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Drivers and barriers for the agroecological transition of the French Polynesian farming systems

Case study on crop farmers

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ABSTRACT

In recent years, the quality of French Polynesian agricultural production has been increasingly criticised by consumers, who are concerned about pesticide residues in vegetables. Parallel to that, farmers are accused of increasing soil erosion with their “bad farming practices”. These critics are difficult to validate as there is insufficient information available concerning the farmers’ practices. Therefore, this works seeks to answer two questions: To which extent do farmers use “agroecological practices” that reduce erosion and dependence on agrochemicals? What are the factors or forces supporting or hindering the implementation of “agroecological practices”? A qualitative work has been conducted with 20 farmers interviewed on four different islands in the Society Archipelago in French Polynesia, following an agroecological analytical framework. After describing the different farming practices and evaluating their alignment to an agroecological approach, four major types of farmers were established: organic, reasoned, traditional and conventional. These types combine similar management practices determined by their socio-economical environments. After articulating the major barriers for each farmer type, potential drivers leading to a broader implementation of “agroecological practices” were underlined. Results show that “agroecological practices” are used by a vast majority of farmers for erosion mitigation and pest management, with an important crop diversity leading to biological pest regulation. Management of soil fertility is far from an agroecological approach, with use of mostly synthetic fertilisers and herbicides. The “reasoned farmer type” have been identified as the target group to push forward the agroecological transition of the farming systems, being the most innovative. Researchers should work hand in hand with these farmers to further evaluate the technical and economic feasibility of implementing “agroecological practices”. Finally, results highlight additional requirements for the agroecological transition such as increasing research on organic management of vegetable production, improving market valorisation for organic products, giving access to small machinery for the resource-poor farmers, promoting agricultural training to improve soil fertility management and raising consumer awareness.

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LIST OF ABBREVIATIONS/ACRONYMS

AE Agroecological practices/principles

CAE Contrat d'Accompagnement à L'emploi (support measures for employment)

CAPL Chamber of Agriculture and of Bay Fishing

CEP Centre of Nuclear Experimentation of the Pacific

CF Conventional Farming

CIRAD Centre for International Cooperation in Agricultural Research for Development

CPS South Pacific Community

CUMA Cooperation for the Use of Farming Machinery

CS Case Study

DAG Direction of Agriculture

EPIC Industrial and Commercial Public Establishment

FED European Fund for Development

FFS Farmer Field School

IFOAM International Federation of Organic Agriculture Movements

IPM Integrated Pest Management

ISFM Integrated Soil Fertility Management

OF Organic Farming

OM Organic Matter

NOAB Oceanic Norm for Organic Farming

PGS Participatory Guarantee Scheme

RQ Research Question

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1. INTRODUCTION

Mitigating **soil erosion** and improving **pest management** have become two major objectives for French Polynesian agriculture (Ministère de l'économie Rurale, 2011). Steep slopes combined to heavy tropical rains are a major driver for important soil erosion, leading to bay sedimentation and reef degradation (Seguin, 2015). Improving the farming practices to mitigate erosion from wind and water is a necessity. Concerning the pesticide use, a couple studies highlight the contamination by pesticides on organisms of various levels of the marine trophic web. Scholars explain that chemicals have contaminated remote areas where there are no agricultural activities, such as atolls from the Tuamotu Archipelago (Salvat et al., 2012). The extremely long residence time (centuries) of these chemicals in soil and sediments (Roche et al., 2011, cited in Salvat et al., 2012) and the scientific uncertainty on their potential cocktail effects with other chemicals (Sheikh et al., 2009, cited in Salvat et al., 2012), are clear arguments pushing for alternative use to synthetic pesticides. This desire to change the farming practices are supported by growing population concerns about the negative impacts of pesticides on human health (Carrère, 2017).

In the context of peak oil and climate change, **food security** of the French Polynesian inhabitants could easily by threatened. Indeed, these 116 islands isolated in the middle of the Pacific ocean are heavily dependent on food importations which increases their vulnerability. In 2015, only 41% of the vegetable consumption and 66% of the fruit consumption were produced locally (Institut d'émission d'outre-mer, 2016). Consequently, increasing the local agricultural production, in terms of **quantity** and **quality** by decreasing the use of synthetic fertilisers and pesticides, is a priority for the country (Ministère de l'économie Rurale, 2011).

On an international level, the South Pacific countries have decided to orientate funds from the 11th European Fund for Development (FED) to the **agroecological transition and the development of organic farming** (Direction of Agriculture, 2018). Four countries share this envelope of more than 8 million euros: New Caledonia, French Polynesia, Wallis and Futuna and the Pitcairn Islands. Part of this fund (the regional envelope) will be used for the design of agricultural development programs. Designing such programs requires to have an important knowledge of the local agricultural situation. Otherwise, actions might not be targeting the desired issues, as explains Dufumier (1996): *"One of the main criteria explaining the failure of agricultural projects is that a single proposition is applied to a large sample of producers, that are meanwhile extensively different"*. Rather, Dufumier (1996) requires to make an "**analysis-diagnosis**" before the implementation of any agricultural development project. This step should enable to understand the complexity and the diversity of needs of the different actors by taking into consideration the ecological, technical, socio-economical, cultural and political phenomena, that influence the farming system. Such an analysis requires to adopt a **holistic approach** of the farming system.

As there is **no pre-knowledge available** describing the farmers' practices in French Polynesia, the first necessity is to collect this information on *what is there*, and second, there is a need to understand *why* certain farming practices are implemented or not. This type of problem area requires a **case study** (CS) approach, that allows to address contemporary phenomenon (in opposition to historical phenomenon) and to answer to "why questions" (Yin, 2009). CS, as for every research method, has strengths and weaknesses. Being part of the so-called "soft sciences" that are often criticised for lacking scientific rigour or being difficult to generalise. However, the aim of this work is not to generalise knowledge by quantifying information following a statistical approach, but rather to understand a very specific context.

The **first objective** of this study is to play the role of a "diagnosis" of the current farming practices in terms of soil and pest management in French Polynesia. The **second objective** is to underline the drivers and the barriers that can explain the implementation or not of farming practices that are in line with an agroecological approach. Understanding the drivers and barriers faced by certain types of famers is an important step allowing to design appropriate agricultural programs. Eventually, potential actions will be formulated allowing to push forward the agroecological transition targeting by the 11th FED.The following **research questions** were defined (RQ1 and RQ2):

RQ1. To which extent do farmers use "agroecological practices" that reduce erosion and dependence on agrochemicals (fertilisers and pesticides)?

RQ2. What are the drivers and the barriers for a broader implementation of "agroecological practices"?

To assess the extent to which "agroecological practices" are used to reduce erosion and dependence on agrochemicals, the farming practices of 20 farmers were characterised. **15 management practices** were estimated as important and widely represented in the sample and therefore, the farmers' were characterised on their implementation of these 15 management practices. A semi-quantitive grading system was developed to evaluate the practices' proximity to an agroecological approach. The drivers and barriers for a broader implementation of "agroecological practices" were analysed by proceeding to a **farmer typology**. Four farmer types were identified in the sample and for each of them, the social, economical and technical environment of the farmers were described, explaining why they implement or not these practices.

In order to grasp the very special context of French Polynesian agriculture, some **background information** is necessary to be able to understand the broader geographical, economical, historical and cultural context of this country.

2. BACKGROUND INFORMATION

2.1 FRENCH POLYNESIA - COUNTRY PRESENTATION

Geographic data:

116 islands in 5 Archipelagos:

- **Windward**
- **Leeward** (300 km North-West from Tahiti)
- **Marquesas** (1500 km North-East from Tahiti)
- **Austral** (between 560 and 1500 km South from Tahiti)
- **Tuamotu-Gambiers** (between 300 and 1600 km East from Tahiti)

Total surface of French Polynesia comparable to the surface of Europe.

Socio-economical statistics

(Institut d'émission d'outre-mer, 2017)

- **Population**: 272'800 inhabitants, with the 2/3 living in Tahiti
- **Unemployment rate**: 21.8%
- **3%** added value in the **primary sector**
- **85%** added value in the **tertiary sector** (service industry)
- **Average income for a full time employee**: 317'000 F CFP (2641 euros)
- **Average income in agricultural sector**: 207'000 F CFP (1725 euros)
- **Gini coefficient**: 0.40 (Institut des Statistiques de la Polynésie Française, 2018) Level comparable to the inequality of distribution of wealth in the USA.

FIGURE 1: GENERAL GEOGRAPHIC AND SOCIO-ECONOMIC INFORMATION
(CARTOGIS SERVICES, COLLEGE OF ASIA AND THE PACIFIC, THE AUSTRALIAN NATIONAL UNIVERSITY)

2.2 MAJOR SHIFT IN POLYNESIAN AGRICULTURE IN THE 1960S

In the 1960s approximately, agriculture that was until then a major pillar of the economy, gains fragility. Different factors explain this situation such as: aging coconut plantations with lower yields, decreasing vanilla production caused by a disorganised sector, overexploitation of nacre and the stock of phosphate from the mines in Makatea that had been entirely exploited (Lextreyt, 1990). The major primary production activities are at their lowest and the economy requires stimulation. The government decides to develop the tourism industry and therefore, to build the first international airport in the town of Faa'a. However, the country does not have sufficient funds to build such an infrastructure. In parallel, it happens that France is interested in investing 100 million of Francs to implement **nuclear trials** on the atoll of Moruroa, which will require construction of infrastructures such as airports (Lextreyt, 1990). Indeed, in the context of the Cold War, Charles de Gaulle who was at the head of the French nation, was determined to develop the nuclear weapons to defend the country. At that time, these nuclear trials were conducted in the Algerian desert. However, the newly acquired independence of Algeria in 1962 forced the French nation to delocalise themselves. This concordance of events was perceived as a great opportunity for France to finance the infrastructures in French Polynesia while leading the nuclear trials on the atolls of Fangataufa, Hao and Moruroa (Lextreyt, 1990).

With the construction of the Centre of Experimentation of the Pacific (CEP) in 1963, important subsidies from the French nation flowed towards the French Polynesian economy, that was based until then on the exportation of agricultural goods. In less than a decade, there is a shift in the economy (see Figure 2 below) leading to mass population movements from the islands towards Tahiti (Blanchet, 1990). Added value from the primary sector decreased from 39% in 1960 to 7% in 1970, whereas the tertiary sector increased from 46% to 80% (Chesneaux, 1995). Overall, the growth domestic product increased of 12,5% per year between 1960 and 1969 (Couraud, 1985).

During these CEP golden years, French Polynesian government had largely put agricultural development aside. However, after a decade, the need for workers decreased as the infrastructures were built, and no alternative jobs were offered to these workers. It was necessary for the government to launch an alternative development to avoid growing unemployment rates (Chesneaux, 1995). Therefore, in the 1980s, investments in the agricultural sector were made, focusing on an **intensification** and **modernisation** of agricultural production. Indeed, the important urbanisation of Tahiti, led to the emergence of a new demand for fruit, vegetables, traditional crops and livestock products (Couraud, 1985). Therefore, agricultural research programs are conducted in order to push forward the development of industries on certain islands such as pineapple production in the Windward islands, potato production in the Austral archipelago and production of melon and watermelon on "motus" in the Leeward islands (Blanchet, 1990).

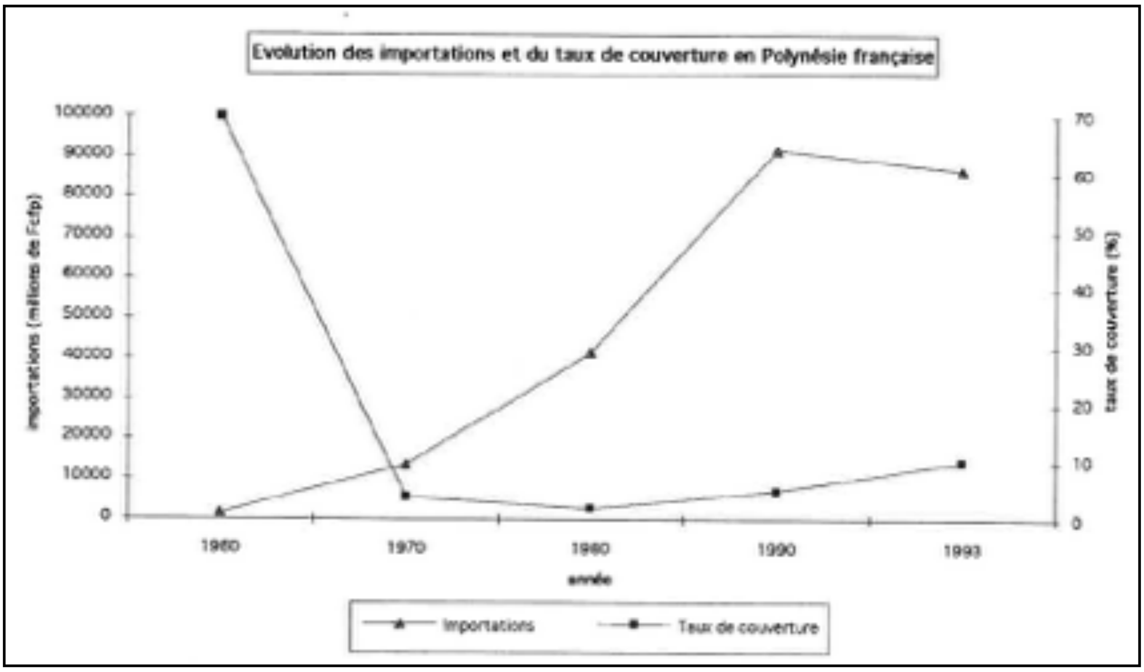


FIGURE 2: DRASTIC CHANGE IN THE IMPORTATIONS AND THE COVERAGE RATE IN FRENCH POLYNESIA (BERTHET AND JOIGNEAULT, 1996)

Meanwhile, even though there had been efforts to relaunch agricultural production, local production was largely exceeded by **importations** especially of food products, in consequence of demographic concentration and new consumption habits. Couraud et al. (1990) calculated that the level of importation of food products went from 237 kg/year/inhabitant in 1957, to 587 kg/year/inhabitant in 1985. Following the increase of living standards, people started consuming more animal-based products (milk and meat) than plant based products such as cereal (Couraud, 1985). Therefore, in 1990, the agricultural sector only represented 4% of the growth domestic product whereas other sectors started to become increasingly important such as tourism, fishery and the tertiary sector.

2.3 FRENCH POLYNESIAN AGRICULTURE & FARMERS TODAY

French Polynesian agriculture occupies less than 9% of the emerged surface of the country, representing approximately 39’000 hectares. This percentage of agricultural land is similar in other regions in the Pacific such as New Caledonia, Wallis and Futuna, very far from the 46% of land used for agriculture in France (Service du Développement Rural, 2012). Approximately 11% of the active population (including retired persons) are working in agriculture. This proportion increases outside of the Windward islands. **Multiple activity** characterises French Polynesian agriculture with farmers searching for a secured income coming from a diversity of sources: 12% of them live from fishery and 4% from craft, 11% are employed in a second activity and 22% of them are technically retired. **Polyculture** is also a very specific characteristic of the French Polynesian agriculture as it concerns 2 farms out of 3 farms. The average Polynesian farmer manages a **family farm** (98% of individual farms) and the labour force is by far constituted of family members (89.5%). The average farm size represents 6,9 hectares, but this average is largely driven upwards by the coconut plantations (average size of 15,7 hectares), as in reality only 48% of the holdings farm on more than **0,5 hectares** (Service du Développement Rural, 2012).

The typical farmer is a man, of an average of 49 years old. **The degree of education is extremely low with 90% of the farmers who never followed any agricultural training** (Service du Développement Rural, 2012). Farmers' social security is mainly non-existent. Only 10% of the farmers contribute financially to the social security scheme for "non-employees" ("Régime des Non Salariés" in French), meaning that the 90% do not receive any income once they stop farming (Service du Développement Rural, 2012). Indeed, there is still **no official recognition of a "farmer status"**. This vulnerable situation pushes farmers to search for multiple actives to secure their income. In the Windward islands, the situation is slightly better with 3 farmers out of 10 who are able to contribute to the social security scheme for "non-employees". Today, efforts are made by the Chamber of Agriculture to improve the farmers' livelihoods by creating a "farmer card" (Fabresse, 2018a). This "farmer card" can be obtained once there is evidence of a minimal production (thresholds defined depending on each crop), indicating that a major part of the income is provided by the farming activity. The farmer card allows to achieve discounts on inputs or machinery and access to financial credits.

Of the 39'000 hectares of agricultural land, 74% is covered by coconut plantations, 18% by pastures and 8% by plant production (Service du Développement Rural, 2012). In terms of tonnage, copra production represents 27% of the total agricultural production, vegetables represent 17%, fruit represent 16% and traditional crops represent 3% (Institut d'émission d'outre-mer, 2016). Figure 3 illustrates the location of the major production. Coconut plantations, mainly produced in the Tuamotus atolls, are not represented as their tonnage exceeds by far the other types of plant production, which decreases the visibility of the figure. The **Windward islands** produce the vast majority of the **vegetable** and **fruit production**, the **Leeward islands** produce a lot of **fruit** (especially melon and watermelon) and nono, the Marquesas islands have important land managed as extensive pastures (Service du Développement Rural, 2015) and they produce fruit (citrus especially), finally the Austral islands produce especially vegetables (potato, carrots, leaks, cabbage) as the climate is cooler and more conducive for vegetable production. The Tuamotus, have exclusively sandy soils, that are difficult to cultivate. Therefore, coconut plantations are their major production.

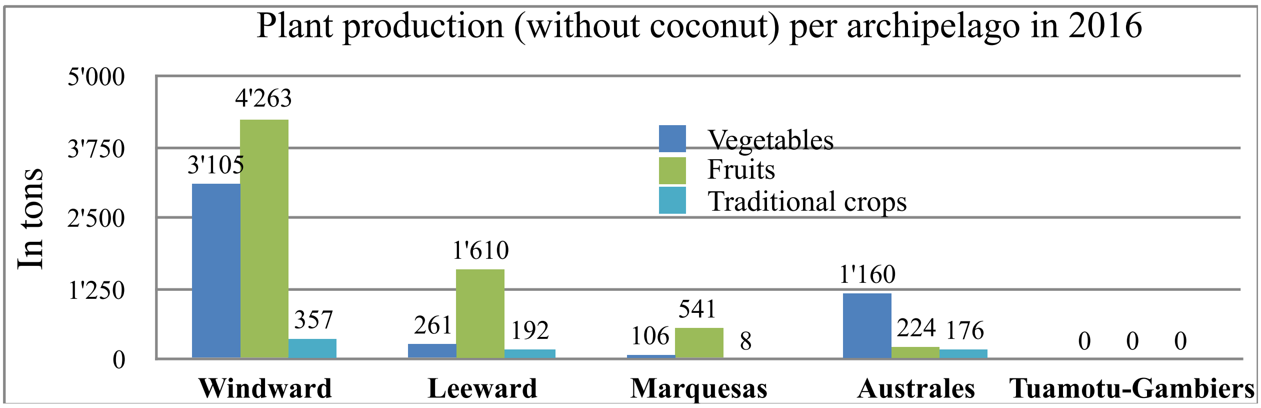


FIGURE 3: PLANT PRODUCTION FOR EACH ARCHIPELAGO EXCEPT COCONUT PRODUCTION (SERVICE DU DÉVELOPPEMENT RURAL, 2016)

Different actors, with different missions, interact in the French Polynesian agricultural world:

- The **DAG** possesses the general competence to organise, propose, inform and support the agriculture and forestry sector. Its mission is to promote economic development of agriculture by strengthening the economic organisation of the sectors (Service Public, 2018). The main section of the DAG is based on the island of Tahiti (Pirae), with a special cell dedicated to Research, Innovation and Vulgarisation in Papara (Direction de l'Agriculture, 2018d). One DAG subdivisions is present on every archipelago. This station conducts agricultural research, publishes different technical sheets to improve the farmers practices, and is an addition the unique nursery where the famers can buy young plants. There are no additional actors in the private sector playing the role of extension service.

