systems for quality control, food safety, good manufacturing practices, environmental sustainability and various other certifications it is becoming mandatory rather then optional to utilize such systems to attain market access.

For the coconut industry, moves toward international certification are mainly confined to the processors as they are ordinarily the closest contact between established first world markets that utilize such standards for protection of their supply chain.

HACCP (Hazard Analysis and Critical Control Points) is a written food safety system that uses a preventative approach that controls for biological, physical, and chemical hazards in food production. It is a 12-step program that includes identification of potential hazards and the points in production at which they might occur, and called the Critical Control Points. They are five 'business jeopardy' areas: Worker safety, Food safety, Quality, Environment and Productivity. Critical control points are different for every business.

In western countries, almost half of vegans and a quarter of vegetarians remain dissatisfied with the choice of food products available to them. Dissatisfaction with product choice is particularly high in the U.S. (50% of vegans) versus the U.K. (36%). This niche market may be a great opportunity for coconut products.

Organic certification is another platform that is gaining significant uptake in several islands across the Pacific and is implemented to the farmer level. To a degree this is providing a level of assurance of quality or compliance to certain standards.

With the current trends developing in the market and the diversity of countries, stakeholders and products across the region it would stand to reason that certification to international standards becomes an accepted inclusion for the development of post harvest systems.

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## 27. HARVEST AND POST-HARVEST HANDLING

*By R. Bourdeix, K. Bennett, and R. Goirand and U. Vave*

### Description

The risk is that a disruption of the timing of harvest or delivery of the crop, or a delay in processing the crop delivered to the factories, could result in poor quality and degraded products.

#### Occurrence and severity

Farmers often don't have efficient access to storage and transportation, which are indeed among the most strategic segments of every long export value chain.

The fragility of mature coconuts is often underestimated, especially when the husk has been removed. Coconut seems hard and resistant but under certain conditions, which remain to be fully specified, they can degrade quickly and lose their organoleptic qualities. On very tall coconut palms producing big fruits with a thin husk, the coconut shell could be damaged if the fruits fall on rocky soils. Such an example was found in the Marquesas Island, where the farmers failed in getting seednuts from a precious old palm producing enormous coconuts with thin husks: all broke in falling.

This appearance of solidity makes visual assessment of the conservation status difficult. Sometimes a nut looks outwardly perfectly healthy but is rotten inside. This happened recently to an African exporter. After five years of activities without problem, he had negative responses from his customers indicating that part of the mature coconuts had a very bad smell due to internal mould between shell and kernel. Analysis showed that this came from: 1) harvest of immature coconut; 2) micro cracks caused by coconut falling from tall palms to the ground; 3) humidity and hot storage temperature increased internal mould risks.

If transportation is delayed, or storage at farm level is too long and in inadequate conditions, the impact on quality is getting more and more important, with bigger consequences on price and income. It may be a real difficulty to reach the quality required for export standards. In some cases, during the high harvest season, long line queueing occurs in coconut processing factories. Coconuts can be stuck beside the factory for 2-3 days which can make coconuts rot, or cracked on the truck, the water inside the coconut is wasted and may lead to huge losses.

#### Mitigation and adaptation

For this risk, mitigation strategies are to improve the practices in harvesting at farm level, and/or to improve the storage method, and/or to reduce the duration of transportation and/or to improve transportation conditions, so that the products do not degrade.

Internal procedure control helps to assess risks. For instance, for mature coconuts, sampling and cracking coconuts are conducted on a statistical basis with farm traceability. This will validate the satisfactory quality of coconuts before final sorting and packing for exportation.

This post harvesting procedure needs to be preceded by controls involving the farmers themselves: avoiding immature and over mature fruits; before dehusking, avoiding direct contact between coconut and the ground, avoiding large heaps of husked coconut under direct sunlight. The ideal would be to harvest without coconuts falling from the tree (coconut bunches must be tied with a rope) but this adds extra cost, and this is not in farmers' habits.

In India, farmers often store coconuts under their roofs; these nuts dry until losing all their free water without germinating or rotting. The kernel retracts and detaches from the shell. It ends up forming what Indian farmers call 'ball copra', a kind of almond egg naturally dehydrated and considered as a delicacy. The same phenomenon occurs sometimes when the fruits remain hooked without falling on the coconut trees. When you shake these nuts, you cannot hear the sound of water, but the dry crackling of the almond egg that hits the shell.

**Actions to undertake**

Popularize and disseminate the techniques for 'white copra' proposed by Marisco (APCC Cocotech). Such white copra has a higher selling price and can be conserved longer.

Actions are first regarding extension services on harvest, storage and transportation good practices. Advice should be delivered on how to plan an adequate storage unit by production area, avoiding mixing good and bad quality copra in the storage facilities. Advice should also concern the right moment to transport the nuts and the way to do so (packaging, control of the heat, precaution when handling, etc.).

Actions to undertake can include improved collective action. Improving collaboration among farmers, private industry, and government may help to facilitate transportation and globally reduce the time between harvest and arrival to the place of first transformation.

Another set of actions concern improvement of farms and factories or intermediary equipment. Depending on the quantity of product along each different step in value chain, it may be relevant to give incentives to farmers, or to other stakeholders, to improve the storage and the transportation conditions. Dedicated loans, with subsidized rates can be decided, or direct grants for facilitating investment. These strategic elements should get more attention from policy makers and development operators.

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## 28. AFLATOXINS, BACTERIA AND CHEMICALS

*By A. Nongkas, S. Amiot, R. Goirand and P. Nguna*

### Description

The risk is that coconut products may be contaminated by organisms that are dangerous to human health; that these products may be refused during import quality controls, or that they may cause illness or death.

### Occurrence and severity

Aflatoxins can occur in foods because of fungal contamination before and after harvest. They are mycotoxins produced by two species of fungus (*Aspergillus*) in areas with hot and humid climates. As aflatoxins are known to be genotoxic and carcinogenic, exposure through food should be kept to a minimum. In the early 1990s the European Union tightened aflatoxin B1 regulations on dairy feed to 5 µg/kg and reduced the limit for aflatoxin B1 in copra by-product to 20 µg/kg. This action put the vitally important export market for copra by-product in jeopardy.

In Canada, various brands of coconut products – mainly shredded coconut, grated coconut, organic coconut flour – were recalled because of *Salmonella*. *Salmonella*, an organism which can cause serious and sometimes fatal infections in young children, frail or elderly people, and others with weakened immune systems.

In the nineties, the occurrence and severity of contamination of copra by aflatoxins and other noxious or harmful chemicals was higher in Papua New Guinea than in other Pacific countries (Pue et al., 1991). Detection, monitoring and mitigation of these toxic substances remains a major problem at the smallholder coconut farmer level in PNG. On the other hand, no case of contamination of virgin coconut oil was ever reported in the country.

In the Caribbean, the standards for coconut water were revised in 2018 after the Caribbean Agricultural Research and Development Institute (CARDI) found unacceptable levels of coliforms in coconut water that was being commercially marketed. Coliforms are bacteria that are always present in the digestive tracts of animals, including humans, and are found in their wastes. They are also found in plant and soil material. Most coliform bacteria do not cause disease. However, the presence of coliforms could be an indicator of poor hygiene standards of the production or processing systems and some rare strains can cause serious illness.

Outside (more than in) the Pacific region, pesticides are commonly used for coconut cultivation. Organophosphate pesticides, mainly monochrotophos (acts as cholinesterase inhibitor) is mostly used. Its injection into the trunk of the coconut trees cause contamination of coconut water and kernel. The insecticide Carbofuran, from the chemical class of n-methyl carbamates, is also commonly employed. Studies indicate that the coconut water may be contaminated with pesticide residues by either way of treatment, trunk injection or bunch spaying. The presence of pesticide residues in coconut water may constitute a health risk to consumers due to their potential to cause toxicity. Hence, the pesticide residues in coconut water need to be monitored periodically from a consumer safety point of view. The maximum limits are 0.02mg/kg for monochrotophos, according to EU standards. Most studies indicate that the observed levels were significantly lower than standards.

**Mitigation and adaptation**

Directive 2002/32/EC limits aflatoxin B1 in copra and products derived to 0.02 mg/kg (based on a product with a moisture content of 12%). Drying uniformly to a 'safe' moisture content within 48 hours of splitting the nut was found to be by far the most important control measure. Average levels of aflatoxin in sun-dried copra were found to be very high. Traditional smoke drying is often correlated with low aflatoxin copra.

In coconut oil naturally contaminated with aflatoxin B1, more than 85% of the toxin is present in the soluble form, the remainder occurring in the sediment. This aflatoxin is detoxified when the oil, in a static layer less than 15 mm thick is exposed to solar radiation

Fediol have published a flow chart of the production chain of coconut oil products. SPC has published in 2011 a Processing Manual for Virgin Coconut Oil, its Products and By-products for Pacific Island Countries and Territories.

According to new CARDI standards, the coconut water bought from a local vendor or exported should be from nuts that did not touch the ground. Further, the nut should have been washed and sanitised to ensure that no unwanted natural or other micro-organisms enter the body, thereby causing illness.

Papua New Guinea launched a 'copra assessors and inspectors training program' to increase farmers' knowledge on the consequences of producing smoked and contaminated copra. One of the simple tests to be done, to indicate the right quality is the copra moisture test using a moisture meter. The test will indicate two things, namely the effectiveness of the drying process and any likely growth of spoilage micro-organisms like moulds and fungus due to a high copra moisture above 15%. Another issue for consideration in the mitigation process is the accessibility to Quality Control facilities like laboratories for testing coconut products.

**Actions to undertake**

In PNG, another step being taken to improve the quality of copra (including the issue of aflatoxin, smoke and other contaminants) was to provide affordable and efficient copra driers to farmers. These driers are prefabricated and are designed to improve heat efficiency, to reduce drying time, use less firewood and prevent damage to kiln pipes (very expensive item for farmers to purchase) by direct heat. This program will intensify in 2019 and will continue for the next three years. Training and awareness on producing good quality white copra is part of this program.

In 2015, French Polynesia developed a new model of copra oven, with two-tier drawers that dry 500 kg of copra in two days. The drying temperature is 120 °C for the first six hours and then drops to 80 to 90 °C for the remaining time. The oven is available as a kit, which can be mounted locally using a video guideline. For further information, contact the Directorate of Agriculture in Papeete.

How to kill old and unproductive coconut palm in an organic way and without sawing? Unfortunately, we do not yet have the full answer to this question. So, research is needed on this crucial point: Find an affordable - and preferably organic - product that, when injected in the trunk of the senile coconut palms, will have four effects, by order of priority: 1) not threaten human health (for instance if children take coconut from treated palms); 2) prevent *Oryctes* proliferation in the trunk; 3) kill the palm, 4) preserve and treat the wood for future utilization. The experiment could consist of testing 10 different products each on 10 different coconut palms, randomly selected in the same block in a zone where *Oryctes* is active.

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**Plate 18.** New copra oven available in a kit and based on a system of drawers mounted on rails, developed in French Polynesia.

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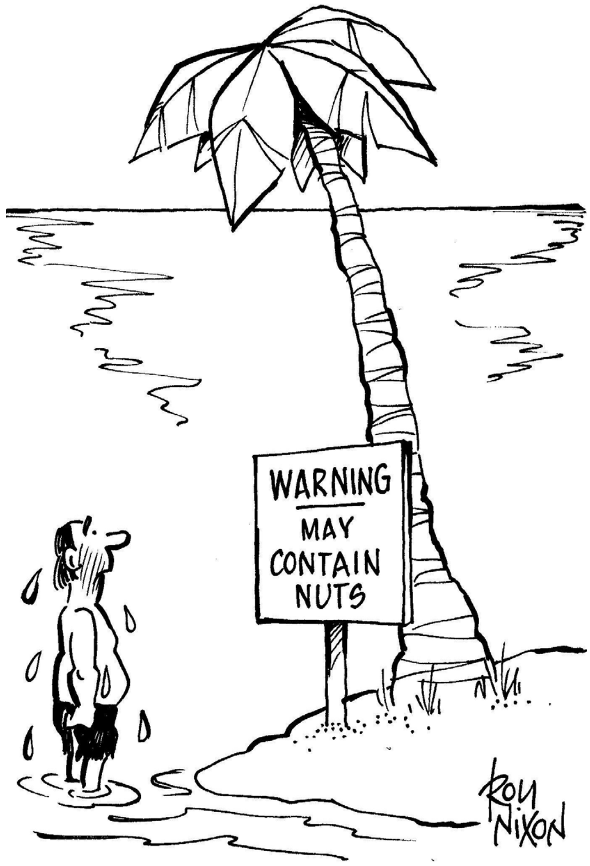

## 29. PALATABILITY AND PRACTICALITY OF COCONUT PRODUCTS

*By R. Bourdeix and J. Lin*

### Description

The risk is that, if coconut products lack or lose good taste, or are unpleasant to use, this can lead to loss of interest among consumers and to an overall reduction in consumption of coconut products which will negatively impact the entire industry.

