Mapping Palm Extractivism in Ecuador Using Pair-wise Comparisons and Bioclimatic Modeling[1]

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Henrik Borgtoft Pedersen and Flemming Skov *(National Environmental Research Institute, Dept. of Landscape Ecology, Grenaavej 12, DK-8410 Rønde, Denmark; email HBP: reco-hbp@post4.tele.dk, FS: fs@dmu.dk).* Mapping Palm Extractivism in Ecuador Using Pair-wise Comparisons and Bioclimatic Modeling. *Economic Botany 55(1):63–71, 2001. The native palm flora of Ecuador consists of 129 taxa, including at least 69 species used by rural people, 19 of which are exploited commercially. This paper integrates bioclimatic modeling of palm distribution and quantitative ranking through pair-wise comparisons of species as a tool to evaluate and map the importance of 14 taxa of commercially exploited palms in Ecuador based on criteria of harvest values, sustainability, vegetation cover and population density. The ranking procedure could find broad application within ethnobotany and economic botany. Results show that extraction of palm products, economically speaking, is most important in the heavily deforested and populated coastal lowland.*

Key Words: palms; Ecuador; extractivism; pair-wise comparisons; bioclimatic modeling.

The native palm flora of Ecuador consists of 129 taxa (Borchsenius, Pedersen, and Balslev 1998). At least 69 species of wild palms are used by rural people, and out of these 19 are exploited commercially. Most of the commercial species are of limited economic importance, but some, such as *Phytelephas aequatorialis* Spruce and *Aphandra natalia* (Balslev & Henderson) Barfod, are quite substantial and the palm family is probably the most important producer of commercialized, non-wood forest products in the country. Economic exploitation (extractivism) of palm products in Ecuador has been studied intensively during the last decade (see Borchsenius, Pedersen, and Balslev 1998, for a complete list of references).

The purpose of this paper is to apply a methodology for the comparison and ranking of species (in the actual case palm species used for extractivism, but the method may find broad application within ethnobotany and economic botany), and to map areas in Ecuador where a large palm extractivism potential exists. Mapping such areas is possible thanks to the large amount of information available concerning the economic botany of Ecuadorian palms combined with recent progress in bioclimatic modeling of plant distributions (Skov and Borchsenius 1997).

The term extractivism is here used to describe the commercial exploitation of nonwood products from wild, native species (however, one palm species, *Iriartea deltoidea* Ruiz & Pav., mainly exploited for its wood is included in the analysis).

The analysis of palm extractivism in Ecuador is based on 14 taxa (Table 1). Five species are confined to the western coastal lowland, six species are only found in the eastern Amazon lowland and three species are found in both lowland areas. In the Andean mountains seven species of *Ceroxylon* (here treated as one entity, see methods) and one species of *Prestoea* are included. *Bactris gasipaes* Kunth, *Parajubaea cocoides* Burret, and *Aiphanes aculeata* Willd. are not included since they are only known in cultivation.

Study Area

Ecuador lies on the west coast of South America and covers ca. 260 000 km^2 excluding areas in dispute. Ecuador is divided from north to south by the Andes mountain range into three geographical regions: the western coastal lowland, the central Andean region, and the eastern Amazon lowland (Fig. 1). The varied topography of the country results in large differences in

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TABLE 1. COMMERCIALLY EXPLOITED, WILD, NATIVE PALMS IN ECUADOR.

