

Fog water interception by *Sophora denudata* trees in a Reunion upper-montane forest, Indian Ocean

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Abstract

The forest water balance has never been studied in Reunion Island (Indian Ocean). This study focuses on the interception of fog water by *Sophora denudata*, an endemic tree, which provides an important water input into the hydrologic budget of the upper-montane forest. Canopy throughfall, rainfall and fog have been compared. The first data were obtained in 2001 in Nez de Bœuf, 2040 m asl, from manual rain gauges. The measurements were made during the day only. The aim was to propose a typology of events, to understand the spatial pattern of canopy throughfall, especially fogdrip, and their relation to the trade-wind direction. A second series of experiments, carried out in 2004 in Piton de Tangués, 2150 m asl, investigated how throughfall and atmospheric water varied with time, using automatic instruments such as the shielded Grunow-type fog collector. Here measurements were made continuously and night data were not excluded. Over a period of 8 months, the throughfall gauges, which were placed under the trees, indicated 1180 mm whereas the total amount of rainfall had reached only 948 mm. The difference (232 mm) is attributed to fog. Of 278 events, 234 showed fog contribution; fog occurred alone in 167 cases. The observations confirm what was found in Nez de Bœuf, namely that fog or rain can occur separately or together. The role of fog contribution to the forest water budget is significant: the spatial variation of canopy throughfall does not only depend on the type of event, but also on wind direction.

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1. Introduction

Reunion Island, a tropical and mountainous island in the southwestern Indian Ocean, is characterized by two coalescent volcanic peaks, Piton des Neiges (3070 m asl) and Piton de La Fournaise (2632 m asl). The mountain ridges disturb the eastern trade-wind circulation thus

creating leeward and windward sides (Robert, 1986). The subsidence inversion layer, which is at an altitude of 2000 m asl, acts as a barrier to the movement of orographic clouds and allows these clouds to collect there. The fog is then intercepted by the vegetation canopy and contributes to the cloud forest water balance (Bruijnzeel and Proctor, 1995). The maximum rainfall lies under this layer. Beyond and below this layer, rainfall decreases (Giambelluca and Nullet, 1991; Minyard et al., 1994; Barcelo and Coudray, 1996). For

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the upper-montane forest (or subalpine vegetation), fog flux is a significant source of water when its droplets hit *Sophora denudata* leaves, an endemic tree (Gabriel, 2000). This observation, made in 2000 on the leeward slope of La Fournaise, led to a series of experiments, never carried out in Reunion Island, i.e. to quantify the canopy throughfall and determine to what extent fogdrip contributes to the forest water budget.

2. Site description

2.1. Study sites

The first study site (55°37'E, 21°12'S) is situated near Nez de Bœuf at 2040 m asl on the leeward slope of La Fournaise (Fig. 1). It overlooks “La Rivière des Remparts”, a deep valley. The second site (55°39'E, 21°11'S) is situated at 2150 m asl near Piton de Tangués, a cinder crater on the leeward slope of La Fournaise. The most common vegetation above 2000 m is an open dry forest dominated by ericaceous shrubs and, in places, by *S. denudata* (Cadet, 1980). There is a high level of plant diversity and this site is among the best preserved natural habitats in Reunion Island (Strasberg et al., 2006). At lower elevations, *S. denudata* thickets were massively deforested and the land converted into pasture and forest crops.

The prevailing climate is dry and cool. No meteorological station operates in the region. The most recent isohyet map proposed by Barcelo and Coudray (1996) gives approximately 2000 mm and 3000 mm of annual rainfall for Nez de Bœuf and Piton de Tangués areas, respectively. A recent climatic study was conducted in Piton Textor from September 2004 to September 2005; 822 mm of fog were collected using a shielded Grunow-type fog collector and 1792 mm of rainfall were collected using an automatic rain gauge (Jauze and Gabriel, unpublished data). A large amount of the annual precipitation (1197 mm or 67%) occurred in summer, from December to March, which is the tropical storm season.

Fog occurrence in Piton Textor is important (237 days) and its frequency is favoured by the presence of steep slopes. In La Fournaise, fog can occur alone or with rain.

2.2. Tree description

S. denudata, locally known as “Petit Tamarin des Hauts”, is a medium-sized tree from 3 to 10 m tall. Its phenology varies from one site to another and from one tree to another. *S. denudata* blooms once a year during winter months (May–October). Its leaves are deciduous,

alternate with variable pairs of leaflets that are oblong to obovate, entire and glabrous (silky when young).

3. Materials and methods

We selected 2 trees (trees A and B) in Nez de Bœuf in 2001. Tree A was isolated and far from any obstacle, whereas tree B was located at the limit of a *Sophora* forest. An isolated tree (tree C) was selected in Piton de Tangués in 2004. The respective crown projections are 19 m², 15 m² and 25 m². The selected trees represent the low stature of the *Sophora* found in La Fournaise (height: 3 m).

In this study, stemflow was not taken into account. For trees A and B, the throughfall pattern was measured by means of 15 manual rain gauges, 50 cm² each, installed under each crown inside a 1.2 m square grid. For each tree, another manual rain gauge was placed in a nearby clearing to compare rainfall with throughfall. The values were read every 15 min from 7:00 to 19:00. The main limitation of this approach was that the experiments could only be carried out in the daytime. In Nez de Bœuf, the purpose of the study was to propose a typology of different events according to personal observations. Four situations were identified: (1) “clear sky”, (2) “rainfall only” day, (3) “mixed rain and fog” day and (4) “fog only” day. In addition, we investigated the spatial variation of throughfall during events and its correlation with the trade-wind direction.

In Piton de Tangués, tree C was equipped with 8 automatic throughfall gauges under a *S. denudata* canopy, 314 cm² each (0.17 mm per tip). A nearby clearing was equipped with an automatic rain recorder (314 cm², 0.2 mm per tip) and a shielded Grunow-type fog collector (35 cm high with a 18 cm diameter, 630 cm² of cross-sectional area) placed above a gauge (314 cm², 0.125 mm per tip) and covered by a 62 cm × 62 cm shield which jutted out over the cylinder by 22 cm. Each automatic instrument was equipped with data loggers (HOBO event, Onset Computer). This enabled us to record night situations, in contrast to only daytime data from Nez de Bœuf. Here the goals were to assess more accurately the hydrologic input during a relatively long period of several months, and to improve the typology of the events.

As described by Holder (2004), negative (gain) or positive (loss) interception (I) was calculated as follows: the value of the rain gauge in the clearing (CR) minus the value of average throughfall (AT) under *S. denudata*. This study assumes that negative interception values (AT > CR) are the result of fog as commonly reported by other studies (Weaver, 1972; Vis, 1986). Fog precipitation is calculated as the absolute value of rainfall minus throughfall (Holder, 2004).

