Inventory and feasible solutions to the pig slurry management issue in the Reunion Island south sector in 2021/2022

Porc Pays Réunion, 2021

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European Engineer Degree in livestock production, pig specialization

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Made with my coach

Marrit Van Engen

Preface

As part of my studies in the European Engineer Degree in Livestock production Cursus, I had to find an internship in the livestock sector. Initially, I wanted to go to an English speaker or northern European country. But the Covid-19 epidemic constrains me because potential training masters were uncertain about the future, and how do they shall manage their staff in a few months. Thus, I chose to look for an internship more easily and to go to a French overseas department. Hence, the juridical and responsibility framework should be easier. Indeed, I postulated to the CPPR, on Reunion Island. It was a good compromise between the current situation, and the will to travel: The juridical frame is easier in those corona-times, and I travel in a different area culturally, locationally, by the landscape, the climate, by the agricultural position, and the pig farming situation.

The CPPR is the only pig cooperative on Reunion Island. This one regroups 137 pig farms, each doing husbanding and fattening (there are approximately 15 other pig farms on the Island). This cooperative was created in 1974 by 14 pig farmers. Till today, the cooperative has been growing, with more and more farmers, and developing other companies for the pork line on the island (*CPPR, n.d.*).

The Reunionese pig farms that work with the CPPR have 38 productive sows on average, against 228 ones in 2015 in Metropolitan France (*IFIP, 2016)*. Their sizes are quite restraints, but the pork market on the island is also different than in the European continent, because of the island situation: it is in the European Union, but far from the continent, and this island in the Indian ocean has solely 860 000 peoples. Indeed, Importations are expensive because there are taxes on products from outside the EU, and because boats have to do a special stopover to deliver their containers (*European Comission, n.d*).

This study could be useful for pig building, equipment sellers and developers on the island, or for the French public services. This study case about equipment, buildings, spreading plans, farm practices, and farmer wills and wishes is gainful for all peoples who work about this topic. Also, the part about the feasible pig slurry processing and solutions could be a base for peoples who wants to develop those solutions on the island.

I thank Alexia Victoire, my training master, for her spent time, her patience, and her job passion transmitted. I also would like to thank all the technical team: Maureen Brisset, Damien Bescond, and Patrice Dalleau for the shared time with them.

Of course, I also thank all other ones from the CPPR, workmates and farmers, for their passion for their job, and the spent time with them.

Abbreviation list :

CPPR	Coopérative des Producteurs de Porcs de la Réunion	Cooperative of Reunionese Pig Producers
CAP	Common Agricultural Policy	
DAAF	Direction de l'Alimentation, de l'Agriculture et de la Forêt	Department of Food, Agriculture and Forestry
ICPE	Installations Classées pour la Protection de l'Environnement	Installations Classified for Environmental Protection
RSD	Règlement Sanitaire Départemental	Departmental Sanitary Regulations
DDPP	Direction Départementale de la Protection des Populations	Departmental Directorate for the Populations Protection

Content

Summary

This report is a study about the pig slurry problems on Reunion Island and its feasible solutions. It was done with the Coopérative des Producteurs de Porc Réunionnais (Cooperative of Reunionese pig producers) and their pig farmers, between the end of September and the beginning of December 2021, in the south of Reunion Island.

Indeed, Reunionese pig farms have problems with their slurry management for a few years, mostly concerning their slurry spreading, quite hard to respect according to the French legislation.

This topic is in relation with several other ones documented in this report, like the Reunionese territorial specificities, fertilizer usage on Reunion Island, the legislative frame, the Reunionese soils, the effects of slurry on those, the slurry spreading, and finally the feasible solutions to resolve this problem.

Hence, the research is done in three parts: a farm typology, then the research of problem sources and links among the slurry produced, the slurry storage and management in pig farms, and their spreading plans. Finally, a solution that should answer the main problems is proposed.

This study highlights several things:

Studied pig farms have generally a modest size compared to French ones, with the most common sow herd size between 36 and 45 sows, and a running herd with 7 sow groups. A lot of those are diversified because 75% of them do other activities (mostly ruminant farming, sugar can growing, and fodder growing).

Their slurry management problems have sources in each basis: the pig slurry produced, the pig slurry storages, managements, and the spreading plans. The main reasons are the farmers are generally not aware of the pig slurry production and composition, some pig buildings were done during the 1980s and 1990s and the regulation about the pig slurry was less specified than today. Also, an important part of spreading plans were done few years ago and aren't in phases with the real herd. Thus, those spreading plans can't be correctly respected by a lot of farmers. Thereby, the problem found is management problems in the farm storage, and a spreading plan problem.

To resolve both important points, the proposed solution should be to create five slurry processing places for studied farms, that should process 8000 m3 of pig slurry a year. The preconise technique should be composting. This solution should answer the management issue, with a regular slurry incoming in the processing place, and a product that can be sold to market gardening farms, with several advantages for those. Something that should be done to do it, and to well manage the slurry, should be to work on the slurry emissions, to be more aware of the N, P2O5 and K2O emitted, and the volume emitted. Hence, the place processing should be well managed, and the pig farmers should get knowledge to do it well.

Chapter 1: Introduction

1.1.The pig slurry in Reunion Island

The CAP and the French government apply Nitrogen rules for all fertilizers and spread matters on fields, with rules who depend on the country, and sometimes of the area. Today, the French government, in partnership with the European Union has the purpose to reinforce the fertilizer controls in farms, to decrease the French fertilizer consummation by 20 % till 2030 *(European Commission, n.d).*

Until recently, only Nitrogen was really controlled in spreading plans on the Reunion Island. But the non-pollution obligation toward farmers requires that no element pollute the environment. Since 2019, the Reunion DAAF inspector is aware of the plant needs, the pollutions, and controls N, P2O5, and K2O. The consequence of those serious controls is farmers spread less pig slurry per hectare and year on each parcel. But the island artificialize lands each year, and the spreadable area on the island decreases year after year (*Lagabrielle, E., Rouget, & al., 2009*; *Rousseaux, F., & Judge, V., 2017).*

Indeed, the mains plant productions on the island are sugar cane (22 664 ha), fruits (2 980 ha), vegetables (2 160 ha), horticulture (102 ha), « Péï » roots with manioc, yam, Cambar and many others edible roots (121.5 ha). Vanilla production represents 194 ha, aromatic and medicinal plants are on 125 ha. Some farmers begin the cacao and coffee growing. By another way, meadows represent 1900 ha on the island. (*Chambre d'Agriculture de la Réunion, 2020 b*)

Among those different productions, only sugar cane, fruits production (with trees), meadows and vanilla can get fertilized with pig slurry. But there is also the concurrency of manures, that plant farmers prefer because they have more advantages for them (technically, by the regulation), and the decreasing of sugar cane production (because the French think to reduce European incomes to growers) (*Deniau, F. X., Aprikian & al., 2021*).

Chemical fertilizers are used in plant productions, especially vegetables. Those work well but have some issues about sustainability: The phosphorus part of those fertilizers are mined in some parts of the world, and it is not known if agriculture should still get it in a few decades. Also, they are expansive because this island with 859 thousand people is far from other big harbours, and boats must do a stopover especially there to deliver their cargo.

A solution is to spread local livestock manure to fertilize the crop soils to resolve this issue. But the law prohibits the raw slurry from spreading on some vegetable production lands because raw slurry has some pathogen agents that could be transmitted to humans by vegetable consumption.

Hence, pig slurry has current utilization issues on the Reunion Island, owing to several technical and legislative indications.

1.2. The Reunionese territorial specificities

<u>The Development of the local urban plan</u>

The Reunion Island is a part of France, where the demography still develops, with 2.41 children per woman. Hence, the demographical pyramid is different from the rest of France as well, because peoples of 20 years old or less are three times more numerous than people of 65 years old and more. Even with an important part of the young population who leaves the territory to go to metropolitan France, the Reunionese population grows by 0.5% each year (*INSEE, 2019*).

Therefore, peoples need to build houses to live in, and buildings for their activities. Hence, the local urbanism plan takes place, year after year on the agricultural fields *(Rousseau, F., & Judge, V. , 2017)),* mostly on areas presented in Figure 2. This soil artificialisation has consequences, like soils permeabilization (see annexe 5), which is a problem on the island. But it also means pig farmers have fewer fields, spreading areas, and have to manage people's complaints more often (*Agreste, 2021*).

Some areas are more interesting to build houses, especially in the south of the island, where there are already a huge part of the urban areas (*Lagabrielle, E., Rouget, M., & al., 2009)*, and still "free" plots to build houses, with buildable areas (see Figure 1 and 2) (*Buildable areas of the Réunion island Rousseau, F., & Judge, V., 2017).*

Figure 1: Urban, agricultural, and forestry areas of the Réunion Island *(Lagabrielle, E., Rouget, M., & al., 2009)*

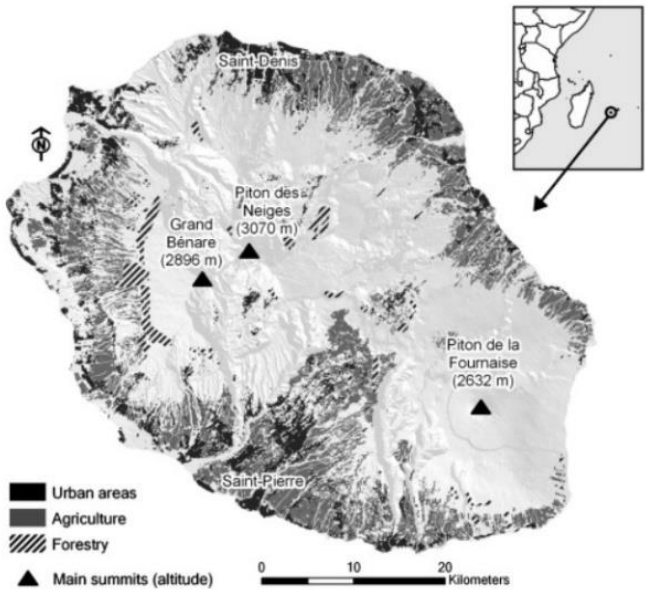
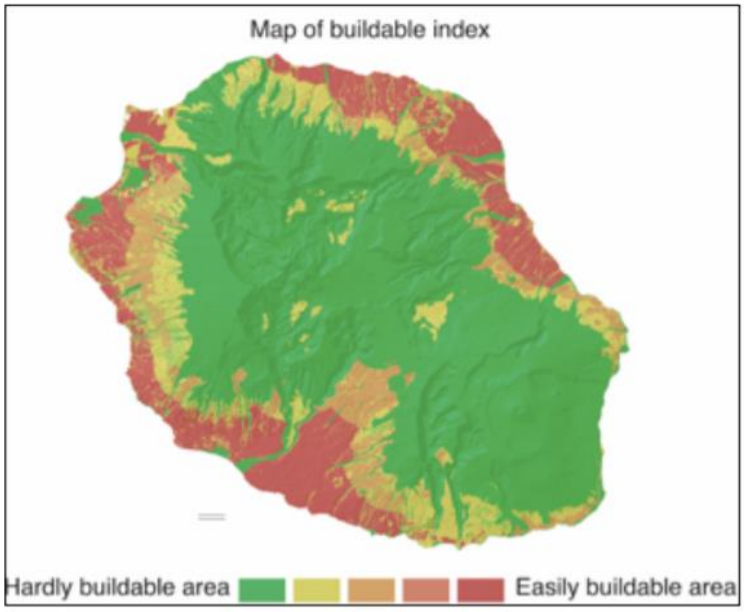


Figure 2: Buildable areas of the Réunion Island *(Rousseau, F., & Judge, V., 2017)*



The Mountain areas

Growing plants or producing livestock in the mountains could have some difficulties (access by way, steeps parcels, weather…). Indeed, the French government created an income fund for mountain farmers. Those difficulties are officially recognised at the Reunion Island from 500 m of altitude (*Code rural et de la pêche maritime, n.d).*

1.3.Using fertilizers on Reunion island

Each year, 222000 tonnes of animal feed and 30000 tonnes of synthetical and mineral fertilizers are imported into the Reunion Island, to stock up local agriculture and livestock (*GABIR, 2019* ; *Chambre d'Agriculture de la Réunion, 2019*). Indeed, Reunionese agriculture depends a lot on import.

Furthermore, the island has a real market for manures, organic matters. They are very wanted by vegetable producers (*Chambre d'Agriculture de la Réunion, 2020,* (p.180)), because of their beneficial effects on the soil. For instance, a part of the bovine manure produced on the island is sold between 10 and 75€/tonne (it depends on the transport), mainly to fruits and vegetable producers (*GABIR, 2019*). *Agreste, 2016,* tells that organic matters are used 4 times more actually than in metropolitan

France. In the same line, *GABIR, 2020,* shows there is still a demand for organic matter in vegetable production inter alia, which is estimated at approximatively 52000 raw tonnes of compost, 380000 raw tonnes of liquid digestate, and 216000 raw tonnes of solid one. *Chambre d'Agriculture de la Réunion, 2019,* indicates by a more precise way the maximum price plant growers should be able to pay for their organic matter is 15€/m3, without any transport.

More technically, Reunionese farming is less mechanised than metropolitan French one. A lot of tasks are done by hand for several reasons, more specifically in vegetable farms. This means that a lot of vegetable farms fertilize their lands by hand. Hence, spreadable organic matters for vegetables must be spreadable by hand and thus have a convenient texture for this: a solid one, ideally in powder or pellets. Thus, the plant producers still demand organic matter. By another way, because importations are little sustainable on the island, local plant producers use a lot of organic matter, and importations are expansive, processing pig slurry to get a spreadable matter on vegetables should be interesting.

Among those reasons for convenient fertilisation, according to the farm place, the access to plots (sometimes very steep) can be complicated. The roads are sometimes in bad conditions, degraded by the weather, steeps, and use those every day with a four-wheel-drive vehicle is possible, but more complicated with a tractor and a spreading trailer, or a truck. This access issue is problematic, added to the fact that some areas where vegetables and others vegetal productions are grown far away from current organic matter producers. Fertilizers with concentrated interesting elements are adapted for this.

1.4. Legislation about the spreading of pig slurry

The CAP governs the big lines of the French farm spreading. The purposes are to decrease nitrate water pollution, eutrophication from agricultural activities, and to prevent those pollution extensions. The official text that legislates this is the nitrate directive (*SIGES Centre-Val-de-Loire, n.d*).

At first hand, the French government enforces the nitrate directive with the water quality monitoring, nitrate vulnerable areas delimitation, the establishment of code of good agricultural practices and measures to implement by programs to apply in nitrate vulnerable areas. (*France, C. D., 2021*). These purposes are legislated by the Decree n°93-1038 of the 27/08/1993 (*République Française, 1993*), which is the official CAP nitrate directives application in the French law.

Another important text in the French law that regulates the fertilizers, and the organic matter spreading is the Arrêté du 27 décembre 2013 […] (*République Française, 2013),* which act the effluent spreading regulation, and the standards to respect.