Species	Marketed products	Observations
Aphandra natalia (Balslev & Henderson) Barfod	Fibres for brooms, edible fruits, vegetable ivory (hard seed endosperm)	Leaves harvested from the ground or by climbing, limited over-exploitation occurs (cutting too many leaves).
Astrocaryum chambira Burret	Fibres for hammocks, carrying nets etc.	Leaves harvested by cutting the palm or from the ground using a pole with a machete tied to it. Destructive harvest can be reduced using existing tools.
Astrocaryum standleyanum L. H. Bailey	Fibres for hats, hammocks, mats and furniture	Leaves harvested with chisels on long poles, palms rarely cut during harvest.
Attalea colenda (O. F. Cook) Balslev & Henderson	Oil seeds	Seeds usually collected from the ground, occasionally climbed, seldom cut. Threatened by habitat destruction. No regeneration in pastures.
Bactris macana (Mart.) Pittier	Edible fruits	No observations.
Ceroxylon spp.	Leaves (fibres) for Easter ceremonies, hats	Leaves from tall palms harvested by cutting the palm. Destructive harvest can be reduced using existing tools. Several species threatened by habitat destruction.
Euterpe oleracea Mart.	Palm heart, fruits	Palm heart harvested by cutting. However, the palm is multi-stemmed and will sprout again.
Geonoma macrostachys Mart.	Leaves for thatch	Understorey palm, harvested from the ground. Prob. sustainable if a few leaves are left.
Iriartea deltoidea Ruiz & Pav.	Stem for furniture, construction	Wood harvested by cutting the palm, mainly old individuals with hard stems are cut, therefore limited impact on populations. Very common palm.
Mauritia flexuosa L.f.	Edible fruits	Fruits harvested from the ground, by climbing, or more often, by cutting the palm.
Oenocarpus bataua Mart.	Mesocarp oil, edible fruits	Fruits harvested from the ground, by climbing or, more often, by cutting the palm.
Phytelephas aequatorialis Spruce	Vegetable ivory, leaves for thatch	Seeds usually collected from the ground. Leaves harvested by climbing the palm.
Phytelephas tenuicaulis (Barfod) Henderson	Leaves for thatch	Leaves harvested from the ground, by climbing or by felling.
Prestoea acuminata (Willd.) H. E. Moore	Palm heart	Palm heart harvested by cutting, however, the palm is multi-stemmed and will sprout again.

temperature and humidity over relatively short distances. This variation has resulted in a high number of climatic life zones (following Holdridge, 1967).

METHODS

The suitability of a given locality for extractivism depends on 1) which palm species are present, 2) how we evaluate and rank the characteristics of each species and 3) on social and infrastructure conditions.

PALM DATABASE AND DISTRIBUTION MODELING

Naming of taxa follows Henderson, Galeano, and Bernal (1995) except in the case of *Geon-*

Fig. 1. Major cities and geographical zones in Ecuador.

oma macrostachys Mart. where a slightly narrower concept is used (Borchsenius, Pedersen, and Balslev 1998). The seven species of *Ceroxylon* occurring in the mountains are here treated as one entity. The seven species are of limited economic importance, and they are all used for the same purpose, exploited in the same way and found in the same overall area, that is, as a resource they are one entity. If treated as seven species the weight of these would distort the analysis.

Spatial modeling was done in a raster based GIS (ArcView) using a spatial resolution (cell size) of 1 × 1 km. The potential distribution of individual palm taxa was determined with a climatic envelope model using mean annual temperature and humidity as described in Skov and Borchsenius (1997). The model identifies the potential distribution range as those cells where all environmental parameters fall within the extreme values as determined for at set of observed records. Cells are assigned the value one if they are inside the range and zero if they are outside. Gridded estimates of mean annual temperature and humidity were derived from a Digital Elevation Model (DEM) based on a digitized topographic map of scale 1:250 000, a precipitation map at a scale of 1:1 000 000, and climatic data from more than 100 weather stations. Modeling was based on 286 geo-referenced palm records of the 14 taxa. Collections came from the herbaria of AAU (University of Aarhus, Denmark), MO (Missouri Botanical Garden, USA), QCA (Pontificia Universidad Católica, Quito, Ecuador), and QCNE (National Herbarium, Quito, Ecuador) supplemented with our observations from various localities.

Ranking Procedure

We have chosen to apply the following three criteria for the evaluation of suitability for extractivism: Present value refers to the present, country wide economic importance of a species. Future potential value refers to the importance that each species is likely to achieve in the future—including such aspects as whether the resource is large enough to sustain an increased exploitation, and whether market trends work in favor or against an increased exploitation of each of the species in question. Sustainability refers to the sustainability of the extraction at the present level and with the present technology/methods. It only concerns the impact on the species in question and does not include an evaluation of the overall impact on the ecosystem.

