Rainfall Variability, Wildfires and Biodiversity Conservation in La Réunion National Park: What Prospects for Climate Resilient Tourism Development?

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ABSTRACT

Reunion Island is characterized by a diversity of situations in terms of ecosystems due to its topography. Evergreen forests adapted to heavy rainfall (over 2500 mm/year) in the East contrast with savanna conditioned by low rainfall (less than 1000 mm/year) in the West; dense forest of low altitude contrast with high altitude grasslands. These xeric ecosystems are particularly vulnerable to rainfall deficits and wildfires during the winter. This is a major problem for the biodiversity conservation of the areas included in La Réunion National Park.

The objective of this paper is to characterize the seasonal and inter-annual rainfall variability over the period 1950–2013. This analysis highlights the evolution of annual and seasonal rainfall deficit. It will also analyse the impact of rainfall variability on the dynamics of wildfires. These data have been extracted from the GIS of the National Forest Office and La Réunion National Park and present the major burned areas in Reunion Island during the period going from 1902 to 2012.

Finally, we discuss the inclusion of climate change in local planning programmes linked to the development of protected areas. While the Reunion Island National Park is inscribed on the World Heritage List of UNESCO in particular because of its richness in endemic species, the main ecosystem service put forward is the enhancement of ecotourism. We then measure the way local decision-makers take into account these climate changes and their impact and question the relevance of the tourism strategies implemented in the light of climate resilience.

Keywords: Rainfall Deficits, Wildfires, Decision-Makers, Tourism Development, Reunion Island

INTRODUCTION

The relations between climate change and tourism are manifold and increasingly taken into account not only by decision-makers (OECD & UNEP, 2011) but also in the academician field (Matzarakis, *et al*., 2007; Dickinson, J. E., 2010). The contribution of tourism to greenhouse gas emission, particularly in the transport sector, is well-known and has largely been reviewed (Dickinson,

Robbins & Lumsdon, 2010; Peeters & Dubois, 2010). From an other point of view, climate change may affect tourism activities and influence the tourist's choice for their destination (Coombes & Jones, 2010; Park & Reisinger, 2010; Uyarra *et al*., 2005).

These issues are particularly important for small islands, whose economy relies largely on tourism industry. In Reunion Island, a working group on adaptation to climate change identified two impacts of climate change to the tourism activities: the sea-level rise on the coastal area and the increase of natural disasters in the uplands, that could affect the ecotourism development (MEEDDM, 2010). While the inscription of La Réunion National Park on the World Heritage List of UNESCO, raised many hopes from the local decision-makers to increase the number of visitors, the large wildfires that recently occurred were said to depreciate the image of the destination. In this perspective, our assumption is based on the demonstration of a potential link between water deficit and wildfires.

In terms of climate, Reunion Island, as other territories of the Indian Ocean, is marked by a high variability of the precipitation regime. Surplus years with an intense hurricane season alternate with extremely lean years. These deficits are particularly noticeable during the winter season from July to October. In Mauritius, for example, observations indicate that the annual rainfall witnessed a decrease of 100 mm over the past 50 years (IPCC, 2007). In Reunion Island, 2013 ending is considered by Meteo France as one of the driest recorded during the last 50 years. The IPCC (2007) predicts a downward trend of the rainfall amount on the Mascarene Islands.

The consequences of this change in rainfall are multiple and in the Regional Scheme for Climate, Air and Energy of Reunion Island (Région Reunion, 2013) " the preservation of the environment and natural environments biodiversity and fisheries" is quoted amongst the 7 vulnerable sectors. The issues most frequently highlighted on terrestrial environments are first the loss of biodiversity (especially for species vulnerable to water deficits) and undemanding spread of invasive alien species, generally. But wildfires represent the most important risk for a large number of ecosystems (especially xeric vegetation located on the leeward side of the island), with a high impact on the conservation of biodiversity, particularly within the core area of La Réunion National Park, which covers 1 050 sq.km (42 % of the total area of the island).

The main objective of this work is to characterize the seasonal and interannual rainfall variability over the period 1950–2013 in relation to wildfires. Then considering these dynamics in a larger system, our second objective is to identify key issues to the induced erosion of biodiversity and question the relevance of the implemented actions to control the risk of wildfires and to increase the resilience of the tourism industry.