- The **Chamber of Agricultural and Bay Fishing** (CAPL), is an administrative public institution that defends the interests of the farmers and fishermen, diffuses information, manages the farmers and fishermen register, and realises forecasts of agricultural production and economic surveys (Chambre de l'Agriculture et de la Pêche Lagonaire, 2018). Indeed, every month they organise an "**agricultural conference**" takes place in Tahiti. One week beforehand, agents of the CAPL visit farmers to evaluate their quotas of production, which allows them to estimate the quantity of production that has to be **imported**, in order to secure the local demand. During the agricultural conference, farmers, retailers and importation companies meet to **discuss of the prices** and find an agreement. The CAPL facilitates these discussions trying to ensure a fair compromise for the farmers (secured price from the retailers and the importation of a limited quantity from the import group).

- The "**Vanilla establishment of Tahiti**" is a Public Industrial and Commercial Establishment, EPIC in French, initiated in 2003 by the French Polynesian government to push forward the production of vanilla (Etablissement Vanilla de Tahiti, 2018). EPIC has many missions such as promoting vanilla produced in French Polynesia, controlling the quality of the production, supporting technically the producers and conducting applied research to develop the sector. **Other crops (fruit, vegetable, traditional crops) do not have a specific administrative establishment supporting their development**.

- The **Agricultural High school of Opunohu** on the island of Moorea is the only Public institution for agricultural education and vocational training. This school is divided in three sections: a high school, an education centre and a farm (Ministère de l'agriculture, 2018).

Concerning **fixation of prices**, they are largely regulated by the Organic Law of 2004, meaning that the control over prices and margins is defined by the government (Institut d'Emission d'Outre Mer, 2017). This market protectionism is argued as necessary to compensate lack of competition (micro-markets) and to maintain socially acceptable prices for goods of basic necessity (Institut d'Emission d'Outre Mer, 2017). The fact that importation quotas are defined every month by the CAPL is claimed by some scholars to decrease the sanitary quality of French Polynesian production and maintain artificial high prices. Venayre (2012) argues that lack of competition from the inside (low volumes) and from the outside (isolated micro-market) does not incentivise to improve quality of production. In addition, the small quantities produced locally and the lack of organisation of the sector do not help to achieve economies of scale (Venayre, 2012). Bertin (2006) emphasises the lack of structure of agronomic research on the territory and an insufficient level of formation of the DAG agents, that does not help to improve the farmers' practices.

Concerning **volumes**, an important part of the agricultural production is sold outside of the market in parallel channels of self-consumption. Bertin (2006) gives the example of the fruit shortage on the market: "*Supplying Tahitian supermarkets with local products is challenging. Farmers unfamiliar with a "quality" approach find it difficult to sell their produce to gross retailers, that require irreproachable fruit and practice significant price reductions when there are needs for sorting*." As long as marketed volumes remain in deficit with respect to local market demand, farmers assisted by the regulatory system will be able to maintain high prices. In such a "market of scarcity", the structuring of the profession is done very slowly (Bertin, 2006).

One of the **challenges** for further agricultural production is the question of the **land ownership.** After the colonisation by the French state, French land reform was applied to French Polynesia, leading to tensions between the **traditional conception** of land and the **colonial conception** of "land property" (Besson & Hertkorn, 1995). However, "*the implementation of French land reform remains incomplete with important land that belongs to either absentee landowners or extended families and is known as family land (terre familiale or fenua toto)*" as explains Donaldson (2018). The common term used to design these lands owned by all is *indivision*, from French *undivided.* Lack of clarity on land ownership hinders agricultural investments on the long term, as there is always a risk for people claiming that the land is theirs. Globally, **50% of the agricultural land is non-divided**, 30% consists of private properties and 20% is rented or shared (Service du Développement Rural, 2012).

In conclusion, agriculture in French Polynesia is based on a **poorly structured family farming model**, consisting of small farms focused on polyculture. Its development is burdened by the lack of arable land (challenging topography of the high islands, poor soils on the atolls, problems with land ownership) and the lack of structuring of the sectors, which favours the flow of production out of marketing channels (Institut d'émission d'Outre-Mer, 2016).

2.4. ORGANIC FARMING IN FRENCH POLYNESIA

Development of organic farming is recent in French Polynesia. In 2008, the South Pacific Community (CPS) composed by 22 countries, created the **Oceanian Norm for Organic Farming** (NOAB). NOAB follows the precepts from the International Federation of Organic Agriculture Movements (IFOAM) but was adapted to the very specific context of the Pacific. The label *BioPasifika* was created for the organic products that respect the specifications required by the NOAB. In 2011, the first "country law" on organic farming was promulgated by the French Polynesian government, followed by the publication of the different application decrees concerning organic farming. The same year, the first official Participatory Guarantee System (PGS) called the *SPG BioFetia*, was created.

In March 2017, **24 producers** achieved the SPG BioFetia guarantee and **6 producers** achieved the BioAgriCert certification (Direction of Agriculture, 2018a). The difference between these two labels is their possibility to export to international markets. The BioAgriCert certification allows the farmer to export to the international market whereas the BioFetia and BioPasifika labels are restricted to the South Pacific Community market (Direction of Agriculture, 2018a). One of the objectives described in the Agricultural Policy for 2011-2020, is to increase the organic production by 2020, covering 30% of the vegetable production, 50% of the fruit production and 60% of the traditional crop production (Ministère de l'économie Rurale, 2011). This objective is still far from reached when looking at the number of guaranteed and certified organic producers in 2017.

2.5. A BRIEF OVERVIEW OF AGROECOLOGY

There are many different definitions of Agroecology in the literature. Historically, scholars from different countries around the world diverged on deciding if agroecology consisted of a narrow set of agronomic practices, a science, or a social movement. Today, it is accepted that agroecology consists of all of these three, meaning a **science**, a **practice** and a **social movement** (Wezel et al., 2009). Indeed, adopting a systemic view on the farming system does not make any sense if not adopting the same systemic view on the factors navigating around the farming system. Francis et al. (2003, cited in Wezel et al., 2014) gives a **definition of agroecology** that underlines the deep intertwined relations between the farming system and the food system: "*Agroecology is the integrated study of the ecology of the food system in its entirety, comprising its ecological, economic and social dimensions or, more simply, the ecology of the food systems.*"

The Climate & Agriculture Food Sovereignty Officer, François Delvaux, published no later than in April 2018, a document defining four dimensions of agroecology: the **environmenta**l dimension, the **social and cultural** dimension, the **economic** dimension and the **political** dimension (Delvaux, 2018). A growing number of scholars try to tackle these dimensions acknowledging their importance as the farming system is connected and dependent on multiple socio-economic and politic aspects. The Food and Agriculture Organisation of the United Nations (2018) recently published 10 key principles of agroecology that can serve as a tool to evaluate and articulate aspects of the agroecological transition, taking into account the ecological, economical, social and political dimensions of agroecology.

Ecological principles behind Agroecological systems

The overall objective of agroecology is to design agroecosystems and food systems that imitate natural ecosystems (Gliessman, 2006). An **agroecosystem** is defined by Conway (1997, cited in Rao et Rogers, 2006) as an "*ecological and socio-economic system comprising domesticated plants and/or animals and the people who husband them, intended for the purpose of producing food, fibre or other agricultural products*". The argument behind agroecology is that by increasing the biological diversity in agroecosystems and by optimising biological interactions, "*it is possible to increase agricultural output quantity and enhance its quality, manage pest populations more efficiently and effectively, and reduce reliance on inputs*" (Malézieux, 2012). Therefore, **diversification** is extremely important as it will increase the resilience of the system to perturbation, such as a disease or a pest, with a stronger self-regulation by (agro)-biodiversity (Wezel at al., 2014).

Agroecological practices (AE practices)

Wezel et al. (2014) explain that AE practices are:

> *"Agricultural practices aiming to produce significant amounts of food, which valorise in the best way **ecologic processes** and **ecosystem services** in integrating them as fundamental elements in the development of the practices, and not simply relying on ordinary techniques such as chemical fertiliser and synthetic pesticide application or technological solutions such as genetically modified organisms."*

In simple words, a practice is agroecological if it does not rely on external inputs but rather on ecological processes. Wezel et al. (2014) define a set of fifteen categories of AE practices, seven of them involving an increased efficiency or substitution and eight of them, involving a redesign of the system often based on diversification. The interesting point the author of the article makes is to consider the practices under three scales of implementation from the easiest to the most challenging. Indeed, some transitions to AE practices are much easier to implement as they require more **efficiency**: reducing input consumption and improving crop productivity. Other practices require **substitution** of an input or a practice and the most challenging to implement require a full redesign of the system, often based on **diversification**.

Differences between agroecology and organic farming

There is often confusion between organic farming and agroecology, although there are quite some differences between them. Organic farming consists of a definite set of practices that allow to achieve a certification. Concerning the technical dimension of agroecology, it should rather be considered as an approach to the farming system, that seeks to increase the autonomy of the farmers, by developing the farmers capacity to be as self-sufficient as possible (Nicholls et al., 2017). On the other side, conversion to organic farming is sometimes interpreted by farmers as a substitution from mineral inputs to organic inputs, which does not address the root causes of a symptom but just improves slightly the situation (Nicholls et al., 2017). This type of problem solving is not what is targeted in an agroecological approach, where a pest outbreak or a lack of nutrients will be interpreted as a failure of certain ecological processes (biological control or nutrient cycling) and will require for the farmer to investigate the deep reasons that led to such an unbalance (Nicholls et al., 2017). In addition, agroecology includes socio-economic dimensions, that are not present in organic farming, such as the creation of collective knowledge and coping ability, fostering farmers' independence from the market and recognising the value of a diversity of knowledge and know-how (Migliorini and Wezel, 2017).

2.6 THE 11TH EUROPEAN FUND FOR DEVELOPMENT

The FED is a cooperation between European Union and the Overseas countries. Created in 1957, the FED includes territorial and regional envelopes (Institut d'emission d'outre-mer, 2017). The 11th FED has come into force on the 1st of January 2014 and is established for the period 2014 to 2020 (European Commission, 2017). The 11th FED is devolved primarily on tourism development. More specifically, the **regional envelope** of the 11th FED, with a total budget of 8'353'000 euros, is focusing on renewable energies, climate change and disaster risk reduction**.** This envelope must be shared by the four overseas countries: New Caledonia, French Polynesia, Wallis and Futuna and Pitcairn Islands. Therefore, French Polynesia will receive a total amount of approximately **3 million euros** to target the **agroecological transition** (Direction of Agriculture, 2018b).

This **background section** should have helped to understand the specific context of French Polynesian agriculture: the vulnerability of farmers lacking official status, the different actors working in the agricultural sector, the contemporary historical development of agriculture leading to special constraints today and the market protectionism. As a reminder before entering the methods section, the objective of this work is double. First, to **describe the practices** implemented by farmers to mitigate soil erosion and decrease pesticide use. Second, to **identify drivers and barriers** to push forward the use of the "agroecological practices".

3. METHODOLOGY

3.1 GEOGRAPHICAL SCOPE

Answering the research questions, required first to define the **relevant location** fro interview the farmers. Therefore, a literature review was conducted to obtain an overview of the different agricultural productions in French Polynesia. The purpose was to identify which agricultural sector (fruit, vegetable, traditional crops, livestock, coconut) has the major needs for improvement of the practices. Livestock production was directly identified as non-relevant as the topography of the volcanic islands (steep slopes) and the lack of agricultural land, are not adapted to having large cattle. Four major documents were consulted to understand contemporary agriculture in French Polynesia:

- The Agricultural Statistics Report from 2015 (Service du Développement Rural, 2016)
- The Agricultural Policy for the period 2011-2020 (Ministère de l'économie Rurale, 2011)
- The General Agricultural Census from 2012 (Service du Développement Rural, 2012)
- Institute of Emission of the Outer Seas (Institut d'émission d'outre-mer, 2016)

Figure 4 underneath shows the plant production in the five archipelagos in French Polynesia in terms of tonnage. Clearly, the Leeward and Windward Islands (Society Archipelago) are the most important plant producers. For this reason, the field work will take place in the islands of **Tahiti**, **Moorea** (Windward), **Raiatea** and **Taha'a** (Leeward), which are the main islands that have agricultural production in the

Society archipelago. Indeed, the island of Tahiti represents the biggest food producer, which could be expected as it hosts 2/3 of the French Polynesian population. The Leeward islands are also the most populated after the Windward islands, and they are the closest to Tahiti in terms of kilometres. Considering the **transport connection** between the islands is vital for the assessment of their potential agricultural development. The dispersion the French Polynesian islands on a surface comparable to Europe challenges the transportation of perishable goods such as vegetables and fruit. For this reason, in comparison to the other islands, the Leeward islands represent good candidates in terms of agricultural development for three major reasons:

- They are very well connected to Tahiti (especially Raiatea, the principal island)
- There is still agricultural land available as pressure from urbanisation is not as strong as in Tahiti
- There is a demand for agricultural products coming from the touristic pool with the islands of Bora Bora, Maupiti and Huahine.

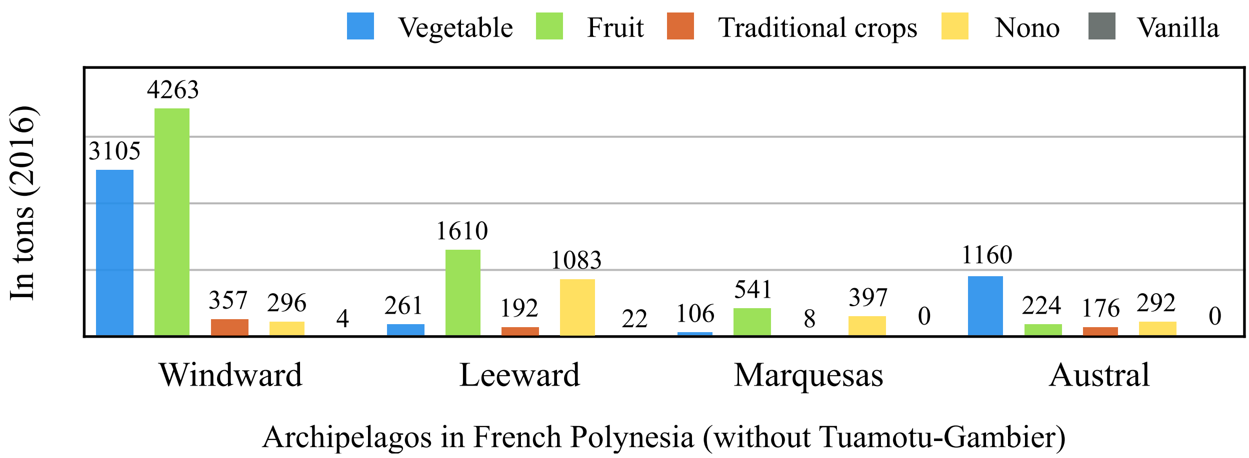


FIGURE 4: DOMINANCE OF CROP PRODUCTION IN THE WINDWARD AND THE LEEWARD ISLANDS (DIRECTION DE L'AGRICULTURE, 2016)

3.2 FARMER SAMPLE

The farmer sample is the key to ensuring a good diversity of all the potential socio-economical and technical constraints, that could explain the implementation or not of certain farming practices. Therefore, the strategy followed was to select on the one hand, **"innovative"** farmers that could illustrate the potential drivers towards better farming practices and more **"conventional"** farmers to illustrate the potential barriers. Consulting local actors from the Chamber of Agricultural (CAPL) and the Direction of Agriculture (DAG), allowed to select the 20 farmers.

Targeting "innovative farmers" is a methodology developed by Meynard (2012) called "**innovation tracking**". Innovative cropping system are defined as *"a cropping system designed to achieve renewed objectives, oriented towards emerging issues and evaluated on the priorities of farmers, sectors and society."* (Meynard, 2012). The rationale behind innovation tracking is that the farmers are underestimated forces of development of alternative practices. Indeed, they are constantly trying to adapt to a changing socio-technical and environmental context. However, these adaptations implemented on field are not sufficiently studied by the researchers, meaning that potential interesting managements, will never be taken over by a broader number of farmers (Casagrande et al., 2017). For this reason, innovation tracking targets these alternative managements in order to generalise the knowledge and make it accessible (Salembier et al., 2016). The fact that these alternative management are produced *in situ* provides a great advantage: they cannot by criticised as coming from the agricultural research (in the lab or on perfectly controlled field experiences), that often propose practices that do not function in real farming contexts (Meynard, 2012). Presence of researchers and technical agents on the field is needed in order to enhance partnership with farmers, by identifying and working hand-in-hand with the innovative farmers (Petit et al., 2012). This **horizontal way** of approaching the farmers breaks from the standard vertical hierarchical relations between these actors, which leads to **co-conception approaches** where farmers and researchers work hand-in-hand (Petit et al., 2012).

In addition to having interesting farming practices, the farmers identified as innovative are very interesting on a sociological point of view. Padel (2001) explains the way an innovation is diffused though-out a population, depending on the "farmer type". She shows that the **innovative farmers** are the ones that take the risks and can influence the others, becoming the **leaders of change**. Therefore, identifying these farmers is an important step, changing the way knowledge is produced and diffused inside the farmer community. Innovative farmers can take the head of the **network** and become **active experimentation and knowledge exchange centres** for alternative practices.

After interviewing "innovative farmers", more "conventional" farmers were interviewed in order to identify the main barriers (economical, technical, sociological or cultural) that can represent **lock-ins for the agroecological transition** (Magrini & Triboulet, 2012). In addition, meeting more "**traditional farmers**" was also bring as they may represent important sources of knowledge (Clarke, 1990):

> "*The merits of traditional polycultures, the often high energy-return rates of non-industrial agriculture, the avoidance of agricultural toxins, the maintenance of genetic diversity, the fine-scale planting of specific crops in microhabitats, the often high elasticity of supply - all of these and more can be seen as benefits (ecologically if not economically) compared with the contrasting costs of industrialised agriculture.*" [Clarke, 1990, p.238]

3.3 IN-DEPTH INTERVIEWS AND TRANSCRIPTION

To be able to tackle the economical, technical, sociological and cultural barriers for the implementation of more "agroecological practices", it was necessary to analyse the farming systems in a holistic way. The framework developed by Capillon & Manichon (1991) provides a **systemic view** on the farming system, integrating aspects such as the farmer's background, the farmer's objectives, the main constraints in the system, the inputs and outputs, socio-economic aspects, pedoclimatic constraints, workforce organisation and availability of machinery (see Appendices). Semi-directed interviews were conducted during approximately two hours with each farmer, following the main themes described in the framework of Capillon and Manichon (1991). The interviews started by asking about the farmer's background and history, his potential education or transmission of knowledge form the parents and why the farmer chose to become a farmer, or to produce a certain type of goods. After having covered the **farmer's historical and sociological background**, the focus was set on understanding the **farming practices** in terms of soil, weeds, pests and water management. Finally, at the end of the interview, the farmer was questioned about what he/she perceived as the major constraints on farm, if he/she had potential future projects, the farmer's opinion about organic farming and the farmers's relationship to the DAG (in terms of research produced and technical supervision on field). The interview guideline can be found in the appendices.

