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Management of trees and palms in swidden fallows by the Kichwa people in the Ecuadorian Amazon

Robin Bredero zur Lage [a,*], Marielos Peña-Claros [a], Montserrat Rios [b,†]

[a] Forest Ecology & Forest Management Group, Wageningen University & Research, P.O. Box 47, 6700 AA, Wageningen, the Netherlands
[b] Universidad Regional Amazónica Ikiam, Parroquia Muyuna, Kilómetro 7 Vía a Alto Tena, Ecuador

A R T I C L E I N F O

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A B S T R A C T

Introduction: The *chakra* is a cropping system used by the indigenous Kichwa people of the Ecuadorian Amazon that is advocated as a sustainable form of agriculture that ensures food production without impeding ecosystem functioning. Trees and palms are central to the benefits obtained from *chakras*, however, little is known about the management of these trees and palms. In this research we aimed to understand how the Kichwa people manage these species in *chakras* and what drives them to do so.
Material and methods: We conducted participatory observation research in three Kichwa communities during which we researched 18 *chakras* belonging to different households. In each *chakra* we identified the tree and palm species, counted their number, and measured their diameter at 1.3 m aboveground. Additionally, each household was interviewed on the use and management of these species.
Results and discussion: A total of 740 individual trees and palms were inventoried. Nearly all species in *chakras* were being actively managed, with the reduction of competition and the protection of seedlings being the most applied practices. This appears to be driven mainly by utilitarian values, as most species were used, most commonly for food and construction. Previous studies indicated that agroecological and mythical values also incite the management of trees and palms, which was not the case in this study. This difference is probably because of cultural erosion or cultural gender roles that affected data acquisition.
Conclusions: Three important implications arise from this research: 1) future research should acknowledge and adequately address the large variation that exists among *chakras*, especially regarding their differences in number and size of trees and palms; 2) trees and palms in *chakras* should not be assumed to be managed inherently sustainably; 3) the understanding that economic and utilitarian considerations induce active management of palms and trees in *chakras* can lead to effective conservation policies.

1. Introduction

The need for alternative agricultural systems that allows for food production with lower environmental negative consequences is

* Corresponding author.
E-mail addresses: Robin.Bredero@wur.nl (R. Bredero zur Lage), marielos.penaclaros@wur.nl (M. Peña-Claros), montserrat.rios@ikiam.edu.ec (M. Rios).
† Deceased.

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large, given that deforestation for agriculture is the main driver of land use change in the tropics (Rudel et al., 2009; Tilman et al., 2002). The deforestation pressure on the Ecuadorian Amazon, including Napo province, is the largest of south America (Quintanilla et al., 2022). At the same time this region is considered a hotspot of biodiversity and home of a vast number of endemic species (Bass et al., 2010; Myers et al., 2000). Consequently, several alternative approaches for agriculture are being explored.

One such agricultural practice is the *chakra* system being practiced by the indigenous Kichwa people (e.g. Arévalo, 2009; Grijalva O. et al., 2011; Jarrett et al., 2017). *Chakras* are small cultivated fields, ranging in size between 0.2 and 4 ha (Perreault, 2005; Sirén, 2007; Torres et al., 2015; Vera-Vélez et al., 2019) on which the Kichwa grow a wide variety of crops. New *chakras* are created by clearing a part of the forest through cutting the vegetation and leaving it to mulch for a few weeks (Holt et al., 2004; Perreault, 2005). During the clearing of the land, several tree and palm species are spared, which are incorporated into the subsequent *chakra* (Irvine, 1989; Perreault, 2005; Sirén, 2007). The *chakra* is then cultivated for several years during which both planted crops as well as resources from the spared trees and palms are harvested. Once the agricultural production of a *chakra* declines, the land is left to fallow, and a new *chakra* is created in the surrounding forest (Holt et al., 2004; Perreault, 2005). It must be noted however, that this is a general description of *chakras* and that, as we describe later (see section 3.1), the definition of a *chakra* is more fluid amongst the Kichwa, resulting in large variation of the main characteristics listed above. Furthermore, the rotational aspect of *chakras* is decreasing due to land scarcity following increasing population pressure.

The *chakra* system is defined by many as a traditional form of agroforestry (e.g. Coq-Huelva et al., 2017; Jarrett et al., 2017; Vera-Vélez et al., 2019) as many *chakras* have a high abundance of trees and palms (e.g. Arévalo, 2009; Irvine, 1989; Torres et al., 2015). These species are central to the benefits obtained from *chakras*. Firstly, trees and palms provide the Kichwa with a wide variety of resources including food, medicine, and timber (Balslev et al., 1998; Rios et al., 2007). Secondly, these plants provide a myriad of environmental services: they prevent soil erosion, help to maintain soil fertility, and create shade. These services can be beneficial for both crops and labour conditions (Coq-Huelva et al., 2017). The abundance of trees and palms is also pivotal in sequestering high amounts of carbon, contributing to climate change mitigation (Torres et al., 2015), and in facilitating the connection of surrounding forests, thus allowing *chakras* to function as biological corridors (Torres et al., 2015; Vera-Vélez et al., 2019). Therefore, *chakra* cultivation is heralded as a way to achieve environmental and social sustainability in the Ecuadorian Amazon (e.g. Arévalo, 2009; Jarrett et al., 2017; Torres et al., 2015). However, little is known about the management of trees and palms in *chakras.* In this research we combined quantitative and qualitative data to investigate i) how the Kichwa manage tree and palm species that are present in *chakras*, and ii) what drives the Kichwa management practices of trees and palms. This understanding is of paramount importance to maximise the potential of *chakras* as a sustainable production system.

The current literature is divided about Kichwa management of trees and palms. Some authors state that no or only very few species are planted and transplanted, and that instead the Kichwa mainly rely on natural regeneration (Irvine, 1989; Torres et al., 2015), whilst other studies show that the Kichwa are increasingly protecting and planting native timber and fruit trees (Sirén, 2006, 2007). Based on the few reports in literature we expected that the Kichwa only actively manage a selected amount of tree and palm species. Additionally, not much is known about what drives the selection of the plant species that are managed by the Kichwa. Previous research shows that the Kichwa manage those plants that provide useful resources, such as food, medicines, and construction materials (Irvine, 1989; Rios et al., 2007). Aside from the resources that can be harvested from plants, trees and palms might also be valued by simply being present in a *chakra*. Firstly, trees are assumed to be important to the Kichwa in a way that can be translated as having an agroecological value: as certain tree species in *chakras* are associated with specific crops, they are supposedly managed to enhance the production of these crops (Vera-Vélez et al., 2019). Secondly, trees and palms might be present in *chakras* for their mythical value: several anthropological studies assessed that Kichwa cosmology influences the presence of specific elements, such as trees, in *chakras*. These values are often related to spirits of the water, garden, or forest (Coq-Huelva et al., 2017; Whitten, 1978). Both agroecological and mythical values might thus drive the Kichwa to manage trees and palms, regardless of the use of their morphological structures. However, agroecological knowledge is eroding, and the younger generation decreasingly upholds values of the Kichwa cosmology (Allison, 2010; Holt et al., 2004; Perreault, 2005). As it is more straightforward to know about a species' economic value than about the ecological associations, the effects of intercropping or the spiritual value of a species, we expected that the majority of trees and palms are managed for their useful resources rather than for their agroecological and mythical values.

It is worth stressing that the division between utilitarian, agroecological and mythical values is an etic conceptualisation of what drives *chakra* management: these values are very likely not seen as separate categories by the Kichwa themselves, as *chakra* management is driven by a confluence of these values. The classification of values into three different categories is, however, necessary if we are to understand the relative importance of each of these values that do exist in the narratives of NGO's and scholars working with the Kichwa.

