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# *ASPLENIUM NIDUS*, A STUDY OF FOREST DEGRADATION BIO-INDICATOR

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**ABSTRACT**

In the face of environmental degradation, certain species adapt more while others become more sensitive, serving as bio-indicators. *Asplenium nidus*, a fern, an epiphyte of the ASPLENIACEAE family, was studied in two forests, one on a slope and the other on flat terrain. How does it behave in a flat area (degraded and non-degraded) compared to a sloped area (lower slope and mid-slope)? Thirty individuals were studied in a flat area (Antetezana), and seventy individuals on a slope (Analamazaotra). Biometric parameters, including leaf length and width, were measured, analyzed using two luxmeters simultaneously within a 30m radius. Chi-square analysis was conducted to determine the orientation dependence concerning the species exposure. The Student's t-test examined the sensitivity of parameters in each zone and variations in brightness between environments. In the flat zone, 48% of individuals are influenced by the West orientation, comprising 45% of individuals (degraded zone), and the East orientation accounting for 50% (non-degraded zone) with orientation dependence (p-value = 0.040). In the sloped area, the luxmeter difference was significant (p-value = 0.001), but both forests showed no significant difference in biometric parameters (p-value > 0.05). Ethnobotany revealed that over 85% of 152 households generally use the forest for medicine and energy wood, with no direct use of the species. Orientation in the flat zone is considered an important bio-indicator parameter, but not the slope.

**Keywords**: *Asplenium nidus*, bio-indicator, flat zone, sloped zone, orientation, Antetezana, Analamazaotra, Madagascar.

## INTRODUCTION

Approximately 10% of the vascular plant diversity in global forests consists of epiphytes, with around 28,000 species recorded, including CARRIAS [1]. Deforestation, defined as the transformation of forested lands for different purposes or the long-term reduction of canopy coverage below the 10% threshold [2], poses a major challenge, especially in developing countries. In the year 2000, the total area of altered forests and wooded lands in 77 tropical nations was estimated to be around 800 million hectares, with nearly 500 million hectares of primary and secondary forests [3]. In Africa, the annual rate of forest degradation equals approximately 50% of the annual deforestation rate [4]. Tropical rainforests are renowned for their significant biological diversity [5]. In these regions, including Madagascar, various ecological changes have intensified the manifestations of climate change ([6]), raising concerns among researchers and natural resource managers [7]. Progressive biodiversity loss, habitat loss and fragmentation, drought, and other forms of ecosystem degradation are attributed to climate change [8].

In this context, the study focuses on *Asplenium nidus*, an epiphytic plant, to understand its response to environmental disturbances in two distinct topographic contexts. One study is conducted in a flat area (littoral) at the Antetezana Forest Station (Atsinanana Region), and another in the Analamazaotra Special Reserve (Alaotra Mangoro Region). The central question is: how does *Asplenium nidus* respond to forest degradation and climate change between a flat area (degraded and non-degraded) and a sloped area (upper and lower slopes)? Two hypotheses are formulated: the orientation of *Asplenium nidus* individuals may be influenced by exposure to light due to forest degradation, and light intensity could determine the species' physiognomy, suggesting that *Asplenium nidus* could potentially serve as an indicator of degradation in specific environments. The main objective is to determine the ecological behavior of *Asplenium nidus* in response to forest degradation and climate change, analyzing variations in its behavior and physiognomy in diverse environments to identify it as a potential indicator of forest degradation.

# I. MATERIALS ET METHODS

## 1. Study sites

The study was conducted in two forests (Figure I): one in a flat area in the Atsinanana Region (Fokontany Antaratasy) at the Antetezana Forest Station (17°46'S / 49°30'E) covering an area of 900 ha [9]; and the other in the Analamazaotra Special Reserve (18°23'S, 48°28'E), Alaotra Mangoro Region (CR Andasibe) with an area of 810 ha. Both forests are located in the eastern part of Madagascar. The Antetezana forest experiences a very humid and hot tropical climate [10] with a monthly average temperature ranging between 22°C and 27°C [11], while Analamazaotra has a humid temperate climate influenced by altitude, with an average annual temperature of 19.4°C [12].

## 2. Biological Material

In the ASPLENIACEAE family, *Asplenium nidus* (see ANNEXE I) is a vascular plant, terrestrial, epiphytic fern with a short vertical rhizome that can also cling to rocks. Its spores are located beneath the frond and extend from the main vein to the margin [13].