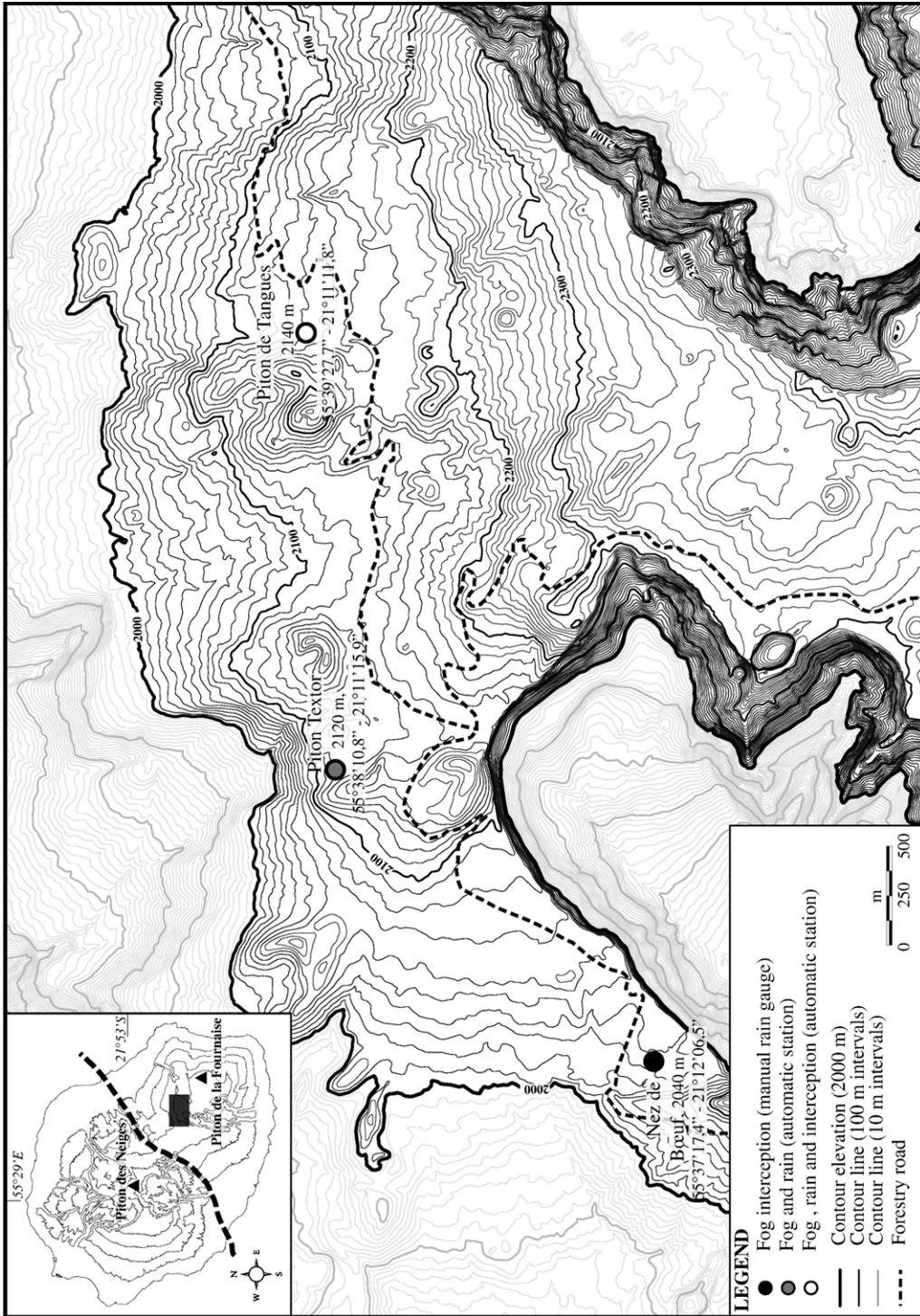


Fig. 1. Location of study area over 2000 m, Piton de La Fournaise.

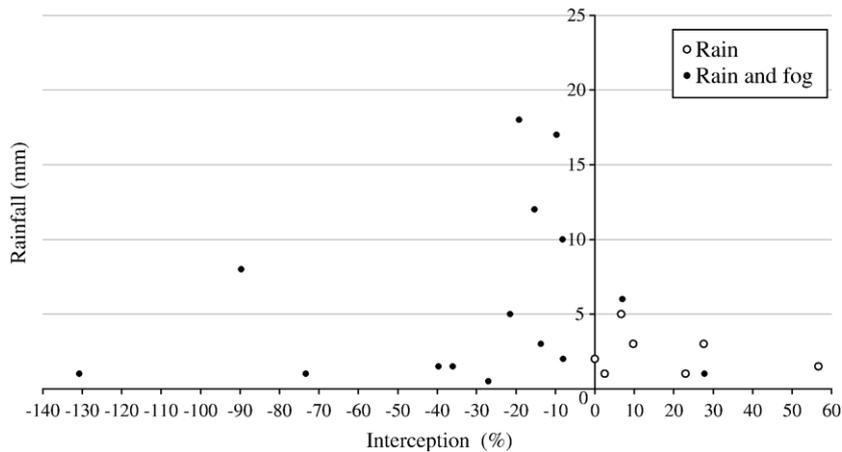


Fig. 2. Relationship between rainfall and interception. Nez de Bœuf, trees A and B (daytime).

A rigorous analysis of the database was made in order to single out each event. An event is defined as an episode of fog or rain, or fog associated with rain. Several events can occur during the same day. The shielded Grunow-type fog collector was used in order to detect fog episodes as best as possible, to show fog evolution in time, and to improve the typology devised in Nez de Bœuf. The quantitative data are secondary in this study. The fog collector is used as an indicator of fog conditions and not as a measure of cloud water interception by *S. demodata*. The collection of data from the shielded Grunow-type fog collector (G), the rain gauge and the throughfall gauges, at close time intervals, enabled us to distinguish each event and to class it according to the typology. When both the Grunow-type fog collector and rain gauge values are null and $AT > 0$, the event is classified as “fog only”. When there is a record for both the Grunow-type fog collector and the throughfall collectors and $CR = 0$, then the event is classified into another “fog only” category. When $G = 0$, $AT > 0$ and $CR > 0$, the event is classified into the “rainfall only” category. When $G > 0$, $AT > 0$ and $CR > 0$, then the event is defined as a “mixed rain and fog” episode. In this

case, the total amounts from G and CR are compared: if $G > CR$ the event belongs to the “fog > rain” sub-category, and if $G < CR$ the event is belongs to the “fog < rain” sub-category.