Thus, French farmers have the responsibility for their effluents until their environmental impacts. To get safe effluents management, farmers have to respect the French regulation, which includes the following several points (*Chabalier, P. F., van de Kerchove, V., & al., 2019*).

<u>The type of spread effluents</u>

The French Law recognises two kinds of effluents, and organic residues **(***Chabalier, P. F., van de Kerchove, V., & al., 2019***)** :

Commercialized fertilizers and compost must be normalized (like organic fertilizer, cultural support), and get a homologation to be sold. In this case, the producer is responsible for his products until the sale, and the spreader farmer is responsible for the way to use those.

Wastes, with livestock effluents, sewage treatment plant sludge, and food-chain wastes, from farms and companies regulated by the ICPE, need to have a spreading plan to be spread. Other livestock effluents from farms regulated with the RSD, don't need a spreading plan to get spread.

For both kinds of products, the farmer is responsible for the environmental impacts of spread products. For each kind of waste, the spreader farmer must-do technical monitoring on its plots, with agronomical monitoring, and the nitrogen quantity produced.

The ICPE or RSD farm registration

A part of the spreading regulation depends on the livestock size on the farm. In France, all pig farms with more than 50 pigs equivalent at same time in the farm are classified to the ICPE. Between 50 and 450 pigs, the farm must be declared to the prefecture. Since 450 pigs, it needs authorization from the prefecture, which can be given or refused. The organism that works with those farms is the DDPP. Farms with less than 50 pigs are regulated by the RSD. Until 6 pigs, it doesn't need any declaration, and between 6 and 50 a declaration to the town hall *(DAAF, n.d. ; République Française, 2021 ; République Française, 1992; République Française, 1976; Chabalier, P. F., van de Kerchove, V., & al., 2019).*

For classified pig farms, the pig slurry spreading is regulated by its specific legislation, the Decree and order of the 27/12/2013 (according to the farm size : authorization, registration, or declaration)(*République Française, 2013).*

The Spreading areas

The water quality monitoring has the aim to have drinkable water for all the population on the whole territory. Water is officially drinkable when it respects standards *(THE COUNCIL OF THE EUROPEAN UNION, 1998; DGS, 2018; ADEME, 2018).*

The water quality monitoring distinguishes two kinds of spreadable areas (*République Française, 1993)*:

The Nitrates vulnerable areas, which are parts of the territory where water pollution from agriculture or other activities menaces on the short term the aquatic environments, and mostly human drinkable water, with nitrates. When a vulnerable area is declared, legislation with more constraints is applied to well keep the environment.

For other areas, spread matters are regulated by article 18 of the 07/02/2005 ICPE decree (*République Française, 2005*) which tells: « livestock effluents for farms (declared or authorised) can be naturally uncluttered by the soil, and its green covers ». Indeed « Nitrogen brought, from all origins, spread on fields, take in account the field particularities, and cultural rotation. Fertilisation has to be balanced and get adapted to exporter capacities of the culture or the meadow ».

Today, there are no vulnerable areas on Reunion Island, thus only the "classical" regulation is applied.

The Organic matter storage

The RSD regulates fermentable matters for soil fertilization (except standard compost), to avoid odour pollution.

If the volume is **below or equal to 5 m3**, there is no regulation for that.

If the volume is **between 5 m3 and 50 m3**, there is not any procedure for that, just to respect the RSD regulation.
When the volume is **between 50 and 2000 m3**, the RSD regulation must be respected, and it must get a declaration to the town hall.
Finally, when the volume is **bigger than 2000 m3**, it needs a prefectural authorisation, and respect the RSD regulation.

The RSD regulates distances to respect from manures and slurries to homes, buildings (200m for livestock effluents), roads (5m), water sources, watercourses, and fish farms (35m). Those matters must be spread one year maximum after their storage (*République Française, 1992*).

The potential spreading area

In the French spreading plan, plots are registered, but the whole plot can't be used for organic matter spreading, and/or fertilizers in general (*Chabalier, P. F., van de Kerchove, V., & al., 2019)*. Hence, some areas in plots can't get spread, and all the plots can't count for the spreading plan.

To get the potential spreading area of a plot, it must subtract the whole plot area from all areas that can't be spread.
Parts that can't be spread are presented in annexes 7 and 8.

The minimal distances to respect for spreading

Distances to living places have to be respected because odours are disagreeable for peoples (see annexe 7) (*Chabalier, P. F., van de Kerchove, V., & al., 2019)*
By another way, some public buildings need to have a respected distance, according to the farm registration and the spread matter (see annexe 8).

The constraints for spreading on sloping grounds

The code of good agricultural practices prohibits fertilizer spreading which make it run off the spreading field. This can be told in the spreading plan and can be allowed or not by the dossier instructors. For this, four slope categories are done, according to the spread matter texture (Figure 3) (*Chabalier, P. F., van de Kerchove, V., & al., 2019)*.
Hence, to be sure that farmers know where and how to spread their organic matters, the French legislation requires them to keep a spreading plan.

Figure 3: Spreadable organic matters according to the slope (*Chabalier, P. F., van de Kerchove, V., & al., 2019)*

Slopes categories	**Spreadable organic matters**
s ≤ 7 %	All kinds
7 < s ≤ 20 %	Solid matter
20 < s ≤ 40%	Standard, counterpart products
s > 40 %	Neither

The Spreading Plan

The French farmer who must realise a spreading plan, valid by the French administration (the RSD or ICPE), has to respect it (*Chabalier, P. F., van de Kerchove, V., & al., 2019).*

This plan contains:

A map 1/12500, another 1/5000 of the spread fields, and their references.
A summary table, in which are parcel number, the total area, the potential spreadable area of each parcel.
The N-P-K mass efficacity is spreadable on the parcel.
The N-P-K mass efficacity is spreadable on the parcel per hectare.
A calculation to be sure that there is **enough area for the spread N-P-K.**
The agreements done with people who lend plots to the livestock farmer.
The cultures implanted.

Also, farmers must keep an updated spreading book, which contains contributions done on each plot. This book can be asked by the farm is inspector and must be kept for 5 years. It contains:

The plot references
The farmer/ farm name
The potential spreadable area (the plot area that respects distances to other buildings and sloped grounds)
The culture done
The average yield of the last 5 years, without the best and worst years.
The N-P2O5-K2O needed per ha
The total N-P2O5-K2O effective needed on the plot.
The spreading dates
The spread matter on the plot
The burial notice
The spread mass matter (tonnes or m3)
The N-P2O5-K2O content of the spread matter
The C/ N-P2O5-K2O ratio of the matter
The effective N-P2O5-K2O spread (Kg)

Spreading periods:

- Spreading periods are regulated by the C/N ratio of the spread matter, but also by the weather, the cultural growth, and some dates (see Figure 4) (*Chabalier, P. F., van de Kerchove, V., & al., 2019*)**.**

Indeed, it is unadvised to spread **during the dry period**, (between September and October), because the soil shouldn't permit a good nitrogen valorisation from organic matters, which will emit gas, and less send molecules to the soil.

In Winter (June to September) for manures and composts, in altitude with low temperatures, because in those times, the organic matter in the soil doesn't degrade the matter swiftly (risk of loss). More, the plant growth is slower in winter, and it needs fewer nutrients.

For slurries and mineral fertilisers in the rainy season (January to March). The main risk is leaching, mostly for nitrogen. If the rain happens 20 days after spreading, the culture doesn't have enough time to use its nutrients.

But these indications can be nuanced locally according to the environment, and the cultural system.

Among cultures, the regulation changes. In the following Figure 4, there are the different periods to spread, according to the cultures.

Figure 4 : Spreading periods according to the crops lands (*Chabalier, P. F., van de Kerchove, V., & al., 2019*)

Culture	Category 1: Manures and composts	Category 2: Slurries and droppings	Categorie 3: Minerals fertilizers
Perennial wasteland	Prohibed		
Vegetable lands	To precise locally	Limited for sanitary reasons	To precise locally
Sugar cane	During the sowing, and before ploughing, and after harvesting, without burying	After harvesting (from July to December)	
Meadows	To precise locally	After harvesting (every six weeks on average, the whole year)	
Orchards	During sowing, in the holes, or before ploughing	According to species : during the flowering, the fruit-setting, and after harvesting.	

1.5. Pig slurry and effect on the soil

The pig slurry composition impacts the soil, by its N P K composition, heavy metals, and many others elements. What impacts the slurry composition are several factors (*République Française, 1998*) :

The pig diet (*Canh, T. T., Aarnink, A. J. A & al., 1998*; Sørensen, P., 2023)
The genetic, with the correlation between the FCR (Feed Conversion Rate) and the RFI (Residual Feed Intake), what means fewer nutrients are let in the slurry (*Soleimani, T., & Gilbert, H., 2020*)
The environment (*Funderburke, D. W., & Seerley, R. W., 1990* ; O'Connell-Motherway, S., Lynch, P., & al., 1998)
The pig age, development stage ((*Chabalier, P. F., van de Kerchove, V., & al., 2019*)

In annexe 9, the slurry mass, volume, and N, P2O5, K2O emissions in the effluents are classified according to the development stage, on average (*LEVASSEUR, P., 2005*).
Generally, in a husbandry and fattening farm, all those different slurries are mixed, because all the different room pits drain in the same slurry tank.
Factually, pig slurries are every time mixed with cleaning waters. Those slurries are told « diluted », and their value is a little bit lower than pure ones (see Figure 5).

Figure 5: Pig slurry emitted per present sow, and composition

Slurry	Slurry volume per present sow (M3/year)	Slurry mass per present sow (Tonnes/year)	Slurry components (Kg/m3)		
			N	P2O5	K2O
Pure mixed slurry	**19.3**	**19.8**	**4.4**	**2.8**	**3.3**
Diluted mixed slurry	**21.05**	**21.5**	**3.5**	**2.2**	**2.9**

(*Chabalier, P. F., van de Kerchove, V., & al., 2019* ; *Chambre d'Agriculture de Bretagne, Chambre d'Agriculture des Pays de la Loire, 2014* ; *LEVASSEUR, P., BOYARD, C., VAUDELET, J. C., & al., 1999* ; *LEVASSEUR, P., 2005* ; *Chambre d'Agriculture de Bretagne, Chambre d'Agriculture des Pays de la Loire, 2014*).

The way to run the herd makes differences in slurry composition among pig herds. Those differences are in N, P and K composition, but also in the volume emitted. Hence, a herd with 28th-day weaning should be diluter (in N, P2O5, and K2O) than another one at 21st. Also, a farm that slaughters its pig fatteners at 175 days will get a more diluted one than another with the slaughter at 195 days.

Indeed, pig slurry composition and volume can differ among farms, because of their way to run their herd, and many other factors in the farm.

By other way, pig slurries have different effects according to the kind of soil where there are spread. There are several kinds of soils on the Reunion Island (*Mvad-Reunion, 2019; United States Department of Agriculture & Natural Resources Conservation Service Soils, n.d*.).

According to a study on three Reunionese soils (see their location in annexe 11 : *Doelsch, E., Masion, A., & al., 2009*), the impacts are different among the kind of soils.

Main soils used for agriculture are the following ones (Maps of the island soils in annexe 4):

Andic and perhydrate andic soils are soils made on young volcanic ash and have a lot of alumina silicate. Those soils have a high organic matter rate. Perhydrate ones have a lot of water inside, due to high porosity, that can keep water.
Andic brown soils are between andic and brown soils. They are old andic ones, in dry areas, and evolve slowly to become brown soil.
Brown soils, Laterite brown soils, and laterite soils are older, more evolved ones, done on old lava ways, and generally in less humid areas than andic soils. Those soils are brown or red due to metallic oxides inside.
Laterite soils are the oldest on the island. They were stripped and covered several times.
Laterite brown soils are between brown and laterite soils.
Vertic soils in the West dry area get the particularity to get a swelling clay. Their profile is, in columns, due to clay retractation during drying.

The soils specifications and fertility (based on sugar cane) are also different according to the kind of soil. Annexe 10 regroups those main particularities for each kind of evocated soil.

<u>The Impacts of pig slurry on the soils:</u>

Indeed, Reunion Island has volcanic soils, but with some differences according to the place.

There are not a lot of soil research and data about Reunionese soils, and some of these studies are in the south of the island. The general soil tendencies are appreciated, and differences picked up differences when there is one (see annexe 1 and 11 *Doelsch, E., Masion, A., & al., 2009).*

According to *Rogério Lourenzi, C., Alberto Ceretta, C., & al., 2011; Goyal, S., Sakamoto, K., & al., 2006*, **the soil organic matter** increases few times after pig slurry spreading, by the fact that huge carbon quantities are spread in lands. But this is also known in the "winter season", it decreases, because a part of this organic matter is mineralised, and another is used by the culture.

Pig slurry contains **mineral matter**, thus heavy metals, like Cu, Zn, Mn in high quantities sometimes. Hence, spread pig slurry adds those minerals in fields (*Rogério Lourenzi, C., Alberto Ceretta, C., & al., 2011; Mattias, J. L., Ceretta, C. A., & al., 2010*).

Concerning **the physical characteristics,** the soil pH doesn't change that much with pig slurry spreading (*Mattias, J. L., Ceretta, C. A., & al., 2010*). Nevertheless, the Ca, Mg, and $CO3^{2}$- slurry composition can sometimes change the pH of the soil, to bring it from an acid toward a more neutral one (*L'Herroux, L., LeRoux, S. & al., 1997*).

As explained before, pig slurry brings **elements** in the soil, and among its N, P, K, which are counted by total N, P2O5, and K2O. The doses in the soil depend on the brought quantity, the soil's organic matter activity, and cultural consumption.

1.6. Inputs in the fields

As previously stated, in the spreading plan part, the provided fertilizer in a plot must be thought and calculated with 4 factors (*Chambre d'agriculture de la Réunion, CIRAD, & al., 2018*):

The characteristics of the culture
All cultures have different needs in N, P2O5, K2O, ashes (Ca, Mn, S…), and physical soil environment (pH, …).

The hoped yield
Depending on the hoped yield, the incomed N, P2O5, K2O must increase with the yield. Thereby, the hoped yield is calculated with the average yield of the 5 last years for the culture on the whole farm, except the best and the worst ones (*Chambre d'Agriculture de Normandie, n.d.*).

The kind of soil
There are two kinds of soils on the island for fertilizer spreading (*Chambre d'agriculture de la Réunion, CIRAD, & al., 2018*):

The high P fixator soils.
Andic soils on the Reunion Island have the particularity to have a high P fixation. Indeed, spreading must highly major in P incomes in the plot for the culture: To get a nice culture, the P income must be doubled than what needs the culture on the potential spread area.

The low P fixator soils.
For other soils on the island, a lower part of the P is fixated. Hence, the P must major in the same way, but the cultural needs must only get multiplicated by 1.2.

