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Research Article

Effect of leaf harvest on wax palm (*Ceroxylon echinulatum* Galeano) growth, and implications for sustainable management in Ecuador.

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Abstract

The wax palm (*Ceroxylon echinulatum*) is an arborescent, dioecious and slow-growing palm distributed on Andean slopes at 1000-2000 m elevation in Ecuador and northern Peru. The leaves of wax palm have been traditionally harvested and used for the making of handicrafts during Easter celebrations. It has been suggested that removal of unexpanded leaves may be the main source of threat to the survival of the species. The goal of this work was to evaluate the impact of leaf removal on growth and development of *C. echinulatum*. Leaf production and growth were monitored in 60 young individuals divided into three treatments: T0 - control, T1- without damage to adjacent leaves; T2- with damage to adjacent leaves. Results from two years of observation reveal that leaf growth rate and the number of new leaves produced per individual are not adversely affected by this practice. Harvest treatments were equal or even higher than the control for both variables. Balance of leaf number in the crown (before and after the extraction) was negative in the harvest treatments, indicating a factor of unsustainability in the annual harvest management of the species. The results suggest that biennial harvesting of one young leaf per individual could be sustainable. An appropriate management strategy could be to distinguish young individual populations by marking palms with nine or more leaves in the crown in different quadrants of extraction, in order to perform rotational, biennial and monitored cropping.

Key words: Arecaceae; cloud forest; leaf harvest; non-timber forest products.

Resumen

La palma de ramos *Ceroxylon echinulatum* es una especie arborescente, dioica y de lento crecimiento presente en las estribaciones andinas de Ecuador y norte del Perú entre los 1000 a 2000 m snm. Las hojas jóvenes (cogollo o ramo) son utilizadas para la elaboración de artesanías durante las celebraciones en semana santa. Se ha sugerido que la extracción de hojas durante este periodo podría ser el principal motivo de amenaza a la sobrevivencia de la especie. El objetivo de este estudio fue evaluar el impacto de la extracción de hojas en el crecimiento y desarrollo *de C. echinulatum*. La producción y el crecimiento de hojas nuevas fue monitoreada en 60 individuos jóvenes divididos en tres tratamientos: T0 - control, T1- corte del ramo sin daño de hoja adyacente, T2 - corte del ramo con daño de hoja adyacente. Resultados de dos años de observación revelan que el crecimiento foliar y el número de hojas nuevas producidas por individuo no fue negativamente afectado por la cosecha, presentando valores iguales o aún superiores al control para las dos variables. El balance de hojas en la corona (antes y después del inicio de la extracción) fue negativo en los tratamientos de cosecha, alertando la no sostenibilidad de la cosecha anual de los cogollos. Los resultados sugieren que la cosecha bianual de un ramo por individuo puede ser sostenible. Una estrategia de manejo apropiada sería la zonificación de poblaciones de individuos jóvenes en diferentes cuadrantes de extracción para la realización de cosechas monitoreadas, rotativas y bienalmente.

Palabras clave: Arecaceae, bosques nublados, cosecha de hojas, productos forestales no maderables.

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Introduction

Thousands of young leaves of wax palm (*Ceroxylon echinulatum* Galeano) are cut every year from wild populations and transported to the urban areas of Ecuador to be used as fiber for the production of handicrafts during Catholic Easter celebrations. The possible impact of leaf harvest on the survival of wax palm populations has raised questions about whether to ban such harvests or to manage the resource. However, the absence of technical data about the impact of the leaf harvest on resilience of natural populations impedes strategies of management and conservation.

The Andean palm *C. echinulatum* (wax palm or palma de ramos) is a solitary, arborescent (up to 25 m tall) and dioecious palm distributed on the western and eastern Andes in Ecuador and northeastern Andes in Peru [1, 2, 3]. This palm species forms isolated and fragmented populations, locally dense, and restricted to humid premontane and lower montane forests at 1200-2250 m elevation [1, 4, 5]. According to local farmers, a particular feature of this palm species is its slow growth. A study of the sister species *C. alpinum* in Colombia suggests that this species requires more than 80 years to start its reproductive cycle [6]. Additionally, the natural regeneration of *C. echinulatum* occurs exclusively inside forests [7]. This species fulfills a key function in the Andean forest where it provides habitat and food to a great variety of cloud forest wildlife species [8]. *C. echinulatum* in Ecuador has been catalogued as a vulnerable species mainly threatened by habitat degradation and destructive harvest of leaves [9].