4. Results

4.1. Overall results

From October 2001 to January 2003, 58 and 47 events occurred for trees A and B, respectively. The data represent only daytime situations. “Clear sky” situations represent 21 days. The clearing manual rain gauge (CR) recorded 168 mm while the average throughfall (AT) was 195 mm for A and 203 mm for B. Relative interception (I) represents -16% for A and -27% for B. It ranges from -131% to 57% for A and from -204% to 21% for B (Fig. 2).

For tree C, data are continuous from December 10th 2004 to July 31st 2005 with 278 episodes (Table 1). Incomplete data were ignored. The clearing manual rain gauge (CR) had 948 mm and the average throughfall

Table 1
Amounts of throughfall, rainfall and fog per event type

Event type	n	Throughfall (mm)	Rainfall (mm)	Interception (mm)	Interception (%)	Grunow (mm)
"fog only"	152	25	0	-25		0
"fog only" (Grunow and fogdrip occur together)	15	39	0	-39		22
"fog > rain"	30	270	126	-144	-114	313
"fog < rain"	37	832	792	-40	-5	334
"rainfall only"	44	14	30	16	54	0
TOTAL	278	1180	948	-232	-25	669

Piton de Tanguets, December 2004–July 2005 (tree C).

(AT) was 1180 mm. It represents an interception (I) of -232 mm (or -25%). Interception values ranged from -6181% to 100% . For easier interpretation of the scatter plot chart, the interception is restricted from -300% to 100% and is expressed as a function of the fog/rain ratio (Fig. 3). A null fog/rain ratio represents a “rainfall only” event, a ratio ranging from 0 to 1 represents “fog < rain” situations, a ratio equal to 1 represents events where the values of both rain and fog are similar, and a ratio greater than 1 represents “fog > rain” events type.

4.2. Rainfall-throughfall relationship

The analysis of the “rainfall only” events shows an average daytime interception loss of 18% , and 4% for trees A and B, respectively. For tree C, 44 events occurred with an average interception loss of 54% . The total rainfall was 30 mm and AT was 14 mm. The interception varied between 6% and 100% . For half of the events ($n=22$), I is always 100% . For the major part of this sampling series, CR never exceeded 0.2 mm ($n=20$). For the other 22 events, the values of rainfall are equally low but the interception is more variable and ranges from 6% to 96% , while CR values range from 0.2 mm to 2.4 mm. The correlation between AT and CR amounts is weak ($R^2=0.636$). For a similar value of CR, AT, and consequently I , vary considerably as shown by the examples of December 18th 2004 and June 28th 2005 (Fig. 4). With a similar value of CR (1.8 mm) and an equal duration of throughfall (4 – 5 h), $I=6\%$ for the first

example and $I=35\%$ for the second example. However, a constant can be isolated: a very low value of rainfall induces a quasi-total interception loss.

4.3. Fog-throughfall relationship

For “fog only” episodes, daytime AT was 9 mm for tree A and 5 mm for tree B. AT was 64 mm for tree C. In Piton de Tangués, 152 fogdrip events (55% of all events) were recorded while the value of the Grunow-type fog collector was zero. This kind of event is very short in time (less than one hour on average) and is characterized by low intensities. It represents a total of 25 mm dripping to the forest floor but the average amount of fogdrip per event is particularly low with 0.16 mm. Out of 152 events, there were 121 episodes (80%) with $AT < 0.1$ mm, 25 with $0.1 < AT < 1$ mm, and only 6 (4%) with $1 < AT < 3$ mm. For the 121 events, AT was 0.04 mm on average. This low value is explained by the fact that only a few throughfall gauges recorded very small amounts of water. Nevertheless, we counted 15 events in which fogdrip and Grunow fog catching processes occurred at the same time. Total throughfall, or fogdrip, reached 39 mm and the average amount of fogdrip per event reached 2.8 mm. The duration of these events usually ranges from 1 h to 12 h (4 h on average). The event of January 24th 2005 contributed 48% of the total throughfall (Fig. 5). Throughfall began 2 h before the first record of the Grunow-type fog collector, then fogdrip and Grunow were simultaneous for 7 h. Intensities measured under *S.denudata* and by

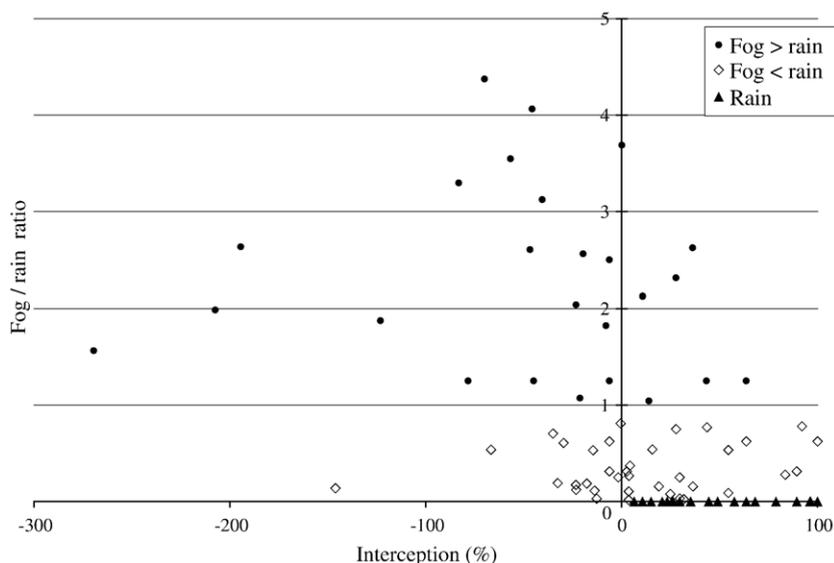


Fig. 3. Calculated interception versus fog/rain ratio. Piton de Tangués (tree C). (ratio=0: “rainfall only”; $0 < \text{ratio} < 1$: “fog < rain”; ratio > 1: “fog > rain”).