Transcription of the interview content was done systematically after each field visit. Two synthetic sheets of one page were filled, in order to be able to compile all the information in a condensed format and to structure the information into boxes following the Capillon and Manichon approach (1991). The first sheet provides a holistic view on the farming system and the second farm sheet described the management practices. The twenty farm sheets can be found in the appendices.

3.4 QUALITATIVE DATA ANALYSIS

3.4.1 Defining criteria for comparison

Once the data collected, the objective was to evaluate the proximity of the farming practices to an agroecological (AE) **approach**. Trabelsi (2017) and Gratecap et al. (2013) have proceeded to a similar approach by evaluating the proximity of farming practices to **organic farming practices**. Their work was greatly facilitated by the existence of specific evaluation criteria, as organic practices are legally defined through the various organic labels. Evaluating the proximity to an AE approach is more complicated as there are no such clear definition of AE practices. Indeed, agroecology is not a technical recipe of farming practices, but rather an **approach** following agroecological principles (Nicholls et al., 2017). These principles will require different applications depending on the region, and therefore, an "AE practice" depends on its spatial location (Nicholls et al., 2017).

After having conducted the 20 farm interviews, **15 management practices** (named in Figure 5) stood out as being important variables in terms of **soil** and **pest management** under French Polynesian pedoclimatic conditions. Choosing these 15 management practices required a **qualitative selection** which can be criticised. However, it was necessary to choose some variables to describe the farming systems on a similar basis and to evaluate their proximity to an AE approach. Concerning the AE principles, in this work, the "6 AE principles for the design of biodiverse, energy efficient, resource conserving and resilient farming systems" defined by Nicholls et al. (2017) were kept. These 6 principles will be used to evaluate the management practices' proximity to an AE approach. Figure 5 shows in a simplified way the articulation between the **15 management practices** and the **6 principles**, as the management practices are local applications of the principles.

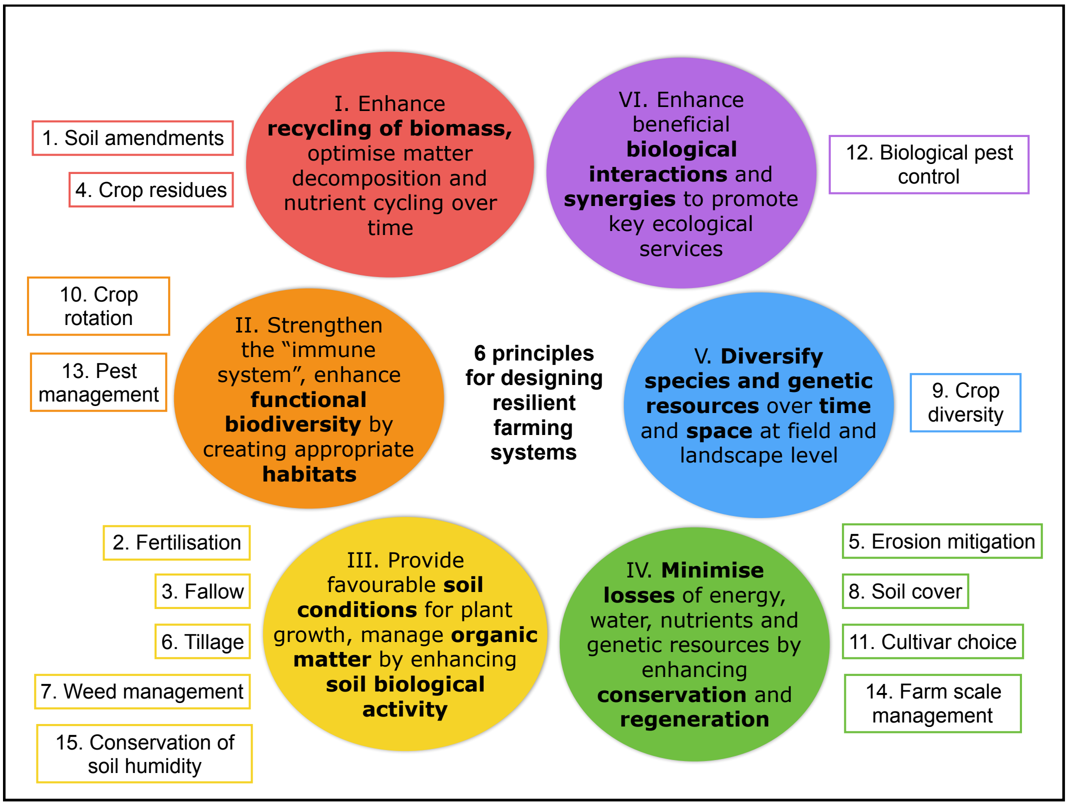


FIGURE 5: ARTICULATION BETWEEN THE 6 PRINCIPLES AND THE 15 MANAGEMENT PRACTICES

In reality, every management practice impacts the totality of the system and therefore, the relations between the principles and the management practices are much more complex than illustrated in Figure 5. Figure 6, extracted from Nicholls et al. (2017), shows better how "each management practice sets in motion some **ecological interactions** that drive **key processes** for agroecosystem function".

	Principle to which they contribute					
Management practice	Recycling of biomass	Enhancement of functional biodiversity	Enhancement of soil biology	Minimise losses of energy, water, nutrients and genetic resources	Diversification at the field and landscape level	Enhancement of biological interactions and synergies
Compost application	x		x			
Cover crops and/or green manures	x	x	x	x	x	x
Mulching	x		x	x		
Crop rotation	x		x	x	x	
Use microbial/botanical pesticides		x				
Use of insectary flowers to enhance natural enemies		x			x	x
Living fences		x	x		x	x
Intercropping	x	x	x	x	x	x
Agroforestry	x	x	x	x	x	x
Animal integration	x		x	x	x	x

FIGURE 6: RELATIVE CONTRIBUTION THE MANAGEMENT PRACTICES TO ONE OR MORE AE PRINCIPLES (NICHOLLS ET AL., 2017)

After choosing these 15 management practices, definitions from literature were used to explicit what will be considered in this work as an implementation close to an AE approach:

(1) Frequent **amendments** of organic matter to the soil via the application of compost or animal manures are expected, allowing to improve the overall soil quality (Altieri & Nicholls, 1999, cited in Clements & Shrestha, 2004).
(2) **Fertilisation** should be organic or mixed with inorganic fertilisation in order to enhance soil biological activity and reduce risk of ground and surface water contamination (Wezel et al., 2014).
(3) **Fallow** should be present in the crop rotations to restore soil fertility through biomass accumulation and biological activation, and to reduce agricultural pest populations via the "interruption of life cycles" (Altieri & Nicholls, 1999, cited in Clements & Shrestha, 2004).
(4) **Crop residues** after harvesting should be reintegrated in the soil mechanically or used as mulch materials/compost in order to enhance nutrient cycling mechanisms (Nicholls et al., 2017).
(5) **Erosion** should be mitigated by planting and managing vegetation strips and hedges in fields and at field borders (Wezel et al., 2014), playing as wind barriers decreasing soil erosion. Simultaneously, these "ecological infrastructures" promote pest regulation though enhanced activity of biological control agents present on these various crops/shrubs/trees (Altieri & Nicholls, 1999, cited in Clements & Shrestha, 2004).
(6) **Tillage** should be reduced (no soil inversion) to decrease the risks of wind and water erosion and increase soil biota activity and soil organic matter sequestration (Wezel et al., 2014).
(7) **Weed management** should be mechanical or manual to avoid use of synthetic herbicides polluting the surface and ground water.
(8) **Soil cover** should be used to decrease weed competition, such as plastic/textile covers or natural covers (crop residues, mulching, compost…), reducing simultaneously herbicide use (Wezel et al., 2014).
(9) **Crop diversity** is vital as it allows to increase the diversity within functional groups, promoting key processes (pest regulation, nutrient cycling) for agroecosystem function (Nicholls et al., 2017). In addition, a higher diversity in the cropping system goes hand in hand with a higher diversity in associated biota (Nicholls et al., 2017).
(10) **Rotations** should integrate different crops, which allows to reduce weed and pest infestations and thus reduce use of pesticides (Wezel et al., 2014).
(11) Choosing adapted crops and resistant **cultivars** to biotic and abiotic stresses, should allow to increase/stabilise yields, pest control and resistance to water stress (Wezel et al., 2014).
(12) **Biological pest control** should allow to control weeds, pests and diseases based on the introduction of natural enemies or pheromones (Wezel et al., 2014). Use of flower beds, pheromone traps, trap crops, grass strips are part of the management practices that allow to decrease the use of synthetic pesticides.
(13) **Pesticides** should be derived from plants or plant extracts (natural pesticides) in order to avoid contamination of water or product from synthetic pesticides (Wezel et al., 2014).

(14) **Farm scale management** (such as greenhouses, appropriate irrigation systems, shade systems…) should allow to preserve the local resources by avoiding losses in water, energy and nutrients (Nicholls et al., 2017).

(15) **Conservation of soil humidity** is enhanced by maintaining high vegetative cover, through the use of mulching systems, cover crops and no-tillage practices (Nicholls et al., 2017). Indeed, avoiding bare soil is important to decrease risks of important nutrient leaching in the systems and improve nutrient cycling and soil organic matter content (Altieri & Nicholls, 1999, cited in Clements & Shrestha, 2004).

3.4.2 Grading of the farming system

Every management practice was evaluated depending on how it was implemented on field.

- When the management implemented was **close** to an AE approach, **10 points** were attributed.
- When the management implemented was **far** from an AE approach, **0 points** were attributed.
- When the management implemented was somewhere between these two extremes (as it is a continuous gradient of implementation), **5 points** were attributed. For example, if the farmer managed his fertilisation only by using synthetic fertilisers, he obtained 0 points. If the farmers uses a mix between synthetic fertilisers and natural (algae/fish based) or organic certified fertilisers, he obtained 5 points. To achieve 10 points, management of fertilisation had to be only based on organic or natural fertilisers.

Table 1 on the following page, extracted from Wezel et al. (2014) and Altieri & Nicholls (1999, in Clements & Shrestha, 2004), describes which grade corresponds to which type of management. Attributing this simplified grading allowed to give a visual result of each farming system that seemed easier to grasp than a long narrative description. However, the grading also led to certain challenges as some cropping systems require the implementation of an important number of practices, whereas others do not. For example, vegetable production is the most complex agroecosystem to manage under tropical conditions. Therefore, vegetable farmers need to implement many managements practices, which is not the case for a shade-cultivated vanilla producer. The latest consist an artificial system and its liana is not rooted in the soil. Some management practices cannot be graded for the vanilla producer, such as tillage or crop rotations…**Therefore, the maximum score that a farmer can obtain depends on his cropping system.** In addition, the “tillage” lever has been left aside for the semi quantitative evaluation (data not specific enough) which leads to a maximum achievable points of 140. Here is the **formula** to calculate the grade:

Overall Grade = Points achieved by the farmer / Maximal points depending on the cropping system

The farmer grades must be taken with precaution, as the evaluation grid serves as a tool to analyse the farming systems. However, the purpose of this study is not to deliver a quantitative evaluation of the cropping systems, but rather to highlight, qualitatively, the main drivers and barriers in the actual farming systems. Therefore, this approach is adapted for the objective of formulating recommendations to implement under the 11th FED.

TABLE 1: ATTRIBUTING THE GRADES

#	MANAGEMENT	MODALITIES OF IMPLEMENTATION		IMPACTS ON THE FARMING SYSTEM
1	SOIL AMENDMENTS	No soil amendments.	0	Soil organic matter depletion
		Application of manure, slurry, compost, wood pellets, lime.	10	Enhance soil stability/fertility on long term
2	FERTILISATION	Use of synthetic fertilisers	0	Risks of ground and surface water contamination
		Use of natural fertilisers (algae, fish) or organic certified fertilisers	10	Enhances soil biological activity
3	FALLOW	Intensification of soil use	0	Increased agricultural pest populations + declining soil fertility
		Frequent in the crop rotation	10	Enhance soil biological activity/ improve soil structure
4	CROP RESIDUES	Exportation (destroyed by fire, herbicide)	0	Soil organic matter depletion
		Reintegrated to the soil after harvest	10	Recycling of nutrients/soil organic matter
5	EROSION MITIGATION	Bare soil + important slope, no physical barriers (shrubs, hedgerows), no raised beds…	0	Risk of nutrient leaching + water contamination
		Semi-natural landscape elements: hedgerows, key line design, raised beds, plastic	10	Decreases erosion (from wind, water) + improved pest control
6	TILLAGE	Tillage > 30 cm depth, use of heavy machinery	0	Risk of soil erosion + soil compaction + consumption of fuel
		Tillage < 20 cm depth, use of light machinery	10	Reduction of soil compaction, increase in soil biota activity
7	WEED MANAGEMENT	Chemical destruction of weeds with synthetic herbicides	0	Soil and water contamination + risks for human health
		Mechanical/manual management of weeds	10	No water contamination + decrease in risks for human health
8	SOIL COVER	Important bare soil	0	Increased risks of nutrient leaching and water pollution.
		Use of mulching (vetiver, crop residues, compost), plastic/textile covers	10	Control weed competition, reduced water pollution.
9	CROP DIVERSITY	Low number of crops + crops of similar family (ex: only leafy vegetables)	0	Higher risks of pest and weeds outbreaks.
		Crop diversity from different families (fruit, vegetables, traditional root crops),	10	Less weed and pest infestation + increase soil biological activity
10	CROP ROTATION	Single crop	0	Low resilience to pests, single type of nutrient uptake in the soil
		Diversified crop rotation with alternation between leaf-fruit-root vegetables	10	Increased resource use (nutrients, radiation, water) + pest control
11	CULTIVAR CHOICE	No selection of adapted crop to local pedoclimatic conditions	0	Risk of increased use of fertiliser/pesticides
		Use of resistant crops from biotic and abiotic conditions (land race, resistant hybrid)	10	Stabilisation of yields, pest control, resistance to water stress
12	BIOLOGICAL PEST CONTROL	None	0	Risk of pest outbreaks with rapid dissemination on farm site
		Flower beds, grass strips, trap crops, pheromone traps, crop associations, …	10	Reduction of soil and water contamination. System resilience.
13	PEST MANAGEMENT	Synthetic pesticides	0	Soil and water contamination + risks for human health
		Natural or organic certified pesticides: bouillie bordelaise, baking soda, black, soap, Bacillus Thuringiensis, ,Neem oil, limocide, smoke, lemon grass, vetiver, …	10	Decrease or absence of water or product contamination from synthetic pesticides
14	FARM SCALE MANAGEMENT	Local climatic conditions not taken into account.	0	Risk of abuse of pesticide and fertiliser use to compensate.
		Greenhouse, water evacuation system, use of shade systems for sun protection, irrigation	10	Lower use of synthetic pesticide and fertilisers.
15	CONSERVATION OF SOIL HUMIDITY	No protection of soil from water erosion	0	Nutrient leaching
		Use of cover crops, mulching materials (crop residues, vetiver, wood pellets), plastic cover	10	Preservation of soil moisture + enhanced soil biological activity

References: Wezel et al. (2014) and Altieri & Nicholls (1999, in Clements & Shrestha, 2004).

3.4.3 Building a farmer typology

In order to identify the main drivers and barriers in the farming systems, Dufumier (1996) requires building a typology of farmers, which allows to achieve a certain level of generalisation, by categorising farmers in groups that are facing similar socio-technical constraints. In the context of the 11th FED, a typology serves as a diagnosis tool to design appropriate measures for the specific needs of the farmers. Building a farmer typology allows to take distance to individual farmer's issues by finding "*discriminant criteria*" that explain the farmers' differentiation process (Cochet, 2011, p.113). However, Cochet (2011, p.114) explains that trying to find "the" best discriminant criteria is vain as it will always depend on an arbitrary selection from the researcher (as many viewpoints as typologies). Rather, identifying these discriminant criteria allow to construct "**ideal types**" that have a maximum of coherence in their way of functioning (Perrot and Landais 1993, cited in Cochet 2011, p.115).

In order to find these **discriminant criteria**, information on the farming practices and on the contextual information coming from the Capillon and Manichon (1991) farm sheets were analysed (farmer's background, main constraints, history, objectives…).

Discriminant criteria were based on the analysis of:

- **Modalities of implementation of the 15 management practices**
- **Socio-economical specificities** of the farmers in terms of mindsets, objectives, market strategies, etc…

Once identified, the four types were described in order to construct these "ideal types" with their **specific attributes,** their **inherent logics** and their potential **trajectories**.

3.4.4 External and internal drivers and barriers for each farmer type

Analysis of the external and internal drivers and barriers was needed to define potential actions to implement during the 11th FED. Understanding the farmers' "*decision process*" provides explanations for why they implement or not certain farming practices (Duru et al. 1988, in Aubry, 2007). Clarifying these **supporting** or **hindering factors** is the first step to potentially overcoming them. For each farmer type, the determinants were divided into "external barriers" (material: capital, land, labour…) and "internal barriers" (immaterial: mindset, objectives, beliefs) that explain why ("*decision process"*) the farmer implements specific farming practices. Identifying farmers driven by **internal supporting factors** (open minded-ness, objectives of environmental impact reduction…) was necessary to target the group of "**innovative farmers**". Indeed, this type of farmer is susceptible of engaging in a transition towards alternative practices as described by Gratecap et al. (2013), in his study on the conversion of farmers to organic, and Padel (2001), with her adoption/diffusion of innovation model.

Figure 7 underneath summarises the five methodological steps of the research in a visual way.