## 3. Characterization of the vegetation structure

Characterization of the vegetation structure was conducted to understand the canopy stratification and openness, assessing light penetration related to the discontinuity of the forest canopy. The GAUTIER transect method [14] was employed to delineate the structural profile of the studied forests. A 50m transect line, 1m above ground and perpendicular to the sea, was set up. Vegetation contact heights were noted using a graduated stake up to 3m, placed vertically, to visually estimate plants exceeding this height. The process was repeated every 1m [15]. The degree of stratum openness referred to GODRON's cover scale (see ANNEXE II) [16]. To better characterize different environments, two transects for each (four in total) were conducted, one in the degraded and one in the non-degraded zone for the Antetezana forest, and one each in the lower and upper slope for the Analamazaotra forest. These transects were chosen where *Asplenium nidus* individuals are concentrated.

## 4. Inventory of *Asplenium nidus* and Biometric Measurements

To understand if *Asplenium nidus* could be a bio-indicator, parameters were studied based on topography (flat and slope), including the ecology and biometrics of *Asplenium nidus*. In the flat zone (Antetezana), 30 individuals were sampled in 2 environments (12 in degraded and 18 in non-degraded) based on their orientation using a compass. In the slope zone (Analamazaotra), 70 individuals were inventoried, and site brightness was simultaneously measured using 2 luxmeters within a 20m radius in the upper and lower slope from 9:15 am to 3:15 pm. Luxmeters were placed 1m above the ground, and measurements were taken every 10 minutes. Unlike the behavioral study related to orientation, the influence of brightness on the forest degradation and the homogeneity of individuals were examined. The main biometric parameters recorded were consistent in both forests, including the length, width, and number of leaves (fronds) of *Asplenium nidus*.

These methods were applied to a random sample in the different studied environments to gain insight into the ecological behavior of *Asplenium nidus* and its role, particularly in forest degradation and response to climate change.

## 5. Statistical Analyses

Statistical analyses were performed to verify assumptions in different case studies:

-The Chi 2 independence test was used to determine the association between exposure and the orientation of individuals, specifically in the flat zone.

-Student's t-test was employed to compare the means of two groups, particularly regarding the plant's biometric parameters in different environments (degraded and non-degraded, lower and upper slope).

-The Wilcoxon test was used to assess whether the two samples follow a normal distribution, especially the brightness intensity in the upper and lower slope. This test was chosen to approximate the exact p-value as the sampling duration was only 3 days.

### 6. Ethnobotany

In the coastal Antetezana forest, spanning 3 Fokontany (Antaratasy, Ambohimarina, and Vohitamboro), an survey was conducted among the residents of the three villages, targeting 152 households. The frequency of local resource use modes was studied using the formula Fr (%) = ni/N100 concerning the number of citations from locals [17]. This practice helps determine the use of natural resources and measure anthropogenic pressure on the forest [18]. In the Analamazaotra Special Reserve, 30 households around the forest were surveyed to determine the local usage index of the plant. This technique was determined by the formula I (%) = n/N100. If the result is above 60%, the species is considered known (see ANNEXE III) [19].

## II. RESULTS

### 1. Structural Profile

A total of 4 transects (2 from each) were studied to observe the vegetation structure in the two forests. For the Antetezana Forest Station, it was deduced that the tree height class in the degraded zone stops at 10 m with a 7% canopy cover, indicating a very open structure. In contrast, the upper stratum in the non-degraded zone reaches 14 m with a canopy cover of 5%. However, the canopy cover for the height class similar to the upper stratum in the degraded zone is 29%, indicating an open canopy (Figure II). At the 10 m height level, the canopy cover in the degraded zone is very open, while that in the non-degraded zone is open. For the Analamazaotra Special Reserve, forest trees reach up to 16 m in height. The height class beyond 14 m indicates a canopy cover below 25% for both the upper and lower slopes, indicating very open strata. However, a stratification scale difference was observed in the 12 to 14 m class, with 36% for the lower slope and 21% for the upper slope (Figure III). The upper slope has a very open stratum, while the lower slope has an open stratum.

### 2. Chi 2 Independence Test

The chi-square independence test indicates a dependence between orientation and exposure, with a p-value of 0.040 below the significance threshold. Therefore, there is a link between the orientation and exposure of individuals.