Based on our knowledge of Ecuadorian palms, each species is assigned a weight reflecting its relative strength according to each of the three criteria mentioned above. These weights are calculated based on pair-wise comparisons of all species in a group using a scale of nine points (Eastman et al. 1995; Saaty 1977). In the process all palms are compared to each other under each criterion. If two palms are of equal importance, the comparison results in the value of one. Values between two and nine indicate that the first palm is from moderate to extremely more important than the second. Inverse values (1/2 to 1/9) are used for the opposite situation. The results are collected in a comparison matrix and used to calculate weights for each species which can be ranked accordingly.

Present value and sustainability are combined by multiplying their weights for each species and normalizing the results to obtain values between zero and one. The outcome of this process is a relative down weighting of species with low sustainability.

Finally, to calculate the overall criterion value for each cell, species weights are multiplied with one if they are present according to the modeled distributions, and zero if they are absent, and the figures are summed. Each cell thus has a value between zero (no palms potentially present in the cell) and one (would only occur if all 14 species were present in a cell).

The use of pair-wise comparisons as part of the Analytical Hierarchy Approach has been described by Saaty (1980), and has been applied by others in the field of conservation (Anselin, Meire, and Anselin 1989) and natural resource management, but to our knowledge it has not previously been employed in economic botany and ethnobotany.

Current and Future Potential for Extractivism in Ecuador

The current use of palms as a resource for extractivism depends on many parameters, including population density and structure, tradition, access to market and general infrastructure. In this study we use population density as a simple proxy for the above mentioned parameters. A map of current population density was constructed based on data from a 1:250 000 topographic map where all population centers were digitized and later converted to a density map that reflect number of settlements per area. This map was then multiplied with the map of present value. The resulting map emphasizes areas with both high present value for extractivism and high population density.

As most palm species will not regenerate outside the forest habitat future palm extractivism in Ecuador depends on patches of natural forest cover. To correct for human induced vegetation changes the map of potential value was overlaid a map of present-day vegetation based on satellite imagery from 1993–1994 obtained from CLIRSEN (Centro de Levantamientos Integrados de Recursos Naturales por Sensores Remotos web site; http:/www.clirsen.com) to remove those areas were suitable habitats (e.g., forest) do not exist today.

Results

Table 2 provides the quantitative ranking of the species resulting from the pair-wise comparisons. All figures are relative, summing to one in each analysis (see methods for details). This means that values are not directly comparable from column to column. It also means that the highest ranking species may not necessarily be a very valuable species, but it is more valuable than the rest. In the hypothetical case where all palms scores equally under a specific criterion, all values would be 0.071, that is, they are all equally good, or equally bad.

Figure 2A shows present value of palm extractivism according to our model; the darker the area the higher the present value. The most important areas are located in the central and northern coastal lowland. The actual importance of the mountain areas is very limited, whereas the Amazon lowland holds some importance. However, the importance of the Amazon lowland is somewhat overvalued—a result of the many, though poorly exploited species present there. To provide a more realistic picture, the present value is adjusted by population densities (used as an indicator of infrastructure, market access, and number of consumers; see discussion). The result is shown in Figure 2B. Since our experience is that extractivism mainly takes place in populated areas close to roads/navigable rivers Figure 2B is believed to be a much more accurate indication of those areas which presently are of importance for palm extractivism in Ecuador.

Figure 3 shows the present value adjusted by the sustainability of the extraction of each of the species. By doing so we highlight important areas not only from a short term economic point of view but also from a conservationist point of view. Only minor deviations can be seen from Figure 2A since the two economically dominant species, *Phytelephas aequatorialis* in the coastal lowland and *Aphandra natalia* in the Amazon lowland both have high sustainability scores. Nevertheless, it is clear that by adjusting the present value with degree of sustainability, the coastal lowland shows even higher overall importance. Figure 4A shows the future potential value of extractivism in different areas in Ecuador. The large potential of the Amazon lowland is clearly seen.

Most of the palms presently exploited grow in almost deforested areas—often the palms are the only woody species present in the pastures and agricultural systems that have replaced the original forest. However, few of these palms are able to regenerate under these circumstances, which means that within the next one to two decades many of them will disappear from those areas. Thus, whereas Figure 4A may be a good indication of the potential available at the moment, the situation will soon change. Figure 4B is a representation of the future potential val-

TABLE 2. RANKING OF SPECIES ACCORDING TO THE SELECTED CRITERIA, VALUES ARE RELATIVE, SUMMING TO ONE IN EACH COLUMN.