2. Material and methods

This study obtained biophysical, ethnographical, and ethnobotanical data on the management of trees and palms by the Kichwa people in the province of Napo, Ecuadorian Amazon. The species that were studied included only those present in *chakras,* and not those managed by the Kichwa in other land uses, such as fallowed land in various stages of succession and mature forests. To our knowledge this is the first research on *chakra* systems that combines in-depth quantitative and qualitative data.

2.1. Study population

The Kichwa, also sometimes referred to as Amazonian or lowland Quichua (e.g. Holt et al., 2004; Uzendoski and Whitten, 2014;

Wasserstrom and Bustamante, 2015) or Runa (e.g. Irvine, 1989; Uzendoski, 2005; Whitten and Whitten, 2008), are the most numerous ethnic group in the Ecuadorian Amazon (Holt et al., 2004). Of the roughly 120,000 Kichwa (Wasserstrom and Bustamante, 2015), most live in the province of Napo, constituting about 52% of the province's total population (INEC, 2010). The Kichwa can be subdivided into four groups with slightly different cultural features, each group living in distinct regions (Uzendoski and Whitten, 2014). This study focusses on the Kichwa people in the province of Napo. They have a long history of contact with outsiders and are thus regarded as one of the most acculturated indigenous peoples in Ecuador (Holt et al., 2004; Muratorio, 1991). Early missionaries in the 17th and 18th centuries and commodity booms in the 19th century are amongst the first events reported to heavily impact indigenous cultures in the Northern Ecuadorian Amazon (Wasserstrom and Bustamante, 2015). However, the most profound changes occurred in the past five decades: agrarian reform laws and the discovery of oil in the 60's and 70's of the past century spurred the colonisation of the land by in-migrants from other areas of Ecuador, leading to rapid deforestation, population growth and disputes over land claims (Baynard et al., 2013; Bilsborrow et al., 2004). As a result of the events in the last five decades, indigenous groups in the Ecuadorian Amazon started to organise themselves into ethnic federations to gain political power for establishing legal land rights (Bremner and Lu, 2006). Kichwa people are organised in federations, representing several communities, each being governed by an elected committee and a president. The land owned by the community is communal land, rather than individually owned. Every family has usufruct rights over a specific part of the land, which in turn will be inherited by the family's children (Holt et al., 2004; Oldekop et al., 2012).

2.2. Study site

This study took place in three different Kichwa communities in a region that is locally known as the Upper Napo, in the province of Napo, Ecuador (Fig. 1). The Upper Napo is the higher part of the tributary of the Napo River and borders the foothills of the Andes on the west and extends into the Amazon region in the east. Annual average rainfall exceeds 3000 mm and the average temperature is around 25 °C (Arévalo, 2009). Roughly 85% of the province's surface is covered by forests (MAE, 2018). Fieldwork was carried out in the period of November 2019 till January 2020, during which a total of 46 days were spent living with and learning from the Kichwa. The selected communities were located relatively close together to minimise differences in physical factors like climate or soil that could potentially affect the composition and structure of tree and palm assemblages in *chakras*. Furthermore, the communities were chosen such that they differed in population pressure as well as in their access to nearby markets. In this way, we were able to observe a

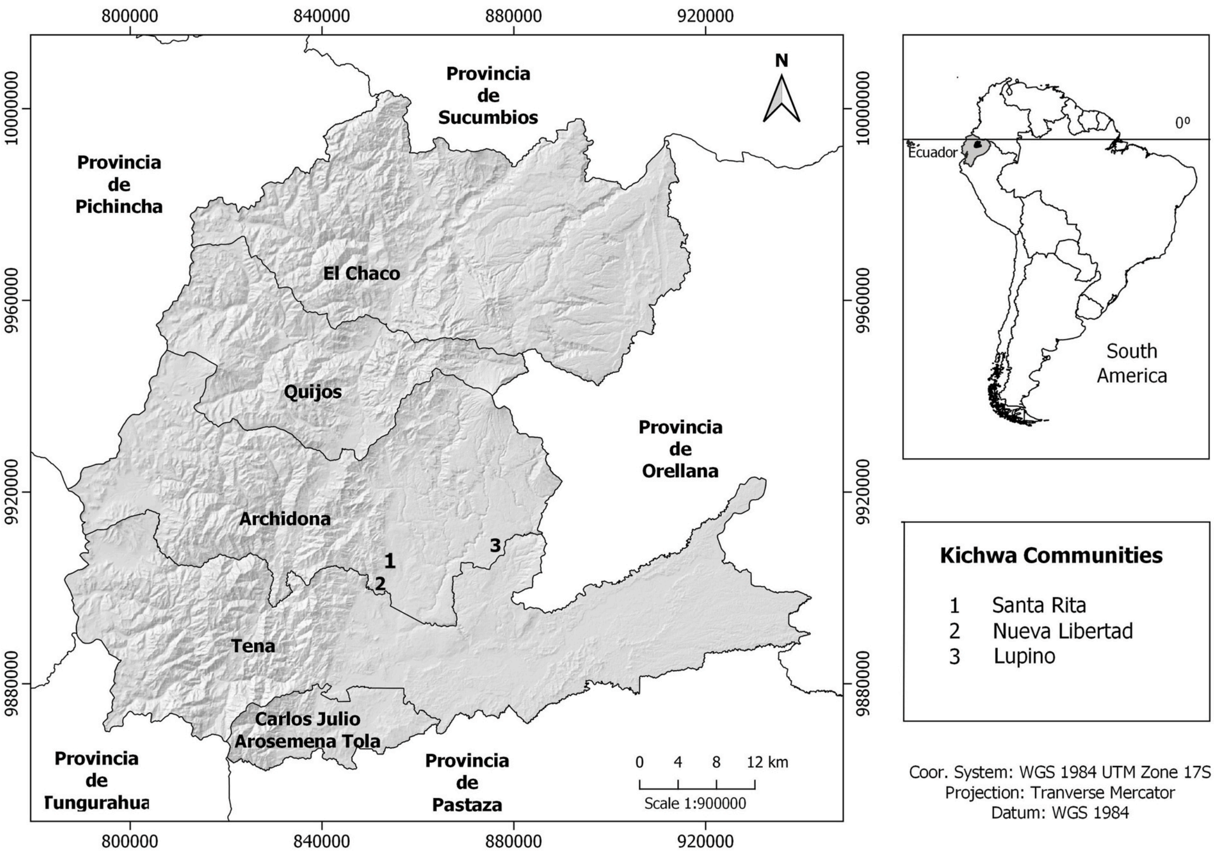

Fig. 1. Locations of the three communities included in this research (see numbers), located in the canton of Archidona, province of Napo. Inset maps show the location of Napo in Ecuador, South America.

large spectrum of practices and drivers related to tree and palm management.

2.2.1. Santa Rita

The community of Santa Rita is relatively large, with a population of roughly 800 inhabitants. Founded 58 years ago, Santa Rita houses a primary school, a high school, a college and a small internet café, and there is a frequent bus connection that runs a few times a day to Archidona and Tena, two regional towns at half an hour driving distance away. Many adults still speak Kichwa regularly but most of the children now only speak Spanish. Several families own a car, and roughly half of the community lives in concrete houses, with fridges, gas stoves and tv's.

The people of Santa Rita, who introduce their community as the 'village of cacao and chocolate', have a steady flow of income through the production of *Theobroma cacao* (cacao) and increasingly through its related eco-tourism. The community hardly owns any primary or secondary forests as most of the land is now in near continuous use for the cultivation of subsistence and cash crops. Food items traditionally identified with the Kichwa culture, such as bushmeat and 'chicha', a drink made from the tubers of *Manihot esculenta* (yuca) or fruits of *Bactris gasipaes* (chunda), are increasingly being replaced by sodas, rice, and canned food from the nearby towns.