The global markets for high-value coconut products are currently expanding, strongly driven by coconut water and VCO. It is highly likely that in the future these markets will become more and more competitive. Producers, processors and exporters will have to make a difference by ensuring and maintaining a high quality of their products. The way coconut palms are cultivated in respect to environment and health of consumers, the special characteristics of the varieties which are cultivated, and the notions of 'terroir' or 'branding by origin' will become increasingly important in marketing coconut products. At it is impossible to include all coconut products in this manual, we focus only on four products: mature coconut, water, sugar and virgin coconut oil.

#### Occurrence and severity

From a western point of view, mature coconut fruits can seem user-unfriendly. The fibrous coconut husk is hard when mature and generally it is impossible to manually remove it. According to Wilson et al. (2018): 'The shell is also hard and can be quite dangerous to break if a suitable tool is not used. The kernel is strongly attached to the shell. It remains often too thin, firm and fibrous and sometimes its consumption can harm gums. Thus, there remains considerable work for breeders to upgrade the coconut palm to the status of a fully domesticated species.'

Regarding tender coconut harvested for water consumption, the husk is too thick, and the water makes up only 15 to 26% of the total fruit weight. The water properties such as flavour, aroma, and taste are easily altered, soon after it is extracted from the fruit by collecting the water in a clean container. The stage at which coconut are harvested for water differs from one country to another, and according to coconut varieties. In Sri Lanka, most of the King coconut sold for drinking in the street are cut long before they reach their sweetest taste, but it seems this is the way Sri Lankan like it, much to the regret of some tourists.

There is a need for a method of preparing coconut water that sterilizes the product and yet maintains its flavour and nutrition. The shelf-life of coconut water can be improved by eliminating the enzyme that causes degradation of the quality, i.e., polyphenol oxidase and peroxidase enzyme. Heat treatment such as pasteurization and Ultra Heat Treatment may inhibit the growth of these enzymes although can result in the loss of coconut water's unique and desirable properties.

Some companies are marketing mature coconut water or a mix of mature and immature coconut water, and do not indicate it clearly on the packaging of the beverage. Coconut water is sometimes diluted with normal water; sugar and other components added to adjust acidity and taste. Packaged coconut water is mostly sweetened, accounting for 75% of the packaged coconut water market. Flavoured products are the newly emerging market segment. In 2014, flavoured coconut products dominated new product launches, accounting for nearly 68% of total launches led by mixes with pineapple, green tea, mango and orange.

Pasteurization slows the growth of bacteria (or kills it altogether), thus extending a perishable beverage's shelf life. Most coconut water is pasteurized via one of the following methods.

- HPP: A form of 'cold' pasteurization in which a packaged beverage is submerged under water and subjected to high pressure. Harmless Harvest uses this form of preservation.
- Flash Pasteurization: A beverage is heated to 71° to 74°C for up to 30 seconds. Most brands mentioned herein use this process.
- Ultra High Temperature Pasteurization: Often used to sterilize milk, a beverage is heated to above 138° for a couple of seconds. In this manual, the brand Zico was the only one that used this process.

In Thailand, processors use microfiltration of coconut water, and the fact that the water sometimes has a pink colour is integrated in their marketing as a natural fact. In Dominican Republic, large companies tried microfiltration, but they did not like it, as the water obtained lost the slightly opalescent characteristic, specific to coconut water, and looked just like plain water. We do not have evidence that the micro filtration processes used in Thailand and Dominican Republic are the same. The industrial processes for coconut water are often kept secret by the large companies.

For virgin coconut oil, the only quality criteria used in the Pacific region are free fatty acid and the moisture content. The quality of VCO produced in Pacific countries is sometimes insufficient for export because the coconut meat is shredded and heated. In Southeast Asia also, a recent study investigated the keeping quality of commercial virgin coconut oil (VCO) and the probable cause of its quality deterioration. Fourteen brands of commercial VCO and a fresh prepared VCO were used. The results indicated that 10 out of 14 commercial VCO had objectionable odour and taste, clearly detected by panellists. This study confirmed that once the VCO undergoes brief photooxidation, subsequent protection using light barrier packaging material will not be effective to inhibit quality deterioration during trading, display, or storage.

Personal observation of Dr R. Bourdeix indicated that coconut sugar from different countries differs in palatability. A few controlled contaminations by natural bacteria help to fully develop the aroma of coconut sugar and syrups. On the other hand, if coconut sap is too contaminated by bacteria, the sugar can no longer crystallize, and the sap is generally used to make toddy honey, as practiced for instance in Kiribati.

**Mitigation and adaptation**

The International Coconut Community (ex APCC) propose quality standards for seven coconut products, including virgin coconut oil. In addition to moisture and free fatty acids, VCO standards take also into account the colour, the iodine value, and the saponification value. Food additives are not permitted, and packaging must also follow some rules. See below.

When marketing, consider cultural specificities. For instance, we conducted a full blind test in Vanuatu comparing several varieties including the Aromatic Green Dwarf (aromatic taste of the water), the Brazil Green Dwarf (said to be the sweetest variety) and the Vanuatu Tall (nothing special). Ni-Vanuatu people appreciate the aroma of the Thai variety, the sweetness of the Brazilian Dwarf, but their blind preference is for the Vanuatu tall.

The mild flavour of coconut water is something accepted, and part of the marketing focus. One of the qualities of coconut water is its relative lack of flavour, together with the subtleties of its aroma and its low calorific content. A new method based on Raman spectroscopy has significant potential for the detection of adulteration of fresh coconut water by dilution and its masking with sugars. This may help to assess the quality of coconut water.

Some internet sites dedicated to health have recently attacked nine main brands of coconut water. They argue that manufacturers have adopted several methods of packaging that ruin its purity: Adopting water from mature coconuts, using reconstituted concentrate instead of fresh coconut water, pasteurizing coconut water with heat, adding preservatives to flavour and sweeten coconut water, and dipping coconuts in chemicals for transportation.

In Fiji, there is a great opportunity to market the water of a special Green Dwarf coconut. Its water is quite sweet and tasty, and naturally pink in colour. In this this case the marketing could be built on the medicinal properties traditionally associated with such coconut palms having the 'Pink colour' of young husk and water.

### Actions to undertake

A global study is needed on the taste and smell of virgin coconut oil from various origins. Sensory evaluation provides important quantitative and qualitative data that aids in product development and influences marketing and business decisions. The use of highly trained sensory panels can eliminate bias that often results from consumer panels; however trained panels are expensive and require training. Analytical techniques provide measurements of the stability and quality of oil and fat-based foods, including oxidation measurement. Often, the best estimates of the quality of oils and fats are evaluated by using a combination of sensory and analytical methods.

Coconut products should be better marketed and branded by variety rather than only 'terroir'. This could be a very precious tool, even if presently the industry is often running after each and every coconut they find. As far as we know, there is presently only one case of branding a coconut cultivar. The Thai coconut variety named 'Ham Hom' is famous for aromatic water. It has now gained international acceptance and, as described in risk description n°32, it has become the 'juiciest' coconut business. The Tahiti Monoï is made only from coconut growing on atolls soils of French Polynesia; it is branded by geographical origin but not by variety. It faces more commercial difficulties with competitors.

Before the varieties disappear, there is an urgent need to find, collect and describe local aromatic coconut varieties existing in the Pacific region. The most convenient way to find such variety is to organize a coconut contest, as advised in risk description n°14.

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# G. RISKS LINKED TO ECONOMICS AND MARKETING

*By J. Lin, N. Hussein and N. Tanawai*

Each country has an economic system and marketing channels that are unique to it settings and context. Even if quality coconut products are produced, without a proper supporting economic infrastructure and proper marketing strategies, challenges will remain for farmers and producers to take advantage of the current boom on some specific coconut products.

Both domestic and international levels are addressed because marketing risks – and ways to mitigate and attenuate them – are linked to domestic and international markets trends, ruptures and policies.

Government regulations often favour one category of stakeholders at the expense of another. Such regulations can hardly improve both the living conditions of small-scale farmers, producers and consumers without external sources of income. In 1986, according to the World Bank, government actions often exacerbated rather than stabilized agricultural supply and prices. The global openness of the markets, and in particular the commodities markets, which includes some coconut products, has increased price volatility and therefore the risks and economic opportunities for producers.

For the Pacific, the fluctuating price of copra has significantly affected the livelihoods of farmers and the production of coconut oil from this region. Many countries, in the Pacific have implemented price stabilization schemes for copra to relieve farmers from this price shock. The stabilization of world prices for agricultural products is to ease economic risks. It is a key issue for many tropical developing countries, with a few agricultural products that can provide foreign exchange inflows. Economic risk remains poorly addressed in societies where financial means are limited, often in Pacific countries. Small island economies are subjected to price volatility, with very little room to maneuver and few policy tools.

In addition, market governance is generally asymmetric, dominated by traders and oriented by down-stream segments operators. High interest rates and the fear of land confiscation due to non-repayment often discourage farmers from borrowing for investment. In order to protect the poorest farmers from profiteering traders, governments sometimes set up official agencies specialized in providing agricultural credit to small farmers. Loans are usually granted for the purchase of usable inputs in the same agricultural season, or for the purchase of equipment and to improve inadequate infrastructure. These loans and credits are usually provided at stable interest rates. Yet, in most cases, the state grants loans only under very strict rules plus there is difficulty for smallholders to access the applicable information forms.

Infrastructure is a big constraint for the transportation of coconuts. Countries in the Pacific consist of islands. Many of them are often small and remote from the main markets. Farmers and traders find it unprofitable to transport coconut to processing centres, especially when prices are low.

In the coconut industry, some coconut products like water and virgin oil have recently grown worldwide on an exponential level. In the 2010s, coconut water, pure or mixed, was the fastest growing drink in the world. However, the Pacific countries have been unable to enter this specific market. VCO exports prove to be difficult because processors face difficulty in obtaining certification. Markets and importers in developed countries require certain standards and certification to guarantee the products' quality.

This section provides an overview of the economic and marketing risks, despite the great potential opportunities for farmers and coconut value chain's actors that are involved in the Pacific Island's coconut industry.

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# 30. PURCHASING PRICE OF COCONUT PRODUCTS

*By J. Lin and A. Pirmansah*

### Description

The risk is that excessive price fluctuation leads processors and users to prefer other agricultural products whose supply is more regular; and makes farmers reluctant to invest in coconut cultivation because they might encounter financial problems or can even be ruined if prices fall.

The production of copra and coconut oil are the dominant products from coconuts for export. For producers in small island countries in the Pacific, their production is unable to compete with bigger countries, such as the Indonesia and the Philippines. World copra and coconut oil prices have been fluctuating in the past few decades due to competition from other oilseeds such as palm oil, soybean, etc. Price of coconut oil has almost same pattern with palm kernel oil since they have substitution role in the market for their properties as lauric oils. Some economists think that prices are driven mainly by large Asian coconut processors. Pacific Island producers suffer from this economic constraint on commodity coconut products and are forced to be price takers, meaning that they need to adapt to market prices without the possibility of influencing them. Climate, natural disasters, currency exchange rates, and trading policies of importing countries also influence prices of coconut products.

Price fluctuations put the sustainable growth of coconut commodities at risk, particularly for internationally traded items. When there is an overreliance of coconut products, farmers are subject to financial risks since price fluctuations are determining their returns. On the other hand, the shortage of coconut supply could cause prices of coconut products to increase.

When the price increase passes onto consumers, it could result in a substitution effect: consumers may switch to other products when prices of coconut products are too high. For instance, in Fiji, coconut oil is seen as an inferior product. That perception combined with imported soybean oil at cheaper than locally produced coconut oil (see risk description n°40 for more details) leads to a shift towards consumption in soybean oil. The subsidies that some countries provide to other oils, such as palm or soy leads affect the prices of not only these oils, but also of coconut oil. Virgin coconut oil (VCO), whose mass production started recently, is used for direct consumption, health care products, cosmetics etc., but not as cooking oil.

#### Occurrence and severity

Coconut products used to be the most important primary product in Samoa until cyclones and price decreases in the late 1980s and early 1990s resulted in considerable damage to the coconut sector. According to a study by UNCTAD in 2003, the price of copra declined significantly in 2000 due to an increase in supply from the Philippines and Indonesia. In 2018, coconut oil exports decreased by 39% due to a world price decline. Prices of the three main coconut products can be seen on the website of ICC (see the 'References' section).

A famine that occurs after a disaster can cause prices to rise: farmers in rural areas; intermediaries who can store products buy at low prices to resell when prices go up. On the other hand, in times of overproduction, prices sometimes fall to unsustainable levels for producers. However natural risk and economic risk often have a cushioning effect on each other: when harvests are low, product prices rise.

The global price for coconut oil depends on the supply and demand of other vegetable and seed oils, such as palm, soy, rapeseed, etc. World market price of coconuts also influences the local coconut market price.