The kind of spread organic matter:

All the organic matters can't get spread on all cultures. Urban sludges or row slurries on vegetable fields can't get spread on vegetable land, because of some pathogen agents in the matter that could contaminate consumers (*Chambre d'Agriculture d'Occitanie, 2013*). Indeed, pig slurry is spread on sugar cane, meadows, and orchards lands on the island.

Moreover, organic matters express their N, P, K values in N, P2O5, K2O, and don't contain all those same compositions and ashes quantities. As previously told for the pig slurry, all kinds of spread organic matter have different compositions in those elements, and all produced ones have differences also. Hence, it is strongly advised to do samples to analyse the spread matter before its

spreading, to precisely know the N, P, K composition, and adjust the organic matter mass spread on the field.

Until recently, only Nitrogen was really controlled in spreading plans on the Reunion Island. But the non-pollution obligation toward farmers requires that any element pollute the environment. Since 2019, the Reunion DAAF inspector is aware of the plant's needs, the pollutions, and controls N, P, and K.

To know how much organic matter to spread in the fields, for a few years, Reunionese farmers have to be aware to take into account the efficient N, P2O5, and K2O contained in the matter. Indeed, to avoid pollution, the regulation requires that each of N, P2O5 and K2O contained in the organic manure are taken into account, which means that when the first element (for instance P), is enough spread on the potential spreading area, for the culture in the field, the maximum income in the field is defined. Hence, one of those three elements can be let like a deficiency or filled with chemical fertilizers, in the respect of that maximum N, P2O5, K2O doses allowed (*Chabalier, P. F., van de Kerchove, V., & al., 2019)*.

1.7. Interesting pig slurry solutions

There are a lot of different ways to less spread pig slurry, and thus N, P205, K2O, on a spreading plan with the same number of pigs. For that, several categories of slurry treatments are done, according to their aims, effects. Moreover, several treatments can be done on the same slurry, to get an organic spreadable product (*M.Pilaral, B., Berta, B., & al., 2015*). For this reason, only treatments alone will be described.

But some specificities in the Island must be considered:

There is **no pig slurry processing company on the island**, which means that proposed equipment doesn't need specific monitoring.
As previously told, **the final product(s) must be usable** by a maximum of Réunionese farmers, which means it can be spread by hand.
Reunionese **pig buildings have rustic technologies**, buildings are simple.

<u>Exporting, selling pig slurry as a product</u>

In this category are regrouped two kinds of technics:

The composting

There are several ways to make compost with pig slurry, mainly with straw and green wastes.
But for the straw composting, there is not enough straw on the island today, and a part of the consuming straw on the island is imported (the local one is the sugar cane straw). The ruminant lines already miss straw, and that is expansive (*ARP, 2016*; *CIRAD, 2020*). For that, a focus on green waste composting, and broiler manure composting is done. Generally, compost platforms must be far from sensitive environmental areas.

- Pig slurry composting with green wastes

This treatment lengths 127 days according to (*BINOT, I., 2014*).

Strengths	Weaknesses
• That is a cheap way to process pig slurry (*Huang, G. F., Fang, M., & al., 2001*). • Pig slurry is fully used in the processing. • This product has qualities in vegetable productions, after hygienization. (*Ozores-Hampton, M., 2017*)	• Green waste incomes need logistics, and in an important quantity. For instance, 10m3 of pig slurry need 16 to 20 m3 of green waste in this Wallisian study (*BINOT, I., 2014*). • Processing slurry-like that requires place. Processing 5 m3 of pig slurry require: o To store 15 m3 of green waste o A platform of 100 m² (10 m X 10m) o To store the slurry o A place to work: to drive tractors to aerate the heap, to grind green wastes, …

- Pig slurry composting with poultry manure

This technic is not well known yet, but farmers are running experiments on the island and could get interesting results. The first results show that the processing length is around 2 months.

Strengths	Weaknesses
• That is a cheap way to process pig slurry • Two livestock effluents are fully used in the processing • It could be practical for farms with both productions (*Chabalier, P. F., van de Kerchove, V., & al., 2019*). • This product is usable in vegetable productions, after hygienization.	• It needs broilers manure, and it could be hard to get if the farmer hasn't, and must look for that. • It presents close weaknesses to compost with green wastes, because for 127 tonnes of pig slurry, 14 tonnes of poultry manure are required (broiler in this case), and 175 green waste tonnes. • The total area requires around 750 m² for 127 tonnes of treated pig slurry. • Thereby, this way to process manure needs place and logistic. (*Chambre d'Agriculture de la Réunion, FRCA Réunion, & al., 2021*).

The bio-digester

Bio-digestion is an anaerobic phenomenon where a microbiological flora follows several reactions to transform organic matters in biogas. The main one is methane (CH4) (45 to 75% by volume), and carbon dioxide (CO2). A lot of different organic wastes can be mixed to get gas but needs to be equilibrated to well produce methane.

By another way, Reunion Island had 86.2% of its energy from fossil fuels in 2017, and 13.8% from renewable ones. It means that a lot are imported and that a market for local energy could interest the energy suppliers on the island.

Strengths	Weaknesses
• It permits to sell several products from one activity: solid and liquid digestate; biogas, and even electricity. (*Chambres-Agriculture, n.d.)*	• The investment is expensive, and the management, skills to get to run it are complicated and wide. (*Solomie, A., Miranda, P. M., & al., 2009*). • A lot of security constraints are required with the gas production, and distance to other buildings also. (*Ministère de l'agriculture et de la pêche & INERIS., n.d.*). • This treatment is like composting for the required area: it needs a place for the treatment, but also the several mixed matters storage in the bio-digester. • Digestate from bio-digestion can't get spread raw on consumable vegetable lands (*Chambre d'Agriculture de Normandie, 2021*).

<u>The optimisation of pig slurry management, with a solid, and a liquid part</u>

Those ways to treat pig slurry don't permit to spread their products directly on vegetable lands: The dry part and the liquid one aren't exempt from pathogens agents. Those products have to be managed with.

Indeed, those treatments are whether used to spread or export dry matter (the richest one) to croplands, whether used to treat raw pig slurry before another treatment in a processing protocol, or used after another treatment, to separate phases of a product.

Heavy metals can be in big quantity among treated slurries and may cause environmental issues in some cases.

The static, vibrating, and centrifugal screening

Those treatments are used as pre-treatments as well, before composting for instance (*M.Pilaral, B., Berta,& al., 2015* ; *Levasseur, P., 2004* ; Watabe, M. C. J., Rao, J. R. & al., 2003).

Strengths	Weaknesses
• Static technology is the simplest one: slurry is pumping to the separator, liquid phase flows through the sieve, the solid one is retained on and removed by gravity • With vibrating one, there are fewer risks of clogging, with vibrations. • A tank is required to keep the liquid part and a platform for the solid one. Their sizes are according to the separation effectivity, and the treated volume.	• The solid part looks more like sludge than a dry matter. The solid part in the slurry mustn't be higher than 6%. • Centrifugal screening needs maintenance every 1000 hours. • The solid phase can't be spread on vegetables because there are too many pathogen agents inside.

The screw press

The most popular configuration is the screw press in which slurry is transported in a cylindrical sieve by screw. The liquid phase go through the screen, is kept in a container near the screen, and at the end of the axle, the solid part is pressed on a plate. Hence, the cake has a high dry matter percentage (*M.Pilaral, B., Berta,& al., 2015 ; Levasseur, P., 2004).*

Strengths	**Weaknesses**
• The dry part is around 25 % dry matter, which is quite dry. • A tank is required to keep the liquid part and a platform for the solid one. Their sizes are according to the separation effectivity, and the treated volume.	• The liquid part is higher than 2% of dry matter, which is consequent, and should be treated also. • The solid phase can't get spread on vegetables, because there are too many pathogen agents inside.

The micro & nano-filtration and reverse osmosis

Strengths	**Weaknesses**
• There is a real separation, the solid part is from 25 to 40% dry matter, and the liquid part is a real pure water, that can be used as cleaning water. Furthermore, the retention rate of fertilizing elements and dissolved salts, like K, ammoniacal N and P. It is more concentrated than in a retentate with a liquid texture. • A tank is required to keep the liquid part and a platform for the solid one. Their sizes are according to the separation effectivity, and the treated volume (*Kertész, S. Z., Beszédes, S. & al., 2003*).	• Those advanced technologies are quite expansive. • The solid phase can't be spread on vegetables, because those filtrations keep pathogen agents in the solid phase, to clean water. (*Singh, R., Bhadouria, R. & al., 2020)*

<u>Reorganisation of spreading plans, for better absorption of pig slurry in fields, and more practicality to farmers.</u>

Strengths	**Weaknesses**
• That is the cheapest way to manage, and maybe a nice one to add to other solutions	• Farmers have to negotiate together, find an arrangement in a big group, maybe to accept to spread fields which aren't their ones, and get spread on their fields by a neighbour pig farmer.

For farmers far away from their spreading fields, and/or who have not enough spreading areas, and/or who spread on plant production not adapted for them (little slurry tank, and big part of their spreading plan with sugar cane), to reorganise pig slurry spreading fields can be interesting. It

consists of reorganising spreading fields on a delimitated area, or to reorganise spreading plans of pig farmers with plant growers who have the fields. This reorganisation aims to work on spreading plans with close plots from the pig farms, adapted cultures with the slurry storage capacity of the farm (For instance, meadows can get spread the whole year, every 6 weeks between two hay harvests, and sugar cane commonly two time per year, between July and December, what needs a bigger slurry tank).

This solution can also be used with other ones, for instance, to spread liquid phases with still N, P, K elements inside, or with other arrangements (*Paillat, J. M., & Guerrin, F., 2011*).

Several possibilities

Of course, several treatments can be done to well valorise pig slurry. For instance, phases separation with composting permits farmers to spread the liquid part on their fields, and to export the dry part from their farm, with the composting and the compost sold.

1.8. Problem definition

The previous parts inform about the context of the island, the French regulation, and technical skills about the pig slurry, the slurry spreading on the island.

Indeed, at Grand-Îlet, Salazie (in the north of Reunion island), farmers already had this problem several years ago and decided to build a treatment place. Today, this place has standards respect problems and is stopped. Pig farmers from Grand-Îlet can't spread enough slurry in their spreading fields with the regulations. This condition will surely close farms in this area of the island. By another way, the Réunionese pork line doesn't want to lose more pig farmers (*LINFO.re., 2021; LINFO.re. 2021 b*). For a few months, pig advisors of the CPPR are faced with those kinds of problems on the south of the island.

To understand the farmer's situation about this topic, and to know their technical limits to respect the law, this research had to be done to find adapted and feasible solutions.

What isn't known yet for this issue are:

The main pig slurry **management issue**
The **solutions** reflected, thought by pig farmers.
The **feasible technical solutions** to get a lasting situation for pig farms, the CPPR, and the local pork line.

Consequently, the main question leading the study is:

How to feasibly resolve the issue of pig slurry management of south Reunionese pig farmers?

To answer this question, three other sub-questions have to be asked:

What is the Reunionese pig farm typology?
What are the issues of pig slurry management in the south of Reunion Island?
What solutions could be done to resolve these issues?

The required knowledge to know the Reunionese pig farm typology are the pig farm sizes, the herd management, and other farms activities.

The required knowledge to know the issues of pig slurry management are the spreading plan composition (areas and N, P2O5, K2O annual absorption), the thought and reflections about the general situation, the own one from local pig farmers, the slurry produced per farm (in volume and N, P2O5, K2O composition), and the volume of the slurry storage per farm (room pits and slurry tanks). Moreover, farmers practices should be useful to explain problem roots.

The required knowledge to get solutions to resolve slurry issues are knowing the pig farm slurry issues, the thought and reflected solutions by pig farmers

This study has the aim to make an inventory of south Réunionese pig farms about their slurry management and to find feasible solutions for pig farms with problems about this. Indeed, this global issue for the local pork line is carried by pig producers today. The CPPR wants to help them to organise solutions, because this cooperative is the link between farmers, the rest of the pork line, and each one wants to keep employees and production on the island. Thereby, this study is intended by pig farmers and the CPPR, because some of them could stop their pig activity in a few years with this slurry issue. This thesis is firstly destined to all pig farmers from the south of the Re union island, the CPPR cooperative, then to organisations concerned by this issue on the island, and finally to other pig farmers and organizations from somewhere else. It could also be interesting for people who work in slurry equipment (sellers, developers, makers), and for potential futures entrepreneurs, who would like to launch a slurry treatment service. The next parts of this research are a material and methods, to describe the context of the research, what is researched or not, how the research is run, the planning of the research, with the timelines. Then, results are shown, explained, and followed by the discussion, to place results in perspective to the research context, conditions. Finally, Conclusions and recommendations close the study to clarify the research.

Chapter 2: Material and methods

To answer the main question “How to feasibly resolve the issue of pig slurry management of south Reunionese pig farmers?”, CPPR pig farmers were questioned, and their pig slurry storages measured, in the townships of Les Avirons, L’Etang-Salé, Saint Louis, Entre-Deux, Le Tampon, Saint Pierre, Petite-Île, and Saint-Joseph (Réunionese Townships map in annexe 6), with questions and asked data in annexe 2. The interviews, and measures were done from September 21st 2021 to December 15th 2021.

Then, collected data were processed to answer the three asked sub-questions, with several researched results.

Concerning the Reunionese pig farm typology, were researched:

The farm’s percentages of sow group number per farm.
The farm’s percentages of sow number per group per farm
The farm weaning age percentages
And **the farm’s percentage with other production(s)**, and the farm percentages among diversified ones for each main production.

For this, for each farm considered in the research, answers from questions in annexe 2 in connection with researched percentages were processed to get farm percentages.

Concerning the issues of pig slurry management:

The answer to the following questions (also asked in annexe 2) was processed to get farm percentages:

What do you think about the **pig slurry management** on the reunion island?
What do you think about **your spreading plan**?
Do you have any **issues** with your farm? And in **the future**?

Collected data in annexe 2 are used to get:
The spreading plan composition (areas and crops), and N, P2O5, K2O composition
The room pits and slurry tank capacity volumes

Then, estimations are done to get important and hardly estimated or known data, like:

The emitted slurry volume per year per farm (according to their practices, herd management, performances), and its **N, P2O5, K2O composition.**
The absorbed N, P2O5, K2O in each spreading plan reserved to the pig farming, **and their annual spreading frequencies**, their volumes.
The pig slurry storage management, with the room pits, emptying, the slurry tank filling and emptying (with slurry volumes).

Finally, those estimated and collected data are used to get the following results:

The percentages of pig **farms with a valid spreading plan**

The percentages of **farm problems about slurry storage, spreading plan, slurry produced and management, according to their township**.

The proportions of **pig farmers without problems in their slurry management**, according to the kind of slurry management.