2.2.2. Nueva Libertad

Though only a few kilometres away from Santa Rita, the community of Nueva Libertad is very different. Founded 18 years ago it has a population of roughly 200 inhabitants that live in wooden houses around a main field. Though just as close to the regional markets as Santa Rita in absolute distance, it is much less accessible: the road that runs from the community to the highway is unpaved and too small for any traffic larger than a personal car.

As there is no bus connection, most inhabitants walk the 1 h stretch to the highway to catch a bus for going to school or the market in one of the nearby towns. Without large transport options, the people in this community still mainly depend on their *chakras* for their food. However, some families own motorcycles which allow them to buy household needs and food from the towns nearby. Most families do grow cash crops such as *T. cacao* and *Ilex guayusa* and they lumber trees, which are sold to cooperatives and independent buyers that pick up the goods with small vans.

2.2.3. Lupino

Lupino is arguably the most traditional of the three communities, as it is reached only by a 3-h bus ride from Tena, followed by a 2 h walk on a muddy trail through the rainforest. The community is 28 years old and is home to roughly 150 inhabitants who live in wooden houses widely spread throughout the land owned by the community. Though most of the people speak Spanish to some degree, Kichwa is still the main language spoken in each household.

Twice a week a small market is held at the end of the road where the forest trail to the community begins. Here the people of Lupino buy household goods and a small range of food products such as rice, oils and condiments and they sell their harvest of *Solanum quitoense* (naranjilla), a cash crop that is grown by nearly every family in Lupino. Most families also earn money through logging of hardwood trees on their lands. These goods are transported between the small market and the community by horse.

A large amount of land owned by the community is still more or less primary forest that has not been used for agriculture in the past centuries, though the impact of logging is starting to become visible in the landscape. Lupino is not connected to the electricity grid, and aside from some radios that run on batteries, the people of Lupino are in little contact with the outside world.

2.3. Chakra selection

In this research 18 *chakras* were sampled: seven in Santa Rita, six in Nueva Libertad and five in Lupino (see Appendix A for pictures of the inventoried *chakras*). A *chakra* was defined as such based on whether the owners considered it to be a *chakra*. Though this means that we did not use a physically objectifiable definition of a *chakra*, which would be desirable from a strict scientific perspective, this approach did allow us to study the Kichwa concept of *chakras* without imposing an external definition of what a *chakra* supposedly is. All *chakras* that were shown to us were actively cultivated and weeded; the fallow period following cultivation was not considered to be a *chakra* by the people interviewed in this study. Households willing to contribute to this research were selected through a snowball sampling (Bernard, 2017) with the help of the host family. When a family owned multiple *chakras*, we inventoried a *chakra* that was different from those sampled previously in that community, in terms of cultivated crop species or land use history. To get a broad overview of Kichwa management practices only one *chakra* per household was studied, allowing us to research various households per community in a limited time. It is worth noting that although our sample size is small for statistical tests (total of 18 *chakras*), and that snowball sampling does not guarantee randomised selection of *chakras*, the merit of this approach is that it enables in-depth research of *chakra* management, and high-quality data collection.

2.4. Data collection

2.4.1. Ethnographic data

Fieldwork in the communities consisted of participant observation and semi-structured interviews (Alexiades, 1996; Bernard, 2017) with the household heads of each sampled *chakra* (Appendix B). When possible both the female and male head of the household were interviewed, as both have an important role in the management of trees and palms: Kichwa women are generally responsible for *chakra* cultivation (Coq-Huelva et al., 2017; Perreault, 2005), whereas men have an important role in the felling of timber trees and the clearing of new *chakras* (Irvine, 1989; Perreault, 2005). Permits for these interviews are not obligatory by Ecuadorian law, but explicit informed consent to use the findings in this research were given, both by the presidents of the communities as well as by the interviewees themselves. In exchange for the help from the various people, the lead author participated in a wide range of activities, such as weeding *chakras*, harvesting and processing crops and transporting goods such as the harvest or timber back to the houses or the market. This participatory approach, in which the first author took part in informal conversations and the daily activities of Kichwa life, provided us with a unique insight into Kichwa culture and the management of *chakras*: through living and working with the people we gained trust, were able to ask culturally informed questions, and could verify our findings in the field.

All interviews were conducted in Spanish, as the majority of Kichwa are bilingual. Where necessary other household members were asked to translate. In the 18 interviews, information on the demographics of a household and the land use history of the inventoried *chakra* were gathered (Table 1). The household heads were also interviewed about the management of the tree and palm species that were present in the *chakras* and their uses (Table 2). These interviews were held as much as possible in the *chakras*, where plants could be pointed out and management recalled. Additionally, household owners were asked about the mythical and agroecological importance of species. As this depends greatly on cultural perception, this information was asked for in multiple ways. In this research we define agroecological and mythical values as those pertaining to the presence of a plant which indirectly benefits *chakra* cultivation, whereas utilitarian values as those that pertain to the direct use of a plant (e.g., food, medicine or as a source of money). Furthermore, specific questions related to three alleged benefits of trees in *chakras* were asked: the positive effects of shade on crops, the improvement of the soil through leaves and, for those *chakras* that were established on steep slopes, the capacity of trees to prevent erosion (Coq-Huelva et al., 2017). Finally, a free listing (Bernard, 2017) of the tree and palms that are considered the most important in *chakras* was conducted (Appendix B). By referring to these species and asking why these species were considered the most important, we obtained a better understanding of the values that the Kichwa attribute to trees and palms.

2.4.2. Biophysical data

All trees >5 cm in DBH found in the selected *chakra* were identified and their diameter at breast height (DBH, measured at 1.3 m aboveground) was measured. *I. guayusa*, *T. cacao* and *Coffea* spp. Were excluded from this inventory, as these species are woody crops that are pruned so that they generally grow as bushes rather than fully grown trees. Since palms do not have secondary growth, only palms >1 m in height, including the leaves, were inventoried. Climbing species of this family were excluded from the survey. Stems of multiple stemmed trees and palms were considered as separate individuals. All inventoried individuals were identified to species level

Table 1
Description of the variables used in this study to analyse the management and use of chakras.

Variables	Unit	Description
Demographic characteristics		
Mean age household owners	Years	The mean age of the male and female household owners
# people in household	–	The number of people sharing the same household
# *chakras* managed by household	–	The number of *chakras* managed by a household
Chakra *characteristics*		
Elevation	m above sea level	The elevation of a *chakra*, measured with GPS
Size	ha	The size of a *chakra*, measured with GPS
Previous fallow length	Years	The duration of the fallow that was cleared to establish the current *chakra*
Current cropping length	Years	The duration of the current cropping length
Time since clearing mature forest	Years	The amount of time that has passed since the initial clearing of the mature forest
Biophysical characteristics		
# individuals	–	Sum of inventoried tree and palm individuals in a *chakra*
Density (both trees and palms)	# individuals/ha	The number of individual trees and palms in a *chakra*, divided by the *chakra's* size
Basal area (only trees)	m^2/ha	Sum of the cross-sectional area of all trees in a *chakra* at breast height, divided by the *chakra's* size
# species	–	Sum of inventoried tree and palm species in a *chakra*
Average DBH	cm	The average diameter at breast hight (1.3 m) of all trees in a *chakra*
Crop cover		
Manihot esculenta cover (yuca)	Ground cover %	Estimated ground cover percentage of *M. esculenta*
Theobroma cacao cover (cacao)	Ground cover %	Estimated ground cover percentage of *T. cacao*
Annual crop cover	Ground cover %	Estimated ground cover percentage of all annual crops
Perennial crop cover	Ground cover %	Estimated total ground cover percentage of *T. cacao*, *Ilex guayusa* and *Coffea* spp.
Total crop cover	Ground cover %	Estimated total ground cover percentage of all crops, including *T. cacao*, *I. guayusa* and *Coffea* spp., but excluding all other tree and palm species
Management practices & uses		
# of management practices per species	–	The average number of management practices applied to a species per *chakra*
Fraction of species being managed	–	The number of species being managed in at least one way, divided by the total number of species in a *chakra*
# of uses per species	–	The average number of uses of a species per *chakra*
Fraction of species being used	–	The number of species being used in at least one way, divided by the total number of species in a *chakra*

Table 2
Classification of the management practices (based on Levis et al., 2018), and use categories (based on Rios et al., 2007) adopted in this study.