### 3. Individual Orientation Rates

Analyzing the rates of individuals based on their orientation, distinguishing between degraded (12 individuals) and non-degraded (18 individuals) areas (Table I). In degraded areas, the East has a higher rate, representing 55%, while the West accounts for 45%. In contrast, in non-degraded areas, the balance is more uniform with an equal split of 50% for both East and West. The total orientation rates (East and West) in the Antetezana forest are 48% towards the West and 52% towards the East. However, one individual shows an aberrant orientation towards the North.

### 4. Biometric Parameters

Comparisons of samples from the degraded and non-degraded zones for the Antetezana Forest Station (flat zone) and those from the upper and lower slopes for the Analamazaotra Reserve (slope zone). The p-values of the biometric parameters (Table II) are above the significance threshold of 0.05, indicating no significant difference between the characteristics of individuals in their respective environments (degraded and non-degraded; upper and lower slopes).

### 5. Brightness Measurement

In total, 37 luxmeter readings were observed over 7 hours per day (3) on each studied slope. The average brightness on the upper slope is 170.20 Fc with a maximum peak of 1197 Fc, minimum 8 Fc, and a standard deviation of 231.673. In contrast, for the lower slope, the average is 48.36 Fc, the maximum 150 Fc, and the minimum 6 Fc with a standard deviation of 27.691. According to the Wilcoxon test approximation for light penetration in both slopes, the calculated p-value is 0.0001, indicating different distributions between the two samples.

### 6. Ethnobotany

Ethnobotanical results indicate that inhabitants around the Antetezana forest generally use forest resources for energy and medicinal purposes. The three villages sharing the forest show a usage frequency of over 80% for energy wood, with 81% in Antaratasy, 82% in Ambohimarina, and 85% in Vohitamboro, recording the highest users of energy wood. Additionally, the ethnobotanical result in this area shows that *Asplenium nidus* is not used, as 100% of surveyed households affirmed not using this plant. Around the Analamazaotra Reserve, *Asplenium nidus* is known to 60% of informant citations, while 40% represent locals who are unaware of the species. However, out of the 18 households aware of the plant, only 33% use it, while 67% do not. Regarding the species' use in the area, *Asplenium nidus* is utilized in medicinal practices (61% of citations) and also in traditional events (39%).

## III. DISCUSSIONS

## 1. Ecology of *Asplenium nidus*: Role and Reaction to Disturbances

The ecology of *Asplenium nidus*, an epiphytic plant often observed in forest environments, holds particular interest in the context of this study regarding its reaction to climate change. Studying responses to light highlights subtle interactions between the species and its environment. Additionally, in the flat zone, examining the relationship between orientation and exposure of individuals sheds light on adaptive mechanisms at play. *Asplenium nidus* prefers bright, warm, and humid areas for growth. Regarding exposure, mature specimens demonstrate the ability to tolerate light levels; however, direct exposure is not favored. Thus, observations indicating that the species avoids direct light confirm *Asplenium nidus*' sensitivity to forest degradation and climate change in the flat zone. This sensitivity could be linked to reaction mechanisms to climatic and anthropogenic disturbances, considering that human activities are the main contributors to current climate changes and their impacts on the environment [20], making it a potential bioindicator of forest degradation. Certainly, the opening of strata (degraded and non-degraded zones) indicates a form of canopy degradation [21]. Moreover, in the Antetezana Forest Station, concerning orientation, the prevalence of eastward orientation (in the degraded part) could reflect a specific response to canopy modification due to degradation. In summary, individual orientation rate results suggest that *Asplenium nidus* may be influenced by the opening of the overall cover in degraded and non-degraded zones.

Observations regarding the influence of brightness on different slope levels, especially upper and lower slopes in this study, add a crucial dimension to understanding the ecology of this plant. According to an article from 2019, *Asplenium nidus* prefers a consistently humid atmosphere and diffuse light [22]. However, while the upper strata (12m and above) are open on both slopes, unlike the flat zone, the middle stratum has a coverage rate of over 50% (GODRON scale) in the lower slope, making it semi-open. Compared to the flat zone, the collected brightness is considered low in the lower slope with an average of 48.36 below 100 Fc, and for the upper slope with 170.20 Fc, it is between 100 and 500 Fc, thus considered moderate light [23]. There is less penetration in the Analamazaotra Forest Station.