Concerning the feasible solutions to the slurry management:

Like for the first sub-question, answers to the following questions are taken into account to get answers percentages:

What **solutions** could be done for this (the **evocated pig slurry management problem(s)**)?
What could be **your ideal spreading plan**?
What **solutions** for that (**to improve your spreading plan**)?
Have you ever **thought to process your pig slurry**?
Should you be interested **to valorise your effluents as a sold product**?
What should be **your processing technical choice?**

Then, the **number of pig farms with slurry management problems**, and **volunteer farmers in the surrounding areas** will be considered to **propose feasible solutions**, as **for Farm technical possibilities**, and **technical possibilities in the area.**

This last qualitative analysis part shall be **based on a Reunionese map**, to watch farms localisations, and what is around those.

Chapter 3: Results

Data are collected from 48 farms from the 65 visited on the island. Thus, several farms were not in the researched geographical area, and some others had specificities. Most actual ones were big pig building restoration works, extensions, and substantial herd removal. Those farms were excluded because measures during the visit were uncertain, provisional, or with a large, estimated part by the farmer. Only one farm makes an exception (GAEC Kerbel) and is located approximately 85 m to the western border of the research.

First, to well understand the pig slurry issue on the island, and to propose adapted solutions to pig farms, it is important to know what kind of pig farms work with the CPPR. Thus, a farm typology is following.

The Reunionese pig farm typology:

Thereby, figures 6, 7, and 8 below show the most common way to run pig husbandry is 7 groups, with 26% run like this. Also, the most common herd size is between 36 to 45 present sows, and no one farm in this study has between 56 and 65 present sows. Then, the largest part of the farms in this research weans their piglets at 28th days old.

Figure 6: Proportions of herd managements

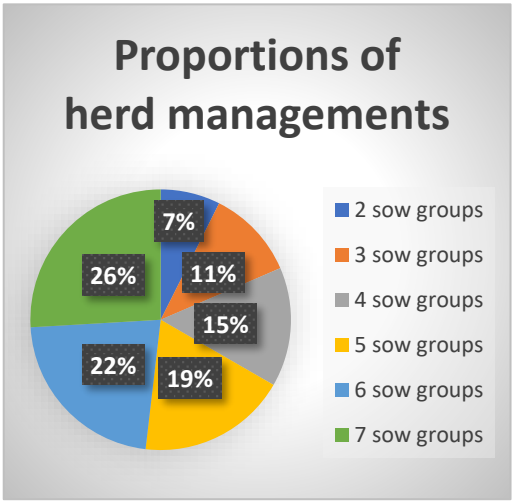


Figure 7: Number of present sows in the farms

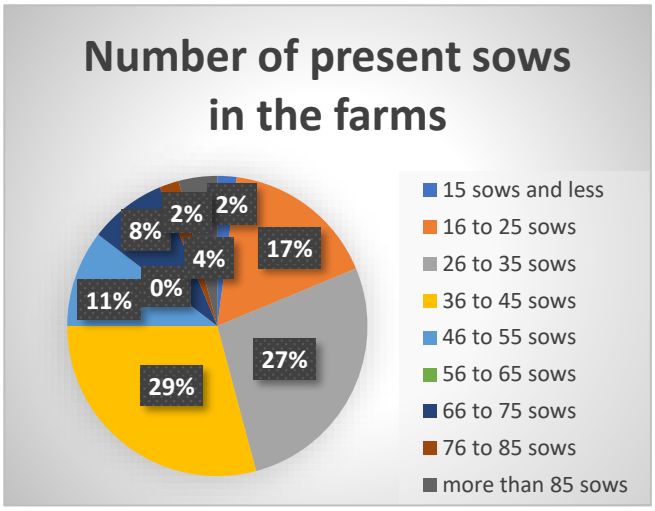
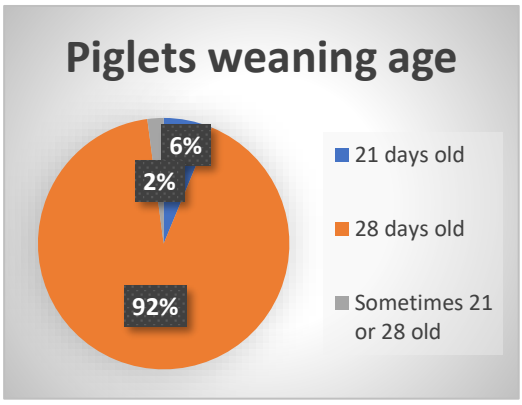
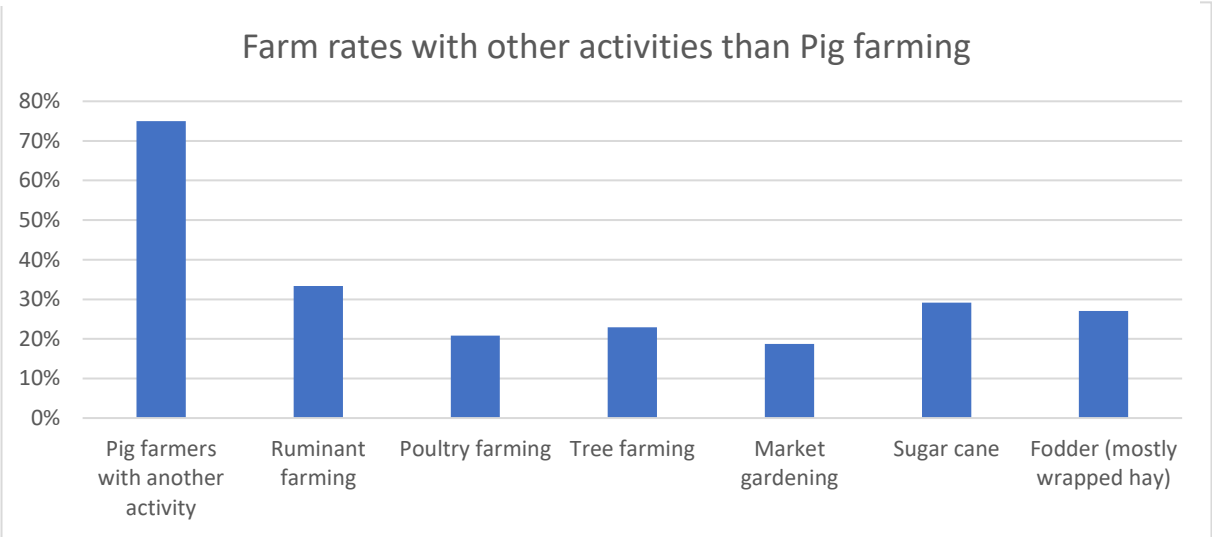


Figure 8: Piglets weaning age



Some Reunionese pig farms have other activities than pig farming (see figure 9). Thus, 75% of studied farms have other activities than pig farming. The main other productions done in those farms are ruminants, with 33% of them, 29% have sugarcane, and 27% produce fodder, mainly sold to dairy farmers on the Island.

Figure 9: Farms rates with other activities than pig Farming



Then, with the previous figures known, the pig farm typology done, the issues of pig slurry management should be more understandable, and contextualizable.

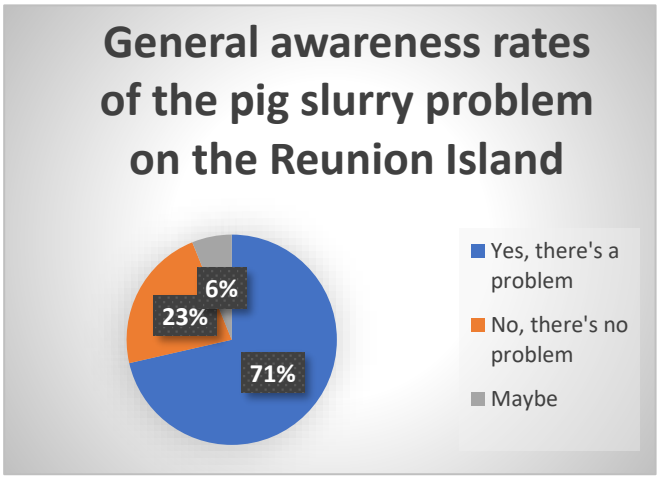
The issues of pig slurry management:

First, to get an idea about the pig farmers awareness of the pig slurry management, and their vision about the situation, questions were asked.

What do you think about the **pig slurry management** on Reunion Island?

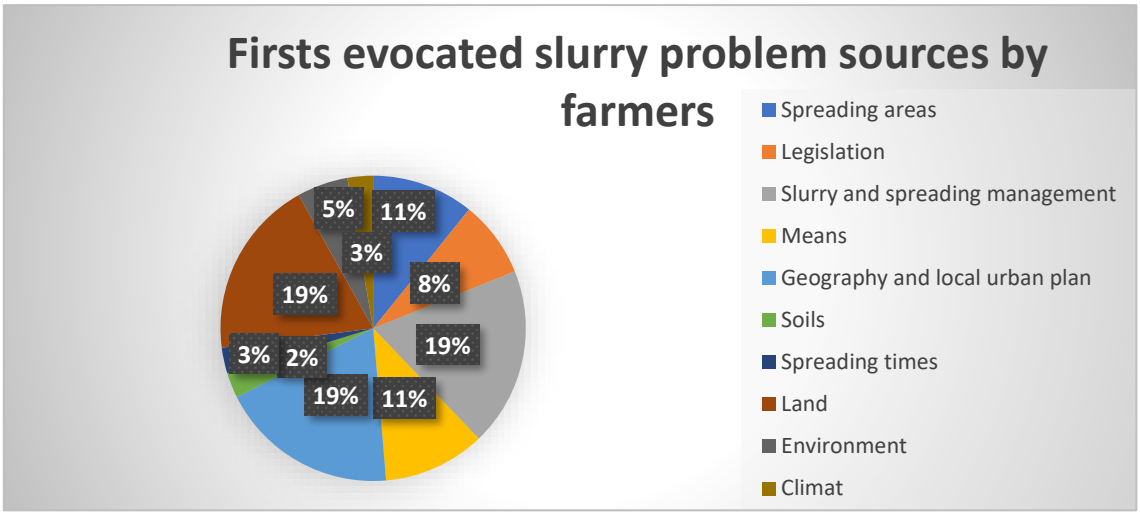
To this question, 71% of pig farmers evocated a real problem in their answer, and 6 % an eventual one, as shown in figure 10 below.

Figure 10: General awareness rates of the pig slurry problem on the Reunion Island *(personal source)*



Farmers who told about a problem were inspirited to develop their answers and to tell the sources of the problems. The firsts evocated ones per farmer were about the lands, the slurry and spreading management, the geography and the urban plan, as shown in figure 11 below.

Figure 11: Firsts evocated slurry problem sources by farmers *(personal source)*

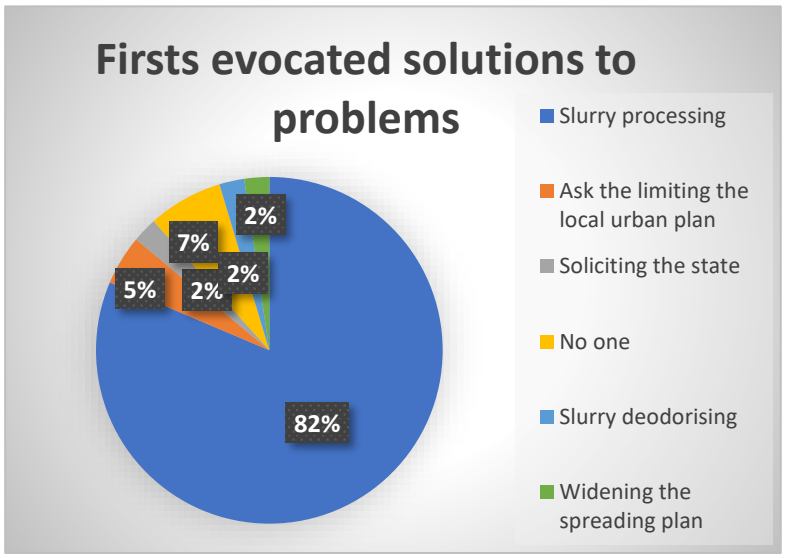


Then, those same farmers had to answer the question:

What **solutions** could be done for this?

And the widest part of them talked about slurry processing (see figure 12).

Figure 12: Firsts evocated solutions to problems *(personal source)*



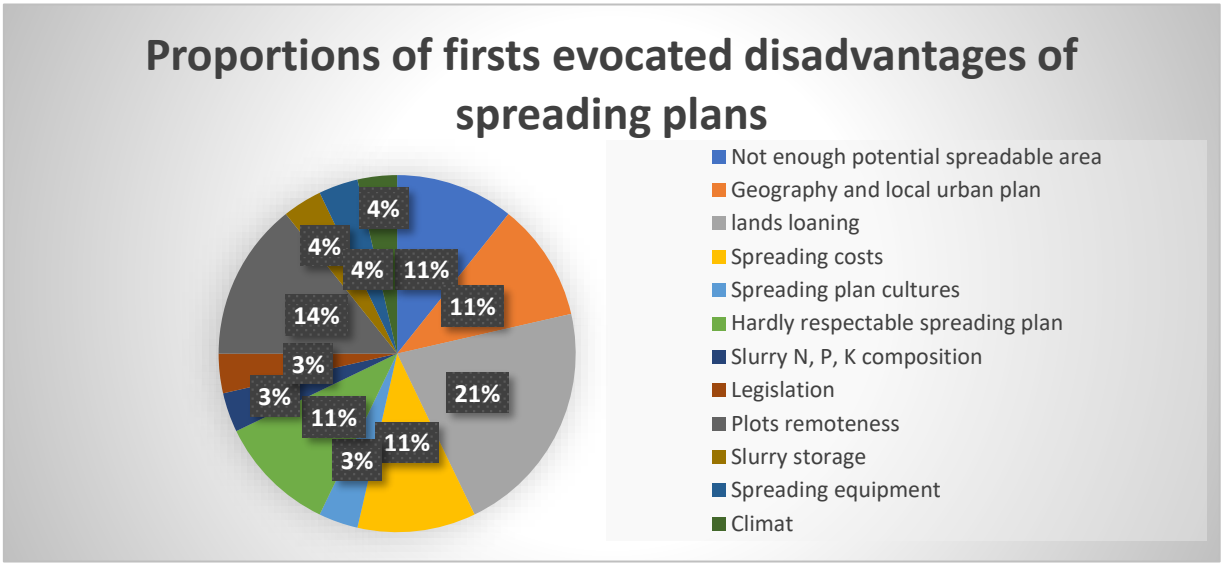
Then, the research protocol during my visits was about the farmers spreading plans. Hence, were asked the following questions:

What do you think about **your spreading plan**?

On 48 Reunionese pig farmers questioned, 31 of them spoke about disadvantages of their spreading plan, even if 32 farmers were pretty satisfied.

The told disadvantages are shown in the following figure 13.