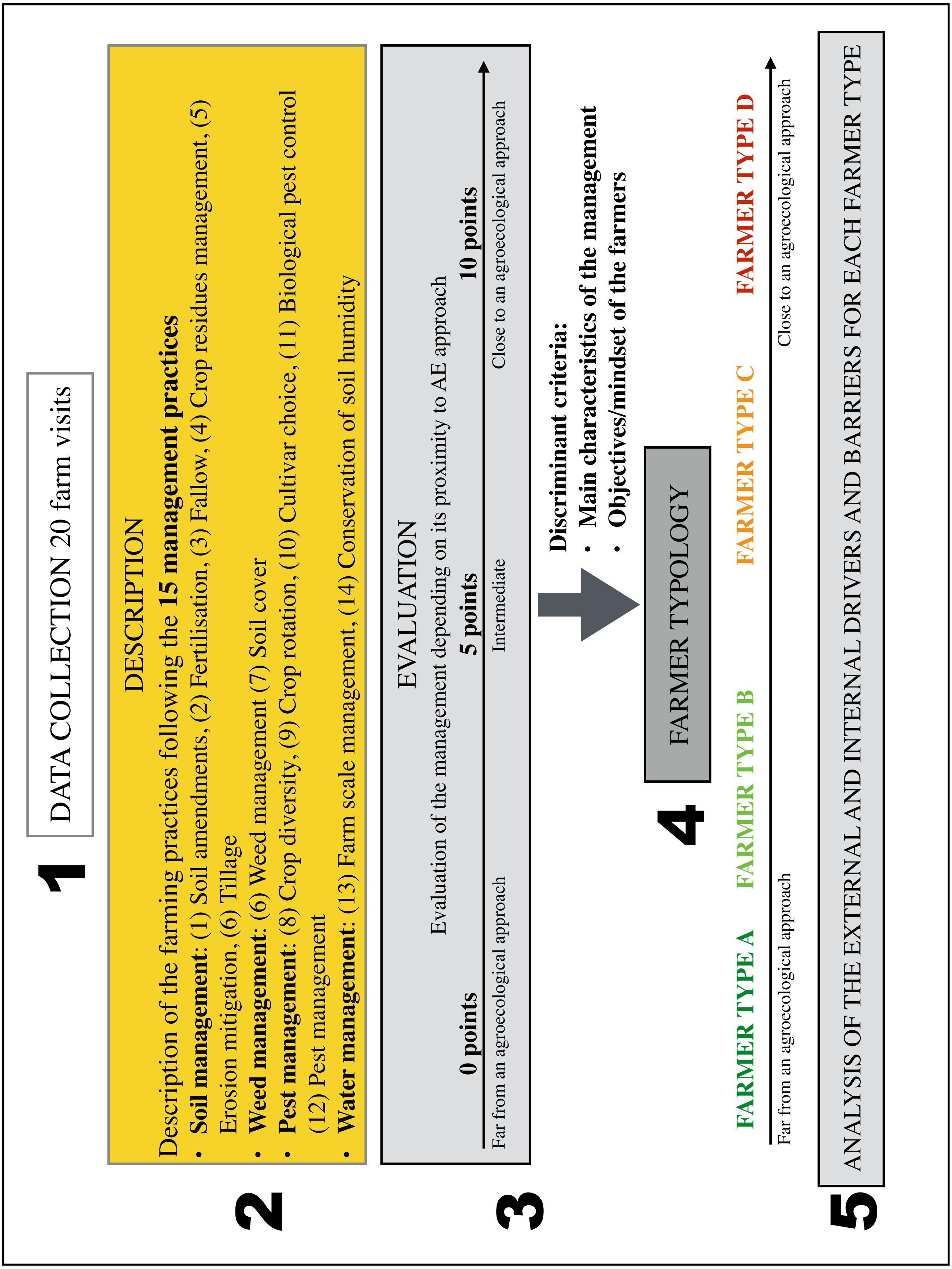


FIGURE 7: VISUALISATION OF THE FIVE METHODOLOGICAL STEPS OF THE RESEARCH

4. RESULTS PART I

4.1 DESCRIPTION OF THE FARM CHARACTERISTICS

Before describing how the farmers from the sample implement the management practices, it seems important to describe the farmers sample. Table 2 at the following page presents some variables that have been identified as important in order to understand the different contexts of the farmers.

- **Location**: 10 farms in Tahiti and 2 farms in Moorea (Windward), 7 farms in Raiatea and 1 farm in Taha'a (Leeward)
- **Land tenure**: Non divided land, precarious arrangements with land owners, or other unclear land tenure schemes, are factors that can lead to non sustainable farming practices. Indeed, lack of land security does not enhance a long term management of the local resources.
- **Type of system**: 6 farmers produce organically (OF) (1 BioAgriCert and 5 SPG's guarantee) and 14 conventional farmers (CF). In the sample, there is a 100% correlation between farmers that have an organic guarantee or certification and farmers that have followed longer education (not always related to agriculture).
- **Surface**: The surface is highly dependant on the type of production as vanilla production for example does not require as much surface as vegetable production. However it is still an interesting variable that gives an idea of the farm organisation. In the sample, there are 3 farmers that have much bigger land surfaces (18ha, 29ha and 35ha), but if these extreme values are taken out of the sample, the average surface of land that is cultivated is **4 hectares**.
- **Number of workers**: Asking about the numbers of workers and the origin of the workers (family members or not) allows to tackle how lucrative the farming activity is. Some famers are employing CAE workers, "contrat d'accompagnement à l'emploi" in French, which means support measures leading to employment. The CAE measure has been implemented by the government to fight against unemployment. Employers are exonerated from some employer contributions to the social security system, and the people that have difficulties to get hired are coached/supported by specialists (Le Portail de l'Economie, des Finances, de l'Action et des Comptes publics, 2018).
- **Main production/Secondary production**: Main production and secondary production is used when the farmer has for example fruit production and vegetable production that are spatially isolated (considered as two activities). Then, if the vegetable production is the activity that brings the most revenues, it will be considered as the main production.
- **External income**: Multiple activity is a feature of French Polynesian farming. Taking into account these other sources of income is important to try to estimate the economic sustainability of the farming system. Table 2 underneath highlights the important correspondence between the organic farmers and the presence of an external income.

TABLE 2: CHARACTERISTICS OF ANALYSED FARMS IN FRENCH POLYNESIA

Farm #	Location	Land tenure	Type of system	Surface	# workers	Main production	Secondary production	External income
F1	Tahiti	Private property	OF BioAgri Cert	18 ha	9 workers	Vegetables	Fruit production (citrus production)	Riding stable (34 horses)
F2	Tahiti	Private property + renting land	CF	29 ha	16 workers	Vegetables (Hydroponic)	Fruit (papaya, lemon)	/
F3	Tahiti	Renting an agricultural lot	CF	4.7 ha	2 workers (CAE) part time	Pineapple	/	/
F4	Tahiti	Renting agricultural lot	OF (SPG)	6 ha	3 workers (family members)	Vegetables, herbs, traditional crops	Flowers (2ha out of 6ha) that she wants to convert to vegetable production.	/
F5	Tahiti	"Precarious arrangement" with a private owner	CF	3000 m2	alone	Vegetable + fruit + traditional crops	/	/
F6	Tahiti	Renting to a private owner	CF	6 ha	7 employees full time + 4 family members	Vegetables	/	/
F7	Tahiti	Non official private land	CF	6 ha	4 workers full time	Taro (trials on ginger)	/	/
F8	Tahiti	Private land	CF	6.5 ha	8 workers full time	Vegetables + herbs production (HP), field production and greenhouse production.	/	/
F9	Tahiti	Renting a private property	OF (SPG)	1.8 ha	Alone	Vegetables, fruit (papaya + trial with noni)	/	Income from the farmer's partner ensures security.
F10	Moorea	Renting agricultural lot	CF	5 ha	2-3 workers part time	Pineapple	/	/
F11	Moorea	Renting agricultural lot	CF	5 ha	3 full time workers	Vegetable and Fruit production	/	/
F12	Tahiti	Private property	CF	35 ha	11 full time workers + 3 family workers	Fruit production (+ some vegetables)	Cattle (20 cows pasturing in the citrus orchards)	Pork production (125 sows + 1250 pigs)
F13	Raiatea	Renting domain land	OF (SPG)	10 ha (only 3 ha cultivated land)	5 full time workers + woofing system	Vegetables, fruit and traditional crops	10 bee hives + 15 new Bee hives (managed by another person)	Support from program BEST 2.0 (2018) and project INTEGRE
F14	Raiatea	Private property	CF	5 ha	15 full time workers + 5 family members	Vegetable HP (3ha)	Fruit production (1 ha)	Egg production (17'000 laying hen)
F15	Raiatea	Family land (from indivision)	OF (SPG)	3 ha	1 worker (CAE) + woofing system	Honey production - 22 Bee hives (managed by farmer's husband)	Fruit trees and traditional crops + 1 sow and piglets	Income from farmer's partner (fisherman) + selling piglets
F16	Raiatea	Renting 3 agricultural lots	CF	3 ha	5 family members	Taro	Fruit, vegetable and flower production	External income from the mother's activity
F17	Raiatea	Renting agricultural lot	CF	1.2 ha	2 workers (Farmer couple)	Traditional crops + bee hives	Vegetable production	/
F18	Raiatea	Private property	OF (SPG)	600 m2	Alone	Vanilla in shade cultivated system	/	Beneficiary of an ICRA program
F19	Taha'a	Renting agricultural lot	CF	4 ha	3 workers full time	Fruit, vegetable and traditional crops	/	Copra managed by the community (fenua feti'i)
F20	Raiatea	renting 2 agricultural lots	CF	4 ha	4 workers (family members)	Vanilla cultivated traditionally	/	Farmer's partner employed on another farm.

4.2 FARMING PRACTICES AND MANAGEMENT PRACTICES

Reminder of RQ1: To which extent do farmers use “agroecological practices” that reduce erosion and dependence on agrochemicals (fertilisers and pesticides)?

In order to answer the **first research question**, this section will be divided in four parts, detailing how farmers implement the 15 management practices, allowing to assess of their proximity to an AE approach.

- Management practices that can improve **soil management**: (1) soil amendments, (2) fertilisation, (3) fallow, (4) crop residues management, (5) erosion mitigation from wind/water and (6) tillage.
- Management practices that can improve **weed management**: (7) weed management and (8) soil cover to decrease weed pressure.
- Management practices that can improve **pest management**: (9) crop diversity, (10) crop rotations, (11) cultivar choice, (12) biological pest control and (13) pest management (localised pesticide application)
- Management practices that can improve the **water management**: (14) farm scale management (against excess rainfall, conservation of soil humidity) and (15) conservation of soil humidity.

4.2.1 Soil management

TABLE 3: SOIL MANAGEMENT PRACTICES A

Management practices	**Modalities of implementation**	**Farms concerned**	**Comments**
Soil amendments	Manure (chicken, pork, horse, cow)	F1-F2-F3-F4-F8-F9-F11-F12-F14	F1 (horse), F11-F12 (pork), F12 (cow)
	Lime (Calcimer)	F2-F6-F8-F9-F11-F12	
	Compost (OM, coconut grove, branches…)	F4-F12-F15	
	Others : noni seeds, coconut pellets.	F4-F6	
	No soil amendments	F5-F7-F10-F16-F19	**Vanilla producers (F18-F20) not concerned.*
Fertilisation	Only synthetic fertilisers	F3-F5-F6-F7-F8-F10-F14-F19	F14: hydroponic production with a secret fertilisation mix Most common mineral fertiliser: 12-12-17+ 2% of trace elements
	Mix between synthetic and natural fertilisers	F2 (20-9-9 and Orgaliz) - F12- F16	F16 uses fish fertilisers on the polyculture farming system and synthetic fertiliser on the taro plantation. F12 uses synthetic fertilisation for his pineapple plantation only.
	Only natural (Algae fertiliser, fish fertiliser, other organic certified fertilisers: Orgaliz, Physalg, Patentkali)	F1-F4-F9-F13-F15-F17-F18	
	No fertilisation	F11-F12-F20	
Management of fallow	Fallow non managed (spontaneous vegetation)	F8-F9-F11-F17	F8 2-3 weeks F9 2 months F11 3-5 months F17 1 month
	Managed fallow (green manure)	/	
	Non existent	F2-F3-F4-F5-F6-F7-F10-F13-F16	F7 considers doing a rotation as he inverts plantation hole for the taro every cycle (10 month approx.). F13 does not have a fallow for the moment because too many seedlings ready to be planted but a fallow period will be designed in the future.

Chicken manure and lime are the **soil amendments** the most widely used as shows Table 3. Chicken manure is easy to achieve from the local laying hen factories and almost half of the farmers use lime (6 farmers in the sample) to basify the acidic tropical soils. However, the price of lime (usually Calcimer) is relatively expensive for small holders which may explain why it is not used by all. Application of compost is only done by three farmers. Producing and applying compost is time-consuming (especially without machinery). The alternative would be to buy it, however many farmers explained that the quality of this bought compost was not satisfying (many components of plastic and aluminium cans found inside). 5 farmers out of 18 do not apply any soil amendments: the taro and the pineapple monoculture farmers (F7-F10) and the 3 more traditional farmers (F5-F16-F19) that produce traditional crops, fruit and some vegetables. Biomass produced on the farm site is not systematically reintegrated in the soil even though it could represent an important source of nutrients and allow to limit exposure of bare soil.

Fertilisation is only synthetic for 8 farmers and is usually applied in one single application during the crop cycle. Split fertilisation, defined by Wezel et al. (2014) as "*fertiliser application (chemical and organic) with several operations, which has the advantage of reduction fertiliser use by increasing the efficiency uptake by the crop and reducing the risk of ground and surface water contamination*" does not seem to be a widely used. Exceptions exist for the long-cycle crops (such as vanilla and taro), where two farmers said they used split fertilisation. The taro monoculture producer (F7) applies approximately one hand-full of complete fertiliser (12-12-17) per plantation hole, 3 times in the taro cycle (after 1 week, 5 weeks and 9 weeks). He explains that it is important to wait for the taro shoot to grow roots before the first fertilisation application, otherwise the nutrients will not be absorbed.

Concerning **vanilla**, one of the farmers (F18) is very precise on his fertiliser application. F18 has collected recommendations from various studies conducted by the CIRAD ("*Centre de coopération internationale en recherche agronomique pour le développement"*) on vanilla to improve his practices. He developed a detailed organic fertilisation calendar to fit the best to the vanilla lianas' needs depending on its growth stage. In March, he applies 5-4-2 when the liana is producing buds. In June just before the buds are flowering, 3-15-0+18% of calcium is applied as the liana needs a lot of phosphorus to produce flowers. In July, just after the farmer pollinates by hand the flowers, there is a need of potassium to make the fruit, and therefore, the farmer adds 0-0-22. The doses of applied fertiliser are difficult to determine as most farmers were reluctant to give this type of specification.

Concerning **natural fertilisation** (usually algae or fish fertilisers), it is used by seven farmers. Fish fertiliser made from the fish bones is a substitute for synthetic phosphorus and potassium. Algae fertiliser is a substitutes for synthetic nitrogen. In addition, some farmers explain that algae fertiliser has other beneficial impacts on ants and other insects, as its salt content destroys them. Given that the preparation of these self-made fertilisers is time consuming, some farmers prefer to buy organically certified fertilisers from the market such as Orgaliz (nitrogen), Physalg (phosphorus) and Patentkali (potassium).

In many vegetable production systems, **crop residues** are destroyed chemically after harvest by using a rotavator or a rototiller to reintegrate the destroyed crop residues in the soil. Only one farmer who does not have any machinery, uses fire to destroy the crop/spontaneous fallow. Finally, four farmers (pineapple and taro monoculture production), do not reintegrate the crop residues in the soil at all. Globally, if six organic farmers try to reintegrate organic matter in their systems, nutrient cycling still seems to lack in a large majority of the interviewed farmers as shows Table 4.

TABLE 4: SOIL MANAGEMENT PRACTICES B

Management practices	Modalities of implementation	Farms concerned	Comments
Crop residues management	Destroyed chemically (herbicide)	F2-F5-F6-F16	
	Destroyed by fire	F17	F17 does not have a brush cutter nor a rototiller, therefore, fallow is destroyed by fire and charcoal is applied on the raised beds as fertilisation.
	Destroyed mechanically, but not reintegrated in the soil	F3-F10	Destruction of the plantation with a dredge.
	Destroyed mechanically and reintegrated in the soil	F1-F9-F8-F4-F11-F12	Use of rotavator or rototiller to directly till superficially and reintegrate crop residues in the soil. F11 uses a soc plow.
Management at farm scale to mitigate erosion from wind and water	Raised beds	F1-F2-F4-F6-F9-F12-F13-F17	
	Key-line design	F3-F12-F19	
	Wind breaks (trees, vetiver, shrubs, hedgerows)	F1-F4-F5-F7-F11-F15-F16-F19	
	Others: water decantation basin	F3	Installation of water collection basins at the bottom of the field to collect the top soil eroded and re-apply it on the top of the slope.
Tillage	Mechanical to a depth of >30cm	F3-F6-F8-F9-F11-F12	F8-F11: Use of a disc or soc plow. F6-F9-F13: Field cultivator to improve soil drainage by aerating the soil. F3 is the only farmer using the subsoiling technique. It is important for him to drain the plot (pineapple plantation).
	Mechanical to a depth of <30cm (rotavator)	F1-F2-F6-F8	The rotavator is often modified by the farmers to be able to make raised beds.
	With a rototiller (<10cm approx.)	F4-F5-F9-F13-F16	
	With an auger	F7	F7 uses an auger to drill the plantation holes for the taro.
	By hand (crow bar/ shovel)	F7-F15-F16-F17-F19	F16 digs the taro plantation holes by hand (crow bar).

Concerning **Mitigation of erosion,** many management practices are implemented in an “unconscious” way. For example by planting trees/hedgerows in the borders of fields, which is also the natural way of marking the boundaries of a property/agricultural lot in the country. Farmers, located on flat plots (mostly hydromorphic soils), usually farm on raised beds. This management allows to evacuate excess water from tropical rainfalls. Farmers located on steep slopes usually choose crops that are tolerant to the challenging conditions (rather fruit trees or traditional crops) and if possible, practice key-line design (farming by following the topographic curves) to decrease water erosion. Examples of managements used to mitigate soil erosion are shown in Figure 8 underneath. The only systems that do not seem to implement measures to mitigate erosion are the monoculture farmers of taro and pineapple (F3-F7-F10) as shows Table 4.

Plantation of vetiver to decrease soil erosion (F15)

Mitigation of soil erosion by installing a water decantation basin at the bottom of the slope to collect the top soil and re-apply it on the top of the slope (F3)

Typical diversified farming system from a “traditional farmer” with multiple shrubs/trees and grass, no bare soil (F16)

Ginger plantation in the back of the picture following the topographic curve lines (key line design) (F19)

FIGURE 8: FARM SCALE MANAGEMENT TO MITIGATE EROSION

Globally, **tillage** is done mechanically for 50% of the farmers that possess heavy machinery such as soc or disc plows. 25% of the farmers till with a rototiller and the last 25% manage tilling by hand (crow bar/ shovel). There are as much tilling practices as there are farmers.

Here are examples of tilling practices:

- **Deeper tilling by a vegetable producer (F8):** After harvest, F8 first uses a disc plow to till the first 30 centimetres of soil to improve it's aeration. Then, he goes through the field with a rotative harrower to improve the soil structure. Finally, he applies lime (Calcimer) mixed with a complete fertiliser (12-12-17) and chicken manure. Two days later (to allow evaporation of excess ammonia gases), the seed bed can be prepared. A modified rotavator is used to till superficially the soil and build the raised beds at the same time (with a special tool fixed at the end of the tractor).

- **Shallower tilling by vegetable producers (F1-F2-F6)**: First, F6 uses a field cultivator to allow a certain ventilation of the soil that goes to a depth of approximately 20cm. Second, he adds coconut tree pellets with a shovel in order to improve the soil drainage (located on hydromorphic clay soils). Finally, he drives though the fields with a modified Rotavator to prepare the raised beds.

- **Tilling for a pineapple producer (F10):** After harvest, the pineapple crops are destroyed with a bulldozer that goes to a depth of 5 to 10 cm. Then, the farmer drives through the field with a field cultivator to a depth of approximately 30-40 cm to improve soil aeration/drainage. The soil is left uncovered for approximately one month, which gives him time to collect the pineapple shoots from another field. Then he builds the raised beds either with a shovel (when the slope is too steep for an efficient tractor use) or with a tractor. Finally, he plants the collected pineapple shoots. No plastic cover is applied as the farmer believes the natural cover from the pineapple crop is sufficient to protection soil from water and wind erosion.