DATA AND METHODS

STUDY SITE

Reunion Island is characterized by a diversity of situations in terms of ecosystems, because of its exposition to the southeast trade winds and its mountain topography. Areas of dense evergreen forests adapted to heavy rainfall (over 3 000 mm/year) in the East contrast with savanna and dry forest areas conditioned by low rainfall (less than 600 mm/year) in the West, while dense forest of low and medium altitudes contrast with high elevation grasslands (Fig. 1).

Reunion Island (2 512 sq . km) is the youngest (2–3 million years) of the three volcanic islands of the Mascarene Archipelago, with a current active volcano in the southeast (Piton de la Fournaise, rising to 2 631 m) and an elder one in the northwest (Piton des Neiges, rising to 3 071 m). The major part of the population lives on the coastal lowlands, where the original vegetation is highly disturbed. The best-preserved ecosystems are found inside the limits of La Réunion National Park, created in 2007.

Like other oceanic islands, it is characterised by a high level of endemism, though its biodiversity is low compared to continental areas of the inter-tropical domain. Belonging to the Madagascar & the Indian Ocean islands biodiversity hotspot, it supports the most extensive and best remnants of the original vegetation of the Masacarene Islands. There are 840 indigenous vascular plant species out of which 46% are endemic either locally (28%) or regionally (18%). Regarding the fauna, 30 out of 45 endemic terrestrial vertebrate species (including a giant tortoise) are known to have become extinct soon after the first European settlement in 17th century (Strasberg *et al*., 2005).

In 2010, the region had a population of 833 000 inhabitants. Unemployment rate is very high (more than 40% in some municipalities) and the service sector employs the majority of the active population. Tourism is considered by the Regional Council as a key sector for the economic development of the island. However, far from the expected number of one million tourists, the annual number of visitors rarely surpassed 400 000 during the last ten years[1].

Data: Several types of data were used:

- Daily rainfall data for the period 1950-2012 provided by Météo France.
- Data on burned areas (more than 30 ha) from the National Forest Office (ONF) and La Réunion National Park.
- Documents on the distribution of plant formations.
- Reports and management plans of natural areas.

METHODS

The analysis of climate data is based on finding a break in the rainfall series on the one hand and on the calculation of drought index other.

Detection of break in the series of rainfall data relies on the Pettitt test (Pettitt, 1979) and the Buishand U statistic (cited by Lubes *et al*., 1994). Their choice is justified by the strength of their procedure and the fact that these tests have already been applied to hydrometeorological series observed in Sudano-Sahelian Africa. A break can be defined by a change in the probability distribution of a time series at a given instant (Lubes *et al*., 1994). The absence of a break in rainfall series does not mean that there is no variation in rainfall over time, but this variation, if it exists, is not very significant.

These methods have the advantage of indicating a probable date of the change in the comportment of the rainfall series.

The drought index is based on the method of Nicholson (Servat *et al*., 1997). It is a reduced centred variable calculated on annual rainfall amounts of rainfall $(x_i-m) / s$

with:

- x_i = amount of precipitation in year i.
- m = the mean observation period.
- s = STDEV of the observation period.

This method has the advantage of highlighting the surplus and deficit years. It can than be compared with wildfires data provided by ONF and La Réunion National Park, with the objective to study the covariation between rainfall deficits and fires.

RESULTS

DETECTION OF RUPTURE IN THE ANNUAL RAINFALL SERIES

Table 1 (below) shows the results of tests indicating the probable date of rupture or the period during which break may have occur.

Analysis of the results reveals a mixed picture, with oppositions between the east and west sides of the island (Fig. 2). Indeed, rainfall stations located on the windward side from Saint Joseph (southeast) to Gillot airport (North) do not show a significant change in their annual rainfall series. This includes high altitude rainfall stations (over 2 000 mm) like Hell-Bourg and Cilaos.

On the contrary, on the leeward side, at low and medium altitude, a break is observed in the rainfall series. This results in a decrease in rainfall from 18 to 26 %, starting from 1982 for 4 out of the 5 concerned meteorological stations: Le Tampon, Pierrefonds, Colimaçons, Les Avirons and from 1995 for Bellevue les hauts.