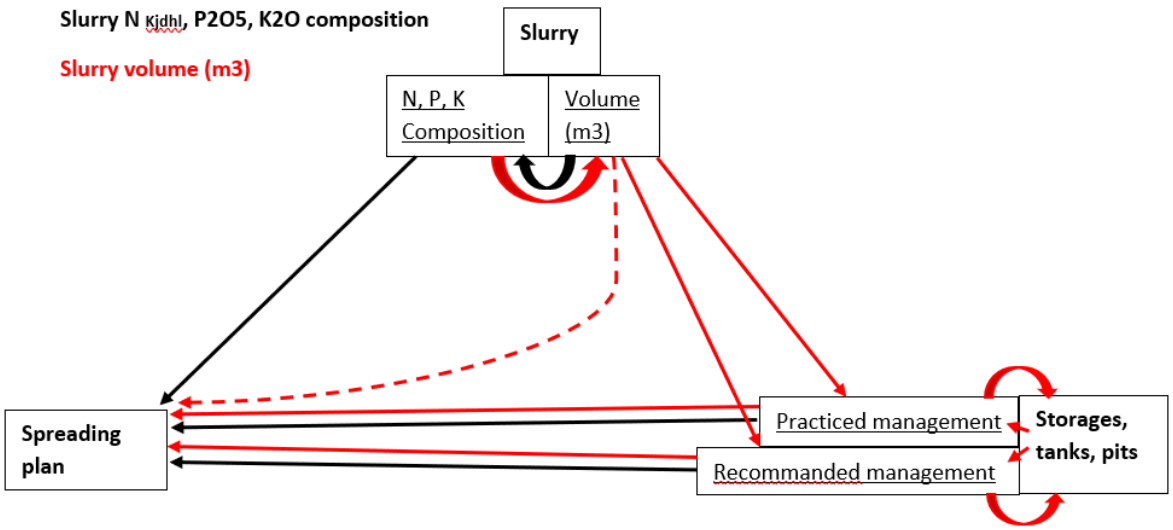
Figure 13: Proportions of firsts evocated disadvantages of spreading plans *(personal source)*



Then, with the farmer's thoughts and reflections known, measures and estimations were used to get results and try to know the problem sources.

While researching the problem roots, relations were found among the slurry emissions, the slurry storage, management, and the spreading plan. This relation is shown in figure 14 below.

Figure 14: Schema of the pig slurry management *(personal source)*



Hence, getting a basis to define the problem requires knowing:

The **slurry volume emitted per year**, and its N, P2O5, K2O, composition, what can be known with the herd management and performances.
The **slurry storage**, with room pits, tanks, and their management, can be known with volume measurements and questions to farmers.
The **spreading plan** must be read and discussed with farmers. Other livestock productions and their effluent emissions must be taken into account. The main important things in this document are the N, P2O5, K2O absorbed by the total area per year, and how many spreading times can be done per year in a plot, according to vegetal productions.

For each farm, the spreading plan, slurry pits, tanks volumes (annexe 2) and slurry emissions estimations (annexe 17) were taken into account to calculate the spreading plan proportions, and the not updated ones, like in figure 15 below.

Figure 15: Pig farms with a valid spreading plan *(personal source)*

Farms without spreading plan	*6%*
Farms with an undersized spreading plan according to their herd	*27%*
Farms with a valid and respectable spreading plan	*67%*

Spreading plans to update because of their old redaction (it doesn't calculate P and K) or their non-existence	*40%*

To make the previous figure 15, was used the N, P2O5 and K2O emitted per farm, and the N, P2O5 and K2O absorbable of the spreading plan reserved to the pig slurry.

Getting more precisions, and more advanced results than the spreading plan, estimations were done between each schema bases, to know if problems occur in each schema relation.

These estimation results are shown in the following figure 16.

Figure 16: Proportions of pig farmers without problems according to managements between two steps *(personal source)*

From	Recommended slurry management		Practised slurry management		Slurry produced			
To	**Spreading plan**						**Room pits, tanks, storages**	
Kind of farms	Farms with enough slurry storage to keep it when all spreading have to be done	Does the slurry volume emitted per year is absorbable in N, P2O5, K2O by the spreading plan? (Yes)	Farms with enough slurry storage to keep it when all spreading have to be done	Does the slurry volume emitted per year is absorbable in N, P2O5, K2O by the spreading plan? (Yes)	Farms with enough N, P2O5, K2O absorbable in the spreading plan to keep all the N, P2O5, K2O pig slurry emitted in a year.	Farms with an updated spreading plan	Farms that can store their pig slurry for 6 months with the recommended slurry management	Farms that can store their pig slurry for 6 months with the practised slurry management
Percentages	**31%**	**67%**	**29%**	**69%**	**67%**	**60%**	**10%**	**42%**

Results show also that not any farmers are exempt of current or potential problems.

Finally, to get an idea about the main township farm repartition in the study, and to maybe find areas with more problems than other ones close researched values than in the figure 16 were classified per townships. This is shown in figure 17.

Figure 17: Farm problems about slurry storage, spreading plan, slurry produced and management in their township *(personal source)*

Townships:	Farm number in each township	Farms with not efficient slurry storage when all spreading have to be done with a recommended management	Farms with a slurry volume emitted per year not absorbable by the spreading plan because of NPK with a recommended management	Farms with not efficient slurry storage when all spreading have to be done with a practised management	Farms with a slurry volume emitted per year not absorbable by the spreading plan because of NPK with a practised management	Farms with a spreading plan too small compared to the pig NPK emitted per year	Does the farm have an updated spreading plan?	Farms without enough slurry storage to store 6 months with a recommended slurry management	Farms without enough slurry storage to store 6 months with a practised slurry management
Le Tampon	4	2	2	2	2	2	0	4	2
Les Avirons	7	4	2	5	1	2	3	5	4
L'Etang salé	1	1	0	1	0	0	1	1	1
Petite-île	8	8	5	8	4	3	2	8	6
Saint Joseph	20	15	5	14	4	5	10	18	13
Saint Louis	6	3	1	3	2	3	2	6	2
Saint Pierre	2	0	1	1	2	1	1	1	0
Total farm number	48	33	16	34	15	16	19	43	28

Now, actual problems are known in the relations among the slurry produced, the slurry storage, management, and the spreading plan.

Hence, with those problems defined, it is possible to propose feasible solutions to those.

The feasible solutions to slurry management:

First, according to Figure 12 (Firsts evocated solutions to problems *(personal source)),* 82 % of questioned pig farmers who spoke about a slurry issue on the island (or 'maybe') firstly answered the slurry processing to the question 'What **solutions** could be done for this (the pig slurry issue(s))? '.

Thus, this popular solution shouldn't require time or big means to convince CPPR pig farmers to work with slurry place processing.

Then, questions about the slurry processing were asked, to know if farmers should be interested to do it and if they had already inquired about this.

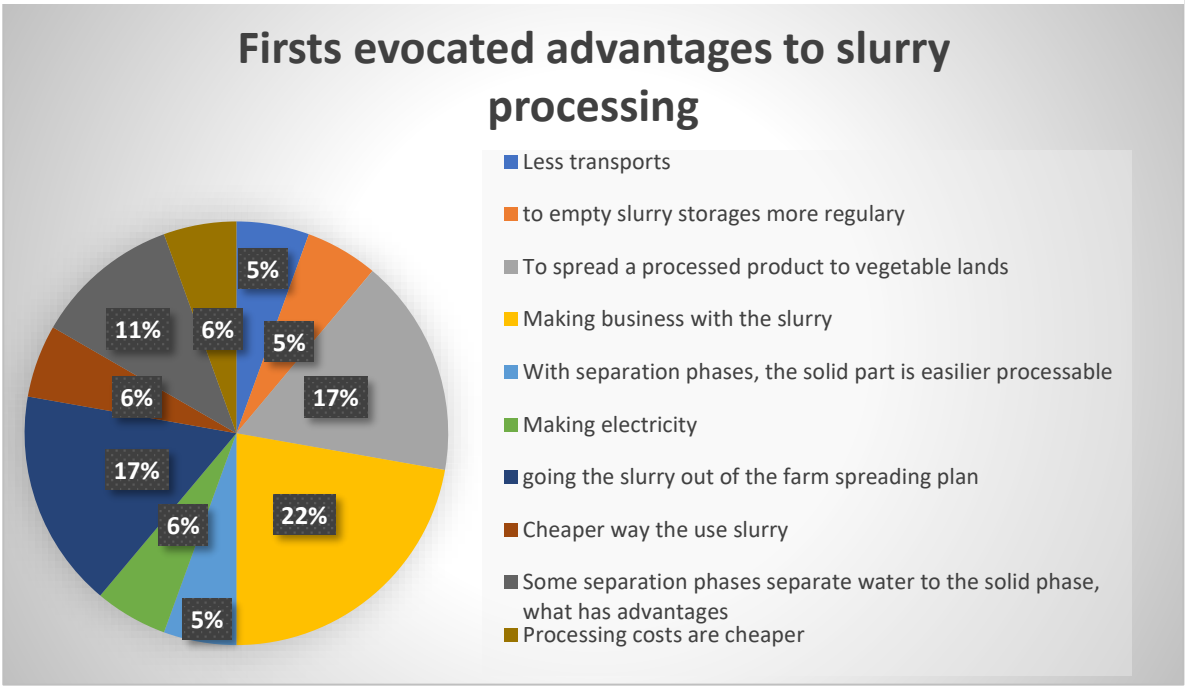
Have you ever thought **to process your pig slurry**?
Should you be interested to valorise **your effluents as a sold product**?
What should be **your processing technical choice?**

What appears to this topic is 67% of farmers are interested to process their slurry, 32 on 48 already thought to do it, and 44 on 48 would like to process their pig slurry regardless of the way to do it.

Getting more precisions, and to be sure to get reasonable answers, farmers were inspirited to quote slurry processing advantages.

The firsts evocated advantages with interested farmers are shown in the following figure 18.

Figure 18: First evocated advantages to slurry processing *(personal source)*



During those interviews, 10 farmers specified their preference to do slurry processing commonly or individually. 5 of them were convinced to do it by a common way, with other farmers or a company, and 5 others by an individual way.

According to the previous quoted results, a way to resolve the slurry issue on the island should be to propose to all farmers process their slurry regardless of the way to do it. Also, making a saleable product with it, and making a business with the brought slurry should interest them (figure 18). The CPPR wants to launch common places processing to do it, but with several conditions:

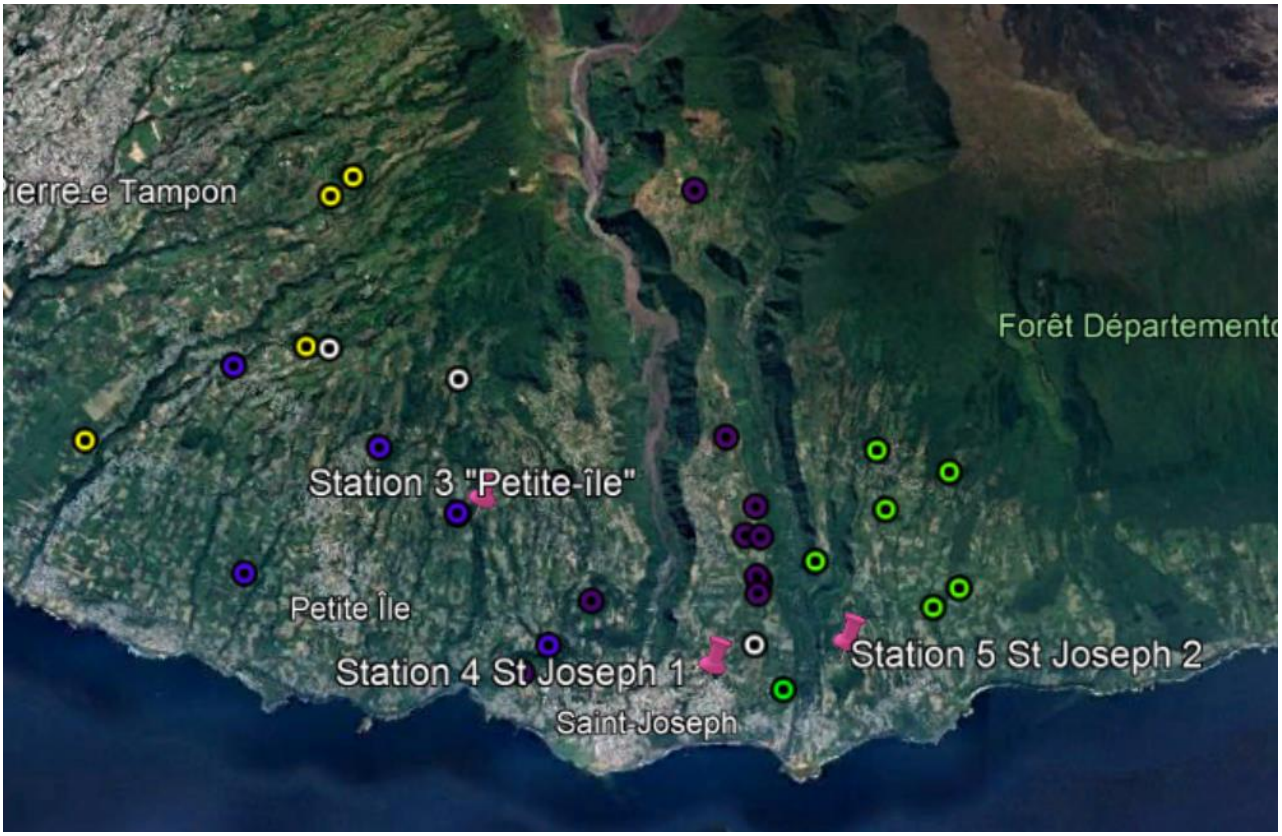
Farmers who should work with their slurry processing should **deliver all their pig slurry** to the place processing.
Each place processing should treat about **pig slurry 8000 m3**
A maximum of farms should **deliver their slurry by themselves.**

Then, according to the quoted conditions, to the farmers maximum distances to transport slurry, and questions asked in annexe 2, and with volunteer farmers, figures 19 and 20 below are the approximative locations of places processing on the map, and farms grouped to those.

Figure 19: Places processing map and their grouped farms 1st part.* *(personal source)*

**Places processing are marked with a pink pin and told 'Stations'.*
White points are uninterested farms to process their slurry
Red ones are farms that should be grouped to the 'Station 2 Avirons'.
Yellow ones are farms grouped to the 'Station 1 St Pierre'.

Figure 20: Places processing map and their grouped farms 2nd part**. *(personal source)*



***Places processing are marked with a pink pin and told 'Stations'.*
White points are uninterested farms to process their slurry.
Blue ones are farms that should be grouped to the 'Station 3 Petite-île'.
Violet ones are farms grouped to the 'Station 4 St Joseph 1.
Green ones are farms grouped to the 'Station 5 St Joseph 2.

Chapter 4: Discussion

This research has the purpose to define problem roots and finding feasible solutions to the pig slurry spreading in the Reunion Island.