Deforestation and habitat fragmentation threaten the conservation of wild populations of wax palm [5, 10-12]. Clear cutting or selective logging generate microclimatic stress by changing local temperature and relative humidity [13], which in some species may exceed physiological limits and lead to the extinction of palm populations in deforested areas [10]. A demographic study of *C. alpinum* [6] found that the harvest of young leaves is a decisive factor affecting the development and survival of harvested individuals, whereas a different study of *C. echinulatum* [14] suggests habitat degradation as the major threat to the survival of these populations.

C. echinulatum and other species in the same genus (*C. ventricosum, C. parvifrons*) have been used in Ecuador as fiber for the production of handicrafts [1, 4, 15]. Such handicrafts require the harvest of unexpanded leaves (*cogollos* or *ramos*), usually from juvenile palms without a visible stem [16,

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17]. Harvesting is performed at least once a year, close to Palm Sunday date (March or April) by peasants who invade or rent available forested areas to harvest these leaves. The harvest technique includes the cut of several open leaves (2 or 3) to access the *cogollo*. The harvest of wax palm´s *cogollos* and its commercialization generate a significant additional income for economically poor villagers from the northwestern part of Pichincha province and artisans from Quito [17].

The correlation between leaf harvest and low palm survival remains controversial. Harvesting can cause differences in growth and reproduction rates, and has a cumulative effect over time, eventually killing the individuals or altering the population dynamics [6, 18-21]. However, other studies suggest that harvest does not affect the survival of individuals (20, 22-25). This controversy stems from different studies in several species of palms in which leaves are used for commercial purposes. Studies of *Sabal* sp., *Chamaedorea tepejilote*, *Chamaedorea radicalis* and *Livistona rotundifolia* have proved that defoliation increases leaf growth rate and the production of new leaves [22, 26-28]. Studies on other species such as *Chamedorea elegans*, *Genoma deversa* and *Astrocaryum mexicanum* indicate that defoliation reduces production rate of new leaves, stem growth, fecundity and vegetative production [18, 20, 21]. These conflicting results could be explained, at least partially, by the morphological variation of the studied palms (arborescent or understory, solitary or cespitous), the criterion for sustainability (population growth rate or life table response experiments), and time of survey.

Although there are studies of the effect of harvesting palm leaves on individual development [18, 22, 26, 31], for the genus *Ceroxylon*, there is not enough evidence confirming a negative effect. The only study reporting the impact of leaf harvest on the *Ceroxylon* genera was a study of *C. alpinum* from the Andean slopes of Colombia [6]. By using matrix models, this study suggests that palm populations of *C. alpinum* are affected by leaf harvest.

In this paper we assess the effect of leaf harvest on growth and development of *C. echinulatum* leaves during two years. The questions to be to tested were: (a) What is the growth rate of sprouts and uncut leaves after the first and the second harvest, and under three different harvest treatments?; (b) Does the number of leaves in the crown have a positive impact on the growth rate of sprouts and uncut leaves? We propose recommendations for sustainable management of the species.

Methods

Study site

This study was carried out at Inti Llacta Reserve (1800 m.a.s.l., 0°02’ N, 78°46’ W) in the northwestern zone of Pichincha province (Ecuador), close to the village of Nanegalito. The study area is classified as a cloud forest with a rainfall average of 2,000-4,000 mm/yr [29], distributed between a distinct wet (December - May) and dry season (June - November). The average temperature varies between 18 and 24° C. The Inti Llacta Reserve is a secondary forest dominated by a patchwork of early- and late-successional stages. This area supports a dense population of *C. echinulatum* with a high density of seedlings, juveniles and adults [7] (Fig 1).

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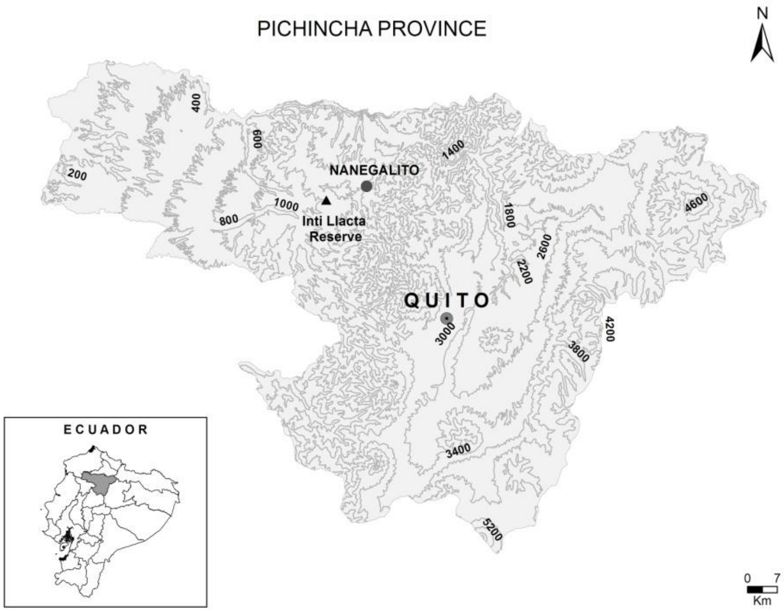