Therefore, analyzing the impact of the studied forest degradation on the physiognomy of *Asplenium nidus* provides a crucial insight into how ecosystems, especially *Asplenium nidus*, react to climate change. However, the study sites, covering different environments (degraded and non-degraded areas in the flat zone - Antetezana, upper and lower slopes in a sloping zone - Analamazaotra), show homogeneous physiognomy for the studied biometric parameters (p-value >0.005). Since light is vital for the species, capturing it for optimal photosynthesis while benefiting from radiation due to photoperiodism, only a part of which can be absorbed by the leaves, is crucial. Moreover, "insufficient light is the most important of the microclimatic factors considered in dense forest, for regeneration." Thus, in the sloping zone, light would be a factor in physiognomic homogeneity but not a determining factor in degradation.

## 2. Ethnobotany: Antetezana and Analamazaotra

Regarding the Antetezana forest, it is noteworthy that although *Asplenium nidus* is not directly used, its supports play a valuable role in the daily lives of the inhabitants. They are exploited as sources of energy and materials for furniture. The most used supports by the locals are Gaertnera macrostipula (RUBIACEAE), Scolopia sp. (SALICACEAE), Dyospiros sp. (EBENACEAE). This indirect use emphasizes the importance of the plant, even if its role is not directly reflected in local traditional practices. The dynamic where plant parts are used for various needs shows how local populations make use of forest biodiversity to meet specific requirements.

In Analamazaotra, the relationship between residents and *Asplenium nidus* is closer. Nearly the majority (60%) of those surveyed recognize the plant, reflecting a considerable awareness of its presence in their environment. However, only a third of this population actually uses *Asplenium nidus*. Notable uses include traditional medicine and cultural events. Some people use the plant to cure stomachaches, and it is also used during tsaboraha (Malagasy cultural event) as a plate due to its large fronds or as packaging for the umbilical cord. The predominance of use in medicine and traditional events testifies to the integration of *Asplenium nidus* into cultural practices and the recognition of its potentially beneficial properties. Ethnobotanical results illustrate the significance of vegetation in the daily lives of the local population.

## 3. Conservation and Ecosystem Management

Throughout history, the Malagasy people have used forest resources such as firewood or construction wood. However, using the trunk is the most destructive aspect for a tree, followed by the forest. In Madagascar, despite the establishment of the Environmental Action Plan since 1990, 200,000 to 300,000 hectares of forests continue to disappear each year, with the forested area representing only about 20% of the island's total surface area, approximately 13 million hectares. Deforestation, over the years, has reached alarming levels. Consequently, global natural preservation is crucial, especially in Madagascar, a country characterized by an exceptionally high rate of endemism, requiring the need to preserve intact ecosystems and adopt sustainable resource management.

A deep understanding of the ecology of *Asplenium nidus* provides valuable insights for the conservation of forest ecosystems, especially in contexts where this species is present. By identifying *Asplenium nidus* as a potential indicator of degradation, it is imperative to strengthen monitoring efforts of forest ecosystems. This species could serve as a biological marker to assess forest health and identify areas requiring intervention. This applies notably to the case of the Antetezana Forest Station, which faces anthropogenic and climatic pressures, factors contributing to degradation. Moreover, the ecological importance of *Asplenium nidus* as a bioindicator should be applied to Eastern tropical forests where the species resides in humid dense forests or riparian forests. This is especially relevant as the fight against climate change became a priority of the international community with the signing of the Kyoto Protocol in 1997.

However, to fully exploit the potential of *Asplenium nidus* as a degradation bioindicator, additional studies are necessary. In-depth research linking the orientation of individuals to light, as well as observed physiognomic variations, is needed. Additionally, the influence of other environmental factors, such as humidity, ambient temperature, and climate variations, should be assessed to obtain a more complete picture of the species' ecology. This is crucial for a better perspective on forest conservation.

The implications of *Asplenium nidus* ecology extend beyond scientific research to the local population and forest resource management. Understanding this species' responses to environmental disturbances can contribute to better ecosystem management, informing decisions regarding conservation and restoration. The integration of traditional knowledge from local populations on the use of *Asplenium nidus* and other plants can offer a holistic perspective, strengthening sustainable approaches to forest resource management.

## 4. Prospects for the use of *Asplenium nidus*

The growing interest in *Asplenium nidus* extends to new frontiers, with innovative explorations of its potential use in culinary and medical fields. Drawing from the knowledge of the residents of Analamazaotra who use the species for culinary and medicinal purposes, usage patterns should be shared in the surrounding villages of the species, especially in the case of the inhabitants of the Fokontany near Antetezana who do not use the species and are unaware of its benefits. Notably, in Rembert DODOENS' book (1557) discussing Asplenium, it is written: "The leaves taken with vinegar for the space of forty days cure the hardened and obstructed spleen..." [31]. This indicates the medicinal virtues of the plant that deserve exploration. The etymological origin of Asplenium comes from the Greek asplenon (spleen), related to ancient virtues attributed to the plant for treating this organ [32]. Furthermore, its use as an ornamental plant offers the opportunity to generate income for the local population while contributing to nature-based tourism. *Asplenium nidus* serves as a microhabitat for certain species of amphibians [33].