Concerning the results, the Reunionese pig farm typology is important, to know what kind of farms are concerned in the research.

The Reunionese pig farm typology:

First, the archetypal Reunionese pig farm has a modest size, with a herd size between 36 and 45 present sows (*figure 7*), with 7 groups of productive sows (*figure 6*). 75% of those farms have other activity than pig farming, and the most common ones are Sugar cane, fodder growing, or ruminant farming (*figure 9*). It is quite common that farmers have employees, even when they only do pig farming.

This typology gives information about the Reunionese pig farming and should give useful ones to the following part.

The issues of pig slurry management:

71% of farmers think there is a problem with the slurry management on the island, according to *figure 10*. This proportion compared to the figures 16 and 17 numbers, and that all farms have current or potential problems shows that a part of farmers has slurry management problems or limits but didn't talk about that during the interviews.

The three most common firsts thought problem roots on the island are the lands, the geography and the local urban plan, then the slurry and spreading management (*figure 11*). "Lands" was a word used to regroup several problems: the N, P2O5 and K2O absorbable by the plots per year, the numbers of possible spreading per year, and the distance from the pig farm to the plots. The geography and local urban plan were problematic because of the distance imposed to the slurry spreading in the plots to natural areas (gullies, ponds…) and dwellings, but also with the residents from around the plot, who dislike the slurry spreading odour. Then, the spreading management was the third problem quoted, because a part of farmers is aware of its slurry management and know that their means don't allow them to manage it correctly.

Then the research part based, problems have roots in each schema basis shown in figure 16:

With the slurry production, only 25 farmers on 48 have an **approximative idea about the produced and spread slurry volume per year**. Other ones haven't any idea about their pig farm slurry production. On another way, 21 farmers supervise their water consumption. This is an important point because it can dilute the slurry and make a greater volume for the same animal number. To get an idea about the slurry volume and N, P2O5, K2O produced per year, estimations were done for each farm, according to their herd management and performances, based on research and theoretical data. Found results indicate that Reunionese farm managements make wealth and quantitative slurries (see annexe 3).

Concerning the slurry storage, with the tanks and room pits, an important part of the visited pig houses was built between 1975 and 1995. Those buildings were made with older legislation concerning slurry management and the environment. Therefore, 34 **farms haven't enough slurry storage to keep all their slurry when all their spreading must be done**, with practised slurry management. This number should be 33 farms if farmers managed their slurry in the recommended

way. Also, the slurry management has almost one way to be done per farm. To get something easier to study, this research takes into account two ways to manage it. The first one is the practised management, room pits are emptied in a tank when it is full, and with the recommended way, room pits are regularly emptied, at the end of each pig group, or a regular interval if the room pit isn't big enough to store all the slurry from a pig group. The room pits and tanks volume were measured and thus well known in this study. But the slurry management should be too complicated to take into account for each farm, in an excel estimation. Thus, I chose to explain both managements for each farm. Unexpected results were got for the slurry storage because a security volume is counted in-room pits and pits volumes (0,4 m under the gratings for room pits, and 0,25 m under the exit for slurry tanks).

Spreading plans also have their limits. Solely 67% are well sized to the annual estimated slurry production. Also, 40% have to be done or updated because they don't take into account the P and the K in the spreading. These unexpected results with the spreading plan were obtained because of limitations in the research methodology, because several farmers explained to me that a part of landowners doesn't want to sign agreements with livestock farmers for their manure or slurry spreading, because of administrative apprehension. Thus, some pig farmers have a part of their regular spreading which isn't declared or exceptionally spread their slurries in some lands. But the research methodology requires real sources, thus the official spreading plans were used in this study to get reliable results. Moreover, this is a good way to learn about the official spreading situation of pig farmers.

There are also problems in the relations between those bases:

First, there are problems in the relation between **slurry production and slurry storage.** As previously told, 34 farms haven't enough slurry storage to keep all their slurry when all their spreading must be done, with practised slurry management. This means the slurry storage isn't well sized to keep enough produced slurry. By another way, the CPPR advise farmers to get enough slurry storage to keep their slurry for 6 months. As shown in the results, practised management doesn't permit 28 farms to get enough slurry storage to do it, and 43 farms for a recommended management.

Then, the relationship issues between **the slurry storage and the spreading plan** are also shown by the 34 farms that haven't enough slurry storage to keep all their slurry when all their spreading must be done, with practised slurry management, and the 33 with a recommended management.

Finally, the relation between **the N, P2O5, K2O emitted per year per pig farm and the spreading plan** also includes problems, demonstrated with the 27% of studied farms that have an undersized spreading plan.

<u>The feasible solutions to slurry management:</u>

For 82% of farmers, the first quoted solution to the slurry management problem should be the slurry processing (*Figure 12*), with the following firsts quoted reasons, shown in *figure 18*: less transport (17%), to spread slurry (by a slurry-based product) to vegetable lands (17%), and making a business with slurry (22%). The CPPR already thought about this solution in the past. Some farmers in the administrative council listened to this feasible solution. Hence, it is possible that by discussions, a lot of farmers spoke about it together, and should be influenced like this.

Concerning the solutions to those slurry issues, a lot of solutions should be possible. The thought one proposed to pig farmers is to propose to all of them to process their slurry in places processing.

Well thought place processing should allow pig farmers to get out their slurry from their farm more regularly, thus, to respect their storage filling by an easier way. Moreover, this popular thought solution to farmers should permit a part of slurry N, P2O5, and K2O to get exited from the farm and spreading plan, which should be a real advantage for farmers.
If a solution like this one should get proposed, conditions should be fixed by the CPPR. The first one is farmers must deliver all their pig slurry to the slurry processing place. This first condition has the reason to taking less mediatic risks, because if a farmer who works with a place processing should do a pollution mistake, the CPPR image should be impacted, and the effort made to build a places processing also.
Secondly, the place should treat approximately 8000m3 per year. A reason for this is that 8000 m3 is a common size for slurry processing places, and in Reunion Island, there are not a lot of builders or sellers for this. Hence, having common buildings or equipment should shorten the delivery delay (from Europe), to keep the place processing. Fortunately, this is approximatively a volume produced in areas where most farmers can deliver their slurry by themselves.
Thirdly, as little as possible farms should use a transport service to deliver their slurry to the place (annexes 12 to 16), for a cheaper way to run the slurry processing place.

The aim should be to produce pig slurry-based products in those places processing, to sell them on the island. The main thought one is the compost because this known cheap and easy solution could fill a market demand from vegetable producers, with a more adapted product for them. Also, this product could get used by cane growers and meadow owners. But other solutions could get used, to answer other market demands.
More factually, this is evidence that a part of farmers will refuse to work their slurries like this. A part of them will carry on spreading their slurries in fields, for several reasons. If this solution should get applied by a part of farmers, it means that lands should have less “slurry pressure”, and last spreading plans should get modified to become bigger and absorb more N, P2O5, K2O from farms who still spread their slurries. Thus, this solution well applied should also carry a spreading plan reorganization.

For the methodology, several ways were used to get this study, with a running in a quantitative way, and another one in a qualitative way.

Concerning the Reunionese pig farm typology:

This part is fully qualitative. To get results from recorded asked questions, the recording tracks were listened to and classified among topics, general tendencies, and kinds of answers.

Then, percentages were done with those answers, to get the results.

Concerning the issues of pig slurry management:

The manner to get percentages to get the farmers thoughts and awareness about the pig slurry management (figures 10 to 13) was the same as the farm typology.

But the way to get quantitative results from obtained and estimated data were done by several steps, each one based on the schema shown in figure 14.

From the slurry spreading to the farm slurry storage, the reasoning has been done per room pit, according to the kind of room (Farrowing room, pregnant room, post-weaning, or fattening room). According to the farm herd management and performances, and the area, places available in buildings, pig numbers per room were distributed to get management as close as possible to the real

management. Concerning performances, except the weaning age and the slaughter age, the average was calculated with all the CPPR farm available performances. Thus, all farms without checked performances or performances below the average were calculated with the CPPR farms average. This way to do were chose because farms with low performances normally have the aim to improve it. If proposed solutions should be thought with low performances from the farm, it should be a problem when it will improve those and produce more slurry. Other farms miss some performances, and it should be damaged to don't take those into account in this study.
Then, the reasoning thought the management per slurry tank, and finally per farm.

In this same excel board, **managements** were elaborated, to estimate room pits and slurry tanks emptying and volume intervals. Those results were returned per farm to get measurable results. Then, percentages were done with all farms to get the presented results. In the same excel board, the filling length of each room pits and slurry tanks were estimated, and according to the management, gave the "Farms with enough N, P2O5, K2O absorbable in the spreading plan to keep all the N, P2O5, K2O pig slurry emitted in a year", and "Farms what can store its pig slurry 6 months with the recommended (or practised) slurry management" results.

From farm slurry storage and management to the spreading plan, interpretation work was done. Spreading plans are done for whole farms, and sometimes for several farms. But farms and livestock per farm are separated to determine from which livestock come from N, P2O5, and K2O.
Hence, to know the spreading plan reserved for the pig slurry, the following reasoning got done:
When spreading plans containing vegetable productions, all the N, P2O5 and K2O absorbed per vegetable productions were taken from the other livestock effluent to fill those lands.
Then, a ratio was done for the N, P2O5, and K2O residual to spread in the spreading plan, and the official N, P2O5, K2O emitted with the pig production from the studied farm (with the quantities written on the spreading plan), to get the N, P2O5, K2O percentage emitted by pigs.
The lowest percentage among N, P2O5, and K2O was kept as a limiting factor, to determine the part of N, P2O5, K2O in areas of spreading plan reserved to the farm pig production. Then, each vegetal production (except vegetables) gets this percentage to their area reserved for pig slurry.
Results were N, P2O5, and K2O reserved to pig slurry from each vegetal production.
According to the number of possible spreading per year, several N, P2O5, K2O can get spread to those vegetal areas, and are converted to slurry volume (m3), according to the estimated slurry N, P2O5 and K2O wealth.
This last result, linked to the slurry storage volumes and management, define the "Farms with enough slurry storage to keep it when all spreading has to be done" results.

Finally, **the estimated N, P2O5 and K2O pig slurry produced per farm were compared to the absorption of the possible land** gave the "Farms with enough N, P2O5, K2O absorbable in the spreading plan to keep all the N, P2O5, K2O pig slurry emitted in a year" and the *figure 15* results.

"**Does the spreading plan updated?**" was checked with the presence of P2O5 and K2O in the spreading plan forestations.

<u>Concerning the feasible solutions to the slurry management:</u>

Regarding the qualitative part of the map creation, the two IT tools used were Google earth pro and Géoportail.
Google earth pro was useful to create a map from farms GPS coordinates. During interviews, I asked farmers what distance they should accept to travel to deliver their slurry to a place treatment. With the told distance, I save the Google earth pro map to load it to Géoportail. Géoportail is a French public map service, with quite elaborated tools to use with maps. The useful one for me in this study

was the isochronal distance function, within from a point on a map, it is gettable a determinate perimeter by road. According to the crossed perimeters, I chose the best potential place to build places processing. It requires sometimes to make compromises, to get 8000 m3 slurry to treat per place processing, and some farms are a little bit further away than expected.
The “Does the farmer should be interested in a transport service?” result was defined with a 0,5 rounded upper of farmers maximum quoted distances, and a two Km distance tolerance between the rounded distance and the effective distance, except for farmers who told me they can’t move their slurry.

More generally in the study:

Several problems happened during the research. At the beginning, the visits were more complete, to collect more farm data. But visits were too long, and I asked the CPPR to shorten the data list to collect, to get the list shown in annexe *2.* Then, the time planned to treat and interpret collected data was too short. The data treatment required a long time and delay the research, and more time shall be planned for the next research like this one. The rest of the research happened as planned.

Concerning the number of data collected, the CPPR asked to get a maximum of farms in this study. Because of the limits of research in time and place, a negotiation to consider fewer farms in this study was done, to get time enough to treat data. Hence, with 48 farms taken into account, the farm number is efficient for this study. Unfortunately, farms haven’t a lot of data, the slurry emitted per farm had to be estimated, and the slurries management in spreading plans and storages had to get partly estimated, with concretes bases.

Chapter 5: Conclusions and recommendations

This research has the aims to research and understands the South Reunionese pig slurry issue, and to find a feasible solution to problems met.

Data have been taken from September 27th to December 15th 2021, in south Reunionese townships. An important part of those were questions to pig farmers, about their practices concerning the herd and slurry management, what they wish to do in the future and their vision about slurry management. Another part was building measures, to get slurry storage volumes, administrative data with their spreading plans, and estimation for their technical slurry management, and their slurry production per year.

Thus, pig slurry management in Reunion Island is an important topic for a few years, because 71% of questioned farmers evocated a pig slurry management problem on the island, and because of several problems since few months, evocated in the local media.

The 48 Reunionese pig farms studied in this research work with the CPPR. They are quite small, most of the studied farms have between 36 and 45 present sows, against 228 ones in the French metropolitan territory.

The slurry management is based on three bases: the pig slurry production, the slurry storage (and its management), and the spreading plan. The Reunionese pig slurry problems occur across those three bases, and even in their relations. Hence, solely 25 farmers on 48 have an idea about their annual slurry production. Concerning the slurry storage and management, 34 farms haven't enough slurry storage to keep all their slurry when all their spreading must be done, with practised slurry management, and 33 farms if farmers managed their slurry by the recommended way. 67% of them have a spreading plan that can absorb enough N, P2O5 and K2O per year, compared to the slurry produced.

A feasible and popular solution among Reunionese pig farmers who think there is a problem with pig slurry should be to propose to all pig farmers to process all their slurries in places processing with 82% of those farmers who think of this solution in the first place. If this solution should be applied, of course, a part of farmers will not agree to process their slurry for several reasons, which means that spreading plans should get modified. Places processing should have a technology that answers to several wanted advantages, like requiring less transport to farmers, spreading pig slurry products based on new lands with vegetable cultures (what means a better pig slurry repartition among lands), and doing business with a slurry-based product. A product that should answer to all those advantages should be the compost because the island gets an important part of its arable area that grows vegetables (2160 ha on 30247 ha in 2020).

Thereby, a way to feasibly resolve the issue of pig slurry management of south Reunionese pig farmers should be making slurry processing places, what could permit to farmers to less transport their slurries, doing business with it, export N, P2O5 and K2O from their current spreading plans to new ones, and especially toward vegetable lands. A good way to simply answer these purposes should be to create common slurry composting places.

All peoples, entrepreneurship or organisms that would like to propose to create slurry composting places for pig farmers in the south Reunion Island, should firstly make a business plan and deepen a marketing strategy, to be sure the proposed solution should be interesting for farmers, and project launchers, managers. Then, to get enough people to make the project, a meeting with all concerned actors should be organised: with concerned pig farmers of course, but also green wastes emitters or

collectors, and why not poultry farmers who produce poultry manure, if the composting with poultry manure is chosen to be done. During this meeting, the proposed maps with slurry processing places should be presented, as the potential way to work with the place for farmers and other companies. Also, the business plan and the way to sell the products should be presented. Finally, when technical accords are done among farmers, organisms, and project launchers, real tenders to slurry processing place builders should be done, and the project should be launched.