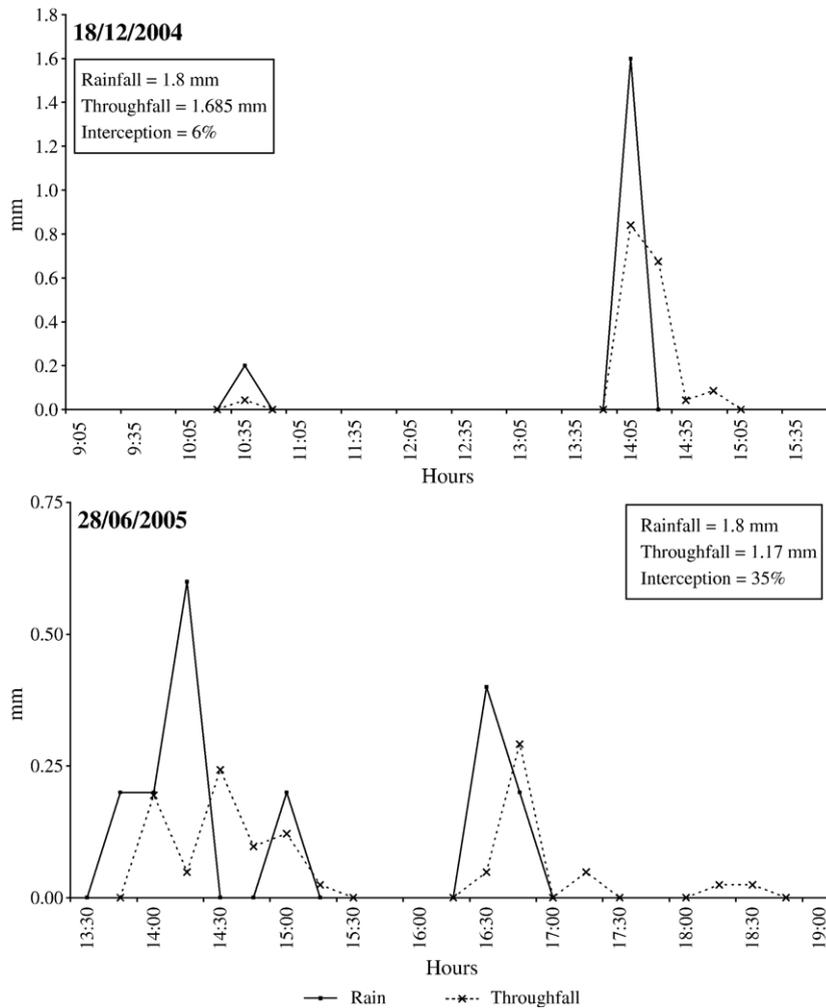


Fig. 4. Evolution of rainfall and canopy throughfall for two “rainfall only” episodes with equal value of rainfall ($R=1.8$ mm). Piton de Tangués (tree C).

Grunow were not equivalent in their amounts but were synchronous. After throughfall stopped at 9:05, the values of Grunow were higher than fogdrip. Out of 15 events, 9 provided 4% (or 1.5 mm) of the total fogdrip amount. Those events are characterized by fogdrip values less than to 1 mm. The example of May 04th 2005 is representative of those situations (Fig. 5) with both the fog collector and throughfall working simultaneously. Of the 15 events, 4 provided 27% (or 10.4 mm) of the total fogdrip and 2 provided 69% (or 26.7 mm) of the total fogdrip.

The 58 and 47 experiments made in Nez de Bœuf showed that there was fogdrip asymmetry when foggy events occur. There is a maxima zone, corresponding to the portion of canopy exposed to the wind. The spatial pattern of fogdrip under tree B on February 19th 2002 is a convincing example (Fig. 6). In the course of this day, the trade-wind blew from the south. Two fogdrip episodes

occurred in the afternoon during this sampling: 14:00–15:30 and 17:00–19:00. Of the 15 rain gauges, only five received some water after the first foggy event with 3 mm being the highest value. An intense and lengthy fog characterized the second event. Over 2 h, the maximum of the windward region tripled (9 mm). Neither north nor north–east portions of the canopy were affected by throughfall. At the end of the event, $AT=2.4$ mm.

This “windward/leeward” asymmetry recurs for each foggy event and for each tree. The trade-wind direction explains the localization of the area where maxima values are recorded. For a south direction ($n=3$ foggy days), the maximum values are south-facing (Fig. 7). For an east–south–east direction ($n=3$ foggy days) we noted two areas with maximum values. The first one corresponds to the wind direction; the second one is explained by a local wind disturbance.

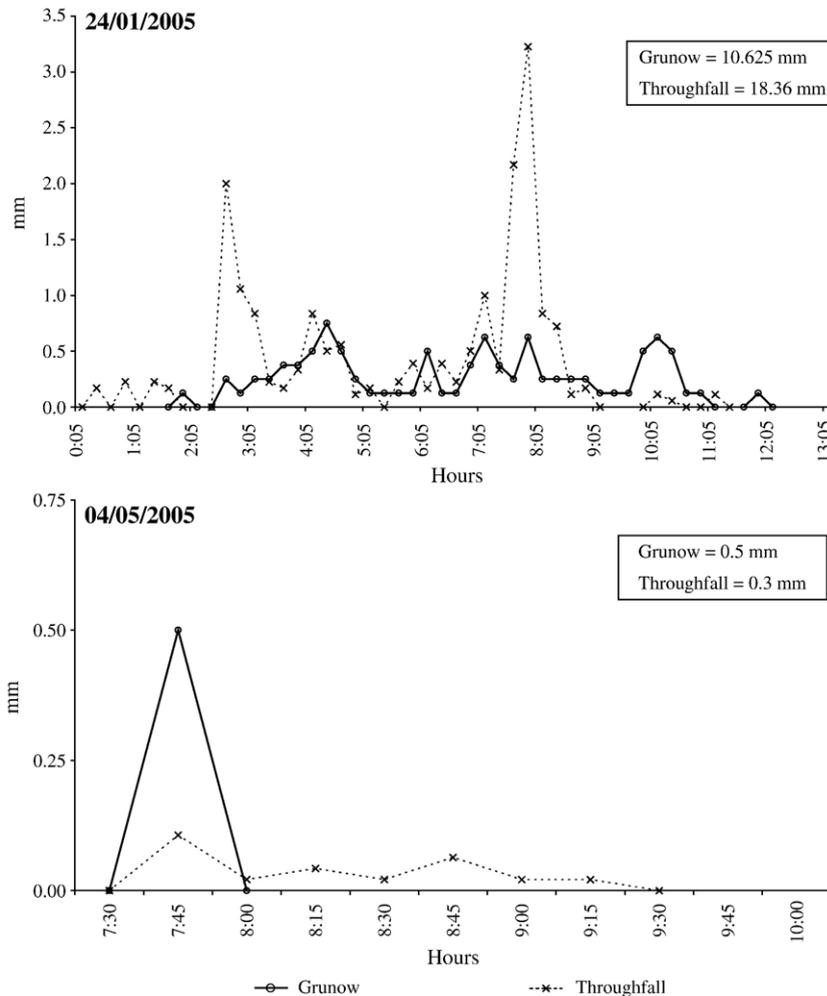


Fig. 5. Evolution of fog water (recorded by shielded Grunow-type fog gauge) and fogdrip under *Sophora* for two characteristic foggy periods. Piton de Tangues (tree C).

4.4. Analysis of mixed rain and fog events

The mixed event is characterized by 151 mm of total rainfall in Nez de Bœuf ($n=16$ events). The daytime average interception was -14% (A) and -27% (B). For tree C we recorded 67 events, $AT=1102$ mm and $CR=918$ mm. The average interception was -20% for 30 episodes of “fog > rain” and 37 events of “fog < rain”.