## CONCLUSION

The purpose of this study is to understand the ecological behavior of the *Asplenium nidus* species in various environments, both in the Antetezana Forest Station and on a slope in the Analamazaotra Special Reserve, with the aim of evaluating its potential as an indicator of degradation. The formulated hypotheses were assessed, and the results provided significant insights. Specifically, the analysis confirmed a relationship between the orientation of *Asplenium nidus* and its exposure, validated by the Chi-square test with a p-value of 0.40 in the flat area (Antetezana Forest Station). This association reinforces the idea that canopy openness plays a crucial role in the behavior of this species as an indicator of degradation. Moreover, the vegetation cover rates revealed notable disparities, as indicated by low percentages indicating degradation in the degraded flat area (7%) compared to a non-degraded area (39%), as well as variations on the slope, with 21% at the top and 36% at the base in the 12 to 14 m class. Furthermore, the Wilcoxon test confirmed a significant

difference in brightness between the lower and upper slope. This brightness disparity could directly influence the physiognomy of *Asplenium nidus* but does not affect its behavior as an indicator of degradation. Regarding the biometric parameters for each environment, most p-values obtained were above the alpha threshold (>0.005). These findings reinforce the idea that specific environmental conditions impact the behavior and physiognomy of *Asplenium nidus*. However, it is important to note that uncertainties persist, and further research could enhance our understanding. Evaluating additional factors such as soil composition, moisture, and microclimatic variations could provide more comprehensive insights into the underlying mechanisms. In summary, this study offers valuable insights into the potential role of *Asplenium nidus* as an indicator of forest degradation and its response to climate change in various environments. It also underscores the importance of adaptive ecosystem management based on the specific characteristics of each area to preserve global biodiversity and forest health in the face of climate disruptions.

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## LIST OF ILLUSTRATIONS

## CAPTION OF SCHEME

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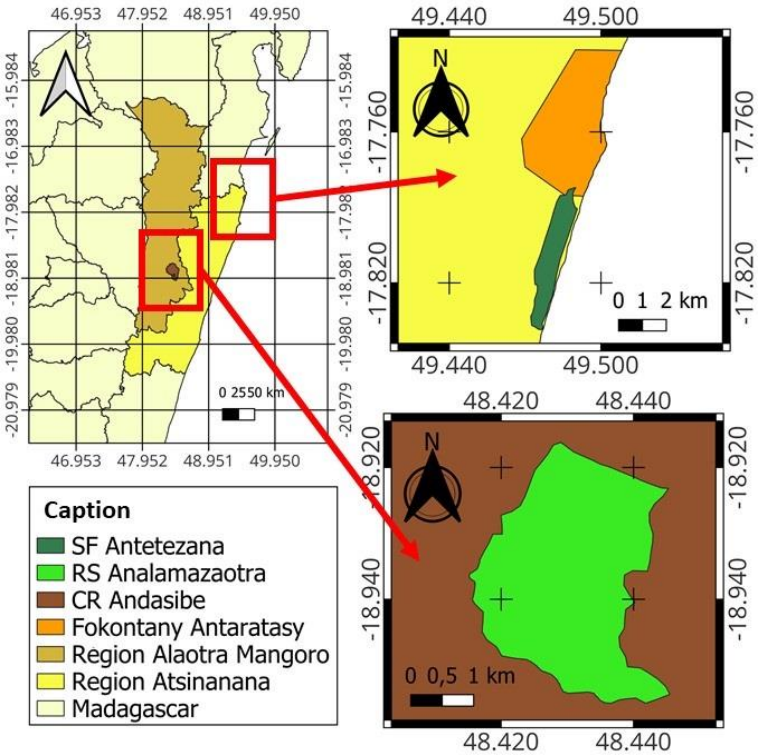