Variables	Description
Management practices	
Competition reduction	Removal of non-useful plants to reduce the costs of competition
Disperser attraction	Leaving fruits of a plant to attract animals
Planting	Intentional sowing of seeds
Protection	Intentional promotion of the survival of a plant. Though various practices serve to protect a plant, in this research only the protection of seedlings was actively studied
Sparing	Non-removal of a plant when cutting down the vegetation for creating a *chakra*
Transplanting	Intentional relocating seedlings and juvenile plants from one place to another
Use categories	*Morphological structure(s) used for the:*
Beverage	Preparation of beverage
Construction	Building of constructions
Cosmetic	Personal grooming or body hygiene
Domestic	Manufacturing of utensils been used in and around the house
Food	Preparation of food or direct consumption
Handicraft	Decorating or adorning of a person
Medicinal	Treatment of human diseases
Poison	Lethal effects when ingested or applied to the skin
Ritual	Magical-religious or cultural value due to its energetic qualities, used in traditional ceremonies, ancestral rites, or mythological acts
Technical	Manufacturing of weapons, canoes, tools, or utensils that are used for subsistence activities

in the field. Species that could not be identified on site were photographed and classified at a later stage with the help from a professional botanist working with the Universidad regional Amazónica Ikiam.

Aside from information on the trees and palms, we documented the total coverage of crops present in the *chakras*, based on visual estimation (Table 1). All annual crops and the perennial *I. guayusa*, *T. cacao* and *Coffea* spp. Were included. Other types of woody species were excluded as these were already surveyed in the tree and palm inventory. *Manihot esculenta* and *T. cacao* were the only crops that were abundantly present in most *chakras*; other crops were less consistently present and were therefore not separately analysed. Additionally, the size of each *chakra* was assessed, by walking the perimeter with a GPS device. When the GPS positioning was inaccurate, for example because of a high vegetation coverage, the perimeter was walked several times to obtain results that were as reliable as possible. As some of the *chakras* had a gradual transition to the surrounding vegetation in both management practices as well as in species composition, only individuals were included that were growing within 2 m from the edge of the *chakra*. We corrected on this when calculating the size of the *chakra*. For an overview of variables measured see Table 1.

2.5. Data analysis

2.5.1. Differences between communities – a first exploration

As a first exploration of the data, Pearson correlation analyses were conducted with all the variables used in this study (Appendix C). Secondly, we tested if communities varied in their demographic, *chakra* and biophysical characteristics, as well as in the management and use of trees and palms, using one-way ANOVA tests for normally distributed variables and Kruskal-Wallis tests for non-normally distributed variables, with the demographic, *chakra*, biophysical, management and use characteristics as dependent variables and the community as independent variable.

Based on the inventoried data we calculated for each *chakra* the density of palms and trees and the basal area of trees. Furthermore, to analyse tree size in communities, the inventoried trees were divided into five size classes, starting with the smallest trees measuring 5–10 cm in DBH, and the consecutive size classes with increments of 10 cm each. For each *chakra* the density of trees per size class was then calculated. To analyse how tree size varied among communities, we conducted a two-way ANOVA with tree density as dependent variable and the communities and size classes as independent variables, followed by Tukey post hoc tests.

2.5.2. Management practices of trees and palms in chakras

Management practices were classified based on categories by Levis et al. (2018) and listed in Table 2. Additionally, we included the management practice 'sparring' as a separate category, to better analyse this practice that is prevalent in *chakra* management (e.g. Arévalo, 2009; Irvine, 1989). As it was difficult for people to exactly recall which individual tree or palm was managed in which specific way, the management practices were recorded that were applied per species, rather than per individual. Consequently, we were not able to compare management intensity among communities, but it did allow us to study how trees and palms are generally managed in *chakras*. To analyse which management practice was most prevalent, the number of species managed in a certain way in each *chakra* was divided by the total number of species found in the corresponding *chakra*. The resulting fractions were then arcsine transformed and used as the dependent variable in a two-way ANOVA test with management practices and communities as factors, followed by Tukey post hoc tests.

2.5.3. Drivers of tree and palm management

The uses of each plant were classified following the categories proposed by Rios et al. (2007). We assumed that when a household mentioned they used an individual of a given species for a certain purpose, all individuals of this species in that *chakra* were used in that way. Thus, in contrast to the management practices, which were analysed at the species level, the uses of plants were analysed at the level of individual plants in the *chakras*, allowing for a better representation of these uses. To analyse which use category was most prevalent, the number of individuals with a certain use in each *chakra* was divided by the total number of individuals found in the corresponding *chakra*. The resulting fractions were then arcsine transformed and used as dependent variables in two-way ANOVA tests with the use categories and communities as factors, followed by Tukey post hoc tests.

Additionally, to see if plants with different uses are managed differently, we analysed the management of plants per specific use. Only the two most common use categories were analysed (i.e. food and construction): other uses were less present and could therefore

Table 3

Overview of variables used to describe the characteristics of the households, their chakras, the biophysical characteristics of these chakras, the crop cover, and the management and uses of the trees and palms in those chakras, in three Kichwa communities, Upper Napo River, Ecuador.

	Santa Rita		Nueva Libertad		Lupino					
Variable	Avg ±SD/ Median	Min-max	Avg ±SD/ Median	Min-max	Avg ±SD/ Median	Min-max	Test used	Statistic	p-value	Post hoc test
Demographic characteristics										
Mean age household owners	57 ± 10	38–68	42 ± 11	23–55	54 ± 8	41–64	ANOVA	2.64	0.10	
# people in household	7 ± 3	3–11	7 ± 2	5–10	5 ± 2	3–8	ANOVA	1.19	0.33	
# *chakras* managed by household	3 **A**	2–3	4 **A**	2–4	1 **B**	1–2	Kruskal-Wallis	11.39	**<0.01**	MW
Chakra *characteristics*										
Elevation	829 ± 58 **A**	769–919	686 ± 25 **B**	661–731	972 ± 17 **C**	957–1001	Welch's ANOVA	239.59	**<0.001**	GH
Size	0.5 ± 0.5	0.1–1.7	0.3 ± 0.3	0.1–1.0	0.2 ± 0.0	0.2–0.2	ANOVA	0.43	0.66	
Previous fallow length	1.61 ± 1.26	0.25–3.50	2.80 ± 3.27	0.00–8.00	13.72 ± 16.57	0.08–40.00	Welch's ANOVA	1.44	0.31	
Current cropping length	6.18 ± 5.29	0.25–13.00	9.86 ± 14.77	0.25–37.00	1.88 ± 1.87	0.42–5.00	ANOVA	0.61	0.56	
Time since clearing mature forest	37.86 ± 15.24	10.00–50.00	28.08 ± 21.83	0.33–50.00	31.00 ± 12.77	20.00–45.00	ANOVA	0.47	0.64	
Biophysical characteristics										
# individuals (both trees and palms)	50 ± 42	7–120	50 ± 88	6–229	17 ± 21	4–55	ANOVA	1.73	0.21	
Density (both trees and palms)	219.7 ± 215.7	17.1–620.0	133.2 ± 92.4	39.1–250.0	89.7 ± 114.2	16.7–289.5	ANOVA	0.85	0.45	
Basal area (only trees)	4.5 ± 3.4 *	0.5–8.1	3.5 ± 2.2 *	1.0–6.3	0.9 ± 1.1 *	0.0–2.6	Welch's ANOVA	5.52	**0.03**	GH
# species (both trees and palms)	11 ± 6	5–24	11 ± 11	4–33	8 ± 5	2–15	ANOVA	0.73	0.50	
Average DBH (only trees)	18.4	11.6–21.5	16.0	11.6–21.5	11.0	0.0–22.1	Kruskal-Wallis	4.09	0.13	
Crop cover										
Manihot esculenta cover (yuca)	0.3	0.0–0.7	0.5	0.0–0.9	0.8	0.4–0.9	Kruskal-Wallis	4.69	0.10	
Theobroma cacao cover (cacao)	0.2	0.0–0.6	0.0	0.0–1.0	0.0	0.0–0.0	Kruskal-Wallis	3.23	0.20	
Annual crop cover	0.3	0.0–0.8	0.9	0.0–1.0	0.9	0.4–0.9	Kruskal-Wallis	4.31	0.12	
Perennial crop cover	0.2	0.0–0.7	0.0	0.0–1.0	0.0	0.0–0.0	Kruskal-Wallis	4.37	0.11	
Total crop cover	0.8	0.3–1.0	0.9	0.7–1.0	0.9	0.4–0.9	Kruskal-Wallis	1.18	0.55	
Management practices & uses										
# of management practices per species	3 ± 1	0–4	3 ± 0	3–4	3 ± 0	2–3	ANOVA	0.53	0.60	
Fraction of species being managed	1.00	0.00–1.00	1.00	0.83–1.00	1.00	0.80–1.00	Kruskal-Wallis	0.58	0.75	
# of uses per species	1 ± 0	1–1	1 ± 0	1–1	1 ± 0	1–2	ANOVA	1.57	0.24	
Fraction of species being used	1.00	0.80–1.00	0.93	0.80–1.00	1.00	0.89–1.00	Kruskal-Wallis	1.50	0.47	