In the long term, this solution should get four advantages:

Making less pollution from pig farms to lands, because the spread pig slurry should be less spread on lands currently spread with this.

Facilitate the slurry management for Reunionese pig farms that participate, but also for other ones, with the potential new available lands.

Ideally **making money** for pig farmers who should participate in the project, with the slurry-based product produced and sold.

Making an adapted, convenient, and sustainable fertilizer to the vegetable production, and an efficient one for the crop production on the island.

But to enhance Reunionese pig farms, a point to be aware should be slurry production. As previously shown, solely few farmers are aware of the slurry volume emitted per year. This topic should be interesting and useful to get a better pig slurry management, thus less pollution, regulation problems, and even for a good slurry processing.

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Annexes

1. Original soil composition

		Soils			Organic wastes	
		Nitisol	**Cambisol**	**Andosol**	**PS**	**CT**
Dry matter	(%)				3.4	78.7
pH_{water}		5.8	4.7	5.2	8.9	8.1
C_{total}	(g 100 g^{-1})	2.32	3.9	19.3	35.7	21.1
N_{total}	(g 100 g^{-1})	0.24	0.39	1.09	5.43	1.4
Cr	(mg kg^{-1})	106	113	475	9.6	60.8
Cu	(mg kg^{-1})	34	89	74.5	1140	79.5
Ni	(mg kg^{-1})	100	88.5	301	15.8	54.7
Zn	(mg kg^{-1})	170	242	104	1150	220
Cr exch.	(mg kg^{-1})	< d.l.[a]	0.02 ± 0.04	0.08 ± 0.04	0.73 ± 0.07	0.1 ± 0.01
	(%)	0	0.02	0.02	7.5	0.2
Cu exch.	(mg kg^{-1})	0.5 ± 0.3	0.45 ± 0.05	0.23 ± 0.13	23.3 ± 0.69	1.76 ± 0.15
	(%)	1.4	0.5	0.3	2.0	2.2
Ni exch.	(mg kg^{-1})	0.1 ± 0.08	0.3 ± 0.04	2.6 ± 0.09	8.2 ± 0.13	0.65 ± 0.11
	(%)	0.2	0.4	0.8	51.7	1.2
Zn exch.	(mg kg^{-1})	0.6 ± 0.4	1.69 ± 0.17	0.3 ± 0.12	24.1 ± 0.46	1.17 ± 0.13
	(%)	0.4	0.7	0.3	2.1	0.5

(Doelsch, E., Masion, A., & al. (2009)).

2. Questions asked to pig farmers and taken measures in this research

(Personal source)

Name of the farm	GPS Coordinates of the farm

Farm	Running herd	Groups number	
		Sow number per group	
	Weaning age (days)		
	Number of present sows		
	Number of present boars		
	Do you have any special habits about the running herd?	Yes/No	
		Precisions	
Sanitary and cleanliness	What are your washing habits?		
	Do you have a water meter?		
	Do you know your water consumption?		
	Do you know your water consumption for washing rooms (m3/months)		
	How many time is your herd space?		
Oral questioning	What do you think about the pig slurry management on the reunion island?		
	What solutions could be done for this?		
	What do you think about your spreading plan?		
	What could be your ideal spreading plan?		
	Do you have any issues on your farm? And in the future?		
	What solutions for that?		
	Have you ever thought to process your pig slurry?		
	Should you be interested to valorise your effluents as a sold product?		
	What should be your processing technical choice?		
	Do you have any projects for your farm? Your pig farm?		
Activities	Do you have other productions on your farm?		Yes/No
			Precisions, which ones?
	Do you have another job?		Yes/No
			Precisions, which one?

Is/are there slurry tank(s) on the farm?	
Is there any pig slurry treatment on the farm?	
Is there any pig slurry treatments shared with other farms?	
What pig slurry volume is treated/spread per year? (m3/year)	
Do those treatments are adapted to your slurry?	Yes/No
	Precisions

What treatment is there?	
Effluent 1 treatment 1	Effluent volume emitted per year (m3/year)
	Effluent N-P-K values
	Dry matter rate of the effluent
Effluent 2 treatment 2	Effluent volume emitted per year (m3/year)
	Effluent N-P-K values
	Dry matter rate of the effluent
Is there a second pig slurry treatment?	

Spreading plan date to my disposition	
Is there a more recent spreading plan?	
Do you have any other livestock than pigs?	
Which ones?	
What are their N-P-K effective emissions?	
Pig slurry N-P-K effective emissions	
Do you pay a service provider for your pig slurry spreading?	Yes/No
	Precisions

Sum of potential spreading areas (per culture)	Cultures
	Area (potential spreading area) (ha)
Potential spreading areas detained by the pig farm (per culture)	Cultures
	Area (potential spreading area) (ha)
Loaned potential spreading areas (per culture)	Cultures
	Area (potential spreading area) (ha)
Do you share spreading plots with other livestock farmers?	Yes/No
	Area (potential spreading area) (ha)
Spreading periods of the farm	From
	To
Does the climate impact your spread?	
How long is the maximum travelled distance to spread your pig slurries? (Km)	
How long should you accept to travel by yourself to treat your pig slurry in a potential pig slurry treatment station? (Km)	

The potential constructible area around the pig buildings (m^2)	Below / on the same level as the pig buildings
	higher than pig buildings
Distance between the area and the closest neighbour (m)	
Distance between the pig buildings and the closest neighbour (m)	
Distance between the area and the pig buildings (m)	
Do you think to have enough place to build what to treat your slurry?	
What are your neighbourhood relations?	Grade (very bad, bad, so-so, good, very nice)
	Precisions

Only main rooms were chosen to get their pit volume. This choice was made to get only the pit volume of "productive rooms", which are pregnant rooms, insemination rooms, farrowing rooms, post-weaning rooms, and fattening rooms. Other pits haven't been taken into account (nurseries, docks), because they are not supposed to work fully, and to keep a lot of slurries.

Pregnant room n° (number of the room on the farm)	
Pit volume in the room	length (m)
	width (m)
	depth (m)
	thickness gratings (m)
	Volume (m3)
This pit is connected to the surry tank n°	
Pens number in the room	
Places number per pen.	

Insemination room n° (number of the room on the farm)	
Pit volume in the room	length (m)
	width (m)
	depth (m)
	thickness gratings (m)
	Volume (m3)
This pit is connected to the surry tank n°	
Pens number in the room	
Places number per pen.	

Farrowing room n° (number of the room on the farm)	
Pit volume in the room	length (m)
	width (m)
	depth (m)
	thickness gratings (m)
	Volume (m3)
This pit is connected to the surry tank n°	
Pens number in the room	
Places number per pen.	

Post(weaning room n° (number of the room on the farm)	
Room dimensions	length (m)
	width (m)
	area (m²)
Pit volume in the room	length (m)
	width (m)
	depth (m)
	thickness gratings (m)
	Volume (m3)
This pit is connected to the surry tank n°	
Pens number in the room	
Places number per pen.	

Fattening room n° (number of the room on the farm)	
Dimensions de la salle	length (m)
	width (m)
	area (m²)
Pit volume in the room	length (m)
	width (m)
	depth (m)
	thickness gratings (m)
	Volume (m3)
This pit is connected to the surry tank n°	
Pens number in the room	
Places number per pen.	

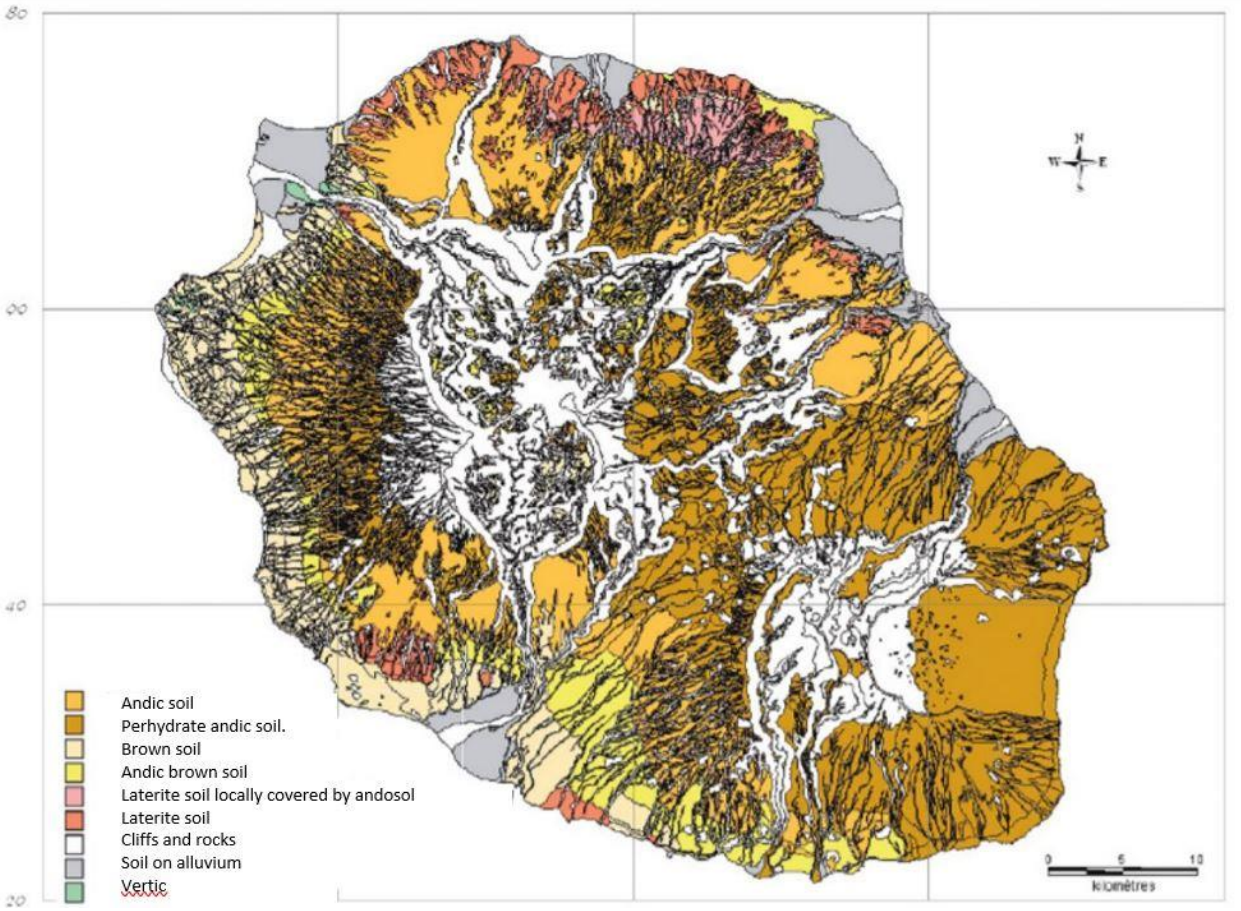
N° of the pig slurry tank in the farm	
Pig slurry tanks	Kind
	length (m)
	width (m)
	depth (m)
	volume (m3)
Slurry storage before the first treatment	Yes/No
	Kind
	length (m)
	Width (m)
	depth (m)
	volume (m3)

3. Pig slurry references and averages

	CPPR estimated averages	References
Nitrogen Kg /Tonne	4,23	3,5 Kg/Tonne
P2O5 Kg / Tonne	2,49	2,2 Kg/Tonne
K2O Kg / Tonne	3,44	2,9 Kg/Tonne
m3 of diluted Pig slurry / present sow per year	21,78	18,4 to 20,7 m3 / present sow / year
Mass of diluted pig slurry / present sow per year (Tonnes)	22,4	18,8 to 21,17 Tonnes / present sow / year
Cleaning water consumed per year (m3 or Tonnes) / present sow	2,25	2,3 Tonnes or m3 / present sow/year

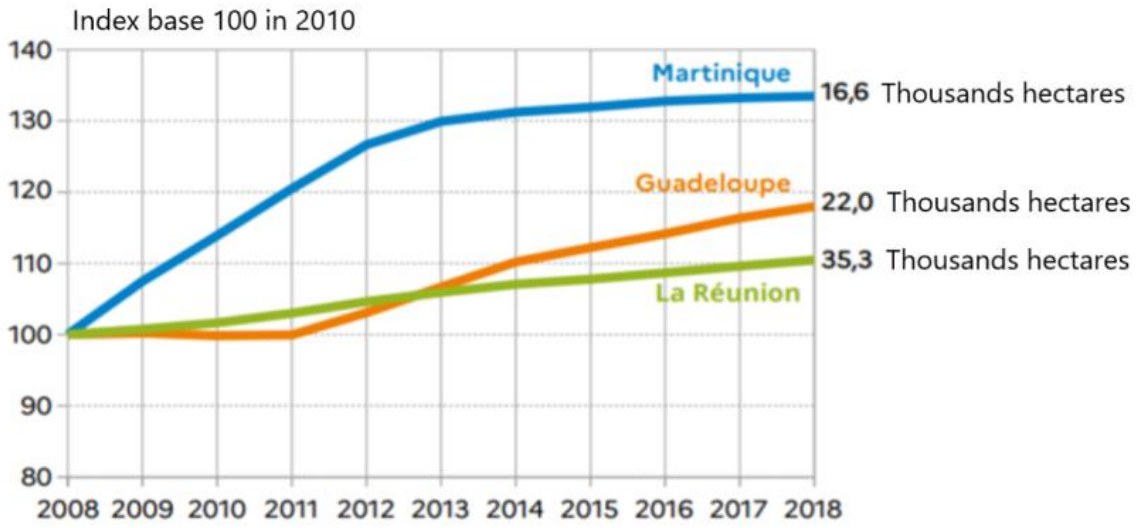
(Chabalier, P. F., van de Kerchove, V., & al. (2019)
Chambre d'Agriculture de Bretagne, Chambre d'Agriculture des Pays de la Loire (2014)
LEVASSEUR, P., BOYARD, C., VAUDELET, J. C., & al. (1999)
LEVASSEUR, P. (2005) ; MARCIAS, S. (2015))