Table 1: Detection of Rupture in the Annual Rainfall Series

Meteorological Stations	Year Showing a Break	Mean Rainfall (mm) 1950-1982	Mean Rainfall (mm) 1983-2012	Percentage Decrease
Les Avirons	1982	1030	760	26 %
Bois de Nèfles	No significant break	1080	1024	5 %
Cilaos	No significant break	2200	1800	20 %
Colimaçons	1982	1700	1300	18 %
Gillot aéroport	No significant break	1620	1640	0 %
Hell Bourg	No significant break	3140	3160	0 %
Pierrefonds	1982	790	645	18 %
Plaine des Cafres	No significant break	2390	1968	17 %
Plaine des palmistes	No significant break	2400	1970	17 %
Saint Joseph	No significant break	1796	1600	10 %
Saint Leu	No significant break	760	600	20 %
Tampon	1982	1700	1400	18 %
Bellevue les hauts	1995	1600	1180	25 %

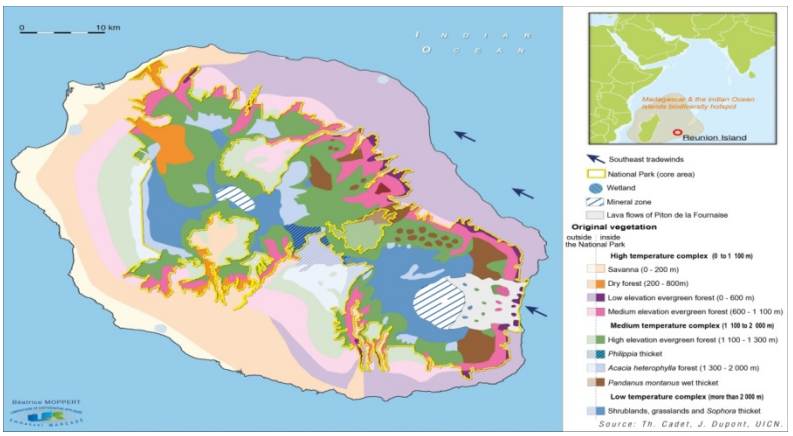


Fig. 1: Vegetation Map of Reunion Island

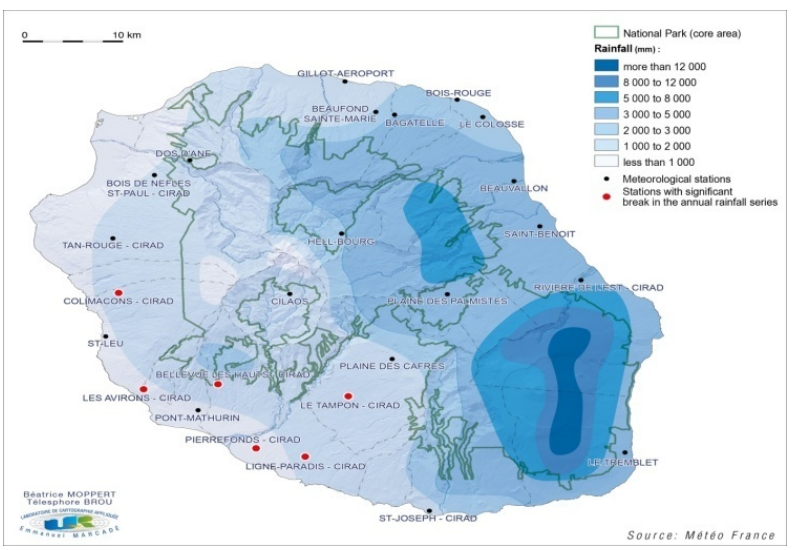


Fig. 2: Location of Rainfall Stations with Known Rainfall Break Around the National Park

CHARACTERIZATION OF INTERANNUAL RAINFALL DEFICITS

Figure 3 below shows the results of Nicholson indices calculated over the period 1950-2012 for the meteorological station "Les Avirons", representative of the stations that have experienced a break in the rainfall series.