Data shown are the average and standard deviation (for non-parametric tests the medians are displayed), and minima and maxima. Letters indicate statistical difference among communities, based on post hoc tests. N = 18 for all variables, except for the previous fallow length (N = 17), the current cropping length (N = 14), and the time since clearing of mature forest (N = 14). Post hoc tests used: MW = Mann-Whitney U, GH = Games-Howell.
*Though the basal area differed between communities according to the Welch's ANOVA test, a Games-Howell post hoc test did not reveal differences. See Table 1 for the units of the variables.

not be validly compared. The species used as a source of food showed little overlap with the species used as a source of construction material, with only three species being used for both purposes. For both use categories separately, we calculated the fraction of species managed in a particular way, by dividing the number of species subjected to a certain management practice by the total number of species with the corresponding use that were present in that respective *chakra*. To examine the difference between the management of food and construction plants we used, for both use categories separately, a two-way ANOVA test with the arcsine transformed fraction of species being managed in a particular way as the dependent variable and the management practices and communities as independent variables.

3. Results

3.1. Differences between communities – a first exploration

During the ethnographic stage of this study, several differences between the communities were observed. Firstly, different concepts of a *chakra* are used by the Kichwa. The people of Lupino only classify a cultivated field dedicated for household consumption as a *chakra*, and not those fields used for the growing of cash crops, whereas the people of Santa Rita and Nueva Libertad labelled any type of crop cultivation as a *chakra*. Therefore, the people of Lupino often owned other agricultural fields (for cash crops) in addition to their *chakras*. Furthermore, the families in Lupino moved every few years to make a new house and a new *chakra* on another location. In contrast, households in Santa Rita and Nueva Libertad were much more sedentary, and as most of the communal land was already in cultivation, *chakras* in these communities were repeatedly established on the same terrain, resulting in longer cropping periods.

Our data support these differences in land use: the most remote community of Lupino, which has a low population pressure and little market integration, tends to have longer fallow lengths and shorter cropping lengths compared to the more accessible and populated communities (Table 3). The majority of the Kichwa that were interviewed in all three communities stated that fallow lengths were decreasing. This was often attributed to land pressure caused by the increasing number of inhabitants in the communities, resulting in less land that was available for shifting cultivation.

Other apparent differences among the communities pertained to the trees and palms growing in the *chakras*: the more populated and accessible the community, the more forested the *chakras* tends to be (Table 3). *Chakras* differed significantly in their basal area, with *chakras* in Lupino having the smallest basal area (Table 3). Tree density was also found to significantly differ among the communities (for communities: two-way ANOVA, $F_{2, 75} = 7.12$, $p = 0.001$), with Lupino having a much lower tree density than the other communities (Fig. 2). Most of these trees were small trees, whereas large trees were much less present in all three of the communities (for size classes: two-way ANOVA, $F_{4, 75} = 11.65$, $p < 0.001$; Fig. 2). There was no interaction effect between communities and size classes (two-way ANOVA, for interaction, $F_{8, 75} = 0.31$, $p = 0.96$).

During this study a total of 740 individual trees and palms were inventoried, out of which 684 were identified to the species level, 53 to the genus level, and 3 individuals could not be identified (Appendix D). Altogether, the sampled individuals encompass at least 185 species, belonging to 31 families. Most sampled individuals, 599 in total, were trees, whereas 141 individuals were palms.

3.2. Management practices of trees and palms in chakras

Species were on average subject to three management practices, and nearly all species in *chakras* were being managed in at least one way (Table 3). Only seven species were not subjected to any form of management. These species were all regarded as weeds and were simply not yet cut down by the owners of the *chakras* at the time of interviewing. Hence, the number of species that are present in a *chakra* closely matches the number of species that are managed in a *chakra* (Table 3). The fraction of trees and palms being managed

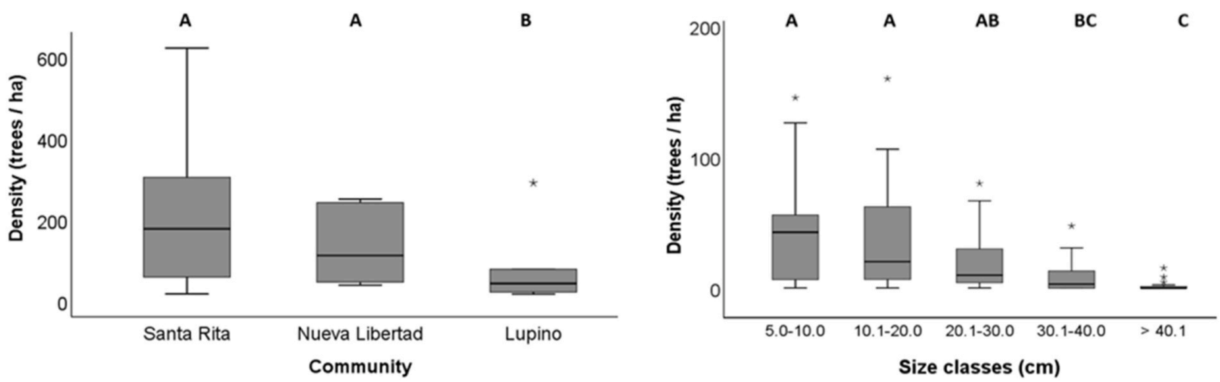

Fig. 2. The density of inventoried trees per community (left graph) and size class distribution of inventoried trees (right graph), recorded in 18 *chakras* within 3 Kichwa communities in the province of Napo, Ecuador. Data shown are the median (dark horizontal line), first and third quartile (rectangles), and 1.5 interquartile range (error bars). Asterisks denote outliers. One outlier of 340 trees/ha in the first size class is not shown in the left graph but was included in the statistical analysis. Capital letters above the graph indicate statistically homogenous subsets based on Tukey post hoc tests (alpha = 0.05).

did not differ among communities (for communities: two-way ANOVA, $F_{2,\ 90} = 0.82$, $p = 0.44$; Fig. 3), but did differ among management practices applied (for management practices: two-way ANOVA, $F_{5,\ 90} = 13.52$, $p < 0.001$; Fig. 3). Competition reduction was the most common form of management: the Kichwa actively remove all weeds, lianas and vines that grow in and around trees and palms. The second most frequent practice is the protection of seedlings: sticks are placed around young plants, to mark their presence and prevent accidental damage when weeding the *chakra*. The practice with the lowest frequency was the attraction of dispersers. Finally, there was an interaction between community and management practices (for interaction: two-way ANOVA, $F_{10,\ 90} = 2.12$, $p = 0.03$; Fig. 3). This interaction was mainly due to differences in the protection of seedlings: this management practice occurred less commonly in Lupino than in Nueva Libertad. Statistically seen other management practices were carried out similarly amongst the communities, though trees and palms tend to be transplanted less in Lupino, whereas they tend to be spared less in Santa Rita.