Present value		Future potential value	
Phytelephas aequatorialis	0.273	Phytelephas aequatorialis	0.284
Aphandra natalia	0.210	Aphandra natalia	0.188
Euterpe oleracea	0.098	Phytelephas tenuicaulis	0.128
Prestoea acuminata	0.091	Prestoea acuminata	0.074
Astrocaryum standleyanum	0.077	Astrocaryum standleyanum	0.051
Iriartea deltoidea	0.059	Ceroxylon spp.	0.040
Ceroxylon spp.	0.048	Euterpe oleracea	0.038
Astrocaryum chambira	0.046	Iriartea deltoidea	0.037
Attalea colenda	0.028	Mauritia flexuosa	0.037
Bactris macana	0.025	Geonoma macrostachys	0.036
Oenocarpus bataua	0.015	Astrocaryum chambira	0.030
Phytelephas tenuicaulis	0.013	Oenocarpus bataua	0.024
Mauritia flexuosa	0.011	Bactris macana	0.018
Geonoma macrostachys	0.011	Attalea colenda	0.015
Sustainability		**Present value adj. by sustainability**	
Phytelephas aequatorialis	0.130	Phytelephas aequatorialis	0.399
Phytelephas tenuicaulis	0.130	Aphandra natalia	0.302
Aphandra natalia	0.128	Astrocaryum standleyanum	0.063
Attalea colenda	0.126	Euterpe oleracea	0.041
Geonoma macrostachys	0.119	Attalea colenda	0.040
Bactris macana	0.089	Prestoea acuminata	0.039
Astrocaryum standleyanum	0.073	Iriartea deltoidea	0.034
Iriartea deltoidea	0.052	Bactris macana	0.025
Prestoea acuminata	0.038	Phytelephas tenuicaulis	0.019
Euterpe oleracea	0.037	Geonoma macrostachys	0.015
Mauritia flexuosa	0.030	Astrocaryum chambira	0.013
Astrocaryum chambira	0.026	Ceroxylon spp.	0.005
Oenocarpus bataua	0.013	Mauritia flexuosa	0.004
Ceroxylon spp.	0.010	Oenocarpus bataua	0.002

ue—adjusted for vegetation cover. In this way Figure 4B is a more realistic illustration of the situation 10–20 years ahead.

DISCUSSION AND CONCLUSION

PRESENT VALUE

An interesting result of the analysis is that part of the coastal lowland makes up the most important extractive region in Ecuador (Fig. 2A). With as little as 10–15% of the original forest cover left in the region (based on satellite imagery from Clirsen, see methods and Fig. 4B), compared to the large tracts of forest still found in the Amazon part, this may be surprising. However, it may be explained by a combination of various factors.

(1) The palms are still there. The massive deforestation is a recent event (mainly within the last three to four decades). Many areas, though almost devoid of natural vegetation, still hold large populations of palms, which were protected when the forest was cleared for agriculture and pasture. However, few of the species are able to regenerate outside the forest, which means that within a decade or two many of the species are likely to disappear from these areas, unless cared for or actually cultivated.

(2) Infrastructure. Roads and public transport is far better developed in the coastal lowland than in the Amazon lowland of the country. This means easy, efficient and relatively cheap access to markets. In the Amazon lowland many products never reach the market because the distance (measured in time, money or effort) makes it unattractive, considering the low price paid for many extractive products. The distance also