For “fog > rain” type, the total rainfall was 126 mm while AT was 270 mm ($I=-114\%$). We counted 23 events with a negative interception that is clearly a function of fog contribution. Nine events were recorded with an interception less than -100% . The interception is important for days with alternate hydrologic inputs: simultaneous rain and fog and “fog only”. In the case of January 23rd 2005 (Fig. 8), throughfall began at 00:35 and ended at 14:50 for a total of 90 mm. All of CR

(24 mm) was recorded between 00:20 and 07:35. In the same period, throughfall and fog recorded only 41% (37 mm) and 39% (15 mm) of their respective amounts. The value of I during this period was equal to -52% . The evolution of throughfall is more influenced by rainfall intensity. The impact of fog on throughfall is noticeable after 07:35 when rainfall stopped and when it constituted the only water input. At the end of the day $G=38$ mm and $I=-270\%$.

On January 25th 2005, the pattern was reversed (Fig. 8). Total throughfall reached 10 mm in 13 h. From 00:20 to 09:00 throughfall depended on fog: $AT=3.21$ mm and $G=1.13$ mm. Rainfall, which was confined to 15 min (10:30–10:45), had 2.8 mm, and influenced throughfall directly (2.75 mm at 10:45). Interception at this precise moment was not characterized by rainy events because of a similar value for AT and CR .

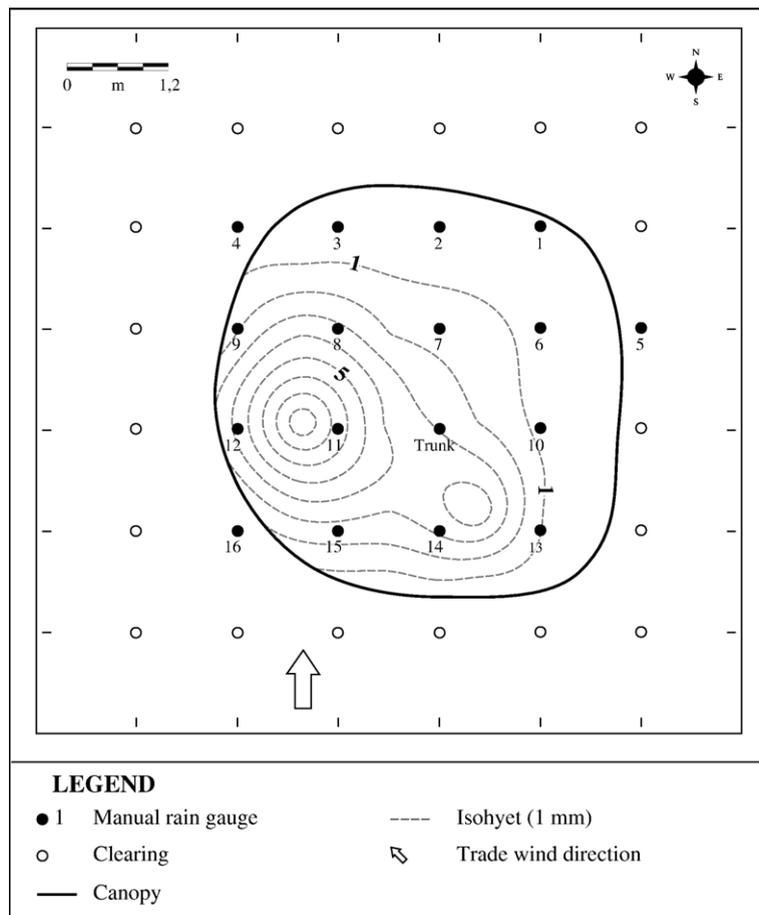


Fig. 6. Spatial distribution of fogdrip in Nez de Bœuf. Tree B, February 19th 2002 (daytime).

After 11:00 throughfall depended on fog again. At the end of the event $I = -208\%$.

Only one “extreme” episode was recorded with an interception equal to -6181% but $CR = 0.4$ mm and $G = 9.375$ mm. When the interception was positive (loss), the values of both rain and fog were extremely low: 3.6 mm on average for fog and 2 mm on average for rain. The maximum value of positive interception is $I = 64\%$ but it was recorded when $CR = 0.2$ mm and $G = 0.25$ mm.

For the “fog < rain” type, total rainfall is 792 mm and average throughfall is 832 mm ($I = -5\%$). Fifteen events were counted with negative interception. The values of I range from -1% to -146% . Twenty-two events induced a positive interception. Seven events with $I > 50\%$ coincide with some low quantities of rain and fog. In this case, the average value of rainfall is 1 mm and the average value of fog is 0.4 mm. There is one event with $I = 100\%$ but $CR = 0.2$ mm and $G = 0.125$ mm.

Analyzing “fog < rain” events is quite difficult. The examples of two episodes, on March 03rd 2005 and

April 10th 2005, show the diversity that can occur for this kind of event (Fig. 9). On March 03rd 2005, from the beginning of the event at 23:00 to 11:00, the rainfall amount was greater than the fog amount: $CR = 52$ mm and $G = 16$ mm. CR was equal to the average throughfall ($AT = 52$ mm). Then the interception is zero and is explained by fog that exactly compensated for water losses. From 11:15 to 22:00 the situation is reversed: $G = 34$ mm, $CR = 19$ mm and $AT = 41$ mm ($I = -114\%$). Throughfall continued until 11:30 the next morning while both the rain gauge and Grunow did not record any more water. At the end of the event, which lasted 37 h, $I = -35\%$.

On April 10th 2005, both rain and fog occurred from 03:50 to 10:20. Throughfall intensity is strongly linked to rainfall intensity. CR and AT amounts were almost equivalent during the length of the event, with rainfall values slightly greater than throughfall values. Calculated interception was always near 0% during this same period. It is due to fog water input, which was constant