4.2.2 Weed management

TABLE 5: WEED MANAGEMENT PRACTICES

Management practices	**Modalities of implementation**	**Farms concerned**	**Comments**
Weed management	Mechanical via false seedbed technique	F1-F8-F9-F11-F12-F13-F14-F15-F17	F8: false seedbed technique Others: brush cutter
	By hand only	F4-F5-F18	
	Systematic use of herbicide	F2-F6-F7-F10-F12-F16-F19	F12 only uses herbicides systematically on his pineapple plantation, His citrus plantation is managed organically.
	Local use of herbicide	F3-F20	F20 uses herbicide to make an alley inside his traditional vanilla plantation.
Soil cover	Mulching (compost, wood pellets)	F1-F12-F13	
	Plastic cover	F2-F6-F8-F9-F18	F18 has a plastic cover that avoids managing the grass inside the vanilla shade cultivation system, but there is no plastic directly under the vanilla liana, which allows to maintain connection with the soil.
	Biodegradable plastic cover	F1-F3-F6-F11-F13	F6 only uses biodegradable plastic covers on the perennial plants such as eggplant, zucchini where it is worth the time investment for the plastic application.
	Others: “textile/ fabric against weed growth”	F12	The fabric is thick and porous (in comparison to plastic covers), which allows a better water penetration.
	No cover (bare soil)	F5-F17	

Concerning **weed management**, approximately 50% of the farmers destroy weeds chemically (Table 5). The systematic use of herbicide comes hand in hand with systems that have less crop diversity and more intensified production managements (F2-F6-F7-F10-F12-F16-F19), such as: intensive vegetable production, taro monocultures and pineapple production. However, **alternative weed management** may still be observed on field as shows Figure 9. For example, one vegetable farmer (F6) uses the false seedbed practice for two reasons. It is cheaper (glyphosate is expensive) and the practice is not time-consuming as it requires only two passages with a rotavator on the field. Conventional pineapple production requires an important use of **herbicides** (usually Ametryne) as the crop is quickly recovered by weeds. F3 would like to avoid using these herbicides. However he claims that alternative weed management is challenging for pineapple production. A hand weeding through the dense and spiky pineapple plantation rows would be challenging. F3 therefore explains that he tries to decrease his environmental impact by using herbicide locally and only when needed, avoiding a systematic herbicide application. He also applies biodegradable plastic to decrease weed pressure and avoid nutrient leaching from water flows. F3 argues this is a perhaps a better solution than a mechanical destruction of the weeds. Indeed, soil tillage could increase soil erosion (the pineapple plantations are often located on steep slopes). Therefore, he balances the impacts from a localised herbicide-use with the impacts of soil erosion (see Figure 9 below).

F16 does not manage chemically the weeds after having planted the taro shoots.

F3 applies herbicides locally and uses biodegradable plastic covers to decrease weed pressure.

Plastic cover on ginger plantation to decrease weed pressure (F2)

Mechanical management of the grass with a brush cutter between the citrus orchard (F11)

Chemical management of weeds between the rows and by hand on the row (F6)

Chemical management of weeds and risks of water erosion as no alternative management to decrease water erosion (no plastic cover, no raised beds) (F5)

FIGURE 9: WEED MANAGEMENT PRACTICES

4.2.3 Pest management

TABLE 6: PEST MANAGEMENT PRACTICES

Management practices	**Modalities of implementation**	**Farms concerned**	**Comments**
Crop diversity	Single crop system	F3-F7-F10-F18	
	Multiple crop system (but only vegetables OR fruit)	F1-F2-F6-F8-F9-F14-F20	Papaya and banana are often present on the farm site.
	Polyculture system with traditional crops, fruit and vegetable	F4-F5-F11-F12-F13-F15-F16-F17-F19	Presence of evergreen perennial and woody perennials (fruit trees) playing the role of natural barriers.
Crop rotations	Non existent	F5-F13	
	Simplified	F2-F5-F8	Random alternation between vegetables depending on market demand.
	Well defined	F1-F9-F11	Defined rotation to reach specific goals.
Cultivar choice	No choice	F3-F10-F5-F16-F17	
	Engineered seeds towards specific resistance (hybrid seeds)	F2-F8-F11-F13	Cucumber (F2), tomato and cucumber (F8), hybrid variety of bean (F11), seeds treated against Tomato Yellow Leaf Curl Virus *TYLCV* and F1 varieties (F13)
	Landraces (rusticity)	F1-F4-F11-F16-F18-F20	
Biological pest control	Trap crops	F8-F15	F8 uses eggplant to attract insects
	Crop associations	/	
	Flower beds	F1-F9	Common mallow- *Malva sylvestris*, Basil- *Ocimum basilicum*, Lemon grass- *Cymbopogon citratus,* French Marigold- *Tagetes erecta*
	Grass strips (potential "trap crops")	F1-F4-F9-F11-F13-F15-F16	Amaranth grows naturally on the grass and feeds insects (F11).
	Pheromone traps	F1-F6-F9-F19	Attract fruit flies
	Natural insect repellent	F4	Planting lemongrass
	Physical hedgerows to spatially delimit units	F1-F9-F11	
Pest management	Use of synthetic pesticides	F2-F8-F11-F12	F12 only uses mineral pesticides to fight against the fire ant.
	Use of natural/organic pesticides	F1-F9-F13-F18-F19	BT Basilus, Neem oil, Limocide, black soap, baking soda, bouillie bordelaise…
	None	F3-F10-F14-F15-F16-F17-F20	

Table 6 shows the **crop diversity** present on the farms. There are only 4 farmers who grow mono-crops (pineapple F3-F10, taro F7, Vanilla under shade system F18). For all the others, there is an important diversity of crops, with the integration of evergreen perennials (such as banana), often playing the role of a natural barrier and woody perennials ("bread fruit" *Artocarpus altilis*, coconut trees or other fruit trees). Some of the farms are close to agroforestry systems. This characteristic of Polynesian agriculture should absolutely be maintained as this crop diversity is the basis for a good resistance to pest and diseases. Indeed, "*specialised insect pest species usually exhibit higher abundance in monoculture than in diversified crop systems"* (Altieri and Letourneau 1982, cited in Waldon et al., 1998).

In vegetable production, the practice of **crop rotation** does not seem to be well implemented as it does not seem to be widely understood. Therefore the implemented rate is low (see Table 6). 30% of the vegetable producers explain that they grow what is needed on the market, not bothering to alternate between certain crop families for example. Table 7 and Table 8 compare two crop rotations seen in an organic farm (F1) and a conventional farm (F6). For a time period of one year, F1 rotates between salad, Chinese cabbage, radish and turnip, followed by approximately 5 months of fallow. F6 grows similar crops, but does not plant them in a specific order to enhance ecological functions, but rather follows the market demand. Fallow is not present in the conventional system, as not cultivating the soil, is perceived as a loss of income. Land is use intensively, with transitions between harvest and sowing that are optimised (between 3 days to 1 week approximately). The important use of synthetic fertiliser applied 7 days and 21 days after planting (split fertilisation), explains how F6 can produce salad in four weeks, whereas F1 needs 6 weeks. Indeed, F1 only applies compost to maintain soil fertility whereas F6 applies synthetic fertilisers and lime every year on his plots.

TABLE 7: CROP ROTATION FROM AN ORGANIC VEGETABLE PRODUCER (F1)

<table>
<tr><td colspan="9">One complete crop rotation last approximately 6 months and then the same plot is left as fallow (6 months)</td></tr>
<tr><td>Salad
6 weeks</td><td></td><td>Chinese cabbage
6 weeks</td><td></td><td>Radish
6 weeks</td><td></td><td>Turnip
6 weeks</td><td>Fallow
5 months

(non managed)</td><td>1. Fallow destruction with a brush cutter.
2. Passages with the rotavator (in the two opposite directions) to flatten and equalise the plot and to prepare the raised beds.
3. Application of chicken manure with a shovel (6 weeks delay before sowing)</td></tr>
<tr><td colspan="7">6 months</td><td colspan="2">6 months</td></tr>
<tr><td colspan="9">Transition between crops: Rotavator passage to reintegrate crop residues in the soil and sow the new crop by hand.
Natural fertilisation: Two weeks after sowing, compost application. (approx. 1 shovel per square metre)</td></tr>
</table>

TABLE 8: CROP ROTATION FROM A CONVENTIONAL VEGETABLE PRODUCER (F6)

<table>
<tr><td colspan="11">No clearly defined crop rotation. The farmer avoids sowing two times the same crop in a row.</td></tr>
<tr><td>Cucumber
4 weeks</td><td></td><td>Pak choi
4 weeks</td><td></td><td>Salad
4 weeks</td><td></td><td>Cabbage
8 weeks</td><td></td><td>Salad
4 weeks</td><td></td><td>More or less similar repetition of crops, depending on the market demand.</td></tr>
<tr><td colspan="10">6 months</td><td>6 months</td></tr>
<tr><td colspan="11">Transition between crops: Chemical destruction of crop residues (glyphosate). Rotavator passage to prepare raised beds and sow by hand.
Synthetic fertilisation: After 7 days + after 21 days => synthetic fertilisation (12-12-17)
Tillage: When the farmer has time, after destroying the crop with glyphosate, a field cultivator with teeth is used to aerate the soil to a depth of approx. 20 cm.
Soil amendments:
- Lime is brought on every plot once per year
- Wood pellets from coconut trees are applied with a shovel from time to time to improve soil drainage (clay soils)</td></tr>
</table>

The choice of **cultivars** differs upon the farmer types. Traditional farmers most often reuse the plant genetic material by preparing cuttings, collecting seeds or replanting shoots, which is time consuming but free. Concerning vegetable production, some of the organic farmers try to use varieties that are adapted to the climate and require fewer treatments by growing uncommon land races like winged beans, *Psophocarpus tetragonolobus* (F4) as shown in Figure 10 below. The more conventional vegetable producers rather use hybrid seeds that tend to be expensive but they allow to have maintain high yield and resistance to pests (F2).

Figure 10 shows alternative pest management such as **biological pest control** methods based on the introduction of natural enemies/pheromones (Wezel et al., 2014). Use of these practices remains low in the farmer sample as shows Table 6. Only the organic guaranteed/certified farmers sow flower beds or plant natural insect repellant plants such as lemongrass. Conservation of **grass strips** in the farms were the most present alternative management. Their presence seems to be linked rather to lack of time/labour available for weeding, than a conscious knowledge of their ecological functions. Use of **pheromone traps** was quite frequent and farmers claimed it was functioning well and decreasing the fruit flies attacks on papaya trees. **Crop associations** were not used inside the farmer sample. Sometimes, seed mixes were sown together, but the explanation behind it was rather practical: the farmer wanted to optimise land use or there were not sufficient seeds of type A, so the farmer added seeds of type B.

Concerning **pesticide application**, 30% of the sample does not use any synthetic insecticides or fungicides in their farming systems (F3-F10-F14-F15-F16-F17-F20) and does not seem to have important issues with pests and diseases. The important crop diversity seems to naturally provide resilience to pest and disease outbreaks (fruit orchard F14, traditional crops F15, F16 and F17). Pineapple, with its thick skin, has a natural defence from insects, which prevents the farmers from using synthetic pesticides (even though pineapple is often grown as a monoculture). The farmers who used **natural pesticides** (limocide, Bacillus Thuringiensis, Neem oil, “bouillie bordelaise”, baking soda, black soap…) usually grow vegetables (F1-F9-F13) or produce vanilla (F18) under the shade cultivation system.

Vanilla producers value the **shade cultivation system** for being more productive in terms of yields than traditional plantations, with the trade-off of increased sensitivity to diseases (lower level of interactions as it is an artificial system). F18 applies baking soda preventively in his shade cultivation system, when there is forecast for important rainfall. Indeed, the baking soda allows to basify the soil pH and to avoid an outbreak of fungus. Therefore it can potentially allow to avoid fungus diseases on the vanilla liana.

Concerning vegetable production, most of the farmers using natural pesticides claimed their efficiency was not always insured, forcing them to implement in parallel other alternative managements. For example, the three vegetable producers using natural pesticides (F1-F9-F13) implement many alternative management (biological pest control, spatial isolation of crops, crop diversity) at the same time to decrease the frequency of use of these products (some are expensive). F1 tries to alternate between Neem oil and Bacillus Thuringiensis treatments in order to maintain their efficiency. As the natural pesticides are used depending on the needs, there is no fixed frequency of application of these products.

Flower beds to attract plant auxiliaries (F1)

French Marigold to fight against white flies (F9)

Important crop diversity and the plantation of vetiver between the papaya and lemon trees (F12)

Winged beans *Psophocarpus tetragonolobus* (tropical legume plant) that are very resistant to pests (F4)

FIGURE 10: ALTERNATIVE PEST MANAGEMENT PRACTICES

Concerning the farmers using **synthetic pesticides**, they are used for the vegetable crops to ensure sufficient production and good looking vegetables (F2-F8-F11-F12). Farmers claim to respect the doses of applications required for each product and to respect as well the delays of application before harvest. For example, cabbage leaves are damaged by the cabbage moth (*plutella xylostella*) and therefore, conventional vegetable farmers apply preventively an insecticide every week (F2 and F8). Some have a more balanced use of these products, such as F11 also producing cabbage. He applies insecticides only twice during the crops' growth to ensure a sufficient size of the cabbage and simultaneously limit the negative impacts of pesticides. For him, selling cabbage with small imperfections is the best proof for consumers, that his management practices respect nature.

4.2.4 Water management

TABLE 9: WATER MANAGEMENT PRACTICES

Management practices	Modalities of implementation	Farms concerned	Comments
Cultivar choice	Resistance to drought	F9	F9 does not have access to any irrigation system
	Resistance to rot	F7	F7 chose to grow only the variety called "Taro from Rarotonga" as it is the only that does not rot in the soil after 8 months.
Farm scale management (against excess rainfall, sun…)	Shade systems (semi-opened tunnels)	F1-F2	F1 uses a shade system on the salad plots as the excess sun and potential heavy rain damages the fragile salad leaves. F2 installed a shade system on the zucchini plantation as zucchini has low tolerance to excess water as well.
	Greenhouse	F8-F11-F13-F14	F14 chose hydroponic production (HP) as the location of the farm was known as very rainy with hydromorphic clay soils which are initial bad conditions for vegetable farming.
	Water evacuation channels	F2-F3-F4	F4 digs channels for water evacuation all around the raised beds as the farm location is especially inclined to water stagnation (flat land).
Conservation of soil humidity	Mulch (compost, coconut pellets, wood pellets, coconut grove, vetiver…)	F1-F6-F12-F13-F15	Compost (F1), coconut pellets (F6), compost and coconut grove (F13), vetiver and other organic material from trimming and weeding (F12), vetiver to cover fruit tree base (F15)
	Plastic cover	F2-F6-F8-F9	F6 only uses plastic cover for the perennial plants (otherwise it requires too much work for a 6 week cycle crop).
	Biodegradable plastic cover	F1-F3-F13	
	Cover crops	F12	
	Others: atomiser sprinkler	F8	Humidity in sandy soils is quickly dried off when there is wind. To fight against that, farmer 8 uses an atomiser sprinkler system during the morning hours (10-11am).

Cultivar choice for water management concerns was only used by 2 producers in the farmer sample, as shown in Table 9. However, choosing a resistant cultivar should be further considered by vegetable farmers. Indeed, many crops suffer from excess water (zucchini) and important variations of between sunshine and rainfall (salad, tomatoes) which destroys them. Most of the vegetable farmers answer to these constraints by investing into greenhouses or shade systems (**farm scale managements**), in order to protect vegetables from heavy rainfall/excess sun. In addition, as many of the vegetable producers farm on flat plots close to the coastal plains, the soil type has important clay content leading to hydromorphic characteristics (often saturated in water), which is not appropriate conditions for all types of vegetables (European Union, INTEGRE, Pacific Community, 2018). Therefore, some farmers try to drain their plots by adding gravels/coconut grove/noni seeds to improve the structure. Others prefer to invest into **hydroponic infrastructures** to produce above ground.

Conservation of soil humidity is necessary for the farmers producing in more sandy soils, that have the tendency to "dry" quickly, or for farmers that do not have access to any irrigation system. This is the case of F12, the only farmer that successfully sowed a legume **cover crop** (Pinto peanut, *Arachis pinto)* below his citrus plantation to maintain humidity in the soil. The pinto peanut cover is managed with a brush cutter every month to maintain its short size and avoid too much competition for nutrients with the citrus trees. A couple other farmers have tried to sow cover crops, but these trials were not successful. 25% of the farmers used different forms of **mulch** to maintain soil moisture. However, efficiency of mulching seems to be mediocre: it is time-consuming and heavy rains tend to destroy the mulch cover. For that reason, another 30 % of the farmers use **plastic or biodegradable plastic covers**. However, these plastic covers can at the same time accelerate water flows and therefore increase soil erosion problems. Figure 11 underneath shows examples of the management to conserve soil humidity.

 Shade systems (semi-opened tunnels) to avoid excess rain and sun on the salad production (F1)	 Citrus orchard with a cover crop of Pinto peanut *Arachis pintoi*, a legume, that maintains to a low height and allows to keep soil moisture during dry months (F12)
 Important recycling of the organic matter on the farm site (F12)	 Wood pellets directly crushed on the farm site applied at the base of every fruit trees (banana on the picture) (F13)

FIGURE 11: FARM MANAGEMENT PRACTICES TO CONSERVE SOIL HUMIDITY

4.3 ASSESSMENT OF THE PROXIMITY OF THE MANAGEMENT TO AN AE APPROACH

4.3.1 Qualitative assessment

After having described the different modalities of implementation of the 15 management practices, some trends can be distinguished in their implementation. Concerning **soil management**, improvements are required to be in line with agroecological principles. One characteristic shared by a majority of farmers, is their lack of understanding of the soil: it's compartments, it's fauna and the different nutrient cycles. Some practices seem to have a low implementation rate because the farmers do not understand their interest (such as fallow and mulching). Fertilisation and soil amendments seem not to be always adapted to the soil type or the crops' needs. A low number of farmers had knowledge of their soil type, explaining that they had done only one analysis when they started to farm, however as "the soil does not change" they do not believe it is necessary to make a new soil analysis. Use of lime is not widespread as it is expensive and many farmers do not seem conscious that soil acidity can be problematic depending on the crop. Finally, many farmers did not seem to understand the difference between applying organic forms of fertilisation/amendments with synthetic mineral forms. For some of them, it is simply "food" for the soil.

A majority of farmers destroy their crop residues chemically instead of mechanically which prevents from a systematic return of organic matter in the soil. Very low implementation of fallow shows that soil is used intensively. Fertilisation is not optimised as most of the farmers do not used split fertilisation. Rather, they apply the fertiliser in one single application at the beginning of the crop cycle. In addition, only one fertiliser is used for all the crops, not adapting to the specific needs of the plant. Percentage of bare soil is overall low except for vegetable farming systems. Soil tillage seems to be in majority shallow, which also decreases risks of important soil erosion, except for pineapple producers and some vegetable producers. Management practices implemented to mitigate erosion are close to an AE approach, such as: agroforestry systems, planting vetiver hedgerows to stabilise soil, following key-line design and covering the plantations rows with plastic or mulching material. The fact that most systems have small shrubs and trees dispersed over the fields or used to mark the field borders, participates naturally to a better wind resistance and biological pest regulation.