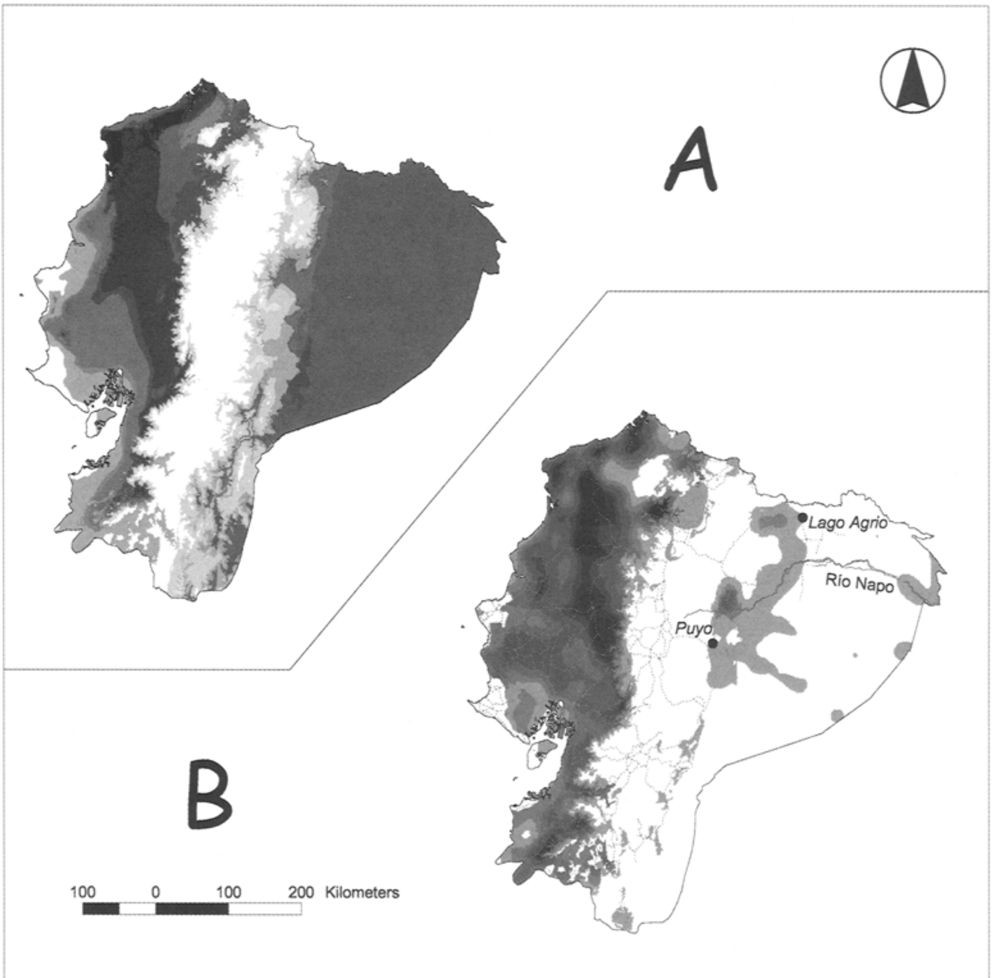

Fig. 2. A. Present value of palm extractivism in Ecuador. **B.** Present value (as in 2A) adjusted by population density (see methods). This map is believed to represent a more realistic picture of the value of the different part of Ecuador. The darker the color the higher the modeled value.

means that certain products are impossible to extract from many areas, simply because they deteriorate before they can reach a market (e.g., fruits and palm hearts).

(3) Population density. The population density is much higher in the coastal lowland and in the mountains than in the Amazon lowland, the projections for 1990 are 80.3 as compared to 3.1 per km^2 in the Amazon part (Mardesic 1988). That is, there are more consumers as well as more marginalized, unemployed people (who often turn to extractivism) in the coastal lowland. Fig. 2B shows the distribution of present value if population density is used as an additional criteria in the analysis.

(4) Survival. Harvesting, processing and trade of extractives becomes a way of surviving in areas where all arable land is occupied.

(5) Deforestation. The deforestation itself increases the commercial demand for a number of products which can be obtained for free in forested areas (e.g., leaves for thatch).

(6) Tradition. The production in the coastal lowland have long been much more market oriented than the more inaccessible Amazon lowland, dominated by subsistence agriculture.