Fig. 1. Map location of the study area, northwestern zone of Pichincha province Ecuador.

Experimental design

We mimicked the harvest process of the villagers who harvest these leaves annually from this forest. To determine the effects of harvesting on growth rate, a harvest experiment was conducted. Sixty young individuals were located inside the forest with: (a) leaves of > 4 m long in a rosette-like form, (b) without a visible stem, and (c) with a total number of leaves within the range of seven to nine. Juvenile palms were chosen because they are most commonly harvested in this region. Twenty palms were selected as control (T0) and 40 palms for two harvest treatments (T1- without damage to adjacent leaves, T2- with damage to adjacent leaves) in which the young leaves were cut 50 cm from the base of the crown. Adjacent leaf damage is characterized by the low cutting of a mature open leaf blocking access to the young leaves within the crown. All crown leaves were marked with red plastic tape.

The survey was carried out consecutively from March 2009 to January 2011. Annual harvest took place during two consecutive years. The harvest occurred before the Easter Celebrations in March 2009 and 2010. Leaf growth measurements (length, m/month) and the number of new leaves produced were recorded every two months after the establishment of the experiment. Growth was monitored in leaves that were cut at the beginning of the experiment (sprouts) and in new leaves that emerged after harvest (uncut leaves). The total count of leaves in the crown of all the individuals was performed every four months after establishing the experiment. The time of new leaf emergence, leaf blade opening and the damage was recorded for each individual in all treatments. The balance of leaves on the crown represents the difference between the total individual leaves after two years of harvest and the number of leaves at the beginning of the experiment. Due to deviations in normality and homoscedasticity within the data, variables among treatments were analyzed through Kruskall-Wallis non-parametric tests. Statistical analyses were conducted using the statistical program INFOSTAT version 2.0 [30].

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Results

At the end of the first study year, significant differences were found in leaf growth of uncut leaves between treatments ($p < 0.001$). Treatment T2 showed the highest rate of leaf growth and it was significantly different ($p < 0.001$) from those of treatments T1 and T0 (Fig. 2a). At the end of the second year there were significant differences between treatments T1 and T2 ($p = 0.0537$; Fig. 2b). In total, during the two years of study, uncut leaves grew an average of 9.82 m, 8.88 m and 9.6 m for treatments T2, T1 and T0, respectively. The growth rate behavior of uncut leaves during two years of monitoring is illustrated in figure 3.

At the end of the first year, trees that were harvested at the beginning of the experiment had no significant differences in the leaf growth rate for the three treatments ($p = 0.2558$; Fig. 2c). However, at the end of the second year, leaf growth rate of sprouts for T2 was higher than for the other treatments, and no significant differences between T0 and T1 were found ($p < 0.0001$; Fig.2d).

Significant differences of leaf growth rates were found between individuals with different numbers of leaves in the crown ($p = 0.0021$). Individuals with the highest number of leaves (nine) in the crown showed higher rates of leaf growth (Fig. 4). During the first year of the study ($p = 0.0192$), the number of new leaves produced per individual per year was significantly higher for the harvest T2 (2.15 ± 0.49) and control (2.05 ± 0.69) treatments than for T1 (1.65 ± 0.49). However, at the end of the second year of consecutive harvests there were no differences among treatments (T0 = 1.85 ± 0.59; T1= 1.70 ± 0.47; T2= 1.80 ± 0.41; $p = 0.6682$).