3.3. Drivers of tree and palm management

3.3.1. Uses as drivers of management

The fraction of trees and palms used for their resources did not differ among communities (for communities: two-way ANOVA, $F_{2,\ 150} = 0.11$, $p = 0.90$; Fig. 4), but did differ among the categories of use (for use categories: two-way ANOVA, $F_{9,\ 150} = 32.81$, $p < 0.001$; Fig. 4). Overall, food was found to be the most common use, followed by construction; other uses were less common. Finally, there was an interaction effect between community and use category (for interaction: two-way ANOVA, $F_{18,\ 150} = 1.56$, $p = 0.046$; Fig. 4), mainly because less trees and palms were used for construction in Lupino than in the other two communities.

The most common use categories were construction and food. Regarding species used for construction, in all three communities a similar fraction of the trees and palms growing in *chakras* were being managed. Overall, the reduction of competition is the most applied practice to trees and palms being used for construction, followed by the protection of seedlings and sparing (Fig. 5). In Lupino seedlings of trees and palms used for construction are less protected than in the other two communities, whereas other management practices were carried out similarly amongst the communities (Fig. 5).

Regarding species used for food, in all three communities a similar fraction of the trees and palms growing in *chakras* were being managed. Overall, the protection of seedlings and competition reduction were the most applied management practices (Fig. 6). All management practices were carried out similarly amongst the communities (Fig. 6).

3.3.2. Agroecological, mythical, and other factors as drivers of management

Aside from the direct uses of a plant, five different households regarded eight different species as having an agroecological benefit:

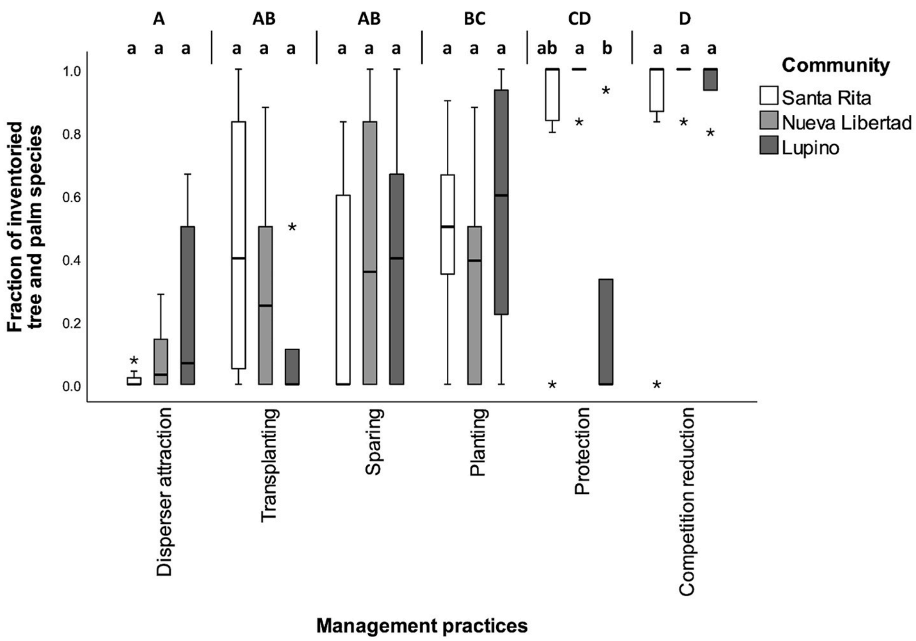

Fig. 3. The prevalence of the different management practices per community, recorded in 18 chakras within 3 Kichwa communities in the province of Napo, Ecuador. The graph shows the untransformed measured data, the statistical analysis was performed with arcsine transformed data. Data shown are the median (dark horizontal line), first and third quartile (rectangles), and 1.5 interquartile range (error bars). Asterisks denote outliers. Values were calculated by dividing the number of species subject to a certain management practice in each chakra by the total number of species present in that respective chakra. Species could be subjected to more than one management practice. Capital letters above the graph indicate statistically homogenous subsets of the management categories, lower case letters above the graph indicate statistically homogenous subsets of communities per management practice (i.e., the interaction effect), based on Tukey post hoc tests (alpha = 0.05).

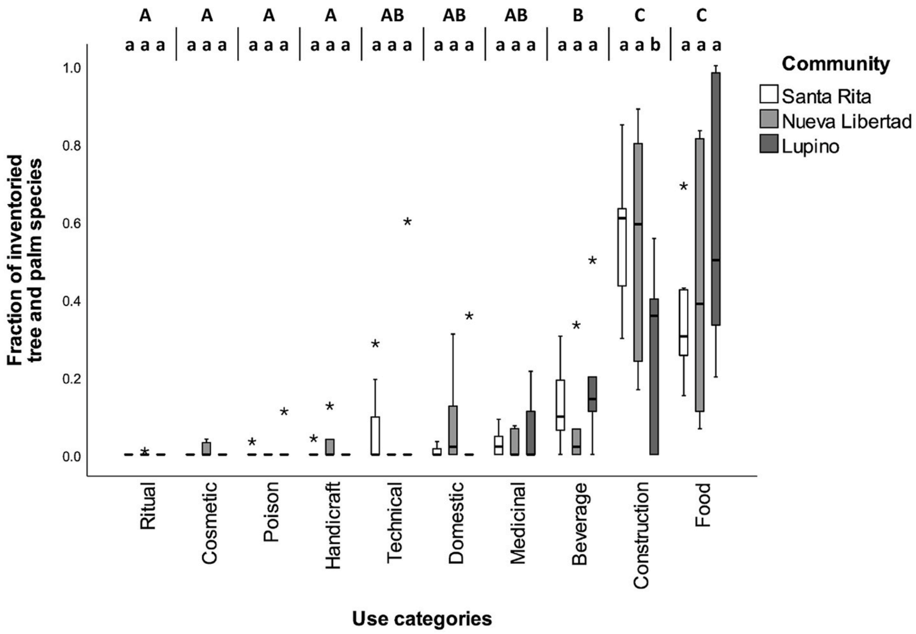

Fig. 4. The prevalence of the different use categories per community recorded in 18 *chakras* within 3 Kichwa communities in the province of Napo, Ecuador. The graph shows the untransformed measured data, the statistical analysis was performed with arcsine transformed data. Data shown are the median (dark horizontal line), first and third quartile (rectangles), and 1.5 interquartile range (error bars). Asterisks denote outliers. Values were calculated by dividing the number of individuals with a certain use in each *chakra* by the total number of individuals present in that respective *chakra.* Species could be used for more than one purpose. Capital letters above the graph indicate statistically homogenous subsets of the use categories, lower case letters above the graph indicate statistically homogenous subsets of communities per use category (i.e., the interaction effect), based on Tukey post hoc tests (alpha = 0.05).

the fallen leaves of these species were considered a good fertiliser for the soil (Table 4). Contrastingly, four households mentioned a total of six species having a negative effect on the cultivation of various crops (Table 4). Not a single tree or palm species inside a *chakra* was reported to have a mythical value. Several trees and palms were valued or disliked for reasons not agroecological or mythical in nature (Table 4).