**Mitigation and adaptation**

This risk could be mitigated by ensuring the regularity of the supply and of the marketing of good quality coconuts. For example, storage or processing facilities can be set up near areas of production so that nuts can be stored properly by farmers before being sold to intermediaries or made into VCO or copra.

More directly, governments can try to ameliorate the losses due to price fluctuations by compensating the producers with price equalization over time. For instance, in 1948, PNG established the Copra Marketing Board (CMB). CMB was not only the regulator but controlled the entire value chain from production and buying copra to marketing. The copra price stabilization scheme began in 1946 to protect farmers from price volatility. It gave income flows to plantation owners, smallholders and workers in the industry with the intention of ensuring the consistent production of copra. However, when copra prices remained persistently low for a prolonged period from the mid to late 1980s, the predetermined threshold price for farmers could not be sustained. The copra stabilization fund was drained. Despite financial contributions from the government to save the scheme, it was abandoned after functioning more than 40 years. A recurring problem of all these stabilization mechanisms is the corruption they often entail. It is therefore crucial for governments to put in place effective control measures to limit these excesses.

Fluctuations in the price of the product are mainly due to the dependency on coconut oil, itself strongly linked to other oilseeds. Non-traditional products can create opportunities in the coconut industry. In coconut producing units, entrepreneurs must give priorities for integrated processing for full utilization of coconut which includes other by-products like husk, shell, leaf, midrib, timber etc. This will enhance the overall income from coconut on a farm level processing. If coconut products diversify from coconut oil and become independent of other oil seeds, this could stabilize prices of coconut-related products.

Niche markets are an opportunity to avoid large variations of prices, if the market remains an economically viable niche, and as long as new players do not enter. The possibility of identifying and branding products geographically can help to avoid disadvantageous competition. In Fiji for instance, a statutory organization helps to promote Brand Fiji and Fijian products. It provides support and assistance in training, market intelligence, promotion, and commercial positioning for exporters. From 2015 to 2018, Investment Fiji worked with 453 Fijian exporters to develop new products and markets. Such organization may also exist in other pacific countries. It may help to develop coconut niche markets.

At the farm level, entering the ecotourism industry may help to stabilize incomes. An Indonesian farmer achieved great commercial success by launching an activity on Airbnb. He is teaching tourists how to produce virgin coconut oil the traditional way. The Pacific region could also benefit from the 'Spice garden' model used in Sri Lankan ecotourism.

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**Plate 19**. In December 2018, coconut farmers in Maluku, Indonesia, are finally taking their grievances to government, protesting the lowest copra prices presently offered at only 800 Rupiah per kilogram, equivalent to about 5 US cents per kilogram. At this lowest of the low prices no rural family can meet their cash needs.

It seems important to diversify customers and not focus on a single buyer. For instance, in the Solomon Islands, the export destination of copra is mostly to the Philippines; if this country decides not to buy, this jeopardizes the whole Solomon coconut Industry. The demand is strongly conditioned by the cyclone occurrence in Southeast Asia

Producing coconut seednuts and seedlings is also a way of diversifying. In most Pacific countries, this market is not regulated yet. When selling planting materials, be mindful of offering good quality seeds, as palms remain for 50 years. Some farmers are using Facebook selling pages (or other similar media) to post good pictures of dwarf coconuts. Some of them get quite lot of customers. In Hawai'i, a gardener is successively selling its coconut variety at USD 100 per seedling.

**Actions to undertake**

The search for long-term contracts, where the different parties share the risks, is a way to overcome the vagaries of conjecture. In this spirit, a regional approach can be useful, and guarantee larger volumes that facilitate the negotiation of contracts.

More aggressive market positioning policies would be useful, coupled with communication to support the quality and 'revelation' of the intrinsic properties of Pacific products. Showing that Pacific products are specific and as such they are in different markets, will help to fight against price volatility. Anyway, the full appraisal of this risk would need further economic studies on the following topics:

- Production of coconut products in the Pacific region compared to the rest of the world.
- Perspective on development of coconut products in the Pacific region for the next decade.

- Link between costs of main Pacific coconut products - such as virgin coconut oil or mature coconut - and the global variation of coconut oil costs.

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## 31. FINANCE AND INSURANCE FOR COCONUT BUSINESS

*By J. Lin and N. Hussein*

### Description

The risk is that farmers find it difficult to access equitable financial services (loans) and insurance preventing from price volatility. Without this guarantee, they cannot make (or lose rapidly) the required investment to start, improve or expand their activities, so the productivity of their farm will remain low, penalizing the entire industry.

Coconut palms start to produce four to six years after planting. Smallholder farmers face difficulties in making investments that do not have immediate returns. They need access to financial services to purchase or lease land, for farm inputs, equipment investment, storage, and other unforeseen costs.

Agricultural technical changes often take place under the auspices of development organizations with a regional and multilateral focus, in liaison with local dedicated ministries. These technical changes are particularly justified when they contribute to counteract the risks associated with the depletion of factors of production (labour and land). They very often require setting up of credits and setting up of efficient regulations against bankruptcy.

#### Occurrence and severity

There are an estimated 500 million smallholder farmers in the world. Only 7% have access to financing for inputs to improve seeds, fertilizer or tools. According to the FAO, the lack of financial access is primarily due to the lack of a formal credit profile of farmers and the cost of developing one.

Information asymmetry occurs when, for instance during an economic transaction, one party has different information to another. Such unequal information may distort the market and leads to market failure. For instance, if the lenders consider that they do not have enough reliable information on the borrowers, they will decide to refuse the loan. This can happen in the case of coconut farmers, as banks sometimes consider that they do not have enough visibility to take the risk of financing them.

Coconut farmers have also very little access to information and/or financial services that are available, especially for farmers in more mountainous, remote island and coastal regions. Even when financial institutions are available, they are mostly concentrated in cities or towns and out of reach of many coconut farmers. Without financial loans, many smallholders are unable to add value to coconut products and participate in the current coconut value chain.

The price of land is often unaffordable for young people who want to start farming.

Because coconut farmers have limited access to financial loans, many end up taking loans from their buyers. This limits their selling power when they have difficulty repaying the same people who are buying their crops. Farmers get further trapped in debt when natural disasters and diseases occur. Smallholders are vulnerable to disasters such as cyclones, typhoons or hurricanes. When their coconut crops are destroyed, they have nothing to sell, hence no means to finance future farming activities.

For farmers in Fiji, it is extremely difficult to get loans since they cannot use land as a form of collateral.

**Mitigation and adaptation**

In Fiji for instance, the local Development Bank (FDB) offers coconut farming loans to producers and processors. Loans can be used for the purchase of coconut farming land, farmhouse construction, and the purchase of farm equipment and seedlings. The maximum term for loans is 15 years. The FDB has branches throughout Fiji and inquiries can be also made online.

Interest rates for agriculture loans generally range from 8.5 to 12 %. Efforts need to also come from the government. For example, loans can be provided for a consistent period and at a lower interest rate.

Papua New Guinea does not have specific loans for coconut farming. However, the National Development Bank has several loan schemes aimed different economic purposes. There are microfinance schemes aimed at smaller producers and starting entrepreneurs. A general loan can potentially assist coconut farmers to purchase land, transportation, and retail trade.

A way to mitigate the long unproductive period of a coconut plantation is to practice intercropping. Additional income from other crops can sustain farmers during the period when coconut palms are growing.

**Actions to undertake**

New data sets have the potential to mitigate information asymmetry. New tools, using satellite data and machine learning, help create credit profiles and financial inclusion for smallholder farmers. For example, real-time monitoring the location and condition of croplands may enable an accurate and quick assessment of the farm's performance and viability.

Support should be provided to help smallholders who are not familiar with the financial loan process. Guidelines should be given on the type of items that could be used as collateral.

Assistance to credit bodies and organizations should be given to know and select the best contracts regarding coconut value chains.

Farmers' organizations supported by international NGOs should organise themselves to propose credit and specific insurance and adapted services. Microloan programs and rural community banking should be expanded. Faced with rising land prices and difficulties in obtaining credit from banks, associations sometimes implement solidarity-based citizen financing. Such NGOs buy land and lease it to young farmers.

ICTs such as mobile phones can prove be an effective technology to disseminate information and services that are available to farmers. In 2016, a project was introduced by the government of Australia, the Pacific Financial Inclusion Program (PFIP), and ANZ Bank to link mobile banking to the coconut industry. This digital banking approach seeks to reach rural coconut communities and provide them with financial services and opportunities.

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**Plate 20**. 'Diamond' coconut for drinking sold in a floating market in Thailand.

## 32. THE PROFITABLE BUSINESS OF AROMATIC COCONUT WATER

*By R. Bourdeix, L. Perera and J. L. Konan Konan*

### Description

The risk is that farmers from the Pacific region will continue to be side-lined from the most profitable coconut growing methods and the most valuable varieties. These farmers will then remain in poverty while, in other countries, some coconut farmers get richer and richer while cultivating the varieties adapted for the most profitable markets.

In the 1950s, Thai growers identified a variety of coconut for water consumption that carries a special fragrance and named it *nam hom.* In 2010, the Thai Government decided to consolidate the 'Aromatic Coconut' as a new agricultural industry and separated it from the traditional coconut industry. In 2016 - 2017, the price paid to farmers was 6-8 baht per *nam hom* coconut (0.15 to 0.21 Euros) during the high season and up to 15 baht (0.39 Euros) during the low production season. In fact, it was 8 baht at the end of 2017 (nuts brought by farmers to the factory), but in August 2018, the price reached 17 to 18 baht (at least), and factory trucks were coming to the fields to pick up the tendernuts.

About 2 million young *Nam hom* coconuts are harvested per day in Thailand, one million go to 'diamond coconut' sold in the country or exported, and another million go to the bottled coconut water industry. There is a strong concurrence between the two sectors. Diamond coconut is not organic (no need for the market) while bottled coconut water try to go organic.


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**Plate 21.** Seed production by Thai farmers in a plantation managed with the canal system.

Coconuts contains 320 ml of water in average, but this can be as low as 240 ml if appropriate fertilizers are not applied. So, the price paid to Thai farmers is about 1.4 Euros per litre of coconut water, while the same aromatic coconut water is sold for more than 10 Euros per litre on the USA market. On Amazon.com, 12 bottles of Harmless Harvest Organic Coconut Water, (5.7 litres), are sold for 148 Euros, so about 26 Euros per litre (viewed on 20 August 2018).

Most coconut plantations produce 140 to 240 tendernuts per palm per year. The return is said by local stakeholders to be about 1,000 Euros per hectare. When calculating based on 200 fruits per palm, 200 palms per hectare, and 10 baht per fruit (0.26 euros) per fruit, the gross income is up to 10,400 Euros per hectare – so the return may be much more than 1000 Euros per hectare.

Most plantations are organized with a canal system between the coconut lines. After harvest nuts are thrown into these channels, which are used for transportation. Organic waste (leaves, raffles) is also thrown into these channels. During the dry seasons, mud and organic matter are extracted from these channels, either manually or with a machine, and deposited at the foot of the coconut trees to serve as fertilizer. Additional fertilization is carried out with a mixture of rice straw and chicken droppings at a rate of 20 to 40 kg per tree per year.

In 2018, Chumphon Research Centre was producing only 2,000 hybrids and 40,000 Aromatic Green Dwarf seedlings. All are already reserved and paid for the next 3 years.

**Occurrence and severity**

Some Thai farmers are becoming millionaires by cultivating coconut, while many Pacific farmers remain poor by cultivating the same plant. The price of agricultural land dedicated to coconut cultivation is said to reach more than 100,000 Euros per hectare in Thailand.

**Mitigation and adaptation**

The Thai coconut cultivation method using canals seems to be performing well. This greatly reduces the risk of drought and makes harvest and transportation much less difficult. On the other hand, this method may not be suitable for most Pacific countries as they do not have freshwater systems. It is still very difficult to predict what can trigger innovation transfers. For instance, parasites or diseases that do not exist in Thailand may develop in the stagnant water of the canals. Such innovation transfer would need a high level multidisciplinary team, including human health specialists.

As an example of such complexity, the development of a large zone of rice field in Burkina Faso (Africa) led to a considerable increase in the number of *Anopheles* mosquitoes, vectors of malaria. However, in this case, the ethology of the mosquito, doubled with preventive measures (mosquito nets for sleeping) have made the transmission of malaria to humans lesser in comparison with the surrounding villages.

Even if innovation is risky, we should try. At least two demonstration plots should be installed in the Pacific region.

**Actions to undertake**

Regarding very high value coconut products, such as aromatic water, marketing actions are as important as the intrinsic quality of the product.

There is a global lack of research on aromatic coconuts, and absolutely nothing is presently done in the Pacific region. It is pretty certain that such aromatic coconuts – or coconuts having another specific good taste – exist in the Pacific region. It may be found in the populations of

Tall-type coconut palms, or in the populations of Compact Dwarfs selected by Pacific gardeners for their daily food, or among the varieties introduced in the past, legally or not.