By our judgement, a general analysis, including all extractive species in Ecuador, would also show the coastal lowlands to be the most import region followed by the mountains above 1500 m

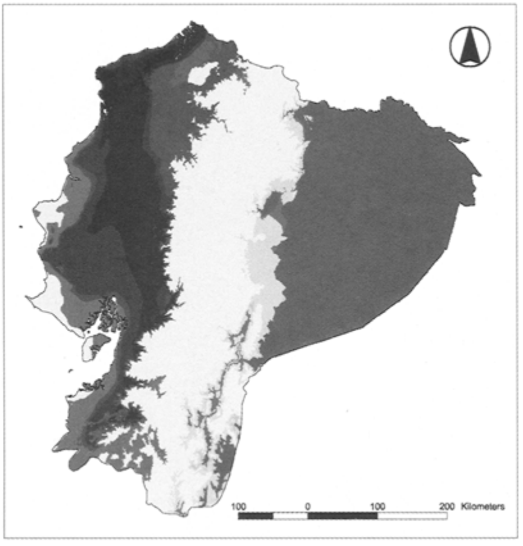

Fig. 3. Present value of palm extractivism (as 2A) adjusted by sustainability of the extraction (see methods). Compare with 2A.

(caused by some of the same factors that cause the high level of extractivism in the coastal lowlands), and with the Amazon part in the third place. However, with respect to palms, the mountains are the least important of the three main regions, due to their low abundance there.

FUTURE POTENTIAL VALUE

The importance of extractivism in the Amazon part of the country is likely to increase in the near future (compare Fig. 2 and 4), as population density rises, infrastructure is improved, and production declines in the coastal lowland because the resource is disappearing (Fig. 4B). It is, however, possible that production from such important species as *Phytelephas aequatorialis* and *Astrocaryum standleyanum* L.H. Bailey will be maintained through increased cultivation, but it will then become a farming activity rather than extractivism.

ACTUAL SUSTAINABILITY

In the coastal lowland several species are already exploited in a sustainable way, tools and techniques exist, and though some destructive exploitation takes place, the overall actual sustainability is relatively high (Fig. 3). According to the analysis the present sustainability in the Amazon region is almost as high as in the coastal lowland (Fig. 3: modifying with sustainability only cause minor changes in present value). However, many species are harvested destructively in the Amazon (e.g., *Oenocarpus bataua* Mart., *Mauritia flexuosa* L. *f.*, and *Astrocaryum chambira* Burret), and the fairly high sustainability is partly because the most important species, *Aphandra natalia,* generally is harvested in a sustainable manner, and partly because many of the palms which are exploited destructively are very abundant. The high abundance means that, even with destructive harvest, many of the palm species can sustain present level of extractivism. If extractivism increases without changing exploitation methods, sustainability will decrease dramatically.

The low actual sustainability in mountain areas with *Ceroxylon* reflects the fact that all species of *Ceroxylon* are being harvested destructively, some to a degree which, together with habitat alteration, is actually threatening the survival of the species. This may change, however, since we consider that sustainable harvest of the leaves of *Ceroxylon* species might replace present destructive methods. The species are easy to manage, they show prolific regeneration in some heavily disturbed forests, and until they reach a certain height (ca. 8–10 m) they can be harvested using a pole with a chisel mounted on the top (see Pedersen 1994).

The main reasons why extractivism is destructive in the Amazon lowland includes tradition, lack of appropriate tools and land tenure issues. Many of the palm species are so abundant that destructive harvest never was a problem. However, increasing population densities, more permanent settlements along with a higher demand from the outside world means that important species are becoming locally scarce. Introduction of appropriate harvesting tools and techniques could solve part of the problem. In some areas lack of well established land tenure rules results in a hit-and-run exploitation—people prefer to harvest as much as possible before someone else does, even if this means they have to cut the palms just to harvest the fruits.

THE METHOD

The use of pair-wise comparisons seems to be a useful method to rank species quantitatively according to selected criteria, and we consider that the method could find broad application within ethnobotany and economic botany. The use of the method is obviously not limited to