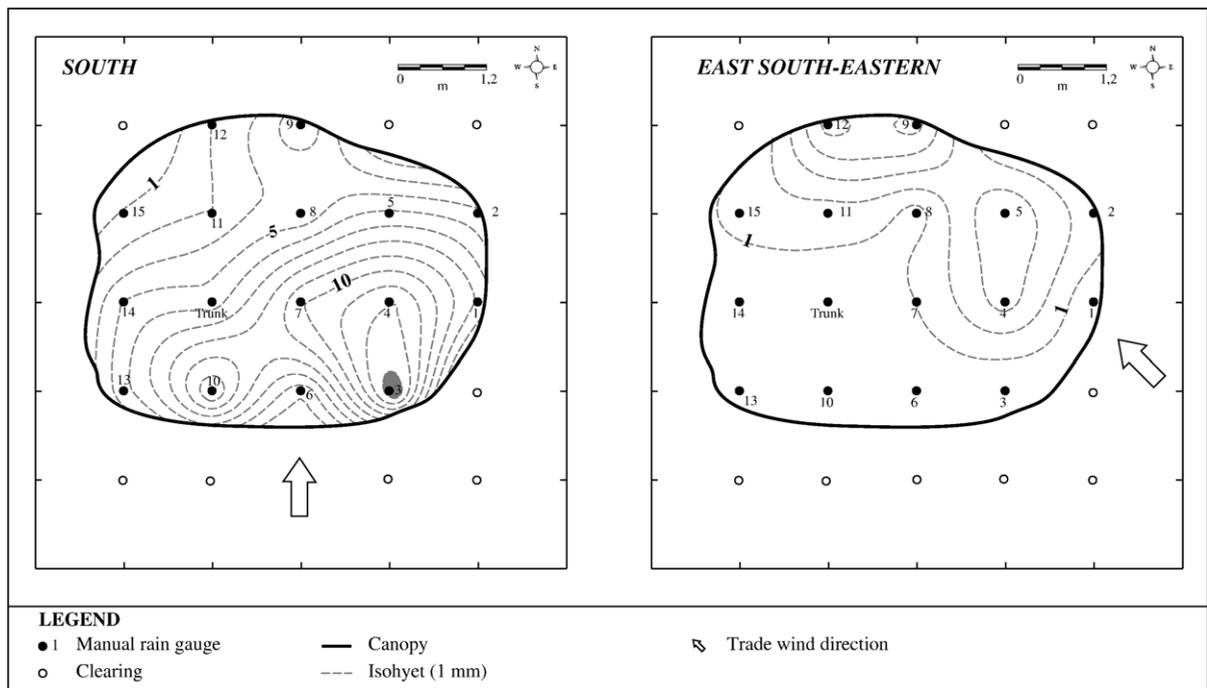


Fig. 7. Spatial distribution of throughfall according to trade-wind direction. Nez de Bœuf, tree A (daytime).

and compensated for water losses, although it did not generate any gain. Finally, $G=12.5$ mm, $CR=47$ mm and $AT=45.3$ mm. The interception was relatively weak with $I=4\%$.

“Fog < rain” day type is composed of events in which rainfall, fog and throughfall quantities are consistent. Those situations are usually found during the summer season when, except for tropical storms, cumuloform clouds frequently occur and generate important water inputs from rain and fog. In this case, the interception can be negative or positive. It depends on the gap between rainfall and fog values; the greater the gap, the more the interception. The two situations are well-represented by the examples of December 14th 2004 and December 18th 2004 (Fig. 10). For the first date, I was negative ($I=-15\%$) for $AT=194$ mm, $CR=169$ mm and $G=90$ mm. For the second example, though relatively weak, I was positive ($I=4\%$) for $AT=165$ mm, $CR=172$ mm and $G=64$ mm.

5. Discussions and conclusions

This study, which was the first of its kind in Reunion Island, is a preliminary approach to evaluating the hydrologic budget of the ecosystems in this island. The results confirm the remarks made in 2000. Fog water contributes an important part of the water inputs when intercepted by

S. denudata. Throughfall under *S.denudata* represents 116% to 127% of the rainfall measured in an open site during our daytime experiments (trees A and B). For continuous data, throughfall represents 124% of rainfall (tree C). These values are in accordance with those usually given for *montane cloud forests*. For both *mossy upper-montane* and *dwarf cloud forest*, throughfall represents 115% to 130% of rainfall (Bruijnzeel and Hamilton, 2000).

5.1. Limitations of the Grunow-type fog collector

The Grunow-type fog collector has been criticized on the grounds that it is too small and it fails to represent the vegetation. Furthermore, water can lodge in the small openings of the mesh and precipitation can sometimes enter directly into the rain gauge portion, with the risk that it can be mixed with fog deposition (Schemenauer and Cereceda, 1994a). It is an accepted fact that wind driven raindrops have a significant impact on fog collection (Schemenauer and Cereceda, 1994b). The span of the shield used here eliminated some, but not all, wind blown drizzle and rain. Nevertheless, the data obtained from the Grunow-type fog collector should be considered very cautiously. Because of the short dimensions of the shield used here, both rain and drizzle drops certainly hit the vertical collecting surface even at low wind speeds.

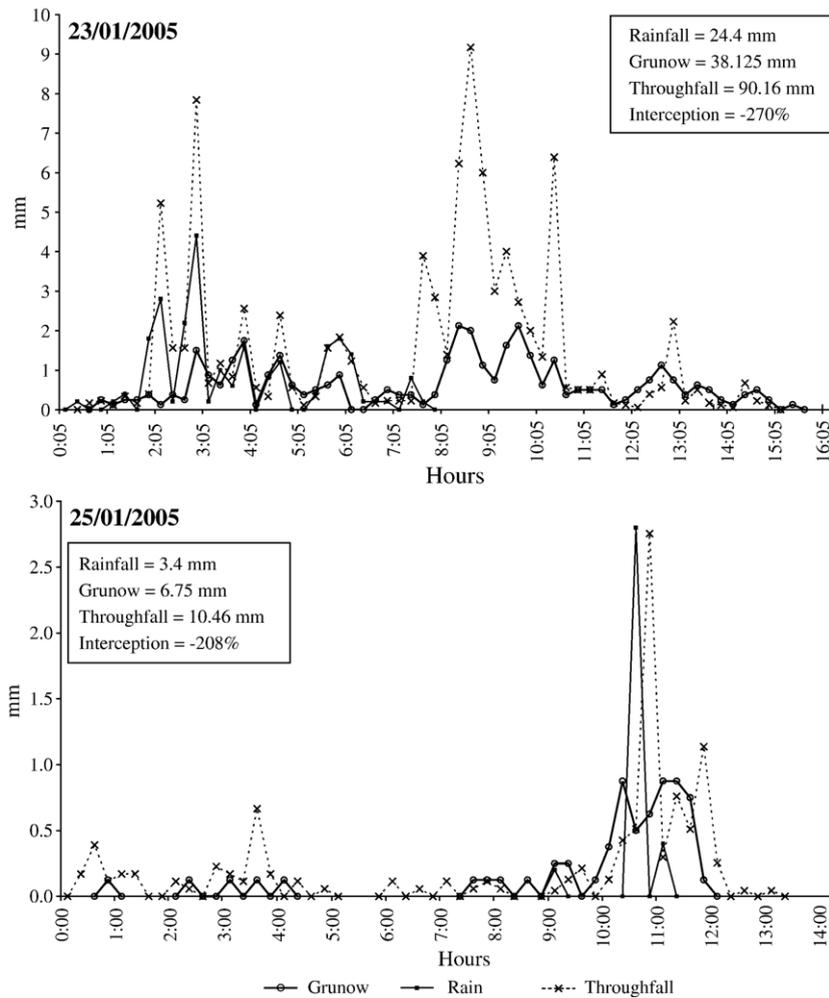


Fig. 8. Evolution of rainfall, fog and throughfall for two “fog>rain” sampling episodes. Piton de Tangues, tree C.