4. Map of the of the Reunion Island soils



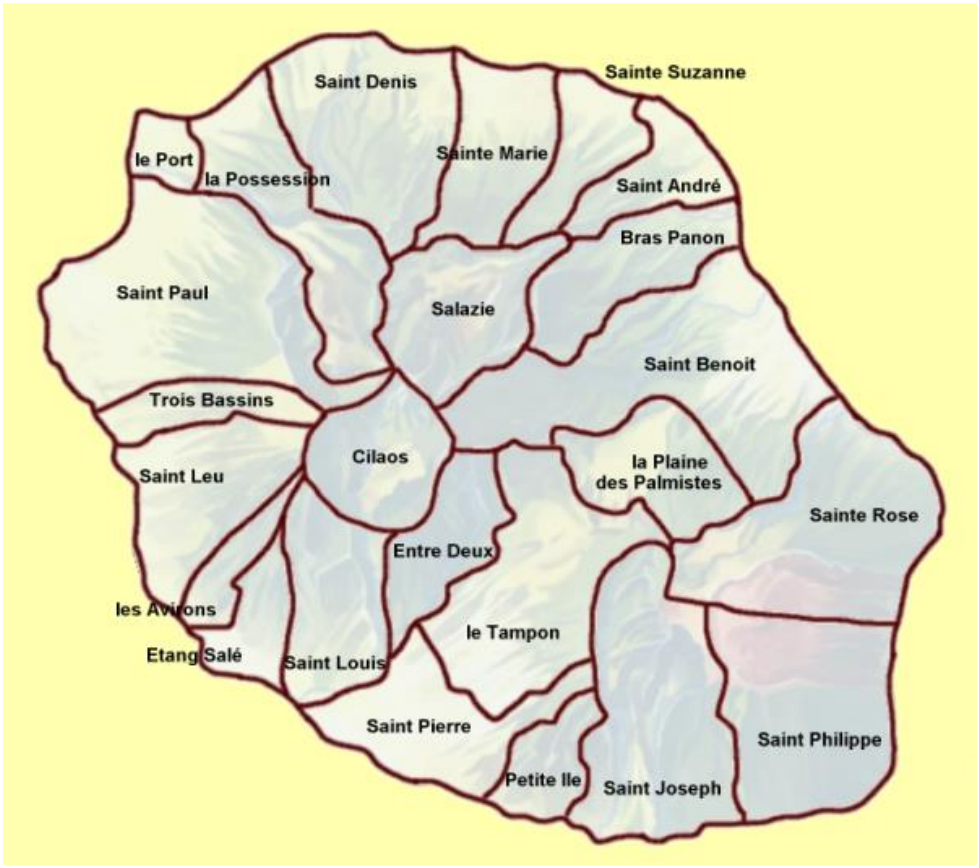
(Chapitre 2: Le sol, milieu vivant et complexe (2019))

5. Evolution of the soil artificialization on the Réunion Island



(Rousseau, F., & Judge, V. (2017))

6. Réunionese townships map



(Carte des communes de l'île de la Réunion. (n.d.))

7. Delays and distances to respect to buildings according to the kind of spreading

Spread/processed matter	Maximal burying delay after spreading (hours)	Minimal distance from houses, and public establishment (m)
Direct injection device in the soil	Right now	15
Carrying out an anti-odour treatment	24	50
After minimum 4 months of storage manure	24	50
Composts	No imposed burying	10
Poultry manure, dry manure, slurry and liquid manure spread with hoses, other effluents	12	50
Others	24	100

(Chabalier, P. F., van de Kerchove, V., & al. (2019))

8. Spreading distance to respect according to the farm registration and the spread matter

Lay-out	Manures	More than 65% dry matter droppings	Effluents, solid excreta	Slurries and liquid manures
Third parties or local dwellings usually occupied by third parties	≥ 100 m [6] ≥ 50 m [7] ≥ 10 m [9]	≥ 50 m [7]	100 m [1] ≥ 100 m [6] 50 m [2] ≥ 50 m [7] 10 m [4]	100 m [1] ≥ 100 m [6] 50 m [2] ≥ 50 m [7] 10 m [4] ≥ 10 m et ≤ 100 m [8] [10] ≥ 10 m [11]
Stadiums approved campsites, except for campsites at the farm	≥ 100 m [6] ≥ 50 m [7] ≥ 10 m [9]	≥ 50 m [7]	100 m [1] ≥ 100 m [6] 50 m [2] ≥ 50 m [7] 10 m [4]	100 m [1] ≥ 100 m [6] 50 m [2] ≥ 50 m [7] 10 m [4] ≥ 10 m et ≤ 100 m [8] [10] ≥ 10 m [11]
Water sampling points for consumption	≥ 50 m ≥ 50 m ≥ 50 m ≥ 50 m			
Bathing places and beaches	≥ 200 m			
Fish farms and shellfish farming areas	≥ 500 m			
Riverbanks (without green strips)	≥ 35 m			

[1] No treatment or process to reduce odours.
[2] Treatment or process to reduce odours.
[3] Manure and dung stabilized by a process recognized by the Prefect. Composted manure (applied only for spreading on bare land).
[4] Use of a device with direct injection in the soil.
[5] Poultry farming.
[6] Farms subject to authorization, of dairy and (or) mixed cows, veal calves and (or) cattle for fattening,
poultry and/or game birds, pigs.
[7] Farms subject to authorization, of dairy and (or) mixed cows, veal calves and (or) cattle for fattening,
poultry and/or game birds, pigs: carrying out treatment or implementing a process to reduce odours (for example, manure after minimum storage of 2 months in the installation and droppings with more than 65% dry matter).
[8] Farms with authorization, for poultry or game birds, pigs, in areas of structural surplus defined in the decree of November 02, 1993, and with authorization from the prefectural authority when the justification for the use of a device with direct injection into the soil.
[9] Farms subject to authorization, of dairy and (or) mixed cows, veal calves and (or) cattle for fattening:
composting or use of a device with direct injection into the soil of slurry and liquid manure.
[10] Farms subject to authorization, of dairy and (or) mixed cows, veal calves and (or) cattle for fattening:
use of a device with direct injection into the soil.
[11] Farms subject to authorization, of dairy and (or) mixed cows, veal calves and (or) cattle for fattening:
Composting
(Chabalier, P. F., van de Kerchove, V., & al. (2019))

9. Pig slurry emitted per animal, and composition

Animals	Pure slurry mass per animal		Pure slurry components (Kg/m3)		
	Per day (Kg)	Per year (m3)	N	P2O5	K2O
Boar	15,345	**5,4788**	**2,2506**	**1,5345**	**1,5345**
Pregnant, waiting for A. I and unproductive sows	15,345	**5,4788**	**2,2506**	**1,5345**	**1,5345**
Lactation sows	16,7772	**5,9901**	**2,8644**	**1,9437**	**2,046**
Post-weaning	1,8756	**0,6575**	**5,4184**	**3,7512**	**4,689**
Fatteners	**3,8258**	**1,3514**	**5,9972**	**3,3088**	**4,9632**

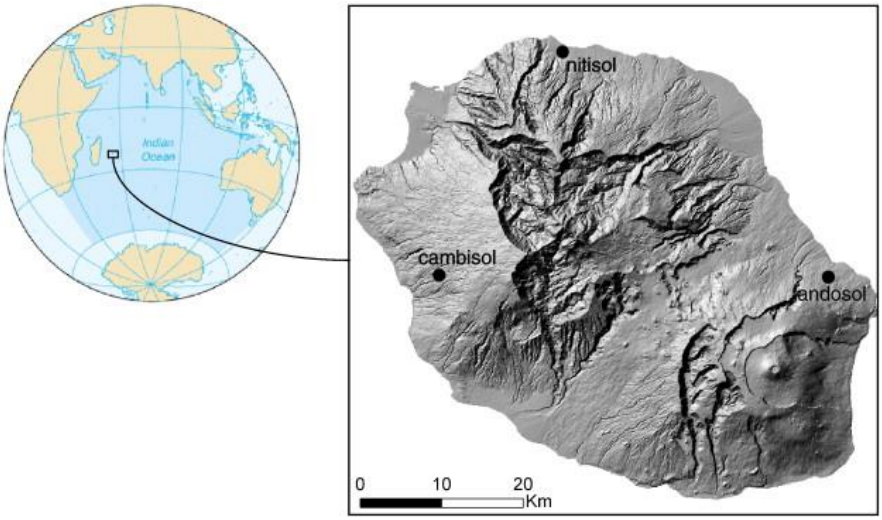
(*Chabalier, P. F., van de Kerchove, V., & al. (2019)* ; *Chambre d'Agriculture de Bretagne, Chambre d'Agriculture des Pays de la Loire (2014)* ; *LEVASSEUR, P., BOYARD, C., VAUDELET, J. C., & al. (1999)* ; *LEVASSEUR, P. (2005)* ; *Chambre d'Agriculture de Bretagne, Chambre d'Agriculture des Pays de la Loire (2014)*).

10. Réunionese soils particularities

Fertility	Weak		Medium		High	
Nitrogen	Andic Perhydrate andic		Andic brown Laterite		Vertic brown	
Phosphorus	Andic brown	Andic Perhydrate Andic		Vertic	Laterite Brown	
Potash	Andic Perhydrate	Vertic	Andic	Laterite brown		Brown andic
Acidity	acid					Neutral
Soil	Andic	laterite	Andic perhydrate	Andic brown	Vertic brown	

(Chapitre 2: Le sol, milieu vivant et complexe (2019))

11. Localisation of the soil samples in the study Doelsch, E., Masion, A., & al. (2009)



(*Doelsch, E., Masion, A., & al. (2009)*)

12. Farms grouped to the 'Station 1 St Pierre' *(personal source)*

Station 1 St Pierre			
Farms	**Slurry emitted per year (m3)**	**Distance by road from the farm to the ideal station location rounded to 0,5 Km**	**Should the farmer be interested in a transport service?**
EARL NOTRE DAME DE LA PAIX	981,068238	14,5	NO
EARL LA FERME DU BONHEUR	977,8619956	8	NO
EARL PANORAMIC	739,9463319	13,5	YES
EARL LES FRANCISEAS	1578,436142	18	YES
BOISVILLIERS FRANCOIS	1011,416507	17	NO
EARL LE MACADAMIA	917,2290456	11	NO
CADET LAURENT	810,0591527	12,5	YES
GOUROUVADOU ALAIN (eng/ repro)	738,2574192	10	NO
GAEC BASSIN PLAT	604,369374	7,5	NO

With a total of 8359 m3 to treat per year, and 3128 m3 to transport per year.

The ideal location of this place processing should be approximatively at the 55.4957; -21.2863 GPS coordinates.

13. Farms grouped to the 'Station 2 Avirons' *(personal source)*

Station 2 Avirons			
Farms	**Slurry emitted per year (m3)**	**Distance by road from the farm to the ideal station location rounded to 0,5 Km**	**Should the farmer be interested in a transport service?**
EARL LES CAPUCINES	885,0228569	1,5	NO
VATEL BERNARD	780,8429076	2	NO
EARL CAMI	468,4023466	4,5	NO
MUSSARD JEAN FRANCOIS	506,5017546	5	YES
EARL BELLECOMBE	740,5191356	2,5	NO
GAEC KERBEL	1796,386908	5,5	NO
EARL CALTEAU	883,576184	5,5	NO
GROSSET MARIE LISETTE	558,7630143	14,5	YES
EARL CHAMAND	712,4538134	30,5	YES
EARL DE BELLE VUE	400,0712189	19,5	YES
EARL DES FLAMBOYANTS	1161,664071	25	YES

With a total of 8894m3 to treat per year, and 3339 m3 to transport per year.

The ideal location of this place processing should be approximatively at the 55.3403 ; -21.2134 GPS coordinates.

14. Farms grouped to the 'Station 3 Petite-île' *(personal source*

Station 3 Petite-île			
Farms	**Slurry emitted per year (m3)**	**Distance by road from the farm to the ideal station location rounded to 0,5 Km**	**Should the farmer be interested in a transport service?**
EARL HKC	1668,947781	8,5	NO
EARL GONTHIER	2293,478837	5,5	NO
EARL LES GENETS	443,5496315	2	NO
SCEA FOLIO	1029,015	4,5	NO
EARL LES TANGORS	1078,633103	1	NO
EARL MEZINO GONTHIER	1394,173413	8	YES
GRONDIN CLAUDE ANDRE	443,4009055	1	NO

With a total of 8351 m3 to treat per year, and 1394 m3 to transport per year.

The ideal location of this place processing should be approximatively at the 55.5914; -21.3392 GPS coordinates.

15. Farms grouped to the 'Station 4 St Joseph 1' *(personal source)*

Station 4 St Joseph 1			
Farms	**Slurry emitted per year (m3)**	**Distance by road from the farm to the ideal station location rounded to 0,5 Km**	**Should the farmer be interested in a transport service?**
BOYER LUCIE	753,5757951	13	YES
BARRET JEAN PAUL	218,1581154	4,5	YES
EARL LES BIGNONIAS	901,6034524	2,5	NO
SCEA DE L ACACIA	1043,953666	7	NO
MUSSARD PATRICK	711,075994	5	NO
EARL DES GOYAVES	904,3264124	4	NO
HOAREAU JAMES	810,251051	4	YES
GRONDIN JEAN PHILIPPE	884,2612485	2	NO
ROBERT HENRI	1401,931724	7	NO
EARL PSF LES OLIVIERS	880,9039154	2,5	NO

With a total of 8510 m3 to treat per year, and 1782 m3 to transport per year.

The ideal location of this place processing should be approximatively at the 55.6319; -21.3689 GPS coordinates.

16. Farms grouped to the 'Station 5 St Joseph 2' *(personal source)*

Station 5 St Joseph 2			
Farms	**Slurry emitted per year (m3)**	**Distance by road from the farm to the ideal station location rounded to 0,5 Km**	**Should the farmer be interested in a transport service?**
HUET MARIE-HELENE	496,6385332	7,5	YES
GAEC PORCELETS DU SUD	984,1685192	5,5	NO
K BIDY JEAN PIERRE	864,2217721	10	NO
HUET PIERROT	865,7076871	6,5	NO
PICARD CHRISTIAN	776,7598495	9	YES
EARL LA CRETOISE	775,3940826	4,5	NO
ALAGUIRISSAMY NADINE	1007,137456	4,5	NO

With a total of 5770 m3 to treat per year, and 1273 m3 to transport per year.

The ideal location of this place processing should be approximatively at the 55.6564; -21.3659 GPS coordinates.

17. Estimated slurry production of studied farms

	Diluted slurry mass-produced (with cleaning water) per year (Tonnes)	**The diluted slurry volume produced (with cleaning water) per year (m3)**	**N Kjdhl mass (Kg) per tonne of slurry emitted**	**P2O5 mass (Kg) per tonne of slurry emitted**	**K2O mass (Kg) per tonne of slurry emitted**	**N Kjdhl mass (Kg) produced per year**	**P2O5 mass (Kg) produced per year**	**K2O mass (Kg) produced per year**
Minimum of the studied farms	224,25849	218,158115	4,08568294	2,41707668	3,2979516	934,153934	548,933006	756,993574
Maximum of the studied farms	2358,57862	2293,47884	4,41225932	2,57467779	3,59903672	9977,56989	5878,99641	8108,57582
Averages of the studied farms	944	918	4,23	2,49	3,44	3996	2352	3247