Figure I Location : SF Antetezana et RS Analamazaotra

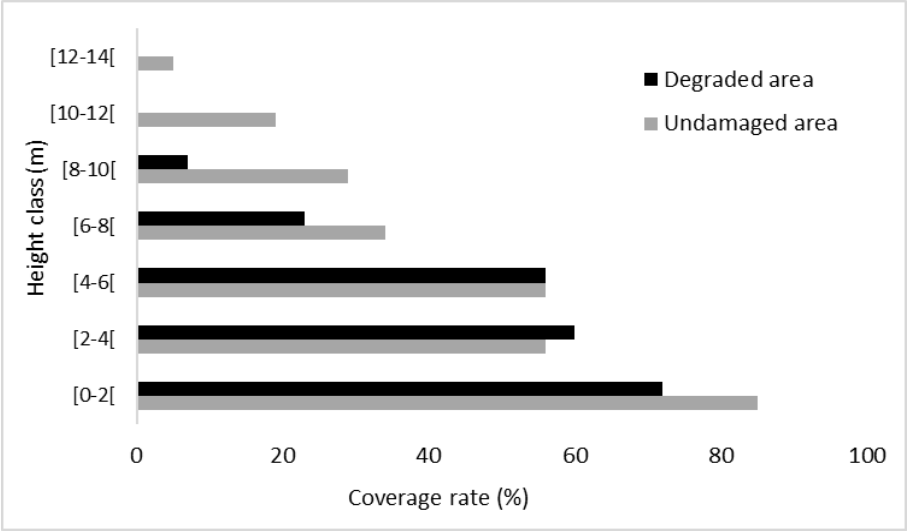


Figure II Flat area coverage rate

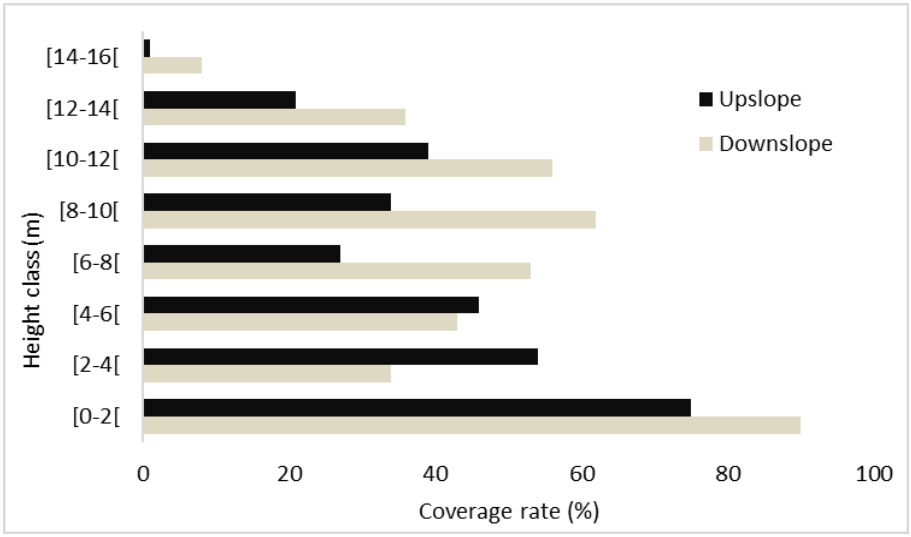


Figure III Slope area coverage rate

## CAPTION OF TABLES

Tableau I Individual Orientation Rates

| | Rate | |
|---|---|---|
| | Degraded area | Undamaged area |
| East | **55** | **50** |
| West | **45** | **50** |

Tableau III Table I P-value of biometric parameters

| Biometric parameters | Antetezana Forest Station | Analamazaotra Special Reserve |
|---|---|---|
| Sheet length | **0.853** | **0.374** |
| Sheet width | **0.610** | **0.787** |
| Number of sheets | **0.682** | **0.605** |

## ANNEXS

**Annex I: *Asplenium nidus***

Figure IV *Asplenium nidus*

**Annex II: GODRON scale (1983)**

- GR ≥ 90%: closed stratum;

- 75% ≤ RG < 90%: little open stratum;

- 50% ≤ RG < 75%: semi-open stratum;

- 25% ≤ RG < 50%: open stratum;

- RG < 25%: very open stratum

**Annex III: LANCE usage index (1994)**

- If I (%) [60-100%], the species is well known and widely used.

- If I (%) [30-60%], the species is moderately used and moderately known.

- If I (%) <30%, the species is little known and little used.

The multipurpose species to be retained are those with a utilization index greater than 20% according to the LANCE formula.

## TABLE OF CONTENS