Another option would be to introduce the aromatic coconut in the Pacific region, but this raises quarantine issues. Many countries (of which Thailand, Malaysia, and Vietnam) have banned the export of *nam hom* seednuts to protect their market. The few palms existing in Côte d'Ivoire are presently being multiplied to produce more seednuts.


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**Plate 22.** Easy transportation of coconut in a plantation managed by the canal system.

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## 33. COST OF ORGANIC AND FAIR TRADE CERTIFICATION

*By S. Hazelman, M. Kumar, E. Tamasese and K. Mapusua*

### Description

> The risk is that, although many coconut palms are cultivated in the Pacific region in an organic and quite 'fair trade' manner, farmers and local processors may not benefit from relevant certification because such processes are too complex, long and/or too costly.

The food safety management systems are based on mandatory public regulations. Even if the products are not organic and not fair trade, buyers require exporters to control food safety hazards in production and processing.

Farmers and resellers can export fresh agricultural products as long they get market access approved the importing countries, such as New Zealand and Australia for instance. It is still possible to export food products with a simple certification of the national biosecurity authorities (depending on the target market). For processed food products, stakeholders need third party certifications for Hazard Analysis Critical Control Point (HACCP), or alternative Global Food Safety labels such as ISO22000. In specific situations participatory labels, a combined producers and consumers' initiative, offer alternative certification. Virgin coconut oil can be rated as food or as cosmetics and so can be exported under different rules.

In addition to basic food safety standards, private standards include organic, fair trade, Rain Forest Alliance and non-GMO certifications.

In the Pacific region, the organic movement is mainly driven by farmers, and often governments and ministries of agriculture are now supportive of the growth of farmer's initiative in organic and fair trade. For instance, in Vanuatu and Fiji, governments have recently developed National Organic Policies.

### Occurrence and severity

Non-regulated organic markets include the whole Pacific, Australia, New Zealand, Hong Kong, and Singapore. In December 2018, New Zealand started discussions with organic stakeholders to regulate organic certification. In the Pacific region, the Pacific Organic and Ethical Trade Community (POETCom) set up Participatory Guarantee Systems (PGS). Built on a foundation of trust, social networks and knowledge exchange, they certify producers based on active participation of stakeholders.

Outside of the Pacific region, the label 'organic' has increasingly become legally protected and regulated. Multiple standards specify the exact requirements for organic production and labelling. While private labels were the first to proliferate, many countries now have organic standards as well, quite a number of them in the form of public regulation. The plethora of available standards, labels, and certifications has led to a complex and fragmented system of regulations. The duplication and overlaps between the systems have created compliance problems and barriers to trade.

For regulated organic markets (like the US, EU, Japan, Canada, South Korea, Taiwan and China) the only access is through accredited organic certification by certifying bodies (NASAA, Australian certified organics, BIOGRO, Bio AGRICERT, Combine Union, ONECERT and ECOCERT). These are certifying bodies that operate in the Pacific region right now. They are accredited by the regulated countries mentioned above. Each certifying body has to get an annual organic accreditation from all countries with regulated markets, and this generally costs the agency more than 100 000 USD per year.

Some consumers demand other kinds of labels, such as Kosher, Halal, GMO free and glyphosate-free. Some large retailers also have their own food certification standards, such as WQA for Woolworths supermarket chain.

Fair trade serves as an alternative to conventional trade and is based on the partnership between producers and consumers with the goal of improving lives and reducing poverty through ethical trade practices. There are several fair trading certification schemes, the most common in the Pacific is FairTrade. The Fairtrade certification system[9] aims to assure consumers that their purchase meets special social, economic and environmental standards. The FairTrade standards are designed to tackle poverty and empower producers in developing countries. Market trends indicate a significant demand for such standards, allowing for product differentiation in consumer markets, and often required by the industry and companies for juicy niche markets. Each certifying body must get an annual organic accreditation from all countries with regulated markets, and this generally costs the agency more than 100 000 USD per year.

Dozens of documents regarding the different certification standards are available online. But when it comes to finding specific practical information, the search becomes more challenging. To overcome this difficulty, we propose to study a practical case; that of a Fijian farmer who has a five-hectare plantation of coconut trees associated with bananas and mango trees, already managed organically for a very long time. This farmer, who employs two workers in a fair trade manner, would like to be certified both organic and fair trade. The questions are: can individual certification happen, if yes where from, how much will it cost and how many months will it take?

Fair trade certification cannot apply to a single coconut farmer; such certification is designed for processors, exporters, traders or cooperatives and associations with well defined formal rules.

For third-party organics, farmers in the Pacific region are certified mostly by Australian and New Zealand bodies. The farmer first must ask for a quote from existing certifying bodies. Then, they will have to fund an expert to visit the farm and set up an Internal Control System (ICS). If this ICS is not working properly, the expert will have to return at the expense of the farmer. This will cost 3,500 to 5,000 USD for organic certification. In addition to this first expense, an annual certification fee of 3,500 USD will have to be paid. Even if the farm is already organic according to the farmer, the delayed conversion period of three years will have to be satisfied for organic certification.

In Samoa in 2018, for a large factory producing five to seven tons of VCO monthly, the cost of organic certification was about 15,000 USD with an annual fee of about 5,000 USD. In its grower group, this factory has many farms that need to be reviewed, so inspectors had to spend quite a long time in the fields. For another factory producing coconut cream, the cost of Fairtrade certification was about 2,000 Euros with an annual fee of 1,600 Euros.

[9] See details on how Fairtrade certification works at the URL: https://www.fairtrade.net/about/certification.

**Mitigation and adaptation**

For third-party certification, farmers should form organizations that will manage global organic and fair-trade certification. For small farmers to afford certification, IFOAM Organic International has permitted organization of farmers under a single organic certification (Internal Control System groups).

For one group in Samoa, the annual fee for organic certification is about 12,000 Euros per year for 796 farmers and about 37,933 hectares of plantations. So, the cost per hectare and per farm is greatly reduced (to about 16 Euros per farmer and 0.3 Euros per hectare) when compared to the example above. The associations can also apply for grants from donors or assistance from Ministry of Agriculture.

PGS involves lower costs than export-focused third-party certification. Most individual producers join a PGS because they want to sell their organic products locally (usually a farmer's market or a retail outlet) and they need a label. If already organic, the conversion period can be reduced 12 months for annual crops and 18 for perennial crops such as coconut. If our Fijian farmers want to follow this way, initial organic certification will cost about 800 euros for a group of 10 to 1,000 farmers, with no annual fee yet (this will change, as the amount of annual fee is presently being discussed).

For farmers, another advantage of local organic certification is that it may boost the selling of coconut seednuts, as such organic certified seednuts remains rare, and there is a market for them. In Niue, Fiji and Samoa, some private companies succeeded in sharing the cost of auditing for organic certification, sometimes with help from governments.

**Actions to undertake**

Training of third-party organic auditors with the hope they will be able to audit on behalf third-party certifying bodies and reduce the certification cost.

During the 2018 COCOTECH meeting, the ICC recommended the following: 'Major challenges are the acquisition and maintenance of organic certification, especially for smallholders. It is necessary for ICC to work with Pacific governments to: (1) ensure that policies are in place for organic farming and certification; (2) assist with the cost of acquiring and maintaining organic certification; and (3) ensure that there are trained personnel to assist and monitor organic farmers and farms, especially smallholders, and instil the disciplines of quality control and assurance. Governments must urgently certify at least some of their agricultural research centres, especially those devoted to production of planting material.'

Under the CIDP project, the National Association for Sustainable Agriculture in Australia (NAASA) is developing a participative manual for organic management and certification of coconut plantation, to be published in 2019.

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## 34. TRADING ACCESSIBILITY IN REMOTE FARMS OR ISLANDS

*By R. Bourdeix and I. Bororoa*

### Description

This risk is linked to geographical isolation and lack of efficient infrastructures for transportation of agricultural products. It may greatly reduce the profitability of exporting agricultural commodities.

#### Occurrence and severity

In 2003, the ADB initiated Alternative Livelihood Project recognised that the growth on Vanua Levu (Fiji) could not be sustained because all products must be transhipped to Suva before they could be re-loaded on container ships for overseas markets. The cost of transhipment within Fiji, from Vanua Levu to Suva, is almost equivalent to the cost of freight to New Zealand or Australia from Suva.

Copra trade is often the main economic reason for ships to travel to remote islands. If the copra deal stops, the island is dead by isolation – if no other ships come people may be forced to leave the island.

Copra transportation in boats needs special care. Closely associated with the process of deterioration and directly due to the presence of moisture in the copra is the phenomenon of self-heating. It is known that temperatures high enough to cause spontaneous ignition may be generated. Though under-dried copra is regarded as somewhat dangerous cargo (Class 3 in the Suez Canal schedule of dangerous materials) conflicting views have been expressed regarding the real possibility of high enough temperatures being generated to cause spontaneous combustion. Literature records show that the highest temperature recorded in the hold of a ship is only 67°C.

#### Mitigation and adaptation

Rather than exporting basic agricultural products, there is an interest in transforming these products locally to increase their values and reduce the volume and cost of transport. There are many traditional recipes made from coconut, such as confectionery or canned food, which could be prepared locally. Many traditional cosmetic preparations, including the famous 'Monoï', deserve to be better valued and marketed.

The name of the isolated island must be used as a trademark, or in a controlled appellation of origin, which will give strong added value to the products, within the framework of a protected niche market.

Copra can be locally transformed into oil, some of which can be used as fuel for the operation of vehicles and electro-generators. This has the advantage of reducing the energy bill on isolated production sites. However, care must be taken that the trade with the outside does not stop and that, in the case of isolated islands, boats continue to come regularly to these islands to collect products, bring fuel, medicines and other indispensable products. Also, by-products of such biofuel generation can be toxic and must also be well managed.

### Actions to undertake

Governments are always interested in keeping isolated and remote islands populated and that not all citizens crowd into often overpopulated capitals. They often initiate practical measures to support these policies. One of these measures is to subsidize the transport of agricultural and artisanal production from these isolated islands.

Such a subsidy system already exists in French Polynesia. Copra cultivation is a core activity in remote archipelagos, including Tuamotu Gambier. It provides livelihoods to isolated, low-income populations in the absence of 'minimum income' type of social assistance or unemployment benefits. For many families, copra is the only cash income. The copra produced in French Polynesia is purchased in its entirety by SA Huilerie de Tahiti, regardless of the quantity and quality, in accordance with the terms of an agreement that binds it to the country. For promoting the economic and social development of islands other than Tahiti, the country is responsible for inter-island sea freight for certain goods. Initially limited to copra, staple foods and bottled water, freight now includes building materials, agricultural products, handicrafts, and some processed agricultural products.

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## 35. SUPPLY OF COCONUT TO FACTORIES

*By R. Bourdeix and N. Tanawai*

### Description

The risk is that irregularities in the supply of raw materials reduce the profitability and competitiveness of the factories, force them to lower purchase prices to the producer and indirectly penalize the whole local coconut industry.

This risk might also occur and impact stock prices at the global level, as described in risk description n° 30, but what is outlined below relates only to local and national levels.

In some Pacific island countries, people are harvesting and selling coconut only when they need money, for example in the period preceding the entry of children into schools or just before Christmas.

When the price of coconut is too low, the farmers do not harvest their coconuts because they find the cost will be higher to harvest their coconut than the profit that they will get.

The fluctuation in the price of coconut affects the production of the coconut industry, and this is likely to intensify in the future. This particularly affects small island countries where there is limited area for planting more coconut trees, and copra remains the main source of income.

### Occurrence and severity

Some coconut factories are overloaded at certain times of the year, while at other times they operate at less than thirty percent of their full capacity. This negatively impacts the activities and benefits of the factories.

There is also a seasonal variation for fruit production in the coconut palm. In most situations, 60% of the fruits are produced during one semester and the remaining 40% during the other semester.

Irrigation can help to reduce this variation but will not make it completely disappear. Even in Ratchaburi region in Thailand, where the Aromatic palms are cultivated with a canal system providing irrigation, there is a high and a low production period with strong variation of the buying price.

The coconut global value chain (GVC) is at a critical juncture, characterized by a rapidly growing demand in global markets and a stagnant supply base in danger of collapse in origin countries. Limited supply of fresh coconuts is the critical constraining barrier to industry growth. The supply bottleneck is rooted in persistent low investment for years in now aging and unproductive coconut plantations. Investment to reverse the sluggish supply is desperately needed worldwide.

### Mitigation and adaptation

Factories should offer good buying prices to farmers all along the year. When buying prices are already good on average, they could increase the prices by 20% during the season when the supply is low and reduce it by 20% during the season when the supply is high.

Marketing and communication actions must be carried out in schools to promote the consumption of local products, including coconut, among the younger generation.