Concerning **pest management**, use of synthetic pesticides was largely limited to the intensified systems such as some of the vegetable producers and the monocultures of taro and pineapple. Most of the fruit and traditional crop producers do not apply any pesticides. Pest management in most of the systems seems to rely by far on the important crop diversity, including evergreen perennials and woody perennials, conferring improved resilience to pest and diseases. Most of the alternative pesticide management (natural pesticides and biological pest control) are used by the organic vegetables producers such as:

limocide, baking soda, black soap, "*bouillie bordelaise*", lime, smoke, lemon grass, flower beds, companion plants.

Considering **weed management**, important improvements must be done to decrease herbicide use in the farming systems. Weed management has been described as one of the major challenges in tropical farming contexts where competition between crops and weeds is fierce. Organic farmers spend a lot of time on mechanical/manual weeding and on the application of mulch/compost on the rows to avoid weeds. Plastic covers, that allows to decrease weed pressure, are used by some of the conventional vegetable farmers. However, plastic covers can simultaneously increase water flow and therefore lead to soil erosion, which is not a desired outcome. For most of the small-scale producers who have little or no machinery, weed are managed by using herbicide, which is much easier than applying plastic.

Concerning **water management**, two major type of topographic and soil type conditions were seen on field. One part of the farmers was located on slopes, which forces them to channel water to avoid risks of important nutrient leaching and soil erosion when it rains. These farmers protected themselves by planting their rows following key-line design, using plastic covers or installing a water decantation basin at the bottom of the slope to be able to collect the eroded top soil to put it back on the field. The other part of the farmers are located on flat coastal plains (mostly clay soil), that are easily saturated in water and require some drainage. Numerous farmers in this second situation farm on raised beds or dig gutters around the plots to evacuate the rain. Some rather use soil amendments to drain the soil with coconut pellets, noni seeds or by leaving/adding rocks in the soil.

In addition, specific remarks concerning **vegetable production** can be added, as most of the vegetables produced are not adapted to the tropical conditions. Clearly, the intensified vegetable systems are the least in line with an AE approach. Exception given to some organic producers, who are able to manage these complex systems by implementing numerous measures to manage pest outbreaks and weed competition.

Globally in the vegetable farming systems visited, it can be said that:

- There is a low use of crop rotations or only simplified crop rotation
- There is low use of split fertilisation and no adaptation of the fertiliser depending on the crop
- The crop diversity is much lower than in the other polyculture farms
- The percentage of bare soil is more important as herbicides are used
- There is still a very low use of alternative pest management such as flower beds, companion plants or grass strips…
- There is also not sufficient use of resistant/adapted cultivars

4.3.2 Semi-quantitative evaluation

After having described the different implementation of the 15 management practices in terms of soil, weed, pest and water management, each farmer was evaluated by taking into account how the management practice was implemented. Table 10 shows how the scores were calculated. Management of tillage was taken out of the semi-quantitative evaluation as the information provided by the farmers was non-sufficient or unclear. As a reminder, here is the formula to calculate the grades:

Overall Grade = Points achieved by the farmer / Maximal points depending on the cropping system

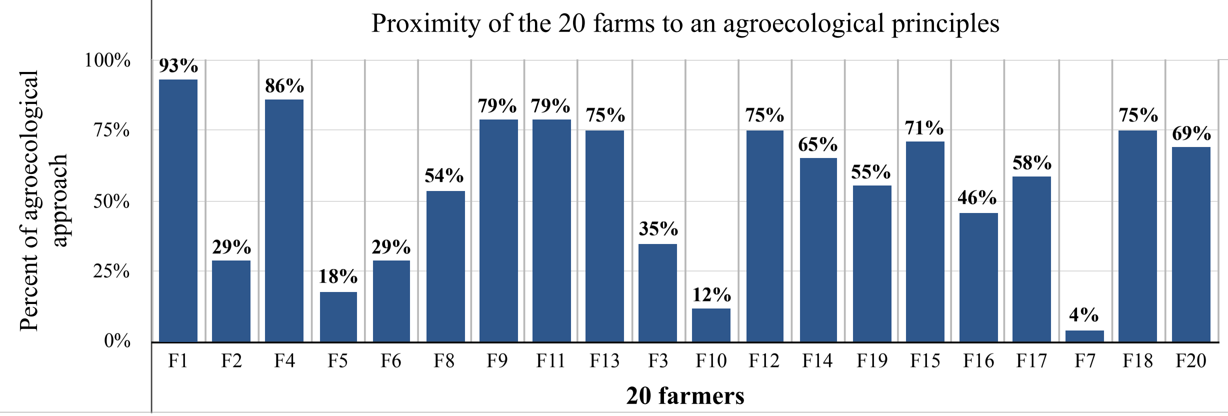
TABLE 10: CALCULATION OF THE MAXIMAL GRADE DEPENDING ON THE CROPPING SYSTEM

Main production evaluated	Farms concerned	# of management evaluated	Maximum points
Vegetable	F1-F2-F4-F5-F6-F8-F9-F11-F13	14	140
Pineapple	F3-F10	13	130
Fruit	F12-F14-F19	10	100
Traditional crops	F7-F15-F16-F17	12	120
Vanilla shade system	F18	6	60
Vanilla traditional	F20	8	80

Table 11 below shows the score obtained by each farmer. The gap between the scores is important with a maximum score of 93% for F1 an organic vegetable producer to 4% for F7 a taro monoculture producer. **The average farmer grade is 55.2%, meaning that overall the 20 farming systems are in a middle proximity to an AE approach**. The management practice, by far the least well graded, is "fallow" with a grade of 2/10 points. The management practice "Conservation of soil humidity" obtained the best score of 7.1/10, followed by "erosion mitigation", "crop diversity" and "fertilisation" (see Table 11 below).

TABLE 11: EVALUATION OF THE FARMING SYSTEMS PROXIMITY TO AN AE APPROACH

	Vegetable									Pineapple		Fruit			Traditional crops				Vanilla Shade System	Vanilla Traditional	Average grade of implementation of the management practice (max points =10)
Management practice	**F1**	**F2**	**F4**	**F5**	**F6**	**F8**	**F9**	**F11**	**F13**	**F3**	**F10**	**F12**	**F14**	**F19**	**F15**	**F16**	**F17**	**F7**	**F18**	**F20**	
1) Soil amendments	5	5	10	0	5	5	10	10	10	5	0	10	5	0	5	0	0	0			**4.7**
2) Fertilisation	10	5	10	0	0	5	5	5	10	0	5	10	5	5	10	5	10	5	10	10	**6.3**
3) Fallow	10	0	0	0	0	5	5	5	0	0	0				0	0	5	0			**2.0**
4) Crop residues	10	0	10	0	0	10	10	10		5	5				5	0	5	0			**4.7**
5) Erosion mitigation	10	0	10	5	5	5	10	10	10	5	0	10	10	5	10	5	5	0		10	**6.6**
6) Tillage	Not sufficient information																				
7) Weed management	10	0	10	10	0	10	10	10	10	5	0	0	10	0	10	0	10	0	10	5	**6.0**
8) Soil cover	10	5	10	0	5	5	10	10	10	5	0	10	5	5	5	5	0	0	10	5	**5.8**
9) Crop diversity	5	5	10	10	5	5	5	10	10	0	0	10	5	10	10	10	10	0	0	5	**6.3**
10) Crop rotation	10	5	5	0	5	5	10	10	5												**6.1**
11) Cultivar choice	10	5	5	0	0	5	5	5	5	0	0	10	5	5	5	5	5	0	5	5	**4.3**
12) Biological pest control	10	0	10	0	5	5	10	10	10	0	0	5	5	5	10	10	5	0			**5.6**
13) Pest management	10	0	10	0	0	0	10	0	10	5	5	0	5	10	5	5	5	0	10	5	**4.8**
14) Farm scale management	10	5	10	0	5	5	5	5	5	10	0										**5.5**
15) Conservation of soil humidity	10	5	10	0	5	5	5	10	10	5	0	10	10	10	10	10	10	0		10	**7.1**
TOTAL points	**130**	**40**	**120**	**25**	**40**	**75**	**110**	**110**	**105**	**45**	**15**	**75**	**65**	**55**	**85**	**55**	**70**	**5**	**45**	**55**	**AVERAGE MANAGEMENT PRACTICE GRADE = 5.4**
Max points depending on the cropping system	140	140	140	140	140	140	140	140	140	130	130	100	100	100	120	120	120	120	60	80	**AVERAGE FARMER GRADE = 55.2%**
FARMER GRADE	**93%**	**29%**	**86%**	**18%**	**29%**	**54%**	**79%**	**79%**	**75%**	**35%**	**12%**	**75%**	**65%**	**55%**	**71%**	**46%**	**58%**	**4%**	**75%**	**69%**	



KEY FINDINGS TO RQ1: To which extent do farmers use “agroecological practices” that reduce erosion and dependence on agrochemicals (fertilisers and pesticides)?

Overall, results show an **average proximity** to an AE approach. Management of **soil fertility** is still far from an AE approach, with often non-appropriated doses of fertilisers used and low use of split fertilisation, use of one single synthetic fertiliser not adapted to the crop and an intensified land use (rare implementation of fallow periods). The **soil amendments** the most widely used are chicken manure and lime, however globally their implementation rates are still low. **Recycling of organic matter** as well requires improvements with an important part of the farm organic matter that is not reintegrated in the cycles. Management practices used to **mitigate erosion** show a closer proximity to an AE approach, with an important diversity of management practices such as application of plastic covers, mulching, key-line design, sowing on raised beds or digging water evacuation channels around the plots. Dependence on agrochemicals remains important with the use of **herbicides** by a majority of farmers to manage weeds and to destroy crop residues. Concerning pest management, a majority of fruit and traditional root crop producers do not use any pesticides and do not seem to face specific pests outbreaks. The important **crop diversity** present on a farm and territorial scale seem to explain this positive biological regulation of the system. However, there are needs for improvements for the conventional vegetable farmers, that rely on the use of **synthetic pesticides** and do not use alternative managements such as **crop rotations**. Use of **biological pest control** or **natural pesticides** seem to be only used by the organic vegetable farmers.

5. RESULTS PART II

Reminder RQ2: What are the drivers and the barriers for a broader implementation of "agroecological practices"?

5.1 FARMER TYPOLOGY

The farmer typology emerged from the assessment of the **management practices** (major modalities appeared in the implementation of certain management practices) and **socio-economical factors** (similar characteristics of market, farmer mindset, objectives…). Four types of farmers were defined as following:

- **"Organic" farmers**: F1-F4-F9-F13-F15-F18 (N=6)
- **"Reasoned" farmers**: F3-F11-F12 (N=3)
- **"Traditional" farmers**: F5-F16-F17-F19-F20 (N=5)
- **"Conventional" farmers**: F2-F6-F7-F8-F10-F14 (N=6)

The choice of the appellation "organic" was attributed to the farmers that were certified or guaranteed organic, but also to the ones in conversion to organic. In terms of practices, this group reflects the specifications defined in the Oceanic norm for organic farming (NOAB). The appellation "reasoned" was attributed and chosen by myself, independently from any "reasoned agriculture label". In addition, these farmers were not claiming to have "reasoned" farming practices. Similarly, appellation "traditional" and "conventional" were attributed by myself and do not correspond to any existing label.

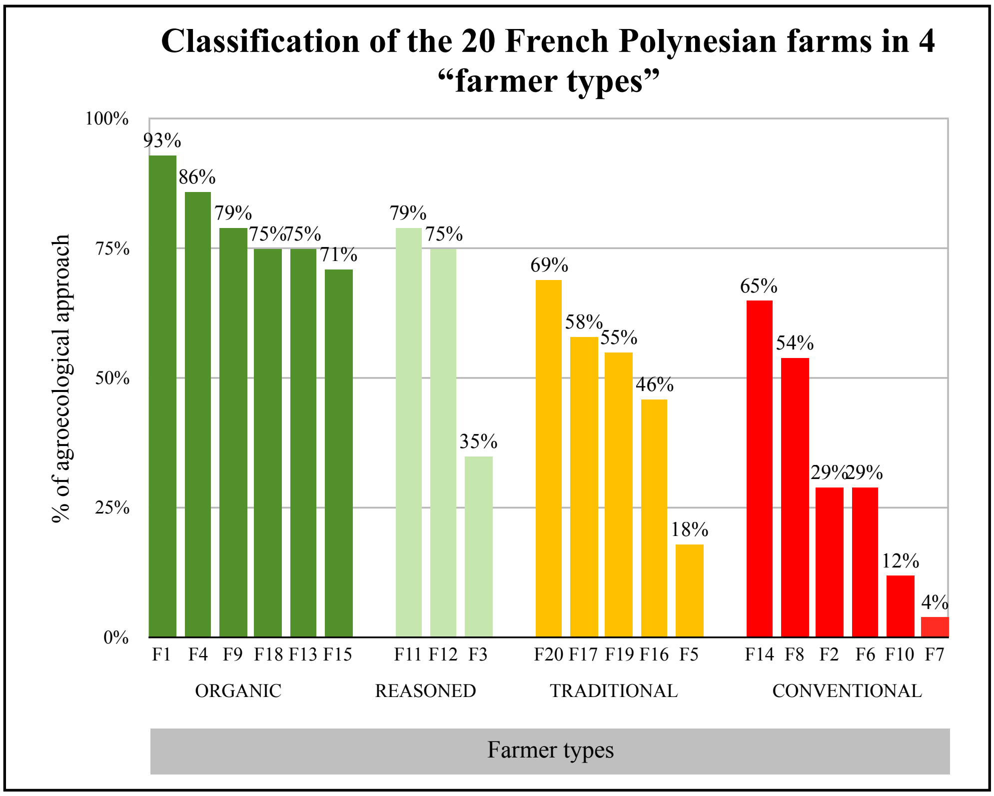


FIGURE 12: CLASSIFICATION OF THE FARMS IN THE FOUR FARMER TYPES

Figure 12 above, groups the farmers depending on their **type**, highlighting at the same time which **score** they obtained from the grading. This figure may give the impression that the clusters are illogic. Indeed, it would have been expected that the farmer types would have naturally drawn from the gradient of proximity to an AE approach. For example, type 1 (0-25%), type 2 (25%-50%), type 3 (50%-75%) and type 4 (75%-100%). This way of clustering would have seemed logic, however *logical* is not always synonym of *relevant*. **Indeed, some management practices seemed to be more meaningful than others, in their explanation of the farmer type, whereas in the scoring, every management practice weighs the same (10 points maximum).** Table 12 further below, shows the major management practices that are chosen by the different farmer types. In addition, farmers could have scored low in terms of management practices, being "stuck" into a high input system and needing to pay back for investment in the farm. However, following the methodology of innovation tracking, the objective is also to identify actors that are the so-called "innovators". Therefore, characteristics of **open-mindedness** and **desire to change** seemed more important when classifying the farmers. Scoring was rather a tool to evaluate the global proximity of the farming systems to an AE approach, but it remains a simplistic way of proceeding, that hides primordial qualitative information.

Heterogeneity of the scores inside the farmer types can be easily explained. The organic type is the only type that corresponds to a label, as explained in the first paragraph. Therefore, these farmers follow specifications in order to achieve either the BioFetia label via the Participatory Guarantee System or the BioAgriCert certification. The other farmer types do not correspond to any label, and therefore, as an opposition to the "organic" they are called "conventional". However, the variety of practices is tremendous, which explains the important heterogeneity of the scores for the "reasoned", "traditional" and "conventional" farmer types. This section is divided in two parts. First a description of the main modalities of implementation of the 15 management practices for the four farmer types (Table 12). Second a description of the socio-economical characteristics of the four farmer types.

5.1.1 Farmer types based on their management

Table 11 gives a description of the main modality of implementation of the 15 management practices for each farm type. Two management practices (fallow, erosion mitigation) cannot be used to discriminate the farmer types, as they are either implemented by all the farmers or none of them. Globally, the **organic type** is easily identified as they are by far the group using biological pest control and natural pesticides, and relying only on organic/natural sources of fertilisation. The **reasoned** type use a mix between organic/natural and synthetic fertilisers and pesticides. They try to improve the sustainability of the farming system by implementing crop rotations, applying soil amendments and choosing adapted cultivars. The **traditional** type are very different from the three others as they do not implement many management practices. They do not apply any soil amendments, do not use mulch or plastic to cover the soil and they do not apply anything against pests. Finally, the **conventional** type is characterised by a low crop diversity (most of them cultivate only a couple vegetables). Their fertilisation and pest management is only based on synthetic products and their management of weeds is dominated by herbicide use.

TABLE 12: DESCRIPTION OF THE MANAGEMENT PRACTICES DEPENDING ON THE FARMER TYPE

	ORGANIC F1-F4-F9-F13-F15-F18	**REASONED F3-F11-F12**	**TRADITIONAL F5-F16-F17-F19-F20**	**CONVENTIONAL F2-F6-F7-F8-F10-F14**
Soil amendments	Yes	Yes	No	Yes
Fertilisation	Natural or Organic	Synthetic or none	Various (synthetic and natural)	Synthetic
Fallow	Pattern does not depend on farm type, Large majority of farmers do not implement any fallow. - No fallow F2-F3-F4-F5-F6-F7-F10-F13-F16 - Fallow (spontaneous vegetation) F1-F9-F11-F17-F8			
Crop residues	Destroyed mechanical and reintegrated in the soil	Destroyed mechanical and reintegrated in the soil (except F3)	Destroyed by fire/ chemically	Destroyed chemically
Erosion mitigation	No pattern. Every category of farmers use AE management practices to mitigate erosion. Raised beds: F1-F2-F4-F6-F9-F12-F13-F17 Wind breaks: F1-F1-F5-F7-F11-F15-F16-F19			
Tillage	Rototiller/by hand	Mechanised	Rototiller/by hand	Mechanised
Mulching	Only F1-F13	Only F12	No	No
Weeding	Mechanical	Various	Various	Chemical
Soil cover against weed	Plastic covers	Plastic covers	No	Plastic covers
Crop diversity	Polyculture systems	Polyculture systems	Polyculture systems	Single crops or only fruit or vegetable production
Crop rotation	F1-F9 well defined F4-F13 not clearly defined	F11 well defined	None or simplified	Simplified
Cultivar choice	Landraces especially and varieties tolerant to certain diseases	Landraces + Engineered species	No specific cultivar chosen (landraces)	Engineered seeds or no specific choice of cultivar
Biological pest control	Yes	None/few managements	None/few managements	None/few managements
Pest management	Natural + organic pesticides	Synthetic pesticides or none	No	Synthetic pesticides or none
Greenhouse, water evacuation system, shade system	Yes	Yes	No	Yes
Conservation of soil humidity	Mulch	Mulch and cover crop (F12)	No	No

5.1.2 Farmer types based on socio-economical factors

Socio-economical factors also influence the farmer's choices of farming practices. Indeed, the **farmers' decision process** are not always linked to the farming system. Socio-economical determinants such as available labour, market demand or market pressure, and political support are major forces that influence a farmers' decision process. Therefore, in order to describe the farmer types other variables are important. The following part describes the differences and similarities between the four farmer types in terms of objectives, organisation of work force and market strategies.