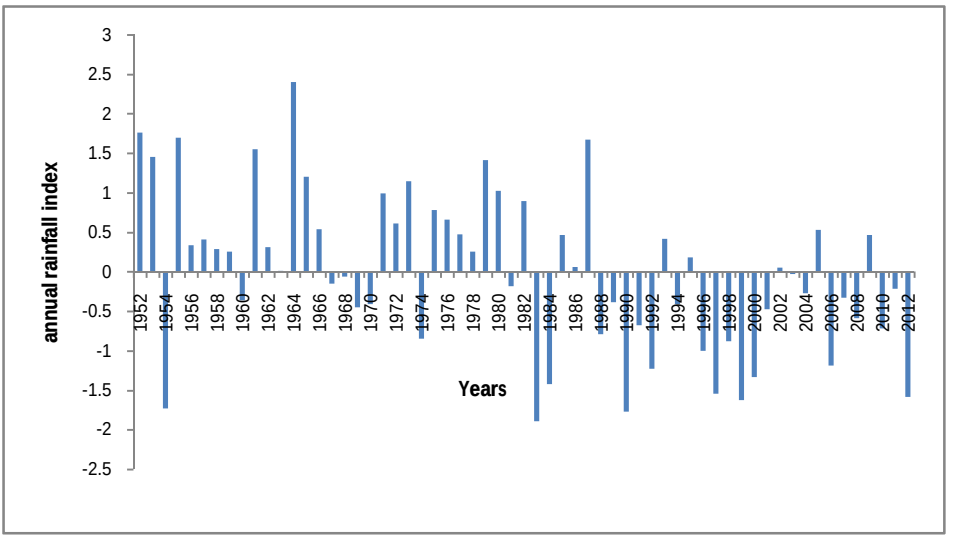
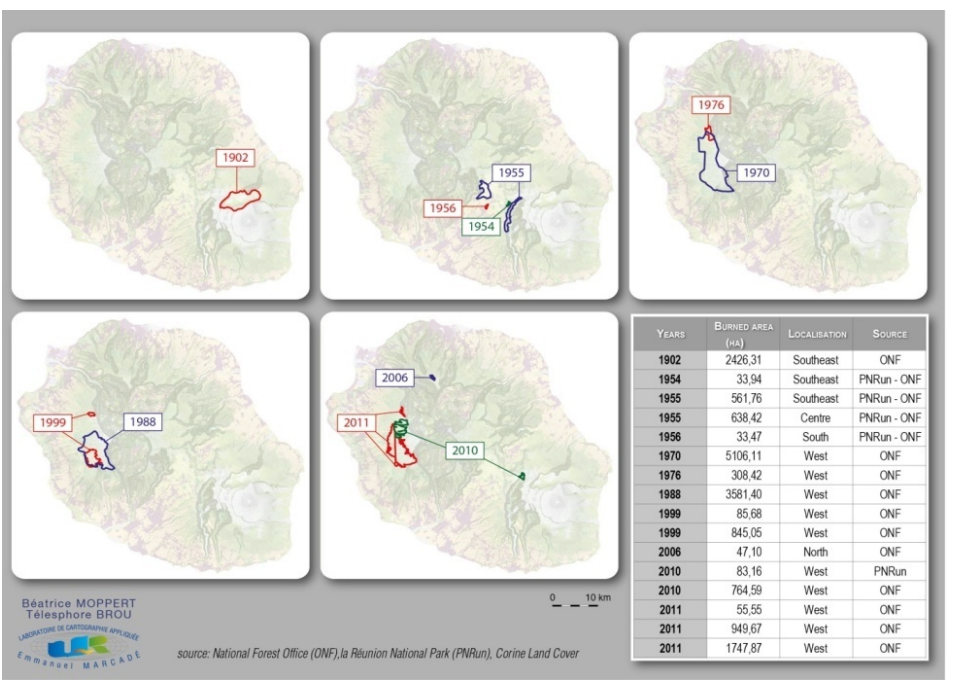


Fig. 3: Annual Rainfall Indices at "Les Avirons" Metorological Station



Years	Burned area (ha)	Localisation	Source
1902	2426,31	Southeast	ONF
1954	33,94	Southeast	PNRun - ONF
1955	561,76	Southeast	PNRun - ONF
1955	638,42	Centre	PNRun - ONF
1956	33,47	South	PNRun - ONF
1970	5106,11	West	ONF
1976	308,42	West	ONF
1988	3581,40	West	ONF
1999	85,68	West	ONF
1999	845,05	West	ONF
2006	47,10	North	ONF
2010	83,16	West	PNRun
2010	764,59	West	ONF
2011	55,55	West	ONF
2011	949,67	West	ONF
2011	1747,87	West	ONF

Fig. 4: Major Known Wildfires in Reunion Island

The figure shows two periods. A period marked by positive rainfall indices from 1950 to 1981, indeed except for a few very lean years like 1954 and 1974, the period is in excess. The period extending from 1982 to 2012 is very deficient. Surplus years are rare. Out of the 30 annual records, only 8 registered excessive rainfall.