**Actions to undertake**

Even though fair trade certifies that farmers and workers receive a decent remuneration, it does not mean that profits are equitably shared. A product can be bought from local farmers at 1 USD per kg and be sent to final customers at 10 USD per kg, and still be 'fair trade' labelled. A possible recommendation (but by whom and to whom?) could be that the price sold to the final consumer should not be more than three times, the price paid to the farmer.

Some studies started to try to optimize the harvest in order to reduce factory shortages (see Thai example below). Interests of the factories and farmers may sometimes be divergent. Farmers would be more interested in studies optimizing the harvest to maximize their own benefits. Both aspects should be considered in future scientific studies.

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# H. RISKS LINKED TO AND IMPACTING CULTURAL HABITS

*By R. Bourdeix and J. M. Sourisseau*

Pacific societies, whatever their anchorage in custom and their level of development, are exposed to all the risks analysed in the present document. But most Pacific communities are driven by specific social hybrid mechanisms, a combination of custom and willingness to adopt a western lifestyle. These specific social behaviours may all together change their exposure to risks and the very nature of these risks, the way they act to prevent these risks, the way they mitigate them and the way they are impacted by uncertain events.

The primary function of a food is to cover the energy and nutrient needs of consumers by meeting their physiological characteristics and their consumption habits. Coconut was part of Pacific diets for centuries, but things may evolve. Food self-sufficiency, if it still exists, is now only concerning a few very isolated populations. In addition, imports of commodities are more and more present on local markets and drive household's consumption toward more normative and globalized diets. In the long run, it may change the very significance of coconut within the society.

People are devoting more and more time and attention to virtual purposes on cell phones and computers. On one hand, such media may help to rapidly diffuse appropriate information. On the other hand, people are now saturated with an excess of diverse information and online entertainment. At least some of them, and more numerous in the younger generation, devote less attention to the real world. The daily and use of the internet, as well as the populist political wave that seems to be linked to it, induces a kind of popular rejection of a world that appears too dizzyingly complex. People often call for simplistic solutions derived from some kind of magical thinking.

Therefore, in contemporary rural societies, the importance of the monetary detour adds commercial risks to pre-existing agricultural risks. Commercial integration and more specifically driving business in a changing society require new skills and knowledge that are still broadly lacking in the Pacific. This situation may increase farmers and traders' exposure to commercial risks. In addition, the mitigation mechanisms of these new risks are not present in the traditional society, even in a hybridization process. Farmers should be informed of the consequences of changes in farming and commercial practices. They should be requested to specify their farming practices (traceability), if these new practices are likely to significantly change the nutritional value of food.

Can increased global consumption of commodities as seemingly inconsequential as coconut products lead to armed insurgencies in parts of the world? Yes! Quite often, when insurgencies do occur, they are linked to agricultural commodities in high demand. In fact, not in the Pacific region but in Southeast Asia, rebellions and agricultural production have gone together for centuries.

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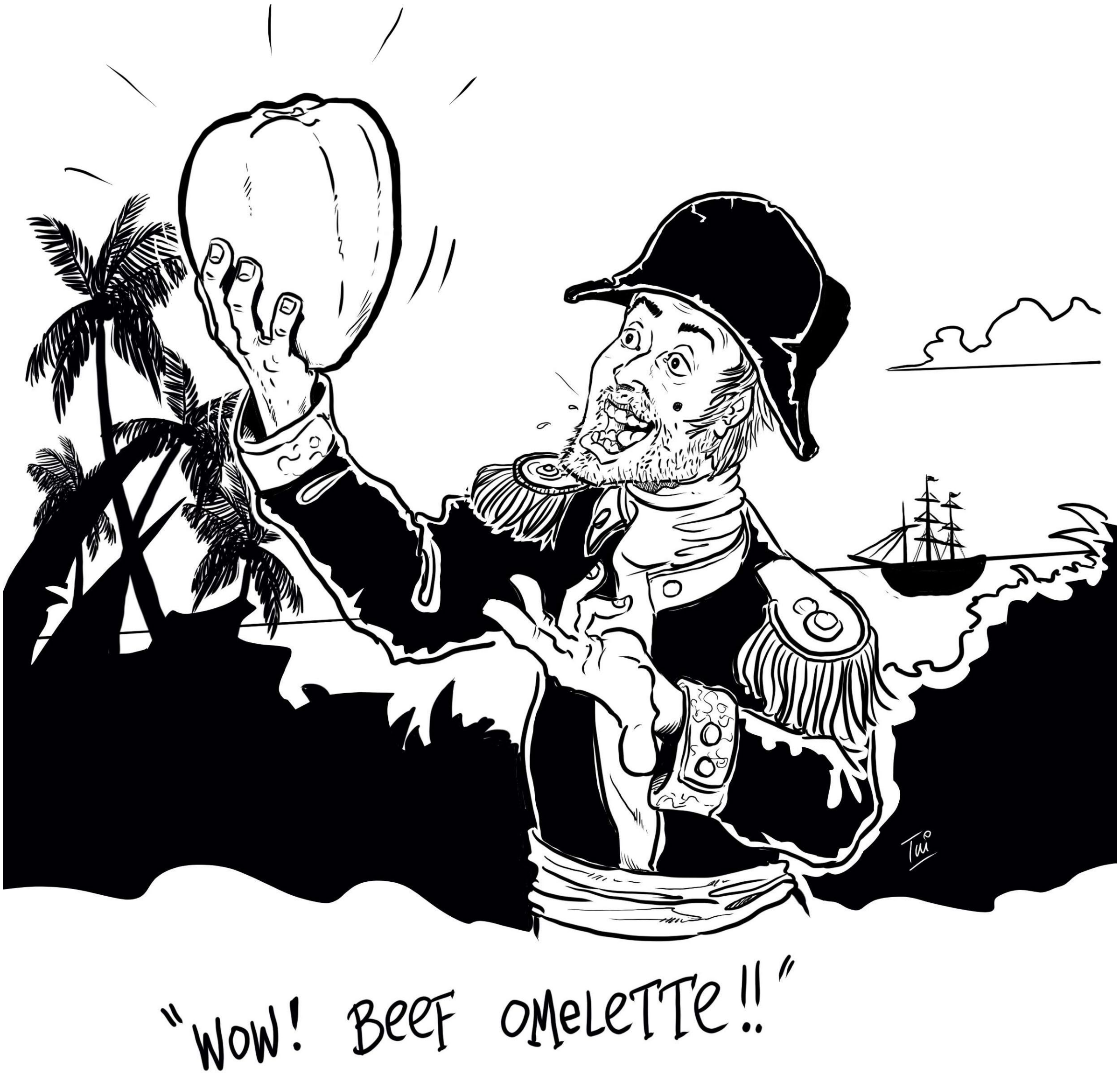




**Note.** This drawing illustrates the next risk which deals with the inappropriate beliefs about the coconut palm and its cultivation. It was inspired by a real story, known to some Tahitians in French Polynesia and passed down for generations. In the 18th century, a sailor disembarking from Europe received as a gift of arrival a young coconut and coconut milk to drink. Seeing this fruit for the first time, he would have said 'What a wonderful country, here the cows lay eggs'. Two hundred years later, Tahitians continue to laugh about it ...

## 36. STAKEHOLDERS' BELIEFS ABOUT COCONUT

*By R. Bourdeix, N. Tuivavalagi and N. Hussein*

### Description

The risk is that some stakeholders remain convinced of their false beliefs e.g., that their coconut farmers and varieties from the Pacific region are the best, that farmers do not need any help regarding coconut, and that coconut palms can grow without any management. If these wrong beliefs continue to be widespread, improvement of the coconut value chain in the Pacific region will be challenging. People do not change practices while they are convinced that they are the best and that they do not need to change their practices.

Such beliefs are encountered even at the highest levels; It is part of the psychological constraints to development in general and agriculture in particular. This feeling is not a risk in itself but it can be responsible for the lack of farmers and policy makers' capacities to react during and after a negative shock, may it be economic, climatic, agronomic or organizational.

At the last COCOTECH conference in 2018, we presented a paper on incentives for boosting coconut production. The conclusion of this paper stated that the most important incentive relates to communication with farmers. Relevant Ministries should make the relevant technical information fully available for farmers; they should ensure that a maximum number of farmers will be aware of this information, will read it, will believe it and will use it

The main contribution of Pacific Islanders to coconut farming does not rely on sophisticated cultivation methods. Other countries, such as Brazil, Thailand and India, have recently developed methods of coconut cultivation that are much more productive than those practiced in the Pacific region. Indeed, this occurs even if, as noted by R Thaman, 'traditional agroforestry practices once made Pacific islanders amongst the most self-sufficient and well-nourished peoples in the world'.

On the other hand, the truly extraordinary contribution of the Pacific region comes from the innumerable and precious coconut varieties that elders created when travelling from island to island, carrying seed nuts. In this aspect, in our opinion, the Pacific remains unmatched.

The exclusive use of traditional knowledge does not resolve all the constraints and may refrain farmers capacity to react in case of a chock. Traditional coconut's representation of Islanders shouldn't limit farmers' access to innovations. The attitude of the Pacific people towards the coconut palm is sometimes special, a kind of mixture of reverence and contempt. This situation has deep historical roots. For reasons linked to both colonization and globalization, many Pacific islanders both 'love' and 'hate' this emblematic palm embedded in traditional social management. This old dynamic may be fading because the image of the coconut palm has evolved significantly over the last decade.

### Occurrence and severity

Policy makers, and sometimes even their advisers, do not always have an appropriate level of technical knowledge. For example, in some Pacific regions, erroneous advice from leaders on planting coconut palms by adding portions of aluminium cans to the soil is known. Indeed, cans which contain iron are sometimes added to coral soils when planting coconut palms, missing this metal (iron, not aluminium). Aluminium pollutes the soil severely, and such a can needs between 100 and 500 years to disappear in the wild. The lack of technical knowledge is not at all specific to the Pacific region: quite recently, an agricultural political leader in the Western world admitted publicly that he did not know which area corresponded to one hectare. This becomes a risk when associated with the opinion that national farmers are the best.

Those who want to monopolize the public's attention are not always the most knowledgeable. For example, a reader of the Tahiti Herald tribune recently explained that by putting a tin in the ground when you plant, it allows the coconut palm to grow directly with a pre-positioned anti-rat ring, as though the can would grow with the tree. The very unsure claim that ‘Coconut trees are native to the Pacific’ is found in many official documents, and even in a ‘Coconut Value Chain Review’ published in 2011 by PARDI and SPC. In 2006, the first contributor to this section was explaining on a live TV show that the coconut palms did not originate from Tahiti Island, but was introduced by Tahitian ancestors coming from Asia and Papua New Guinea when they reached Polynesia; the show's listeners did not respond well to this statement.

Why is it so difficult to sustainably fund coconut gene banks and research? The ambivalent and multifaceted symbolisms associated with the coconut palm sometimes make stakeholders and even decision-makers forget that coconut cultivation strongly influences the livelihoods of millions of poor farmers. An ethnological approach to coconut symbolisms and their consequences was recently developed for the Pacific region (Bourdeix et al., 2013: Hegde et al., 2018). The modern representation of the Pacific people's coconut palm often appears as ambivalent. In the collective Western imagination, the coconut palm has become the ubiquitous and anonymous symbol of exoticism and tropical beaches. It is well-known that the image of the coconut palm is widely used to promote tourism and numerous associated products ranging from fashion accessories to financial investments. The combination of coconut with ‘hammocks’ or ‘monkeys’ sometimes reinforces the stereotype of peaceful and lazy paradise, far from the stresses of everyday life, an image which does not reflect the real situation of Pacific people. Islanders become disengaged when confronted with such counterfeit representations that standardize the tropics and deny their cultural identities.

**Mitigation and adaptation**

Regarding coconut cultivation methods, Pacific people still have much to learn from other countries. To illustrate this claim, CIDP and CIRAD recently released two short movies (see the ‘References’ section). This first one is about coconut nurseries, and compares methods used in Brazil and Côte d’Ivoire (West Africa) to those of six Pacific countries. The second movie illustrates how Thai farmers cultivate the Aromatic Dwarf with an organic canal-based system (see also risk description n°32).

It is challenging to transfer a cultivation method from one country to another. It becomes more difficult when you deal with people who resist change. For instance, concerning the channel cultivation system presently used by Thai people, one can worry that this system, if not to other countries, may induce human diseases due to the abundance of sleeping waters.

The CIDP's effort to send Pacific technicians to practical courses in Sri Lanka is excellent; those who come back from these trips will have a less self-centred vision of the coconut world. This initiative should be pursued by sending a few agricultural officers to Brazil and Thailand, two countries that have developed highly efficient methods of growing coconut.

Fortunately, the western representation of the coconut palm is evolving from a ‘holiday and comic‘ to a ‘healthy and natural‘ palm. This new representation of a single plant is impacting the western perception of tropical island countries. It will also facilitate the raising of international funding for coconut R&D activities.