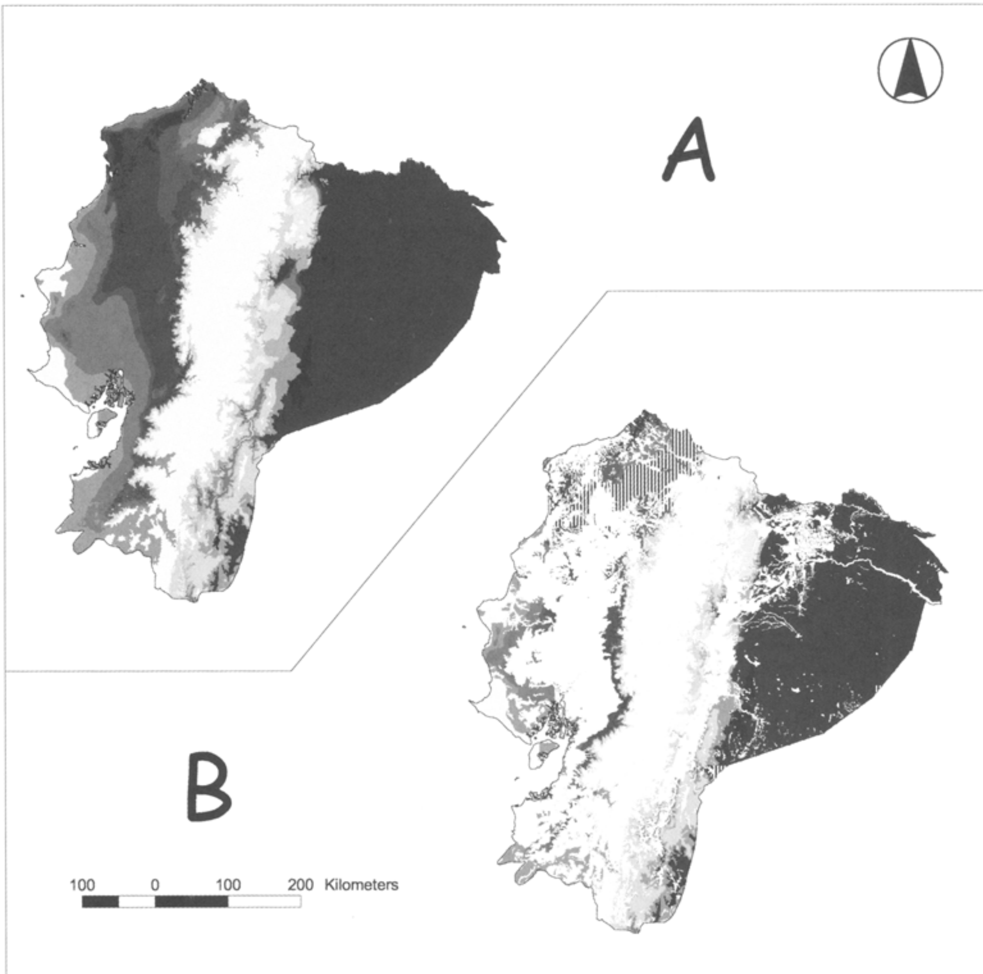

Fig. 4. A. Future potential value of palm extractivism. **B.** Future potential value of palm extractivism adjusted by vegetation cover. No vegetation data are available from the hatched areas due to cloud cover. The darker the color the higher the modeled value.

ranking species, but may also be used to rank use categories (medicinal plants, firewood, construction, food) or services provided by the forest (shade, recreation, wildlife, clean water, erosion control) to name a few examples. However, when many species or categories are involved (more than 10 to 15) the matrix becomes complicated and it may be necessary to split the analysis into several matrices.

The combination of the results from the ranking procedure with the modeled distribution of species provides an overview of, in this case, areas of importance for palm extractivism. Obviously this is a rough way of mapping extractivism, and the limitations of the method becomes clear when evaluating the results on a more local scale, e.g., the important areas in the Amazon lowland shown on Fig. 2B. From our knowledge, the most important area would be near/south of Puyo, probably with the upper Rio Napo area as number two (on Fig. 2B the upper Rio Napo area is number one, and the heavily colonized area near Lago Agrio in the northern part is number two).

This deviation from the expected may be caused by a number of factors, including that the correlation between extractivism and population density may not be linear as assumed in our model, the fact that the model for palm distribution do not consider local variation in abundance and that the actual distribution ranges differ from the modeled ones.

If data are to be useful on a local scale, the evaluation of the species must be based on knowledge of the management, trade, and distribution of the species in that specific area. This will best be done by involving local people in the evaluation of the species, that is, having individuals and/or groups from the area to perform pair-wise comparisons using relevant criteria and to discuss the distribution of the resource.

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