The drainage capacity of the Grunow-type fog collector is weak when fog episodes are short in time and with low water content. This flaw is difficult to remedy. Gauging the tipping buckets at small intervals (0.125 mm here) can be adopted in order to detect as many events as possible. The fact that 152 out of 167 “fog only” events were not detected by the Grunow is attributed to a lack of accuracy. Out of those 152 events, which were short, 125 events (or 82% of 152) had an AT that did not exceed 0.125 mm, the calibration value of the Grunow tipping bucket. With direct observations, it can be considered that this kind of foggy event is characteristic of episodes with very low fog intensity and duration. The very weak value of throughfall in those cases implies that the intercepted cloud water does not systematically provide water benefits to the vegetation. It may just temporarily reduce evapotranspiration because those events are usually “isolated”.

5.2. Rainfall interception

Interception loss ranges from 4% to 54% for *S. denudata*. In Nez de Bœuf it is difficult to compare our results with international data (Table 2). The comparison is made difficult not only because the methods are different, but also because the characteristics of the rainfall events and the vegetation species are not the same. For two specimens of the same species and of comparable size, interception was different as shown for Nez de Bœuf where significant differences were noted for trees A and B, 25 m apart. The extreme variability of intercepted amounts is explained by tree architecture, tree phenology and epiphyte density.

The canopy saturation value corresponds to the amount of water required to wet the full canopy surface and let throughfall begin (Jackson, 1971). For *S. denudata*, the lower threshold of storage capacity is 0.2 mm because

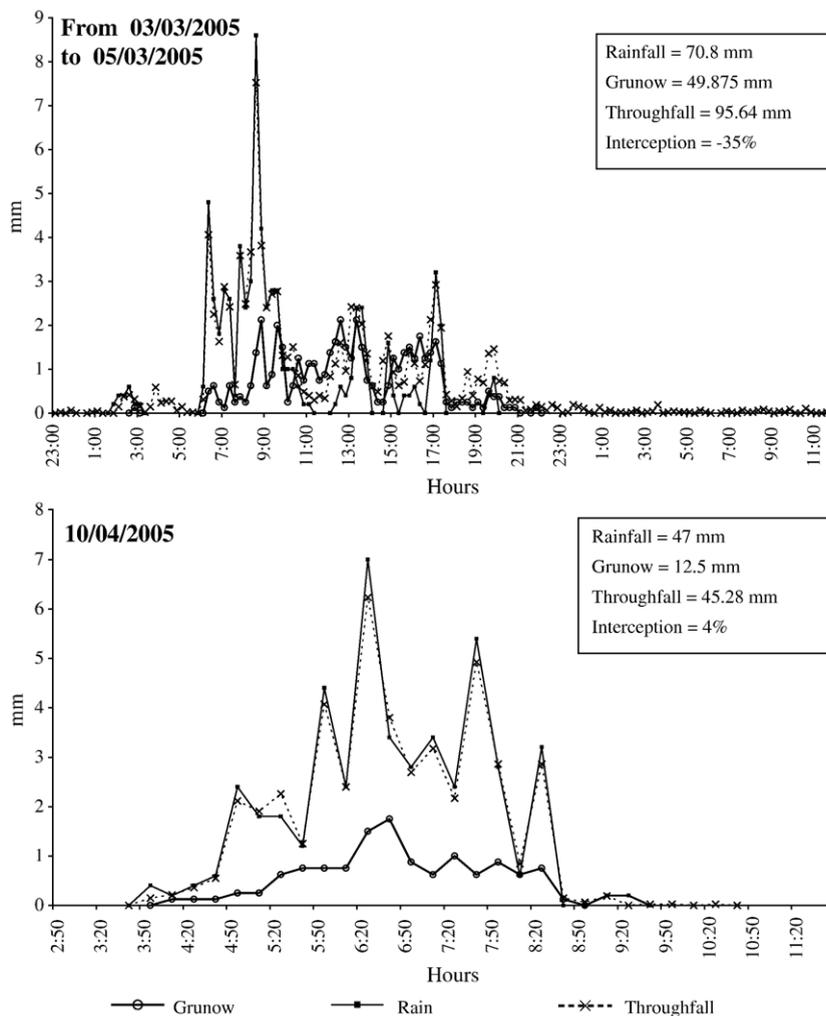


Fig. 9. Evolution of rainfall, fog and throughfall for two “fog<rain” sampling episodes. Piton de Tangués, tree C.

$I=100\%$ for 90% of events with $CR=0.2$ mm. A value of 1.4 mm is estimated for the upper threshold. Once the canopy saturation was exceeded, the interception rate declined as more rain poured down.

5.3. The importance of fog for subalpine vegetation

The occurrence of fog at Piton de Tangués is important: 234 events occurred in which fog was the only source of water or fog was associated with rain. The recurrence of “fog only” events may reduce vegetation moisture stress in an environment regarded as dry because of the high permeability of the land, high interception loss during rainy days, and the fact that a large amount of water (rain or fog) falls within a few days or events only, in summer months.

The difference of 232 mm between total rainfall and total throughfall implies that fog interception contri-

butes to the water budget of the subalpine ecosystem found in La Fournaise in general, and of *S. denudata* stands in particular. Fogdrip widely offsets evaporative losses during rainy days. However, the data analysis hides the various kinds of fog incidence. This is clearly demonstrated by the intricate “Mixed rain and fog”-type. No typical case was found for this kind of event. The intercepted amounts depend on duration, whether mixed rain and fog occur simultaneously or alternately. The time interval between rain and fog values is a prevailing factor. The presence of fog does not systematically generate a gain. Many cases are to be distinguished: (1) fog is not efficient enough and just reduces evapotranspiration, (2) fog amount is efficient but negligible, (3) fog just reduces interception loss, (4) fog exactly offsets the loss with I close or equal to 0%, (5) fog amount is enough and induces a gain ($I<0\%$).