**Actions to undertake**

Continue to share in the Pacific region all the technological advances carried out in the other countries, by reinforcing the direct contacts of the Pacific stakeholders with the best performing producing countries.

Strengthen the participation of Pacific Island countries in associations, networks and forums such as ICC (International Coconut Community, formerly APCC), COGENT (International Coconut Genetic Resources Network) and the 'Coconut Google Group' created by Hugh Harries.

Protect and value more highly the aspects where Pacific Island countries are really the best, i.e., the creation and maintenance of traditional varieties. The amazing work was achieved by islanders' elders. It seems that the modern generation sometimes do not care about conservation of different coconut varieties. Tonga is probably the place where elders made the most amazing contribution and where people now pay less attention to traditional varieties.

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"...He REALLY THINKS THIS IS NEW!"

## 37. RELIABLE INFORMATION ABOUT FARMING AND TECHNOLOGY

*By R. Bourdeix, O. D. C. M. de Almeida and S.B. Woruba*

### Description

The risk is that farmers and extension officers do not have access to, do not access, or do not understand and use the information that they really need. This can be caused either by a lack of available information, by an inappropriate information format, or by an overabundance of unreliable or inadequate information. Missing the right information, farmers will not solve their technical problems and the production of their farms will not increase, penalizing the whole industry.

Sometimes too much information from too many sources is available. It makes it challenging to find the information you really need. When found, it may remain difficult to know if this information is trustworthy or not.

### Occurrence and severity

In the Pacific region the case of coconut hybrids offers a perfect example of how the limitation of knowledge or understanding of accurate information can lead to the dissemination of the incorrect information.

Some Pacific countries have stopped the production of hybrid seednuts during the last decades. It happened that some farmers came to the extension division and asked for hybrid seednuts. Instead of simply saying that hybrids are unavailable, official national nursery provided seednuts harvested on Dwarf x Tall hybrids and presented those as 'hybrids'. Farmers were planting them thinking they were real hybrids and good planting material. They will obtain a heterogeneous mix of fast and slow growing coconut palms, with small and large fruits, and with some good and many low producers. Their opinion about hybrids will become worse and worse.

The coconut industry also advises farmers against hybrids: the kernel oil content is higher for Tall-type variety. Copra millers and oil producers are winning more profit when buying a ton of coconut or copra from Tall varieties than when buying the same from hybrid varieties such as MRDxRIT[10]. Indeed, they recover a larger quantity of oil from the local Talls. However, if you look carefully from the farmer's side, the issues are very different. On average, when planted in appropriate conditions, Tall-type varieties will produce about 1.8 tons of copra yearly containing about 1.2 tons of oil per hectare per year; on average, Hybrids (MRDxRIT for instance) will produce 3.6 tons of copra yearly containing 2.0 tons of oil per hectare. Therefore, farmers, please make your own calculation, please prioritize your own profit, and do not blindly follow advice from other coconut stakeholders.

Another reason why some agricultural extension services do not promote hybrids is insufficient resources. It is complicated and quite costly to produce hybrids. It is so much simpler to go to any farmers' field – without conducting any analysis to assess the real value of the variety and the mother palms - and buy seednuts from the farmers – especially if those farmers are your relative.

[10] Hybrid Malayan Red Dwarf x Rennell Island Tall.

Another example is pest and disease management in nurseries. In some Pacific countries, many farmers no longer trust national nurseries. Even if the seednuts are provided free, they will not accept seedlings for planting that come from those nurseries.

In the smaller island countries, extension services lack information to adequately disseminate to their farmers. In Papua New Guinea, many coconut farmers are rural subsistence farmers with limited educational qualifications. Some of them cannot read and write. This creates a barrier in the uptake and adoption of information and practices.

**Mitigation and adaptation**

Ministries and extension services should make the relevant technical information fully available for farmers; they should ensure that a maximum number of them will be aware of this information, will read it, will believe it and will use it. Governments should adopt a diversified and pluralistic national strategy to promote agricultural extension and communication for rural development. Videos published in local languages may help to sensitize illiterate farmers.

Who is the person to contact if I am a coconut farmer needing technical help? Where are nurseries located close to my farm? Such information should be made available with only 2 to 3 'clicks' and simply searching the word 'coconut' on the website of the Ministries of Agriculture. Such information should include all relevant contacts and should be developed in a user-friendly context, accessible via farmer's organization and other related communities.

In Timor-Leste, factors related to adoption of the improved varieties have recently been studied. The factor most strongly related to adoption by farmers was having a relationship to a grower of improved varieties and the closeness of this relationship. Dissemination strategies should embrace social relationships.

**Actions to undertake**

Extension services should not try to make decisions and think instead of farmers. When well informed, farmers are perfectly able to make good decisions by themselves. Extension services, when facing an agricultural risk or problem, should not propose a unique solution, presented to farmers as a panacea. They should propose a diversity of responses to farmers, explaining to them the advantages and risk of each option.

All information linked to nurseries is highly sensitive. A periodical multi-crop report regarding the phytopathological status of national nurseries should be published online. This report must be signed by a designated service and a designated officer who will fully assume responsibility for its contents. Nurseries should preferably be certified, both for quality and organics.

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# 38. DIETARY HABITS IN THE PACIFIC REGION

*By R. Bourdeix, R. K. Myazoe and J. Lin*

## Description

The massive and growing importation of food is a risk for agricultural production and for Pacific region as a whole. It triggers a spiral of increased external dependence, a growing trade imbalance, an allocation of foreign exchange available for consumption and not investment, the acceleration of rural-urban migration and urban unemployment, the aging of the farming population, and finally stagnation and decline in agricultural production. In the case of the Pacific region, westernization of dietary habits also has strong health issues.

### Occurrence and severity

Pacific Islands Countries and Territories (PICTs) have some of the highest rates of obesity and diabetes in the world. Childhood obesity is a growing problem in Pacific island countries and has risks for the long-term health and development of children. A lack of data, especially in younger children can hinder efforts to effectively target prevention efforts.

Research has demonstrated a strong link between sugar-sweetened beverage (SSB) consumption and subsequent risk of overweight, obesity, dental caries (decay) and type II diabetes. As more and more young people are obese, they find it more difficult to climb the palms to harvest young coconuts. The price of young coconut to drink is increasing and their availability is decreasing, further reinforcing the consumption of soda in a vicious circle.

In 2000, during a survey in the Cook Islands, we succeeded with considerable difficulty in locating a rare palm from the ‘Sweet husk’ type named there *niu mangaro*. The survey was conducted in conjunction with a government agricultural officer. He took a tender coconut and started to chew the sweet husk. Then he stopped saying: ‘I do not want people here to see me eating *niu mangaro*, because they will say I am a poor man’. The consumption of traditional varieties may be perceived as socially stigmatizing, even by an agricultural officer supposed to be aware of the value of biodiversity.

On the other hand, the consumption of imported food is considered as a mark of modernity and wealth. For instance, in Pohnpei, it is more prestigious to offer imported foodstuffs to visiting guests (e.g., rice and coca cola rather than taro and drinking coconut). Such behaviour also occurs in some in western countries, such as for instance in Paris, where French hosts often invite guests to restaurant serving foreign food instead of local.

For economic reasons, in the event of serious damage to cash crops, the government often plans official assistance. Food assistance is for convenience and opportunity often of rice, flour, sugar, canned meat etc., thus confirming the devaluation and decline of customary foods.

Who is to blame for obesity? Policy makers, the food industry, or individuals? A research survey conducted by two food economists revealed that most people believe individuals are to blame for their own obesity - not restaurants, grocery stores, farmers, food fad effects. or government policies. In our expert view, the opinion of people about obesity is, at least partially, a psychological conditioning. The first cause of obesity might be a genetic burden. In the past many of our ancestors died of hunger. Most of those who survived had a metabolism that stores fat for survival in times of starvation, and they transmitted this characteristic to their descendants. The second cause is very probably a set of social burdens, including food fad effects, eating habits induced by advertising, and the 'ocean of food' permanently available, as described by Richard Beyer.

**Mitigation and adaptation**

Nutritional risks and dietary risks are two distinct concepts that do not depend solely on the availability of food. Nutritional status results from interactions between food consumption, lifestyle, infectious environment, and pathological history of the individual. Unlike dietary risks, nutritional risks are unevenly distributed according to age groups. They mainly affect children under six years of age and especially the age group of 12 to 36 months.

In recent years, sustainability of both tourism and agriculture have been linked to the development of 'alternative' food networks and a renewed enthusiasm for food products that are perceived to be traditional and local. Local foods are conceptualised as 'authentic' products that symbolise the local traditional heritage. Youth are more focused on modernity; we must therefore encourage them to perceive the use of local products as modern.

Family food traditions should be passed down and developed along with social and technological progress to retain ethnic cultural identity. The crucial role of women in this process is to be recognized and awarded.

Respect for tradition can foster economic competitiveness. For instance, the Samoan *niu afa* variety, which was until recently in danger of extinction, could generate a lucrative 'niche' market. Samoan communities in Australia and elsewhere will prefer to buy products made from this variety. Making better use of their heritage varieties, Samoan farmers and small producers of virgin coconut oil could increase their incomes and improve their livelihoods.

**Actions to undertake**

Promote coconut as functional food and beverage. Improved understanding of the relationship between nutrition and health results in the development of the new concept of functional foods. Those are defined as any food that has a positive impact on an individual's health, physical performance, or state of mind, in addition to its nutritious value. This practical and new approach may achieve optimal health status by promoting the state of well-being and possibly reducing the risk of disease.

Festive and ceremonial traditional events, purchasing food ingredients, regular cooking and consuming practices are some of the behaviours identified to help introduce and pass on traditional food knowledge to the younger generations.

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## 39. ADOPTION OF AGRICULTURAL INNOVATIONS

*By J. M. Sourisseau, R. Tautua and R. Bourdeix*

### Description

The risk is that the first farmers who decide to try or apply an innovation find themselves in a difficult situation because their community or some of its members do not appreciate the changes brought by this innovation. This may happen because the innovation did not work as expected, but also in cases where it worked perfectly.

Agricultural innovation is a socially constructed process. Innovation is the result of the interaction of a multitude of agents and stakeholders. If agricultural research and extension are important to agricultural innovation, so are markets, systems of government, social norms, and, in general, a host of factors that create the incentives for a farmer to decide to change the way in which they work, and that reward or frustrate their decisions. Combined with the highly volatile cultural dynamics of the Pacific Society, this influences the whole dynamics of adoption of innovation.

#### Occurrence and severity

Introducing changes in agricultural practices most often means introducing changes in interpersonal relationships and in the global social organization of a community. This social and cultural dimension may be risky for the farmers implementing the innovation, but may also, indirectly, change the farmer's exposure to other diverse risks, and their capacity of prevention, mitigation and adaptation to risks.

An example from Samoa illustrates an innovation not applied in the right way that could have caused serious problems. In Upolu Island, a dozen coconut palms, located in a small farm and around, started to die. Trapping *Oryctes* beetle with pheromones is a widely used method, for oil palm and coconut, in many countries but not yet in Samoa. It generally works perfectly. In this farm, the first pheromone beetle trap in Samoa that was tested.

This trap proved to be very efficient with up to 80 beetles trapped per week. Only a single trap in the middle of the coconut plantation was first tested. So, many beetles were attracted, and a few of them remained in the palm's crowns; where they fed and killed many coconut palms from the poor farmer and his neighbours, creating in fact an unexpected event and introducing a new risk. Our recommendation was installing the traps close by but *out* of the coconut plantations, and preferably to install several traps simultaneously in the same zone.

Such a situation illustrates the need for very careful communication and implementation. Otherwise, it may jeopardize the national acceptance of this innovation, and create community troubles for both the farmers and extension services. In the case of inappropriate communication, this example could have resulted in all the farmers refusing to use pheromone traps, compromising a crucial part of the beetle risk mitigation strategy. The farmers may also ask for compensation for the palms killed because of the trap.

Other examples illustrate the possible negative impact of a successful adoption of an innovation. In French Polynesia, we observed that seedlings of rarest varieties of coconut (Compact Red Dwarfs) were stolen overnight in farms and gardens, as too many people had been informed of their great interest. Elsewhere, a Pacific farmer who decided to grow Dwarf coconut varieties with Brazilian or Thai advanced techniques, would probably become very rich if they succeeded in both cultivation and marketing their production with tourism industry. But accomplishing this, they will jeopardize the existing trading system, in which harvesters climb Tall palms with great effort to get only a few tendernuts. Some of these climbers may lose their business and conflict may result.

The success can generate tensions and new social risk exposure. An innovation resulting in the emergence of commercial success for one single farmer can introduce social disparity and inequalities. The risk of a too fast commodification by innovative farmers can be seen as severe and undesirable by traditional authorities. Therefore, a social control may constrain the innovative farmers and generate economic and social risks of exclusion for these farmers.