Households were also interviewed about the alleged benefits of trees and palms in general. Overall, twelve out of the eighteen households regarded shade as inherently bad for the cultivation of crops, whereas four households said that crops need a little bit of shade, irrelevant of the type of crop. Two households stated that shade is beneficial for some crops, but that it greatly depends on the type of crop. The fertilizing effects of leaves for the soil were only recognized by five households. Finally, out of the four households that grew crops on steep slopes, two households did not regard erosion to be any problem and they did not perceive trees as having to do much with erosion. Two households did state that trees were beneficial for preventing erosion, but this was not brought into practice as there were hardly any trees on the sloped terrains (pers. observation).

4. Discussion

In this study we researched how the Kichwa manage tree and palm assemblages in *chakras*. We found that the management of trees and palms is more extensive than generally assumed, and that this is driven mainly by utilitarian values. In this section these findings are further discussed and put in a broader perspective, followed by the implications of these findings for conservation efforts in the North-Eastern Ecuadorian Amazon.

4.1. Management practices of trees and palms in chakras

The results of this study show that trees and palms are much more carefully managed than generally assumed; we found that nearly all species in *chakras* are managed through multiple practices (Table 3, Fig. 3). This result was unexpected as we hypothesised that Kichwa only manage a selected amount of tree and palm species, as found in previous studies (e.g. Irvine, 1989; Torres et al., 2015). The most common form of management was the reduction of competition, as weeds, lianas and vines in and around trees were consistently removed. This can be explained by a cultural factor related to *chakra* management: the Kichwa prefer their *chakra* to be “*limpia*” (clean). In practice this means that a *chakra* needs to be empty and open with as little weeds as possible. Other authors have mentioned similar findings, in which a ‘dirty’ *chakra* with many weeds is stigmatised (Allison, 2010; Coq-Huelva et al., 2017). The second most common practice is the protection of seedlings through the placement of sticks in the ground as also reported earlier (Irvine, 1989; Sirén, 2007). This practice occurred less commonly in Lupino than in Nueva Libertad (Fig. 3). Given that trees and palms

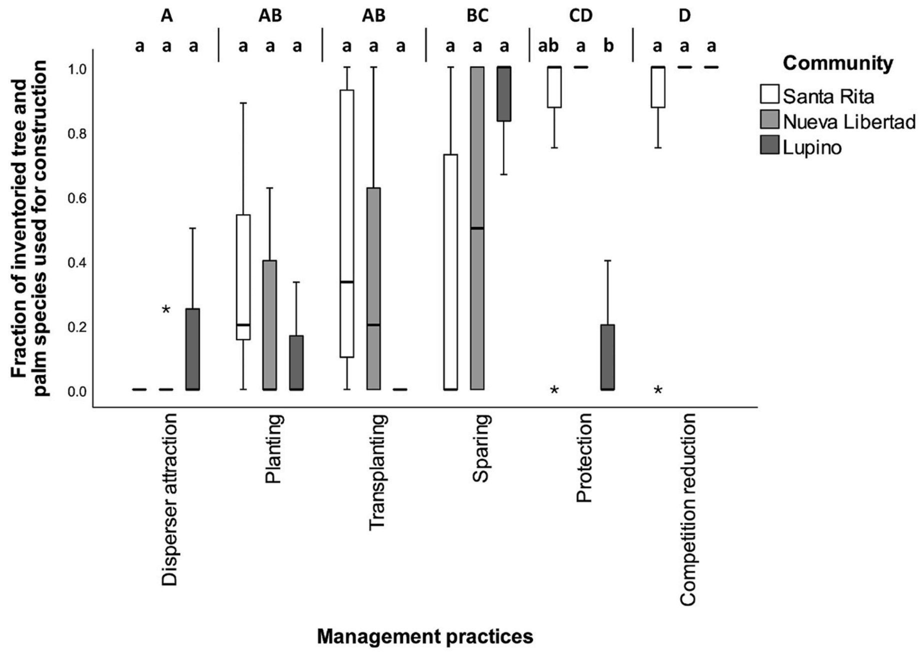

Fig. 5. The prevalence of the different management practices of plants used for construction per community, recorded in 18 *chakras* within 3 Kichwa communities in the province of Napo, Ecuador. The graph shows the untransformed measured data, the statistical analysis was performed with arcsine transformed data. Data shown are the median (dark horizontal line), first and third quartile (rectangles), and 1.5 interquartile range (error bars). Asterisks denote outliers. Values were calculated by dividing the number of species used for construction and subject to a certain management practice in each *chakra* by the total number of species used for construction in that respective *chakra*. Species could be subjected to more than one management practice. Capital letters above the graph indicate statistically homogenous subsets of the management categories, lower case letters above the graph indicate statistically homogenous subsets of communities per management practice (i.e., the interaction effect), based on Tukey post hoc tests (alpha = 0.05).

also tend to be transplanted less in Lupino (Fig. 3), these findings suggest trees are in general not much favoured in *chakras* by the people of Lupino (see section 4.2 for explanations why this might be the case).

Additionally, we found that a large proportion of species was being planted and transplanted. This contradicts previous studies, which state that few species are planted and transplanted (Irvine, 1989; Torres et al., 2015), but in line with reports stating that management practices aimed at conserving native timber species and fruit trees are increasing (Sirén, 2006, 2007). Most o f the trees and palms that are planted are used as a source of food; species used as a source of construction material appear to be planted less (Figs. 5 and 6). Relatively few species in *chakras* were being spared. This is surprising as this is one of the most described management practices in other studies (e.g. Arévalo, 2009; Irvine, 1989; Perreault, 2005). Possibly, this is a result of agricultural intensification: seven out of the 13 researched *chakras* in Santa Rita and Nueva Libertad had fallow lengths shorter than a year, which is insufficiently long for trees to regenerate. As a result, trees could no longer be spared at these locations as they were not present when a new *chakra* was made.

4.2. Drivers of tree and palm management

4.2.1. Useful resources, agroecology, and mythical values

Out of the three hypothesised drivers that influence management, i.e. useful resources, agroecological values, and mythical values, the first driver is dominant: nearly every inventoried tree and palm species had at least one direct use of its morphological structures (Table 3), which were employed for various applications (Fig. 4). This is in line with previous research, that showed that the Kichwa make use of a wide array of plant species (Irvine, 1989; Rios et al., 2007). Food and construction were found to be the main uses of trees and palms in *chakras* (Fig. 4). These two use categories are vital for the subsistence of the Kichwa: natural sources of food ensure food security in the face of economic uncertainty (Perreault, 2005), while species used as a source of construction material, most of them being timber species, provide the Kichwa with an important source of income (Jadán et al., 2015).