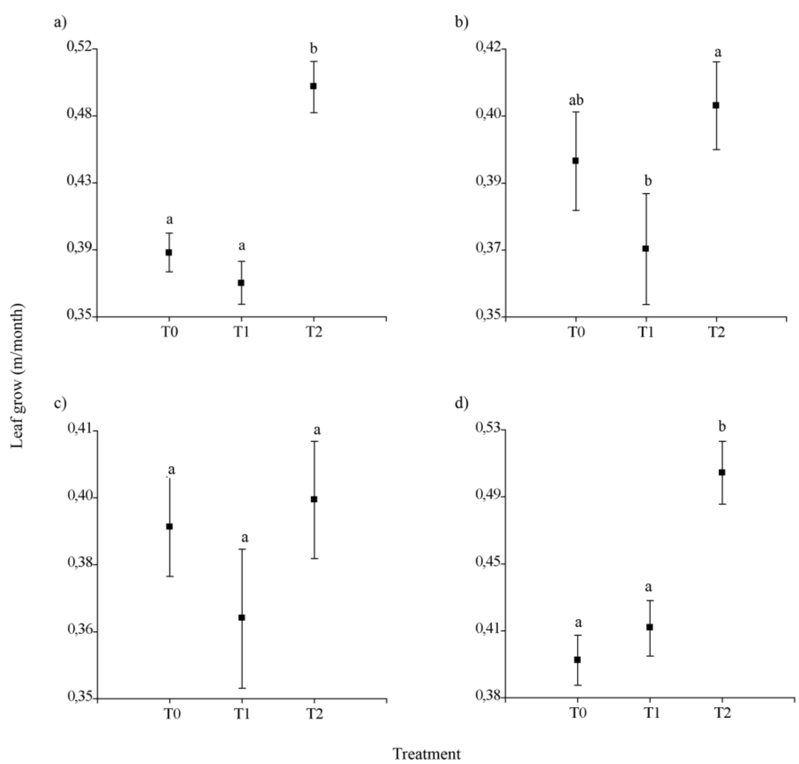

Fig. 2. Leaf growth rate of sprouts and uncut leaves for control and defoliated *C. echinulatum* plants at Nanegalito, Ecuador. a) uncut leaves at the end of the first year of the study; b) uncut leaves at the end of the second year of the study; c) sprouts at the end of the first year of the study; d) sprouts at the end of the second year of the study. Vertical lines indicate one standard error. Common letters indicate no difference among treatments (Kruskall-Wallis; $p < 0.05$).

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Every leaf that was cut grew again, but in harvest treatments these leaves were shorter than the control (T1 = 2,41 m ± 0,67; T2 = 2,84 m ± 0,85; T0 = 3,95 m ± 1,05; $p < 0.0001$). Leaves that sprouted after the extraction of *cogollos* developed less, and in some cases, completely lost all their leaflets. When we compared the final length of the leaves that were not cut during the experiment we found that there were no significant differences among the three treatments (p = 0.1071; Table 1).

Table 1. Final length of uncut leaves (during 12 months period) and balance in the total number of leaves (during 24 months period) on individuals of *Ceroxylon echinulatum* at Nanegalito, Ecuador.

Treatment	Final length (cm) of unharvest leaves (p = 0,1071)	N	Balance in the number of leaves (p <0,0001)	N
T0	3,95 ± 1,05 [a]	35	0,90 ± 1,33 [b]	20
T1	3,93 ± 0,56 [a]	11	0,00 ± 1,21 [b]	20
T2	4,59 ± 1,05 [a]	12	-1,40 ± 0,75 [a]	20

[a,b] Differences among treatments are compared using the Kruskal–Wallis test. Data are expressed as means (mean ± standard deviation). Common letters indicate no difference among treatments ($p < 0.05$).

The balance of open leaves in the individuals after two harvests showed a leaf deficit in individuals being harvested: there were fewer leaves on the crown at the end of the second year than at the beginning of the study.

The balance in the number of leaves on the individual was significantly different between harvest treatments and control (p <0.0001). Individuals in the control showed a positive balance between living and dead leaves but the harvest treatment had negative balances (Table 1).

Discussion

Results from two consecutive years of observation reveal that leaf growth rate and the number of new leaves produced per individual were not adversely affected by this practice. Harvest treatments (T1, T2) had equal or even higher growth rates and number of new leaves than the control (T0); but the balance of leaf number at the end of the second year was higher for the control (T0).

In the first year of study, palms with adjacent leaf damage (T2) showed a high response in leaf growth and production of new leaves. This compensatory mechanism is evident in many species of palms [20-22, 28]; it acts through the foliar meristem activation, increasing the production of new

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leaves as a strategy to normalize photosynthetic capacity [31]. This mechanism is also favored by the reduction of self-shade caused by cutting large leaves, allowing an increase in photosynthesis rates in the remaining leaves [32]. A similar suggestion has been proposed for defoliated palms such as *Livistona rotundifolia* [22], *Sabal yapa* and *Sabal mexicana* [27].