The same mechanisms can occur in the adoption of a wide range of innovations: new coconut varieties, new inputs, new techniques, new trading practices, etc. For instance, in the Solomon Islands, coconut palms serve as ancestral landmarks and heritage proof. This sometimes jeopardizes replanting programs: since the old palms possess an ancestral significance the clan may decide to isolate the farmer trying to replant, as punishment.

**Mitigation and adaptation**

Mitigation and prevention may rely on a careful choice of the mode and the timing of the communication regarding innovation. For the first risk described, it is important to anticipate the possible negative impacts of a change of practices, and to communicate them. This requires multi-dimension analyses: agronomic knowledge is not sufficient and needs to be complemented by social understanding of the possible consequences of changes.

In the same vein, recognition and reward processes should be implemented for those who first dare to try innovation. Mitigation of the marginalization process needs progressivity, precaution, and a prior effort to understand the socio-economic dynamics of the targeted society.

**Actions to undertake**

Socially marginalized people or groups are defined as those who are typically disadvantaged or excluded from certain activities of programs and projects because of environmental, economic, social or cultural characteristics. Even though social marginalization is a key aspect of poverty, it is difficult to create and sustain coordinating organizations that include marginalized actors, especially women and landless farmers. Such organizations are often opposed by civil servants, politicians, intermediaries, or wealthier farmers who see their power challenged. Despite opposition, they can offer some solutions to facilitate the social acceptation of innovations.

- Improve ability of extension staff to mediate between the conflicting principles of farmers' self-organization and government control. This is a key challenge for increasing innovative capacity. The idea could be to introduce a participatory progressive process, through platforms or other mechanisms, in innovations diffusion and promotion.
- Run workshops to enlighten local people and talk separately with people negatively affected by innovation. Example: Local healers who may be negatively affected by a recently introduced health product based on coconut
- Make sure that benefits of new innovations/developments are shared equally with the local community. More broadly, to avoid marginalization, collective action should be enhanced and reinforced. When an innovation and changes are brought collectively, respecting the customs pathways and rules, the social reception and acceptance are improved.

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# 40. CONSUMER INTEREST IN COCONUT PRODUCTS

*By R. Bourdeix, A. Auroyé, and A. Pirmansah*

## Description

This risk is that the present upturn of consumer demand for coconut products may be only temporary, as a fad. After a euphoric period, the market would collapse and decrease in volume and price, to the detriment of both producing countries and the coconut sector.

The current upturn in coconut products is not the first. We are currently experiencing the second economic boom of the coconut palm. The first one started around 1830 and ended in 1930. Analysis of the past is crucial to understand the present and prepare the future.

### Occurrence and severity

From the 1960s, the lobby by soybean producers financed extensive communication campaigns against coconut oil. Caricaturing, the lobby funded studies by unethical scientists who engorged rats with considerable amounts of coconut oil, totally unrealistic for health studies. Then these scientists found that the rats were unwell. They published these results in very serious scientific journals. Certain press, funded by the lobby, widely disseminated the results. The same lobby also funded a campaign denouncing palm oil –another competitor of soybean oil - as carcinogenic. Nowadays, in some Pacific countries, supermarkets are still selling imported soybean oil cheaper than coconut oil. This is mainly due to subsidies given to US farmers by their government.

This trade war occurred in various ways of which few are officially known. For instance, in the 1950s, according to K Maramorosch, the whole technical assistance program for Cadang-cadang disease in the Philippines was abandoned under the pressure of the soybean and corn oil lobby groups.

Misinformation is continuing; The Harvard professor's assertion that the oil is like 'poison' is just one more battle in the coconut oil wars, using scandalous and mistrustful means. Any food that is beneficial to health, if consumed excessively, can become harmful. However, this attack will not affect the crude oil industry and coconut cosmetic products, which are the main outlets for the copra sector.

Any food industry seems doomed to failure if it neglects the continuous and continuing development of new products. Our markets live in a sea of food and persuading people to eat new coconut products means they have to stop eating something else.

### Mitigation and adaptation

*Understanding the past*

Before 1830, European imperial powers did not trade extensively in copra, the dried meat of a coconut. Within hundred years, however, demand for copra would make it one of the most extensively traded agricultural goods throughout the world. Copra's rise as a necessary import within the western world was a result of industrialization, war-time experiences, and the importance of fats and oils for food, feed, and the raw material for industry. It seems that the first copra boom was linked, at least partially, to the fact that European people started to wash themselves. The greatest demand for coconut oil and copra came from manufacturers of soap.

In Great Britain and Ireland, the annual consumption of soap products per head quadrupled between 1801 to 1891.

Oils are called 'concretes' when, like coconut oil, they solidify below 15 °C. Lauric concrete oils (coconut palm, oil palm kernels) are mainly used for soap and cosmetics in Europe or North America. These concrete oils are widely used for food in tropical countries and increasingly so in Western countries.

A disruption of the relative positions of the main oilseed crops took place in the second half of the twentieth century. These changes included:

- The end of the predominance of fats of animal origin; the successive emergence of soybeans (1950s in the US, then 1980s in South America), palm oil (1970s), sunflower and canola (1980s), these four oils representing in 2000 more than 77% of the world production of vegetable oils. Global trade has focused on a few dominant products.
- The relative decline of peanut oil and especially coconut oil, which ranked first in the world in vegetable fats until the 1930s.
- Since the 1980s, the vegetable oils sector has seen many upsets: the arrival on the world market of massive volumes of palm oil, the ups and downs of the debate on the health threat posed by Trans fatty acids, the tropical oils controversy, and the progress made in producing new oilseeds as transgenic rapeseed, etc.

Soybean was first cultivated for animal feeding, the soybean oil being almost a by-product. Palm kernel oil, obtained from oil palm kernels, is also a kind of by-product when compared to the oil from the red oily palm husk. International prices of palm kernel oil and coconut oil are generally highly interdependent because of their high lauric acid content. Western countries did not have any crop producing lauric acid. To reduce their dependency on imports, they created transgenic rapeseed and canola.

*Preparing the future*

Even if coconut oil has serious competitors, the food and non-food uses of lauric oils are expanding. This has resulted in market growth and increase in production. The variability in production volumes, especially coconut oil, affects the movement of prices. Some economists think it is the root cause of the sharp fluctuations observed. These fluctuations are perceived as a risk by users and processors, who turn to competing products whose supply is more regular. The consequence is that the real demand oscillates around a low level. These oscillations are perceived, in turn, as a risk by the farmers, who sometimes hesitate to invest in coconut cultivation.

**Actions to undertake**

Diversification of coconut products should be pursued, together with the expansion or creation of new high value-added markets. In this way, even if the demand for a specific coconut product diminishes, stakeholders can easily shift to another market. This could be the case, for example, regarding coconut water and desiccated coconut. In this case the selected coconut varieties should be sufficiently versatile to support various uses

Contrary to the soybean lobby, ICC (ex APCC) has entered the commercial oil war with a relative 'fair play' and positive attitude. They promoted the healthy aspects of coconut oil without communicating the negative properties of other competing oils. This is a good start. The slogan 'Don't wash with transgenic' could be an efficient campaign to promote natural lauric oil instead of transgenic colza and canola oils. As Palm oil is already impeded by the negative feelings linked to oil palm, coconut oil will remain the main natural source of lauric acid. Such campaigns could be also dangerous: it remains difficult to assess the consequences of launching another commercial war.

Coconut water is the only drink that can be stored and transported in its own natural and sanitized container, the coconut shell. In the long run, it may seem illogical to extract this water for packaging in plastic. The partially chopped tendernuts called 'diamonds' still have too much 'wrapping' (the white husk). Some manufacturers have proposed a better method, by pre-cutting the shell over part of its thickness, and gluing a pull tab that makes it easier to open the fruit. They sell their husked drinking coconut at 4.5 euros in European supermarkets, which seems still too expensive to attract a large volume of consumers.

Recent changes regarding the coconut image may impact the global representation of tropical countries when compared to temperate climate countries. Coconut is the main symbol of the tropics, and its image is changing from 'Holiday and comics' to 'Natural and healthy'. On the other hand, Western countries are more and more seen as polluted places and the main contributors to pollution and global warming. Promoting coconut products can also impact the tourism industry, because the healthy reputation of the coconut palm extends to the countries where coconut is growing. Communication and marketing strategies of Pacific countries should consider and strengthen this symbolism.

Coconut field work remains too hard when compared to other oil crops. All must be done to help farmers reduce this burden. It is expected that this manual will be a small step forward in the right direction.

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# 5. ANNEXES

## A. RESULTS OF THE ONLINE SURVEY

*By R. Bourdeix and J. M. Sourisseau*

As of 9 August 2018, 49 significant replies where obtained. Respondents are located in 26 different countries or territories: India (10 respondents), Australia and Indonesia (4 in each), Malaysia (3), French Polynesia, Papua New Guinea, Philippines, Tanzania, Tonga, Vanuatu (2 in each), and one reply for each of the following countries: Brazil, Benin, Côte d'Ivoire, England, Fiji, Hawai'i, Kenya, Nicaragua, Nigeria, Pakistan, Samoa, Seychelles, Solomon Islands, Sri Lanka, Thailand and Vietnam.

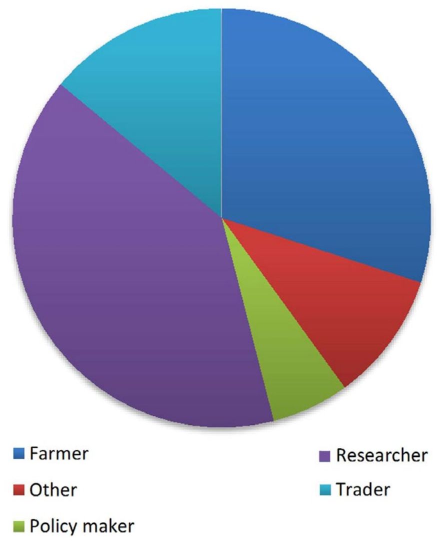


**Plate 23.** Main occupation of respondents.

The sampling is not statistically representative, but the objective is to capture a diversity of the main focuses of people directly involved in the value chains, and inside a dedicated network. Responses came back from 24 different countries, with an over-representation of India (10). The respondents find it difficult to identify themselves in one single occupation. sixteen of 50 consider themselves as multi-stakeholders, involved in farming and trade, or in research and farming, or in farming and policy making. Indeed, this situation illustrates the high level of integration of coconut value chain segments. This is a strength, but it may also be a weakness in governing and coordinating the processes.

Finally, as shown in Plate 23, regarding their main occupation, our 'sample' over represents researchers and farmers.

**Analysis of replies regarding incentives**

We defined a typology using a two-step process. A first typology was drafted by evaluating all the replies. Second, we refined the typology during the analysis of the individual replies. We finally defined 11 categories.

Some of the replies went out through the typology. For instance, for the second incentive, the reply 'Major national effort in getting the right cultivars into large scale nurseries. Mapping out the correct land for these to be planted in' added a value of one to both the categories 'planting material' and 'Land'.

We conducted twice the repartition of suggested incentives in categories, and we chose the average (highest entire value) of the two notations. We calculated for each category a total (sum of the values obtained as first, second, and third incentives) and a pondered total (first prioritized incentive counted as 3, second as two, and third as one). The categories were classified according to the pondered total, as shown in table 4.

The most favoured incentives were those related to planting material (both in total and pondered total); then 'Securing farmer's income"; 'Land and landscape for coconut cultivation"; 'National policies", and 'Diversification for higher value of coconut products".