Comparison of the "Reasoned" and "organic" type

Reasoned farmers show similarities to organic farmers in terms of objectives, acknowledging the environmental pollution and health issues linked to intensified industrial agriculture systems. However, reasoned farmers are not entirely ready to commit to full organic/alternative management methods, mainly in terms of pest management, as they fear not being economically profitable. Often, organic farmers have turned themselves towards strategies of "***low input systems***", meaning that they accept lower outputs, as they spent less on purchasing farming inputs. For example, organic farmers will save money by collecting their own seeds, choosing land races, producing their own fish and algae fertilisers and their own compost. The trade-off of these "low input practices" is that they are time consuming. In addition, organic farmers optimise their farming income by suppressing the intermediaries and selling directly to consumers (vegetable box schemes) through **innovative marketing channels** (Facebook). In terms of labour, two organic farmers out of six (F13-F15) were using the "***woofing system***" to attract volunteers around the world who are hosted for free in exchange for their work on the farm. This type of strategy is not used by the reasoned farmers. The latter continue to buy most of their inputs, possess important machinery and continue to distribute their products via standardised channels (gross retailers).

Their common characteristic is that most of them possess external resources (land, capital, political support), which decreases the pressure from the farming income. Indeed, F1 and F12 are farmers who own important land (18ha and 35ha) in Tahiti, which allows them to implement innovative practices (extensive land use), such as having livestock or horses pasturing in citrus orchards. F9 and F15 can implement trials in their farming systems, as each of them have a spouse who secures an additional income. F13 and F18 started farming recently and have innovative farming ideas, enabling them to benefit from political support or administrative support. Finally, F12 and F3 have multiple activities and the main activity (pork production for F12 and coconut and bovine production for F3) secures their income, allowing them to be more flexible and to take more risks in terms of farming practices.

Comparison of the "organic" and "traditional" type

Most of the traditional farmers in the sample come from outside Tahiti and represent the farming population who has lower incomes. They are usually still based on a self-consumption model. As shown in Figure 12 scores of the traditional farmers have an important variability, which can be explained by the important heterogeneity in terms of **fertilisation** and **weeding** within the group. The small-scale low input systems (F16-F17) manage weeds by hand and fertilise naturally with algae or fish fertilisers, whereas the fruit producer (F19) and the vegetable producer (F5) use synthetic fertilisers and herbicides to manage weeds. The major downside in terms of environmental sustainability is their use of **herbicide** to manage crop residues and weeds. This practice seems to be linked with their **lack of machinery**. Concerning pest management, traditional farmers do not apply any pesticide. Meanwhile, their important crop diversity and the fact that they grow essentially root crops and fruit, enhances the agroecosystem resilience capacity. Finally, it is the only group which does not use any **soil amendments**. The main differences between the traditional farmers and the organic farmers is that the traditional farmers use herbicides and that they do not implement many alternative management practices for water, soil and pest management (mulching, plastic covers…). However, traditional farmers are usually not producing vegetables. Therefore, there is a lower need to implement many alternative management.

Comparison of the "reasoned" and "traditional" type

It is difficult to find similarities between these two farmer types, even though the two of them score in an intermediate proximity to an AE approach. The traditional farmers are not implementing a lot of management practices as they grow especially adapted crops (traditional crops and fruit). They do not posses many resources (no agricultural education, no machinery, little capital family farming). Their major issue is the use of herbicide. The reasoned farmers are the most innovative group, implementing many trials to improve their management practices and at the opposite of the traditional farmers, they posses many resources (capital, labour, knowledge, machinery).

Comparison of the "organic" and "conventional" type

These two farmer types differ in terms of objectives and farming practices. Conventional farmers are blocked into the productivist paradigm, "***high input systems***", where they invested a lot of money for certain infrastructures, forcing them to produce important yields to pay back for the investments. The only similarity between them is that they usually produce vegetables. The **market situation** for organic or conventional vegetables is completely different. Consumer demand is important for organic vegetables and offer is not there, which leads to having more friendly relationships between the organic farmers, than for the conventional farmers competing on a stringent market.

Comparison of the "reasoned" and "conventional" type

Conventional and reasoned farmers differ from their objectives, as the conventional farmers usually are mostly oriented towards economic growth, whereas reasoned farmers try to decrease their environmental impact. Therefore, the reasoned farmers try to avoid use of synthetic pesticides and try to integrate as many alternative practice as it is economically feasible. On the other side, the conventional farmers are not as open minded towards alternative practices. They have many preconceptions that these practices fail. Usually, these two types of farmers are the best equipped in terms of machinery and they apply soil amendments, such as liming. These systems follow the "high input system" strategy, with a lot of money spent on inputs (fertiliser, lime, pesticides, seeds, machinery, greenhouses, worker wages and so on), which is counterbalanced with important amounts of outputs, sold through standard channels (market, gross retailers, restaurants, shops…). Both types of farmers wish to optimise work, leading them to being the most "**professionalised**" farmer types. For example, they know exactly how many salads they will grow on which surface and how many seedlings they need to prepare for the next cycle. In addition, they are the only ones who can afford to hire **external workers** in their farms, whereas most of the traditional and organic farmers work alone or with family members.

Comparison of the "traditional" and "conventional" type

Traditional and conventional farmers are similar in their use of herbicides to manage weeds and to destroy crop residues. Meanwhile the explanation behind herbicide use is different: **production optimisation** for the conventional farmers and l**ack of machinery** (allowing a mechanical weed management) for the traditional farmers. These farmers differ in terms of objectives. Traditional farmers content themselves of satisfying their family needs with their production. Conventional farmers are oriented towards maximising their profit.

5.2 EXTERNAL & INTERNAL DRIVERS AND BARRIERS PER FARMER TYPE

This section describes the external and internal drivers and barriers for each farmer type, underlining why some of the 14 management practices have low implementation rates. Describing the **internal barriers** is a vital step to defining the **target group** in which the agroecological transition should be promoted. Indeed, the biggest challenge is to overcome internal barriers (values/opinions) that are deeply rooted in the farmer's mind. Figure 13 shows the phases in the adoption process of an innovation that has been described by Rogers (1983, cited in Padel 2011). Innovative alternative practices are first implemented by a minority of "innovator" farmers, followed by a "early adopters" group, and gradually the early and late majority takes over. With the "snowball effect", the innovative practice becomes the new dominant practice. Therefore, in order to push the agroecological transition of the farming systems forward, targeting specific farmer types is vital.

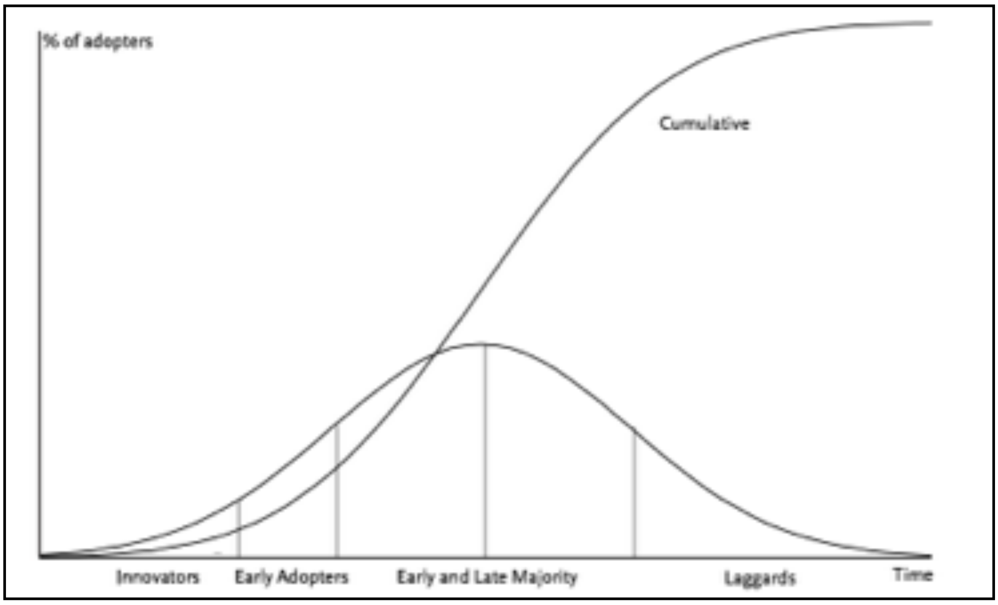


FIGURE 13: PHASES IN THE ADOPTION PROCESS (ROGERS, 1983, CITED IN PADEL, 2011)

Table 14 allows to link the management practices that have low implementation rates, with their main explaining factor (low implemented practice n°1 linked to external barrier n°1). In addition, the table highlights the mindsets and relation towards change for each farmer type, which allows to estimate if they are good candidates for the agroecological transition or not. The following pages contain comments for each farmer type, suggesting **drivers** that could allow to overcome these challenges.

TABLE 14: EXTERNAL AND THE INTERNAL DRIVERS AND BARRIERS FOR EACH FARMER TYPE

	PRACTICES WITH MARGIN FOR IMPROVEMENT	EXTERNAL BARRIERS	INTERNAL BARRIERS/DRIVERS	
			Farmer's mindset/goals	Relation towards change
ORGANIC	1. Low use of spontaneous fallow 2. No managed fallow 3. Low use of mulching 4. Simplified crop rotations 5. Low use of flower beds	1. Land scarcity 2. Complexity of management between cover and weeds 3. Lack of machinery (brush crusher) 4. Lack of knowledge about good rotations 5. Price of flower seeds	• Healthy products affordable for all (F1-F4) • Decrease environmental impact from agriculture (F13-F15-F18) • Produce healthy food (F9-F13-F15)	• Implementing trials on farm scale => **Risk takers**
REASON-NED	1. Low use of spontaneous fallow 2. Synthetic pest management	1. Land scarcity 2. Maintain competitive prices and maintain high yields	• Decrease environmental impact from agriculture while maintaining economic gains (F3-F11-F12-F14-F19) • Follow natural cycles (F12-F20)	• Improving continuously their system • Finding new markets • Not waiting for external help => **Risk takers and availability of resources (machinery, labour, capital)**
TRADI-TIONAL	1. No soil amendments 2. Chemical destruction of crop residues/fallow 3. No pest management 4. No mulching 5. Not only organic fertilisation	1. Price of hen droppings/lime/compost… 2. Lack of machinery and lack of knowledge about herbicide impacts 3. Lack of knowledge 4. Lack of knowledge 5. Time consuming to produce natural algae/fish fertilisers	• Sustain the family needs (F16-F17) • Maintain the system (F5-F10)	• Satisfaction about their system => **"Living in the moment" Not into a dynamic of change**
CONVEN-TIONAL	1. Only synthetic fertilisation 2. Chemical destruction of crop residues 3. Only chemical weeding 4. Simplified crop rotations 5. Synthetic pest management	1. Time optimisation 2. Facility and rapidity 3. Facility and rapidity 4. Following market demand 5. Maintain control and "clean plots"	• Economic gains and yield oriented (F2-F6-F7-F8)	• Not questioning their practices => **Productivist paradigm "business as usual"**

5.2.1 Drivers and barriers of the organic farmer type

Presence of **external resources** (income, land, capital) allows the organic farmers to implement trials and to "risk" vegetable production, that is technically challenging in tropical climates requiring to implement many alternative pest management (crop rotations, biological pest control, natural pesticides, pheromones traps…). For other types of crops (fruit, traditional crops, vanilla), producing under organic specifications seems feasible and successful. Indeed, these crops are adapted to the local pedoclimatic conditions and the crop diversity present in the farming system is usually sufficient to ensure a biological pest regulation. Therefore, the main drivers for more organic vegetable production consists in **increasing agricultural research on resistant cultivars** and **efficient crop rotations** that would allow to decrease the risk of failure for the farmers. Indeed, at the moment, vegetable production requires financial back-up. There is a need for **more technical support on field**, that could also increase chances of successful implementation of certain practices (cover crops, flower seed beds, production of compost…). Organic farmers claimed that managing cover crops (such as pinto pinto) is very difficult, and taking into account the expensive seed price, farmers cannot afford this type of management.

In addition, in Tahiti, the **market situation** for organic vegetable differs broadly from the situation for conventional vegetables, where competition is scare, pushing farmers to lower their prices. This market situation impacts the farming community in a detrimental way: they are **competitors** and do not have interests in exchanging knowledge concerning resistant cultivars or any other farm trial that might have been successful. The situation for organic vegetable production is different as the market is not saturated. The low number of organic producers is not able, for the moment, to match the consumer demand, explaining why there is more knowledge exchange in this second community. This **willingness to pay** for more expensive but higher quality organic products, is a driver for further development of organic farming systems.

Nevertheless, in parallel to this market opportunity, there are problematics of lack of market valorisation of organic products. Indeed, farmers have been claiming that there is no **spatial delimitation in the shops** between organic and conventional products, which puts them in a situation of "unfair competition". How to attract consumers if smaller spotted organic lemons are directly located next to larger bright-yellow conventional lemons? Especially when the organic lemons are more expensive than the conventional ones. In addition, the **price to differentiate organic production** (plastic cover, paper bag, nets, stickers…) must be entirely assumed by the farmer, which adds an extra significant amount of money (to an already higher organic production cost). If some organic farmers avoid these issues by selling directly to consumers (vegetable boxes, on farm sales…), these niche markets will unlikely become mainstream. Indeed, an important part of the population is attracted to the facility of consumption of grocery shops centralising everything in one same location. Therefore, trying to improve the situation for organic production on these more conventional markets, could be a way of motivating farmers to go organic.

In addition, organic farmers claim that the final product price is not sufficiently high to cover the production cost and ensure economic benefit for the farmer. Indeed, an important **barrier** concerning organic farmers from the sample, concerns their **economically sustainability**. Often, they were able to implement alternative practices thanks to their possession of external resources (land owners, partners' income, external activity). Economic sustainability is as important as ecological sustainability and for this reason, it can be argued that the reasoned type of farmers are more resilient on the long term.

Concerning organic production, a recent decree of the Council of Ministers, dated April 30th 2018 (article 841 CM-2018), decided to **exempt from import duties and taxes** a list of inputs used in **organic farming** (Direction de l'agriculture, 2018e). This economic measure seeks to encourage the development of alternative agricultural practices, as prices of organic inputs were claimed as too expensive. It is too early to discuss of the impacts of this decree on the farming system, however it is a first clear **driver** from the state that hopefully should bear fruit. Still, issue raised by the farmers concerns the **availability** of certain organic inputs in remote islands. Access to certain organic inputs outside of Tahiti is challenging.

5.2.2 Drivers and barriers of the reasoned farmer type

The management practices implemented by reasoned farmers are close to an AE approach (use of mulching, soil amendments and use of cover crops). However, there is room for improvement as they still use some **synthetic pesticides** and **fertilisers**. It seems that the drivers are similar to those for organic farmers: research on **efficient crop rotations** and **adapted cultivars** should be conducted to support these farmers, who cannot spend too much time on implementing trials on their farm site. In addition, increased presence of **technical advisors** on field is necessary to support farmers to implement alternative pest management and organic fertilisation.

When analysing the goals and the relation towards change of the reasoned farmers, it appears they are the "**innovators**" in the sample, referring to the terms used by Padel (2001). They are constantly trying to find **new markets**, to adapt to consumer demand, to travel in cities where workshops/seminars on farming are organised, to get inspired from youtube videos and to read books. As these farmers are in possession of many **resources** (capital, machinery, labour force) and **capacities** (knowledge, curiosity, desire to improve), they represent excellent candidates to push forward the agroecological transition of the farming systems. They should be targeted by researchers to **co-develop** alternative management practices. In addition, the capacity of reasoned farmers to employ external workers and buy machinery are proof of **financial stability**.

5.2.3 Drivers and barriers of the traditional farmer type

The traditional farmer type seem to be representative of the farming population outside Tahiti. Globally, their main barriers are their **low level of mechanisation** and their *apparent* **lack of agricultural knowledge**. For example, when asking questions about diseases or choices of varieties during the interviews, most of the farmers were not able to answer. Nevertheless, if this group is not the best at *communicating*, it does not mean for sure that they do not *have* knowledge. If these farmers have the experience in growing traditional roots, they do not manage well crop rotations, alternative pest management and do not have machinery to till. Therefore, vegetable crop production should be avoided (examples of failures for vegetable production in the sample: F5 and F17). In terms of economic sustainability, their systems are quite **resilient** as they depend on little external inputs (except for herbicide and sometimes synthetic fertiliser):

- They produce most of their inputs themselves such as **fish/algae fertiliser** (F16-F17)
- They exchange **shoots** and **seeds** within their community (F16)
- They produce an important **diversity of crops** as they seek to reach self-consumption (F5-F16-F17)
- They sell to **multiple channels** (on the road, market, small shops, gross retailers…).
- In addition, some of them have **additional activities** to secure their income, such as copra for F19 and production of flowers for F16.

The main drivers for these farmers would be to help them gain access to **small machinery** (e.g by pooling the machinery), that would relieve them from time consuming tasks (hand weeding or tilling practices by hand). Indeed, their major barrier is **time management**. Perhaps, building a centre for fish and algae fertiliser and compost production, could be interesting to decrease the time they invest on producing their fertilisers and improve quality of the fertiliser. These farmers do not implement any pest management. Therefore, **vulgarisation** is needed concerning alternative pest management, to push forward the use of easy applicable techniques such as sowing flower beds or planting vetiver and lemongrass. Most importantly, they should not be pushed towards producing *only* vegetables, as most of them do not have the technical skills to manage such complexity. Concerning the agroecological transition, traditional farmers mostly located outside of Tahiti, do not appear as priority candidates: economically, the supply and demand on these islands is almost at **equilibrium**, and sociologically, these farmers produce in the same way for many generations and tend to **reject change**. The good news: they are not scoring to far from an agroecological approach (especially for their important **crop diversity** integrating evergreen perennials and woody perennials). Therefore, there is no urgency to change their practices.

5.2.4 Drivers and barriers for the conventional farmer type

The barriers for the conventional type of farmers are the most difficult to overcome: their primary goal is **gain maximisation** and they deeply **distrust organic farming practices**. During field interviews, many answered that they do not believe it is possible to profitably farm organically under tropical climates. Some even commented that organic farmers might be cheating (spraying synthetic pesticides overnight). Working on these misbeliefs requires **long term education** of farmers and consumers to potentially impact the mindsets. **Agricultural training** is also needed concerning maintenance of **soil fertility.** These farmers do not reintegrate organic matter in their systems and there is an important presence of bare soil due to the important doses of herbicide applications (increasing risks of erosion). In addition, there are economical and structural external barriers. Economically, the investments in these “***high input systems***” forces farmers to maintain high productivity in order to pay back their loans/investments. Structurally, the **system of quotas** on agricultural importations guarantees the market access for these farmers. Therefore, this **state protectionism** does not push them to improve quality of production as their is no beneficial price competition between farmers, as explained in the background section (2.3). This situation does not push for change in the farming practices. In addition, **lack of agricultural training** and **low presence of extension services** on field, reinforces the feeling of loneliness of these farmers, struggling to compete on a stringent market and not desiring to exchange knowledge. This current situation is not beneficial when considering the agroecological transition.