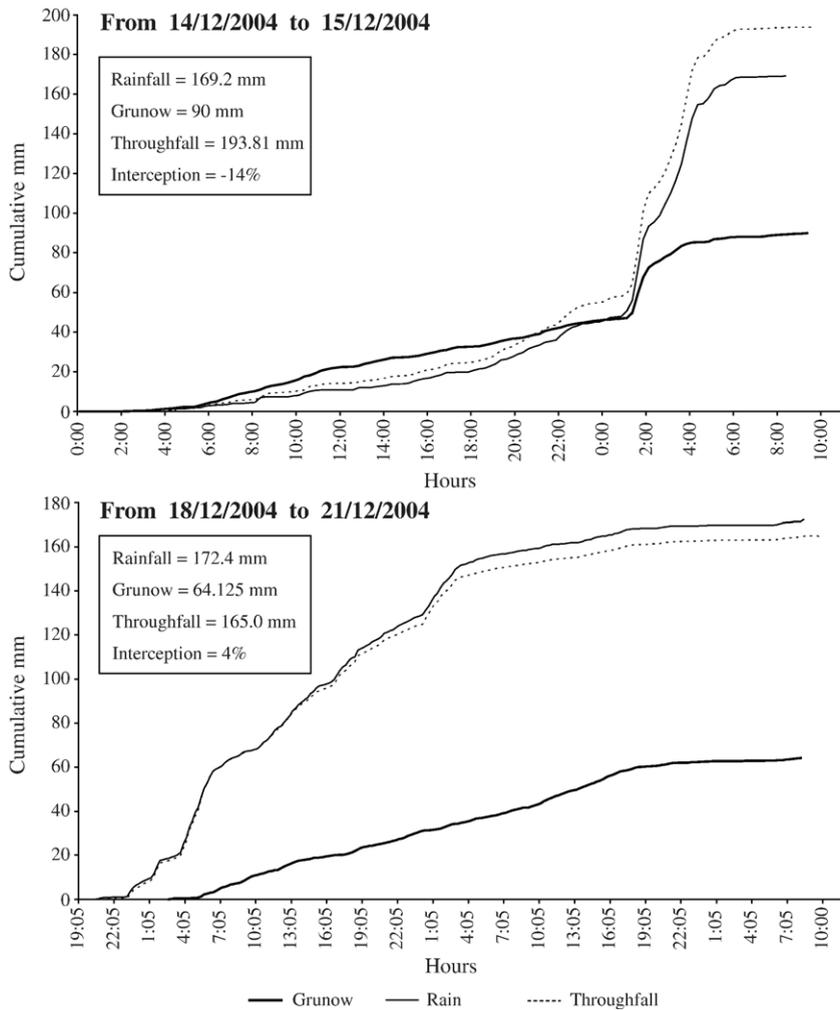


Fig. 10. Cumulative rainfall, fog and throughfall for two extreme episodes. Piton de Tangues, tree C.

The subalpine cloud forest in La Fournaise is still developing: it is marked by the colonization of *S. denudata*, which spreads through the ericaceous bushes. Interception of cloud water by *S. denudata* is of hydrologic and ecological importance. It plays a significant role in plant succession communities. The “fountain tree” provides additional water input benefits and creates new topoclimatic conditions. Beneath the trees, the favourable precipitation regime enables the growth of herbs, ferns, and grass species. A similar vegetation pattern is termed “fogdrip community” and occurs in the alpine scrub (composed of *Sophora chrysophylla*) of Haleakala (Maui, Hawaii) and Mauna Kea (Hawaii) (Leuschner and Schulte, 1991). Studies on the Hawaiian *Sophora* indicate that cloud–water interception in high altitude regions can provide a significant source of water, particularly during dry months (Juvik and Nullet, 1995). A similar conclusion can be put forward about the extraordinary capacity of

S. denudata to catch fog water. High fog frequency allows the existence of forest communities in the arid conditions of the La Fournaise highlands.

For foggy events, there is also a threshold value to trigger throughfall. Storage capacity is interesting to define

Table 2
Interception loss differences between Reunion subalpine ecosystem and other forest sites

Location	Ecosystem or species	Interception loss	References
Reunion Island	Subalpine, <i>Sophora denudata</i>	4% to 54%	This study
Hawaii	Subalpine, <i>Sophora chrysophylla</i>	25%	Juvik and Nullet (1995)
Tropics	Tropical cloud forest	8% to 32%	Bruijnzeel and Proctor (1995)
Colombia	Tropical forest	11% to 15%	Vis (1986)

but it is more difficult to calculate than for rainfall episodes. The comparison between Grunow and throughfall shows that tree water provision was always higher than from the artificial fog collector. The difference lies in the fact that tree foliage is more effective at “stripping” fog during light and short foggy events. Dawson (1998) described the same phenomenon for *Sequoia sempervirens* in California.

In terms of throughfall spatial distribution, forest margins and individual trees catch more fog water than the inner part of the forest (Stadtmüller, 1987; González, 2000). *S. denudata* canopy not only induces a gain of water but also redistributes it. When fog is the only water input or when it is associated with rain and dominates the latter, a characteristic feature emerges: the side of the tree oriented to the wind always records the maximum values of throughfall. When the wind speed is sufficient, the same occurs for drizzle or rain drops. The existence of many local concentrations is explained by branch and leaf localization or by a higher leaf area index (Calamini et al., 1998).

The hydrologic importance of *Tropical Montane Cloud Forests* has been widely demonstrated. These ecosystems have been massively deforested. As a result, turning forests into annual cropping or grazing is almost inevitably followed by ever-increasing erosion and reduction in groundwater reserves (Stadtmüller, 1987; Hamilton et al., 1995; Bruijnzeel, 2001). The native forests of La Fournaise, between 1600 m asl and 2000 m in the leeward side, are fragmented and degraded. During the last century, *S. denudata* clumps have been largely eliminated through the combined effects of pasture and plantation of exotic species for commercial logging. In addition to the loss of foliar surfaces, *S. denudata* regeneration was strongly affected. The same fact was noted in Hawaii where native forests of *S. chrysophylla* have been drastically reduced by browsing pressure (Jacobi, 1980; Scowcroft, 1983). As was shown in Hawaii, the examination of hydrologic processes, the impact of *Sophora* on soils and ecology should be taken into account. *S. denudata* is a host-plant for numerous insects and its flowers are a major source of food in winter for two endemic passerines (*Zosterops* sp.) (Gill, 1971). The conservation of a high floristic and fauna diversity in tropical montane cloud forests has been noted worldwide (LaBastille and Pool, 1978; Doumenge et al., 1995). Above 2200 m, in an undisturbed habitat, the regeneration of *S. denudata* has been successful. Fog catching processed by *S. denudata* plays a significant role on the plant succession community found on recent volcanic materials. Sustainable management concerning both the restoration of degraded hab-

itats and the active protection of natural environments is of paramount importance.

Longterm climatic studies are needed to better understand the local causes of fog formation in Reunion Island. It would be interesting to study the interception for diverse indigenous or exotic forests along an altitudinal transect. Some additional tests with a Standard Fog Collector (SFC) (Schemenauer and Cereceda, 1994a), are needed in order to improve the quantification of fog contribution to the ecosystem. SFCs have proved efficient under many conditions and can help assess it low-intensity fog events. It is important to study wind speed and direction in order to appreciate the role wind plays in determining the amount of water a tree collects from fog, drizzle or rain.

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