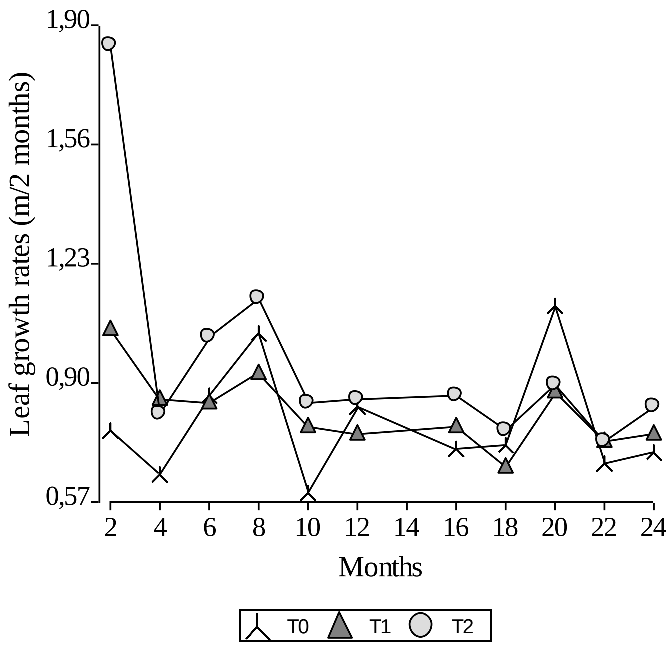

Fig. 3. Growth rate behavior of uncut leaves for the three treatments in *C. echinulatum* plants during 24 months of study period at Nanegalito, Ecuador.

However, this mechanism is directly influenced by the availability of light and soil resources such as water and nutrients [19, 32-34]. According to Anten *et al.* [31] defoliated individuals respond best under high light availability. Several understory species are able to resist higher harvest levels and have greater regeneration capacities in secondary forests than in primary forests [19, 24]. There is therefore a potential for favorable recovery of wax palms, as they usually grow best in disturbed areas of the cloud forest [7].

The compensatory mechanism is also affected by the size of the individual. In the case of *C. echinulatum*, initial leaf number in the crown affected leaf growth rate. Individuals with the greatest number of leaves (nine) showed higher rates of leaf growth, suggesting that older individuals can recover from the impact caused by cutting the leaves more easily. Reports of other palm species (*Sabal yapa* and *S. mexicana*) indicate that the reduction of compensatory capacity due to decline of plant resources was more evident in small palms than in large ones, suggesting that the nutritional reserves of small palms are particularly scarce [27].

The first year of the study showed that the ecologically sustainable harvesting potential of *C. echinulatum* is high. However, if the individual is subject to annual cropping, it is unknown whether this potential for recovery can be sustained over the years. As in the first year of study, in the second year the growth rate of sprouts in T1 and T2 were not affected, indicating that up to two consecutive harvests have no negative effect on leaf growth rate of the *cogollos* that were cut.

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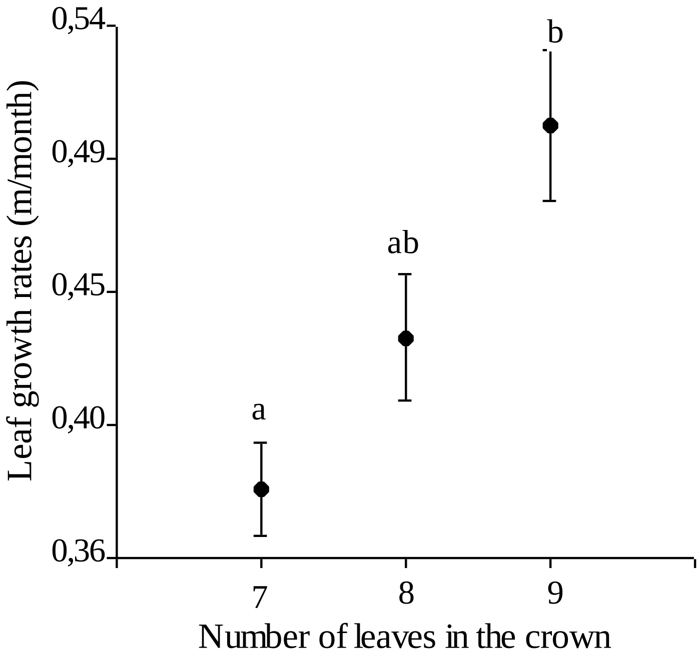

Fig. 4. Effect of leaf number in the crown on leaf growth rate of *C. echinulatum* during 12 months at Nanegalito, Ecuador. Vertical lines indicate one standard error. Common letters indicate no difference among treatments (Kruskall-Wallis; $p < 0.05$).