Relationship between Rainfall Variability and Fire Analysis of the Spatio-Temporal Dynamics of Fire

Wildfires are very frequent in Reunion Island but their extent is usually very small[2]. For our purpose we took into account only the known fires of more than 30 ha (Figure 4). The eldest record is dated in 1902 and took place in the massif of La Fournaise. Before 1970, only a few fires occurred in the central part of the island. The most important fire was recorded in 1970, with 4 500 ha of burned area. The year 1970 is recognized by climatologists as one of the driest in the tropics during the past century. Similar events were, for example, noted in West Africa. Major droughts have indeed caused fires of large magnitudes in plantations and forests (Brou, 2010; Paturel *et al*, 1995).

This incident was also the first to affect the western uplands of the island and since then, most of the important wildfires are located in this area.

Analysis of the Covariability between Drought Index and Occurrence of Wildfires

To analyse the covariability between rainfall deficits and wildfires, we focused on the dry season from July to November, the most favourable to wildfires. Figure 5 shows that no substantial surplus year records any large fires (see Table 1). In contrast, years with large extent fires coincide with high deficit years except in 2011 (slightly in excess). Indeed, the high deficit years like 1955 and 1988, recorded important burned areas (respectively 1 500 ha and 4 500 ha).

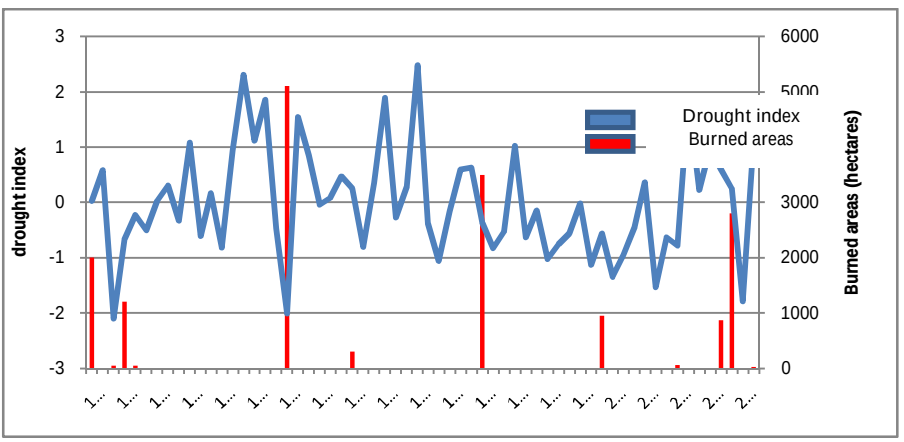


Fig. 5: Drought Index at "Les Avirons" and Major Wildfires Since 1952

[2] Slash and burn cultivation has been practised for a long time, especially in the uplands where the maroons had taken refuge.

As the risk of occurrence of years with important rainfall deficit is increasing during the current period, the chance of occurrence of large extent fires is also increasing.

IMPACTS ON BIODIVERSITY CONSERVATION AND RECREATIONAL ACTIVITIES

From the point of view of the impact of wildfires on biodiversity, significant threats especially on endemic animal and plant species. Particularly, several protected birds species (like *Coracina newtoni* (Tuit-tuit), *Circus maillardi* (Papangue), *Pseudobulweria aterrima* (Pétrel noir de Bourbon, *Pterodroma baraui* (Pétrel de Barau)) are extremely vulnerable to fires. Plant formations are also weakened by the increasing frequency of fires, as their spontaneous regeneration requires a period of at least 20 years without disturbance. Moreover, the increasing presence of invasive alien species (specially *Ulex Europeus* (European gorse and *Acacia mearnsii*) prevents spontaneous recolonization of burned areas by native species. Revegetation actions are initiated by conservation stakeholders (La Réunion National Park, National Forests Office, the Mascarins Botanical Garden, the Coastal Conservancy, in partnership with scientists and environmental NGOs).