**Table 4.**
Categorization and prioritization of suggested incentives from the online CIDP survey.

| Categories | | Priority | | | Total | Pon-dered total |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | | |
| 1 | Good planting material for farmers | 18 | 9 | 4 | 31 | 76 |
| 2 | Securing farmer's income | 10 | 5 | 4 | 19 | 44 |
| 3 | Land and landscape for coconut cultivation | 8 | 8 | 3 | 19 | 43 |
| 4 | National policies | 3 | 10 | 10 | 23 | 39 |
| 5 | Diversification for higher value of coconut product | 5 | 8 | 8 | 21 | 39 |
| 6 | Professionalizing coconut producers and their organizations. | 4 | 5 | 3 | 12 | 25 |
| 7 | Good cultivation practices | 3 | 4 | 7 | 14 | 24 |
| 8 | Pests and diseases | 4 | 2 | 2 | 8 | 18 |
| 9 | Processing from farm to consumers | 2 | 4 | 3 | 9 | 17 |
| 10 | International policies | 1 | 3 | 5 | 9 | 14 |
| 11 | Reducing cost of product transportation | 0 | 1 | 1 | 2 | 3 |
| Total | Total | 58 | 59 | 50 | 167 | 342 |

**Table 5.** Rationale for incentives typology in link with individual replies.

| | Categories | Notes on individual incentives proposals |
|---|---|---|
| 1 | Good planting material for farmers | Free of charge seedlings; provide quality planting material adapted to each region; Train farmers to harvest and prepare themselves best planting material; Diversify the genetic base of planting material; More nurseries; promote hybrids; promote local varieties; use molecular approach to improve breeding techniques; Government to support public and/or private coconut breeding programs and gene banks; While maintaining bio security, to simplify import and export of planting material. |
| 2 | Securing farmer's income | Stabilize the selling prices; secured local and international market; Minimum price guaranteed even in situation of oversupply; Insurance against low prices. Special incentives for insulated and marginal farmers. |
| 3 | Land and landscape for coconut cultivation | Devote more and more suitable land for coconut cultivation; Subsidies for land preparation; policy for identification and reservation of most adapted land to coconut cultivation; Land distribution to coconut farmers; Comprehensive program from leasing the land; prioritize and help replanting senile plantations; segmenting the coconut communities within each region for targeted specific products. |
| 4 | National policies | Increase communication between private and public sector and organize better sharing of investments in coconut value chain; promote interdependence among the producers and processors- Legislate that processors must offer shareholding in the company to farmers; promote cooperative farming; license approved buyers/collectors to cut down the middle man; promote local market for value-added products, revive local consumption; segmenting the coconut communities within each region for targeted specific products; labelling coconut products; recruit competent agricultural and extension officers working exclusively on coconut; Organize access to financing and micro financing; governments to recognize publicize the value of coconut farming and the ease of cultivation after the planting phase. |
| 5 | Diversification for higher value of coconut product | Develop the use of by-products (husk and shell) for copra producers; develop other products than copra and oil; Market germinated coconut as source of essential fatty acid for preventing human diseases; promote coconut chips that remains a untapped potential, as snacking is a global habit amongst all age groups; providing awareness to the farmers on selling stem and husk for firewood; provide a better access of farmers to market for high value coconut |

| | Categories | Notes on individual incentives proposals |
|---|---|---|
| | | product; training on improved techniques in processing and marketing; provision of processing equipment for Small and Medium scale enterprises with start-up capital. |
| 6 | Professionalizing farmers and their organizations. | Help farmers increase the productivity of their plantation; facilitate adoption of innovative techniques; cooperative farming to reduce the disadvantages of small plantations; educate the farmers; rehabilitation incentives for low productivity farm; promote existing harvesting equipment such as coconut sickle or coconut climbing machines: organize contests between coconut growers with big prices funded by the government; create demonstrations sites. |
| 7 | Good cultivation practices | Shift to organic cultivation; promote intercropping; promote irrigation; subsidy in fertilizers– Promote organic fertilization; promote the use of cover crop; well planned bonus schemes, from land clearing, proper spacing, intercropping, then pay farmers after a 2 to 3 year period. |
| 8 | Pests and diseases | Develop biological control; teach farmers to locate and destroy Oryctes breeding sites; molecular markers for pathogen studies; incentives for farmers to cut diseased palms and replace them with improved varieties; subsidies in pesticides and insecticides. |
| 9 | Processing from farm to consumers | Improve the processes of preparation and storage of high value coconut products; post harvest management; develop end to end cold chain for coconut water; assist with processing equipment for virgin coconut oil; developing automation of coconut nectar (toddy) extraction; set up small/medium integrated value added coconut product processing. |
| 10 | International policies | Increase international cooperation in coconut research; produce training manuals; long term loan with technology support to push quality products to market; communicate with national health authorities about healthy value of coconut product; increase links between coconut growers, scientists, processors, the states and the consumer market. |
| 11 | Reducing cost of product transportation | Support logistics for freight of coconut products. |

**Analysis of replies regarding risks**

Adding the 3 levels of risks all together, the respondents raise 148 propositions. The most cited items are price and marketing issues (30), genetic and replanting (26), policy and coordination (23), and pest and diseases (21).

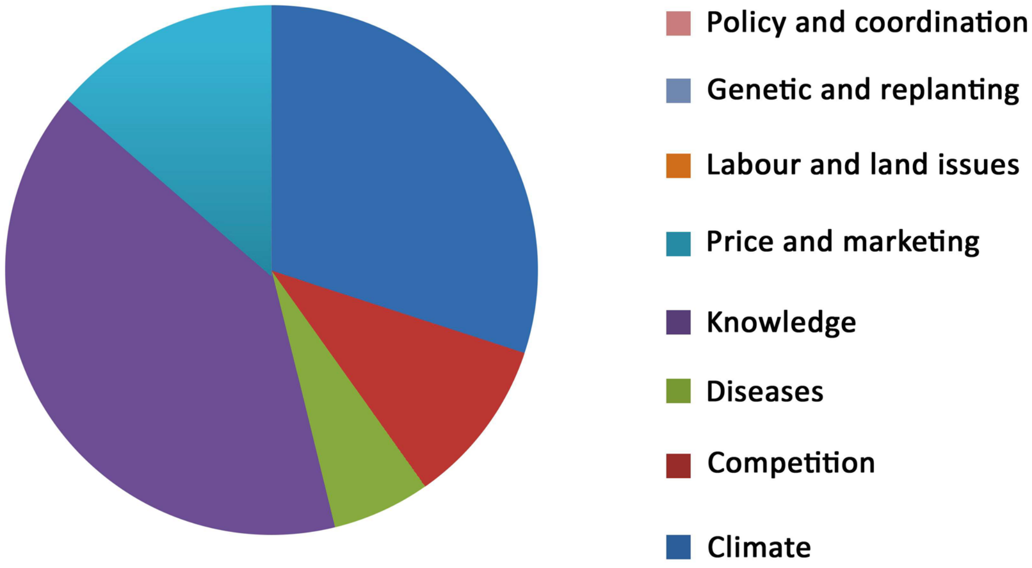


**Plate 24.** Type of risks and constraints (total).

Price volatility and market failure are real concerns when anticipation is quite impossible and when farmers depend too much on coconut activity. But only half of answers on marketing are effective risks, i.e., markets' failure. The second half concerns the economic under valuation of coconuts' basic products. One can understand that to prevent from markets' uncertainties, farmers and their organizations may change their strategy toward more value-added products (art craft, high quality water and milk, etc.).

In the same vein, the old age of trees is a real concern because it exposes the plantation to climate events and diseases but cannot be considered as a risk in itself. Therefore, replanting good varieties in shorter intervals appears to be necessary to both improve performances and resilience. The issue should be studied further, but even if the respondents didn't mention it, rustic low yield variety may have, in the contrary, a positive effect on climate and diseases' prevention. It seems that the necessity to close the yield gap (with genetic improvement) over-determines to researchers and farmers priorities. The lack of adequate and massive policies is also a constraint that exposes to financial and environmental risks. The respondents claim for yield improvement, market protection and quality improvement (to get higher prices) to raise farmers' incomes and resilience. But the lack of coordination of the different actors along the value-chains is considered as important and policy failure. The fourth more cited item is typically an agronomic risk. Pests and diseases remain as a major threat, and have large occurrences, with dramatic consequences on production and farmers' incomes and livelihood.

Policy and coordination issues reflect both constraints rather than risks. Some items refer to risks of failures along the value chain. For instance, when a processer is not able to make the job, the consequence may be a commercial lost for the producer. But these risks are not often mentioned. Most of the occurrences refer to structural dysfunctions in commercial or logistic coordination, and in policies implementation. Once again, the survey insists on the weak incentives offered by coconut production economic environment and on the lack of infrastructure (due to policy failure). These weaknesses result in producers' high vulnerability to market failure, climatic events and pests and diseases sudden attacks, which remains the 3 main categories risks quoted by the respondents. Pest and disease risks are more precisely described and documented, even if they represent only 14% of the total propositions. It's quite surprising that climate risks count for only 10 occurrences among the 148 responses.

As shown in Plate 25, when crossing respondents' jobs and the nature of constraints and risks declarations, it's interesting to notice that farmers' declarations are the most diversified. This result may reflect the wide diversity of producers, regarding agronomic, economic and organizational conditions. Traders have a clear focus on price and marketing issue, which seems quite natural, but are also conscious of the economic consequences of the age of the plantation and of policy and coordination failures.

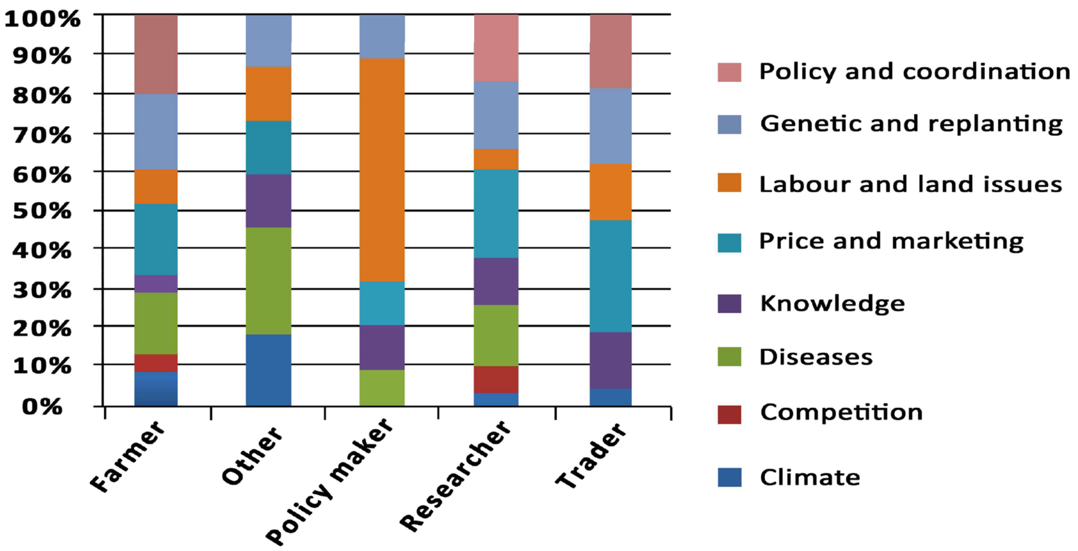


**Plate 25.** Crossing respondents' jobs and the nature of constraints.

Another result that calls for further investigation is the focus of policy makers on labour and land issues. Perhaps it's because they feel they can play on these two factors through laws, regulations and incentives, when the other constraints and risks are out of their field of action. Researchers' responses are also diversified, but one could have expected a greater focus on pests and diseases and on the lack of knowledge of the farmers. These two items count only for 3 and 5 of researchers' 20 first choice, against 6 for price and marketing.

As shown in Plate 26, the prioritization of the risks and constraints gives, for the whole sample, the priority to the risks related to genetics or replanting, before prices and marketing constraints, and only in third position, the pests and diseases. The distribution of answers for the second choice is relatively close to the first priority ranking. On the other hand, it is only at the level of the third choice that the constraints and risks regarding policies and coordination become significant.

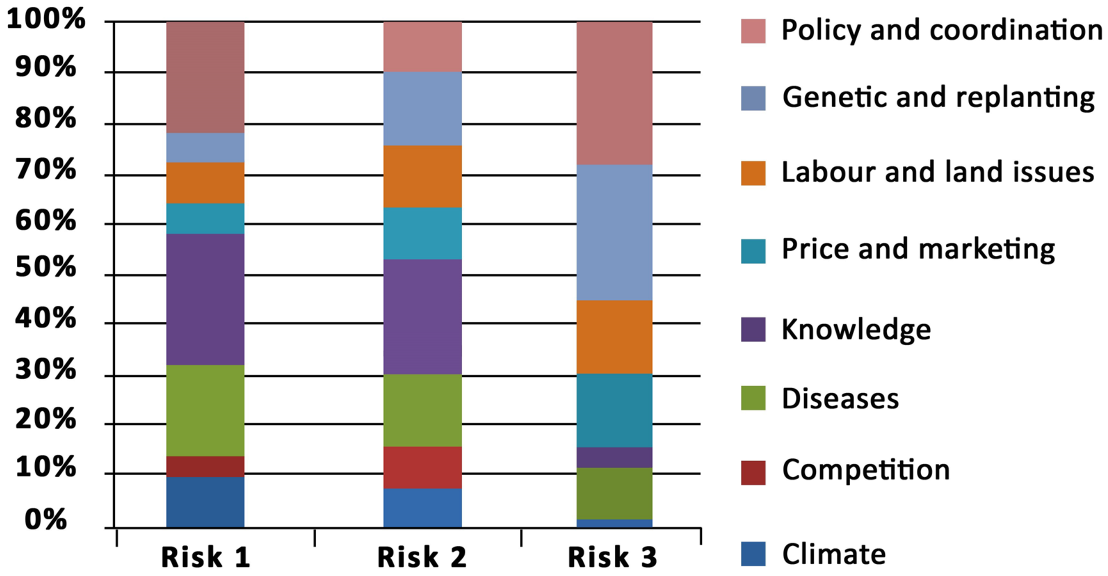


**Plate 26.** Prioritization of the risks and constraints.

The climate, yet emblematic of the risks in this region of the world, and strongly put in front in international medias, is only rarely mentioned, whatever the level of prioritization.

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