At the end of the second year, the growth rate of uncut leaves with adjacent leaf damage (T2) was reduced. This fact can be explained by the loss of the photosynthetic capacity of the individual under consecutive harvest and with adjacent leaf damage. According to Chabot and Hicks [35] the compensatory mechanism can be reduced if the individual is subject to intense or constant defoliation. In spite of this, the averages did not differ from the control, indicating that there is still no treatment effect and therefore, for the variable leaf growth, harvest activity does not affect normal development of the individual.

Another important variable is the balance of the number of leaves in the crown of each individual after each year of extraction, and how this variable behaves over time. The effect of harvesting on the number of opened leaves in the individual's crown varies according to the height of the cut. When large unexpanded leaves (5-6 m) are harvested, the recovered leaf has lost its middle and upper leaflets, never completely forming a whole leaf. This causes a shortfall in the number of leaves in the crown. In contrast, smaller unexpanded leaves (2-3 m) reach larger final sizes and have their leaflets open in the final stage of leaf growth, appearing as a normal leaf with the bottom half in good condition and the top pruned. According to Flores and Ashton [18] and Ticktin [19] the way in which the palm is cut can also result in different population growth rates. In the treatment with adjacent leaf damage (T2), leaf deficit in the crown is even higher. Thus, each year the individual will reduce the number of leaves at the base of the crown, making this model of extraction unsustainable over time. In practice, however, the damage to the adjacent leaves does not occur regularly and systematically. It depends on the level of difficulty in accessing the main *cogollo,* the conscience of the harvester and the willingness to prevent the maximum damage to individuals during harvest.

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Even when leaf growth rate reveals a potential recovery in two consecutive harvests, the balance of open leaves indicates a deficit in the development of individuals under harvested conditions. Therefore, the balance of leaves is a warning factor of unsustainability in the management of the species. Considering that sustainability in the use of forest products requires, at least, that harvest rates do not exceed the resilience of populations [36], the type of harvest and management performed on individuals of *C. echinulatum* plays an important role in sustaining populations and the extraction of this non-timber resource. Our results indirectly suggest that biennial harvesting of one young leaf per individual could be sustainable. An alternative to reducing the harm done to individuals is to use small and sharpened *machetes*, which enter more easily into the crown and facilitate the harvest of the *cogollo*. This harvesting technique would allow the complete recovery of individuals and consequently the sustainability of harvests and species conservation.

Implications for conservation

The lack of scientific data on the impact of harvesting wax palms has resulted in speculation about the ecological sustainability of this practice. This has generated the Ecuadorean government's current prohibition of the extraction of leaves. However, this public policy has affected the income of poor villagers during Easter Celebration and favored the replacement of wax palm natural stands with pastures. Additionally, this policy has converted the leaf harvest, possession, transport and the processing of handicrafts with wax palm leaves into an illegal activity (Fig.5).

Fig. 5. a) Populations of wax palm (*C. echinulatum*) on pastures close to the village of Nanegalito. b) Farmer collecting *cogollos* from juveniles of wax palm. c) Ecuadorean authorities controlling the trade of *cogollos* from countryside to the cities in the Andean region. The commercialization of *cogollos* is forbidden for the Environmental Authorities of Ecuador from 2008. d) “Misa de Ramos” in San Francisco church, Quito year 2009 (Photos R. Montúfar, M. Jácome).

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We suggest that the extraction of unexpanded leaves from *C. echinulatum* could be a sustainable activity if it follows such management criteria as (a) the level of damage to adjacent mature leaves, (b) the number of leaves of the individuals harvested, (c) the harvest frequency, and (d) the level of cut in the unexpanded leaves. By avoiding cutting adjacent mature leaves and reducing the number of *cogollos* harvested in the individual palm, the balance of leaves in the crown should be positive. An appropriate management strategy would be to divide the population of young individuals with nine or more leaf numbers in the crown into different quadrants of rotational, biennial and monitored cropping.

This study, particularly the recommendations for sustainable management, should be used to increase awareness and education of farmers involved in this issue. Furthermore, it should influence public policies that promote sustainable management of non-timber products for long-term conservation.

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