Still, some drivers exist for this type of farmer, as they usually own **machinery**. For example, F8 uses a false seedbed technique to manage weeds. This is a rapid and cheap way of dealing with weeds that could be further promoted. Furthermore, taking into account the economic orientation of these actors, if it could be proven that AE practices are profitable on the long term, some might be interested in changing their practices.

KEY FINDINGS TO RQ 2: What are the drivers and the barriers for a broader implementation of "agroecological practices"?

Organic farmers suffer from a lack of market valorisation of their products in the food departments. This market situation decreases their economic profitability and the major barrier for these farmers seems to be their economic vulnerability. Decreasing the risk of failure when implementing AE management practices by increasing agricultural research and improving presence of extension services on field, would allow to ensure economic profitability. For **traditional farmers**, the main barriers are their time management and their mindset. Indeed, these farmers are producing most of their inputs themselves, which is positive (independent from external sources). However, these time demanding tasks impact the quality of their work in other management practices. Access to small machinery was estimated as a potential driver towards more AE management practises. However, in terms of objectives, these farmers are deeply embedded in self consumption models and reject change, which are barriers to implementing more AE practices. For **conventional farmers**, barriers are predominant: structural (quota system not encouraging to improve quality of production), economical (pressure to pay back for farm investments pushing for intensive production systems) and sociological (distrust towards organic farming practices). Finally, **reasoned farmers** represent the farmer type with the most numerous drivers toward more AE practices. They are economically resilient, they desire to improve their farming practices to decrease their impact on the environment/public health, and they possess resources (capital, labour force, machinery). Still, transition to more AE practices will require an increased support from agricultural research and presence of extension services on field.

6. DISCUSSION

6.1 AGROECOSYSTEM CONVERSION TO AGROECOLOGY

Results from this research highlighted some modalities of management practices that are close to an AE approach. Even though this work followed an "innovation track" strategy to target farmers having alternative practices, diversity of such practices in the sample is quite poor. Only 3 farmers were identified as being these "risk takers" by implementing with success, a pinto peanut **cover crop**, using **mulching** techniques (recycling crop residues) and basing their fertility on **soil amendments** by digging deep holes filled with logs and compost before planting fruit trees. The diversity of alternative management practices used by the farmers in the sample could be improved. Wezel et al. (2014) propose a list of 15 AE practices and most of them are not used inside the farmer sample such as biofertilisers, intercropping, crop rotations including allopathic plants or agroforestry systems with timber/fruit or nut trees. Can be added from Altieri & Nicholls (1999, cited in Clements and Shrestha, 2004) that there are very little integration of livestock with crops, no push-pull strategies and there is a low use of cover crops and fallow. Some of these practices seem interesting in the context of French Polynesian agricultural systems. **Integrating small livestock in mixed farming systems** (chicken, pork, goats…) could be a solution to the reduce dependance on agrochemicals. Farmers in the sample claimed that land availability leads to the impossibility to have fallow. For this type of resource-poor farmers, Altieri & Nicholls (1999, cited in Clements and Shrestha, 2004) suggest to implement **green manures** during crop rotations, such as the velvet bean (*Mucuna pruriens*) a tropical legume, as it restores fertility by fixing nitrogen and can be used as a fodder crop.

Even though the number of AE practices observed on field was quite low, the most difficult **conversion** step has already been implemented, or rather, has never been destroyed. Indeed, French Polynesia did not undergo extreme simplification of its farming systems and therefore, agriculture is still dominated by polyculture. On a landscape level, hedges and trees have been maintained, providing habitats for multiple species. These characteristics of French Polynesian agriculture puts them further on the gradient of conversion than many other agroecosystems. Indeed, conversion to AE systems is described as a process undergoing three steps: (1) efficiency increase, (2) substitution and (3) redesign, in an analytical framework proposed by Hill and MacRae (1995, cited in Wezel et al., 2014):

> *"**Efficiency** increase refers to practices that reduce input consumption (e.g. water, pesticides, and fertilisers) and improve crop productivity. **Substitution** practices refer to the substitution of an input or a practice (e.g. replacing chemical pesticides by natural pesticides). Finally, **redesign** refers to the change of a whole cropping or even farming system."* [Wezel et al., 2014]

Crop diversity and landscape heterogeneity are part of the AE practices the less implemented worldwide, as they require complex systemic change. French Polynesia should therefore realise its lucky position. The conversion"only" requires **efficiency increase** or **substitution** of practices. Still, as Cadiboche et al. (2005) underline via a study concerning the technical feasibility of organic farming in Martinique: "*The transition to organic or agroecological systems will require a great deal of competence, a capacity for innovation, and an assiduity that is difficult to reconcile with multi-activity.*" Similar conclusions can be drawn for French Polynesian farmers that are also characterised by multi-activity. Focusing on **knowledge exchange** inside farmers' network will be extremely important, for supporting the farmers in a transition that requires a more complex management.

In order to facilitate the **adoption** by farmers of AE management practices, it is necessary to start evaluating them on a technical, economical and agronomical point of view. It is only after having a deeper **scientific understanding** of these AE practices, for French Polynesian agroecosystems, that it will be possible to start diffusing them via technical sheets, agricultural training… Indeed, Manner (2008) claims that the entire Polynesian region lacks a **long-term monitoring** of the farming systems. Starting this documentation by setting a certain number of indicators, is necessary to be able to evaluate their efficiency quantitatively. Similarly, Bertin (2006) studied the situation of fruit production in French Polynesia. He claims that the **lack of structure of agronomic research** in French Polynesia leads to a certain scientific isolation of the farmers. Apparently, lack of resources, leads to hiring punctually highly specialised scientific support. However, a **permanent presence of researchers** would be more valuable for a continuous monitoring and support of the farmers. It is only with support from agricultural trainers and researchers, that will publish technical and economical evaluations for each management practice, that there is hope for broader diffusion of AE practices.

6.2 INFLUENCES FROM THE FOOD SYSTEM

Conversion of the farming systems towards more AE practices will require a **strengthened coordination** with actors from the **food system**. Duru & Therond (2014) emphasise that the agroecological transition requires the need for a participatory, holistic, transdisciplinary and "localised" design approach. Numerous actors are interacting through-out the complex **food web** between the stages of food production, processing, transportation and consumption. Actors along these long chains need to coordinate their actions. Ozier-Lafontaine et al. (2018) have studied the agroecological transition of crop production in French Guiana, following a similar approach to this work. They conclude that the transition requires a development of **income-generating opportunities** through certification schemes, processing and packaging activities, or by developing local, national or international marketing channels. In the French Polynesian context, seeking **agrotransformation** could allow to decrease waste and to increase the economic income for the farmers. Agricultural waste appears to be an issue as there is more production during the fresh season whereas the demand is lower (holiday period). Storing agricultural production via processing of perishable goods (fruit, traditional root crops) would allow to reach a higher self-sufficiency of the country. In addition, creating these **new market opportunities** could push the farmers to diversify their farm-productions. **Consumer demand** can also be seen as a driver for change in the practices. Bricas et al. (2001) did a study on the marketing and consumption of horticultural and fruit food products in French Polynesia. These authors highlight the potential of marketing for certain products: organic products, local traditional crops, local processed foods. Therefore, consumer education should be conducted in parallel to farmer training, via **well-targeted campaigns** on these new products. Promote the consumption of local products such as the "Eat Local" campaign launched recently by the Chamber of Agriculture under the direction of the Ministry seems very important (Fabresse, 2018b).

The Agricultural Policy for the period 2011-2020 underlines the importance to facilitate access to local products because their **price** often represents an obstacle for part of the population (Ministère de l'Economie Rurale, 2011). Indeed, the price margins for the local supply appears to be disconnected to prices on foreign markets. The **geographical isolated situation** of the country and the **higher price of wage** makes it challenging for French Polynesia to compete on international markets. However, there seems to be a certain abuse when defining the prices: lack of econometric tools and lack of professionalism leads to farmers that do not calculate their production price, but set a price that satisfies themselves without any economic basis.

Finally, Wezel et al. (2014) underline four parameters explaining why AE practices are diffused or not. Diffusion requires a **high level of experience**, **knowledge**, **low level of system change** and **time**. If efforts can be set in research and farmer support to accelerate the three first parameters, time cannot be accelerated. This seems to be an important point for French Polynesian agricultural systems. The organic certification scheme appeared less than a decade ago and if some interesting initiatives are emerging (such as farmer-canteen associations, vegetable box schemes, compost production programs and so on), these initiatives remain isolated. **Time** is needed for consumers and farmers to be educated and heighten awareness about the environmental and health impacts of an agrochemical agriculture. Therefore, **Education** will be primordial to support the AE transition of the farming systems.

6.3 LIMITS AND CONSTRAINTS OF RESEARCH CARRIED OUT

The research procedure is extremely important when analysing qualitative data in order to achieve credibility of the results (Graneheim and Lundman, 2004). Meanwhile, selecting the 20 representative farmers within the diversity of the farming community, collecting the data during the farming interviews and analysing it, led to a certain number of biases. Concerning the data collection, the interviews with the farmers did not always allow to get the same quality of information. The reason being either the *ability* to communicate (not sufficient understanding) or the *willingness* to communicate (history of relationship with the DAG). Of course, being introduced as a trainee at the DAG might have impacted the interview. However, these challenges in the data collection occurred only with the intensified vegetable producers (4 farmers). In addition, I sometimes might have not asked some important questions due to my lack of expertise concerning local traditional root crops. However, taking into account the overall goal of this work, it is not essential if some details have been left aside.

Concerning the analysis of data, finding a "common grid" to analyse such diversified farming systems was challenging. It obliged to defining criteria non specific to the cropping systems in order to be able to evaluate all the farms with the same grid. However, even with these evaluation criteria, the process of evaluation might have involved a certain arbitrage. What had been perceived during the farm visit might have influenced me during the evaluation, decreasing my objectivity. Indeed, conducting a fair analysis of an important amount of qualitative data, avoiding to see what the researcher *wants to see*, is the most challenging aspect of CS (Yin 2009). If such an analysis was to be conducted again, I would recommend focussing on one single type of cropping system (fruit/vegetable/traditional crops or vanilla) which would allow to decrease risks of arbitrages.

6.4 IMPLICATIONS OF THE RESULTS

The CS approach allows to get updated knowledge for a very specific socio-economical context. Results are therefore *de facto* not generally applicable to other contexts (Yin, 2009). However, these results might be interesting for other islands in the "Polynesian Triangle" (formed between New Zealand, Easter Island and Hawaï). These islands have been colonised by South-East Asian populations, who imported the same types of vegetation and share a similar historical background (Guérin, 1990). More precisely, small volcanic islands such as Tonga, Cook, Fidji, Samoa and Wallis and Futuna are good candidates to show similarities with the French Polynesian farming systems, as their level of agricultural intensification is still low. Manner (2008) gives a description of a majority of the traditional farming systems present in these zones:

> "*Those simple to complex farming systems developed mainly by the* ***indigenous inhabitants*** *of a region is primarily oriented towards* ***subsistence****. These systems are adapted to a* ***localised cultural-ecological*** *context. They do not necessarily rely on the* ***energy-intensive technologies*** *of modern agriculture, namely, mechanisation, chemical fertilisers and pesticides.*" [Manner, 2008]

This definition of traditional farming systems highlights some key characteristics of an AE farming system: **autonomy** from external inputs, **adapted** to the local context and **developed/managed** by the indigenous inhabitants (Delvaux, 2018). The fact that agricultural intensification has not simplified to the extreme French Polynesian farming systems, consist of a great opportunity for the AE transition. In the light of the 11th FED, precautions must be taken to avoid implementing actions that lead to mainstream agricultural intensification based on increasing the production yields. Considering the population of French Polynesia (270'000 inhabitants approximately) and the dispersion of these islands in the middle of the Pacific, agricultural production should seek to answer the needs of the population and allow producers on the different islands to be as independent from inputs as possible. In that sense, development of organic certifications that require importation of specific inputs is perhaps not the priority for French Polynesian agricultural production (except for certain niche export markets that require to meet international standards). Rather, following an AE conversion based on intensification of ecosystem services should be the goal of French Polynesian farmers, in order to achieve **resilient** farming systems that are simultaneously **autonomous** from external inputs.

7. RECOMMENDATIONS

Farmers criticise the DAG for their lack of support and agricultural research. The DAG criticise farmers for being too passive and waiting for simple "one size-fits-all" solutions. It is not unexpected to have conflictual relationships between these two actors. Keeping an external eye, it seems that there are a lot of information published on the DAG website (Direction de l'Agriculture 2018c). For example: Fish fertiliser sheets, green manures depending on the soil type, technical sheets for the organic cultivation of six crops… **Information is formally there, however there is a lack of transmission of knowledge**. Farmers in French Polynesia globally have a low level of education (Service du Développement Rural, 2012) and strongly prefer oral transmission. It seems that publishing long technical sheets is not adapted to the farmer profile in French Polynesia (the situation in Tahiti is perhaps different, with an average higher level of education). **Use of "how to" videos** should be considered by the DAG.

DAG should reflect on **resource allocation**, rethinking the roles and specifications of each employee. There is a need for more presence of technical services on the farm sites. Presence on field and discussion with the farmers seems like the most appropriate way to transmit knowledge. New positions could be defined such as employees in charge of the **mediation** and **facilitation** of knowledge transmission to the farmers. Decreasing the gap between the administration and the farmers is also important, in order to reverse the current rather negative relationships towards more **proactive collaborations**. The agroecological transition is deeply based on knowledge transmission and therefore, it is vital to improve these relationships to enhance fruitful collaborations. Therefore, rethinking the organisation of the employees working in the different units of the DAG seems like a necessary step to push forward the agroecological transition of the farming systems.

Underneath are 3 **potential actions** identified as relevant in the French Polynesian context to push forward the AE transition:

- **Soil fertility**: Implement a program to explain differences on soil amendments and fertilisation, the cycling of nutrients, the process of digestion of organic matter by micro-organism… Organise a workshop on soil fertility and soil management. For each farmer participant, offer a free soil analysis and a technical follow-up in order to interpret the results. Another potential interesting format to improve soil management, would be via the implementation of a Farmer Field School (FFS). FFS consist of a group-based learning process, first used by the FAO to promote Integrated Pest Management (IPM) in Indonesia. This approach could be interesting in the French Polynesian context, for IPM and an Integrative Soil Fertility Management (ISFP). Recently the Food and Agriculture Organisation of the United Nations has published an implementation guide for Farmer Field Schools available in French here: http://www.fao.org/3/a-i5296f.pdf and in English: http://www.fao.org/docrep/016/i2561e/i2561e01.pdf

- **Pool farm equipment:** Taking into account the small average farm size in French Polynesia (Service du Développement Rural 2012), it seems relevant to pool farming equipment following the model of French CUMAs "*Coopératives d'Utilisation de Matériel Agricole*" (Coopérative d'Utilisation de Matériel Agricole, 2017). For example, many farmers who want to produce wood pellets have shown interest for brush crushers. Pooling machinery will require a certain management to secure a good maintenance of machinery. However, this investment is worth it, as pooling machinery will simultaneously bring farmer together and potentially enhance farmer-to-farmer knowledge exchange. Indeed, the collective dynamics emerging from a CUMA often can lead to spreading innovative management practices between farmers in a certain region (Coopérative d'Utilisation de Matériel Agricole, 2017).

- **Production of fish/algae fertiliser and compost on a communal level:** The example of Taputapuatea municipality on the island of Raiatea, that is producing municipal compost and selling it to the farmers, could be implemented in other municipalities (Ademe, CCISM and DIREN, 2014). It seems like a relevant way of relieving organic and traditional farmers (the main farmer types using them), from time consuming tasks. In addition, quality of the inputs can be improved as they would be produced professionally. Here again, as for the pooling of machinery, the production site of theses inputs could serve as an exchange platform between industrials and farmers. Reflexion on which actors (CAPL, DAG, Communal services) should be in charge of the manufacturing of compost/algae/fish fertiliser should be discussed.

8. CONCLUSION

This work aimed at describing what practices are used by farmers to improve pest management and mitigate soil erosion and understanding what are the drivers and barriers behind the implementation of practices in line with an AE approach. To meet this goal, a farmer typology was used to identify categories of farmers with similar technical and socio-economical characteristics. Describing the major drivers and barriers for each farmer type, allowed to prioritise measures to implement with the funds from the 11th FED to push forward the agroecological transition.

Results show an overall **average proximity** to an AE approach. Management of **soil fertility** is still far from an AE approach, with often non-appropriated doses of fertilisers used and low use of split fertilisation, use of one single synthetic fertiliser not adapted to the crop and an intensified land use (rare implementation of fallow). The two most widely used **soil amendments** are chicken manure and lime, however globally their implementation rates are still low. **Recycling of organic matter** as well requires improvements with an important part of the farm organic matter that is not reintegrated in the cycles. Management practices used to **mitigate erosion** show a closer proximity to an AE approach, with an important diversity of management practices, such as application of plastic covers, mulching, key-line design, sowing on raised beds or digging water evacuation channels around the plots. Dependence on agrochemicals remains important with the use of synthetic fertilisers and **herbicides** used by a majority of farmers to manage weeds and to destroy crop residues (leading to low levels of organic matter recycling in the systems). Concerning pest management, a majority of fruit and traditional root crop producers do not use any pesticides at all and do not seem to be facing specific problems of pests outbreaks. The important **crop diversity** present on a farm and territorial scale seems to explain this positive biological regulation of the system. However, there are needs for improvements for the conventional vegetable farmers, that rely on the use of **synthetic pesticides** and do not use alternative managements such as **crop rotations**. Use of **biological pest control** or **natural pesticides** seem to be minor, only used by the organic vegetable farmers.

Categorising the farmers in four types, organic - reasoned - traditional and conventional, with their specific socio-technical constraints allowed to assess where are the main issues in terms of sustainability and where are the main margins for manoeuvre. The **organic farmers** implement farming practices that are close to an AE approach, however the economic viability of these farmers is questionable, as practically all of them came from specific context with access to external resources (land, capital, political support). The major point of improvement for the **traditional farmers** is to decrease their herbicide use, and their most positive assets is their important biodiversity (traditional crops, fruit and vegetables). These farming systems show low levels of intensification and important proximity to natural ecosystems. The **conventional farmers** have an important margin for progression, but when taking into consideration their mindset, chances of pushing these farmers to improve their practices are small. For this reason, the **reasoned farmers** have been identified as the target group when considering the AE transition. They are the most innovative farmers, the “risk-takers”, that can play the role of leaders in the process of change.

General recommendations highlight the needs for farmer education concerning **soil fertility management** and for rethinking the **transmission of knowledge** between researchers and farmers. Three potential actions to overcome these challenges have been identified: (1) Implement a Farmer Field School on Integrated Soil Fertility Management, (2) Promote pooling of machinery, (3) Install a communal production of compost, algae and fish fertilisers.

Finally, this work was a first **qualitative approach** to the assessment of the performances of the French Polynesian farming systems. In order to validate the trends and farmers typologies proposed in this work, it would be interesting to tackle more **quantitatively the economical and technical performances** of the systems. For example, **mass balances** would allow to compare all the farm inputs with the outputs, in order to highlight potential nutrient leaching and organic matter losses/gains. In addition, this work was not able to describe with sufficient details the **tillage** practices for vegetable producers. Tillage management practices could be deepened in a further study, to understand if reduced tillage can represent a driver to mitigate soil erosion or not.

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