In connection with biodiversity conservation, issues in the tourism sector are also important. The inscription on the World Heritage List of UNESCO was expected to permit the recovery of the tourism industry (after the Chinkungunya crisis in 2006). This attractiveness is largely based on the biological wealth of the island and the exceptional character of its landscapes. But consideration of climate resilience in the tourism development programs still appears timidly. In January 2012, soon after the last major wildfire, a tourist service-provider[3] established on the Maido road regretted the absence of countervailing measures on the shortfall due to the three months long closing of the road access to Maido (second visited site of the island, according to data from the National Forest Office). However, this same provider indicated that upon reopening, attendance had quickly resumed its usual pace.

DISCUSSION

The recent period reveals both water deficits increasingly important and an increase in fire frequency. But the link between dry years and large fires is not systematic in particular over the last 5 years (with respect to the meteorological station of “Les Avirons”). Several factors must be taken into consideration to understand recent dynamics.

On the one hand, the criminal origin of the fire appears to be obvious to the managers of protected areas, although the authors of these fires have rarely been alleged and sentenced. It is therefore difficult to interpret the motivation and meaning of their act, but it seems that the creation of the National Park in 2007 and the ensuing restrictions are causing discontent to justify these crimes.

[3] Author’s enquiry in January 2012.

The results also showed that the western part of the island is the most affected by fires since the 1970s, especially in the Maido sector. While the first large extent wildfire took place during a year of severe drought (1970), the period also corresponds to the opening of these mountain forests to the public (Robert, 2002). From a systemic point of view, this reveals the importance of two-way relationships between leisure activities and natural hazards.

In addition, the fire of 2011 has highlighted the lack of appropriate means to fight against fires, in particular the absence on the island of bomber aircrafts that had to be transported from France, after several days of hesitation. Since then, various actions have been implemented to better manage fires in the context of the revision of the Departmental Plan for the Protection of Forests Against Fire (PDPFCI). The Department is now equipped with a bomber (Dash 8), which helps to fight faster against fires as soon as they start. In addition, the National Park has launched a prevention program, in collaboration with the county fire and rescue (SDIS) service by recruiting twenty eco-guards, responsible for field monitoring, both for identify the starting fires and for warning the visitors. During the year 2012, though a deficit in terms of rainfall was noticed, no major fires have been declared during the dry season. But the limits of the effectiveness of these measures were again highlighted in October 2013, when a fire again devastated 46 ha in the northern part of the island in the Sanctuary of "La roche écrite". However, the fire was quickly circumscribed within 4 days of intervention. In comparison, the fire of 2011 lasted 15 days and has finally been declared extinct after three months. It seems therefore that as in other places (Butler & Goldstein, 2010) the establishment of a collaborative network has shown its efficiency.

CONCLUSION

In Reunion Island, many devastating weather events such as heavy rains, floods, hurricanes, forest fires and, less often, volcanic eruptions or tsunamis reveal the importance of natural hazards' issues. Moreover, as 80 % of the territory is located in mountain areas and some areas of the island have no road, the response time of services of civil security is often extended and frequently requires helicopter intervention.

With water shortages experienced in the western part of the island, forest fires constitute a hazard, likely to increase both in frequency and in extent. These changes are effectively taken into account in the management and prevention of wildfires, but the analysis of their impact at different levels remains to be explored.

Remote sensing studies on post-fire invasive species (specially the European Gorse) are underway[4]. Mapping and extent estimation of European gorse from remote sensing will be compared with maps obtained from field

[4] In the framework of a Master thesis in partnership with the local satelitte station (SEAS-OI) and La Réunion National Park.

data (GPS delimitation), with the objective to conduct a multi-temporal monitoring of invasive plants after wildfires.

From the point of view of the impact on tourism, the resilience of Reunion Island tourism system remains to be analysed. There is a lack, indeed, of studies taking into account these hazards and on the way tourism agencies consider them. Moreover, the perception of risk by tourists and its influence on the choice of destination, as well as knowledge of the risk and responsibility of visitors of the National Park have not yet been explored. The issue is owever important both to protect and increase the touristic value of this property inscribed on the World Heritage List of UNESCO.

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