Possibly, the reliance on resources in *chakras* is increasing as exploitable resources from nearby forests are becoming scarce. The more populated Santa Rita and Nueva Libertad own substantially less forests than Lupino, and their *chakras* are nearly permanently cultivated. With little exploitable forests and few fallows, the *chakras* in these two communities have to provide the Kichwa with both food and timber. In both Santa Rita and Nueva Libertad, several interviewed households stated that people had started to plant trees inside their *chakras* since several years, as people became aware that the number of trees that could be harvested outside of the *chakras* was becoming scarce. Though previous studies showed that scarcity leads to conservation of mainly common pool resources (Oldekop

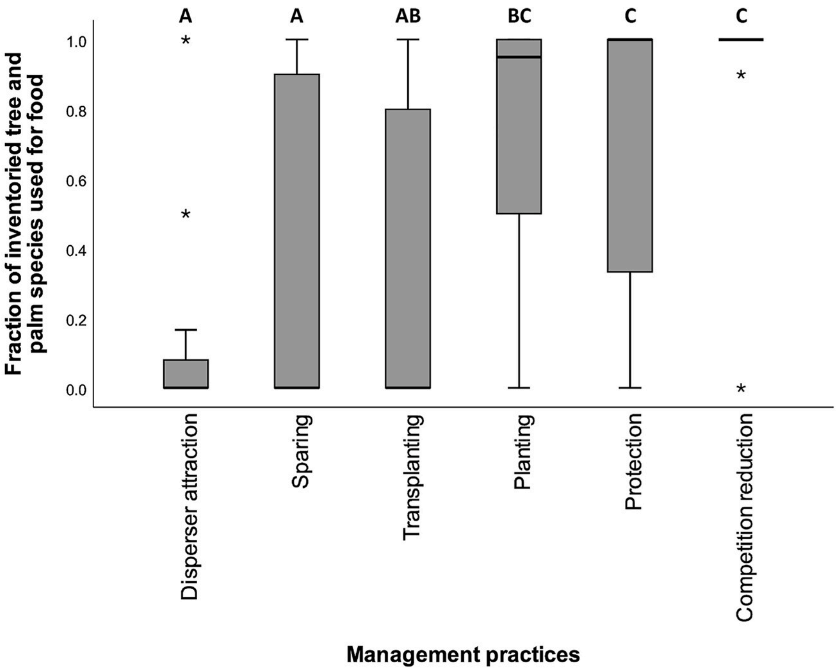

Fig. 6. The prevalence of the different management practices of plants used for food, recorded in 18 chakras within 3 Kichwa communities in the province of Napo, Ecuador. The graph shows the untransformed measured data, the statistical analysis was performed with arcsine transformed data. Data shown are the median (dark horizontal line), first and third quartile (rectangles), and 1.5 interquartile range (error bars). Asterisks denote outliers. Values were calculated by dividing the number of species used for food and subject to a certain management practice in each chakra by the total number of species used for food in that respective chakra. Species could be subjected to more than one management practice. Capital letters above the graph indicate statistically homogenous subsets of the management practices based on Tukey post hoc tests (alpha = 0.05).

et al., 2012; Sirén, 2004, 2006), this research thus suggests that the same holds true for privately owned trees and palms.

Regarding the expected agroecological benefits of trees and palms, we found that trees and palms are generally considered to be adverse to the growing of crops (Table 4). Most of the interviewees regarded shade to be disadvantageous for growing crops, and very few interviewees recognized the benefits of trees and palms for improving soil fertility or preventing soil erosion. The analyses of the biophysical data substantiate these ethnographic findings: total crop cover tends to be negatively related to tree and palm density (Appendix C), many *chakras* have a low tree and palm density and basal area (Table 3), and large trees are hardly present in *chakras* (Fig. 2). These results are contrasting to previous studies that found that specific tree species are associated with certain crops in *chakras,* with the aim to benefit crop establishment and development (Vera-Vélez et al., 2019); or that assumed that trees are valued to maintain the soil fertility, prevent soil erosion, and create shade in *chakras*, and that these values lead to practices that are focused on maintaining tree cover (Coq-Huelva et al., 2017).

A possible explanation for the lack of observed agroecological values in the three studied communities is that the Kichwa do not value trees and palms for agroecological reasons but that such appreciations are only ascribed to them by scholars. Such a potential misconception could be rooted in the common image of indigenous peoples as 'ecologically noble savages', in which native people are often thought of as living in close harmony with their surrounding environment (Redford, 1991). It must be stressed though, that *chakra* agriculture allows for the cultivation of crops on the same terrain for many years, as shown by variable 'time since clearing mature forest' (Table 3). In contrast, modern colonial agricultural practices, such as monocultures or cattle ranging, exhaust the land in short amounts of time (Porro et al., 2012). Thus, weather management practices are consciously aimed at this or not, Kichwa land management is better at maintaining soil nutrients. Alternatively, it might be that more profound agroecological knowledge existed in the past but is now generally forgotten: cultural change in Kichwa communities has been found to lead to the erosion of knowledge regarding *chakra* agriculture (Holt et al., 2004; Perreault, 2005). It might be that the Kichwa continue to carry out certain practices without really knowing why. Finally, the results of this study might have been affected by gender: as the first author is a male researcher, he got to interview mainly male household members. Since Kichwa culture is heavily gendered (Coq-Huelva et al., 2017; Perreault, 2005), it was difficult to build up rapport with female household members. Since women generally have most knowledge on *chakra* cultivation (Coq-Huelva et al., 2017; Perreault, 2005) we might not have gathered reliable data concerning agroecological values. Ideally, future research should take these important cultural factors into account and ensure that men and women are interviewed separately by researchers with corresponding genders.

No mythical values were observed for any of the inventoried trees and palms. We did, however, come across three other plants that were managed for mythical values. Firstly, in one *chakra* a tree fern (*Cyatheaceae* sp.) was left standing by the owner. The owner

Table 4
Overview of benefits and drawbacks of trees and palms in chakras, other than the resources these plants provide, recorded in 18 chakras within 3 Kichwa communities in the province of Napo, Ecuador.

Mentioned effect of species	Species	Times mentioned
Agroecological benefits		
Fallen leaves are good fertilizer	*Acacia* sp.	1
	Cabralea canjerana	1
	Cedrelinga cateniformis	3
	Handroanthus chrysanthus	1
	Inga edulis	1
	Inga spectabilis	1
	Nectandra sp.	1
	Vochysia spp.	1
Agroecological drawbacks		
Damages *I. guayusa*	*Cordia alliodora*	3
	Inga edulis	1
	Piptocoma discolor	1
	Vochysia spp.	1
Damages *T. cacao*	*Cordia alliodora*	2
	Piptocoma discolor	1
	Vochysia spp.	1
Damages *Coffea* spp.	*Cordia alliodora*	1
Extensive roots	*Bactris gasipaes*	1
	Cedrelinga cateniformis	2
Other drawbacks		
Falling fruits can harm people	*Theobroma bicolor*	1
Large spines	*Bactris gasipaes*	1
Attracts aggressive ants	*Inga edulis*	1
Other benefits/value		
Attracts birds and/or game	*Aiphanes ulei*	1
	Bactris gasipaes	2
	Batocarpus orinocensis	1
	Geonoma interrupta	1
	Grias neuberthii	1
	Miconia sp.	1
	Pourouma cecropiifolia	1
	Pouteria caimito	1
	Schefflera morototoni	1
Used as post for supporting vining crops	*Erythrina poeppigiana*	1
	Unidentified species	1
Species considered rare	*Aiphanes ulei*	1
	Geonoma interrupta	1
Unclear sentimental value: “I don’t want to kill that tree"	*Cecropia ficifolia*	1
Ornamental	*Senna bacillaris*	1

explained that the stem of the fern would be the only thing that would still burn and serve as fuel when the end of times would arrive. Secondly, in multiple *chakras* a herbaceous plant called *tiutia* (likely in the *Zingiberales* order) was cultivated to ensure that *yuca* crops would not be damaged when the land was struck by an earthquake. Thirdly, in various *chakras, Banisteriopsis caapi* (*ayahuasca*) was cultivated, which is an important ingredient for the entheogenic brew by the same name. The interviewees stated this plant was important for the shamans. Such practices demonstrate that the Kichwa do attribute certain mythical values to plants, resulting in the management of these species. However, as such values were not observed for any of the inventoried trees and palms, it seems that mythical values do not influence the tree and palm species in *chakra* agriculture.

This is contradicting to several studies that found that Kichwa cosmology influences the presence of trees in *chakras*, which are related to spirits of the water, garden, or forest (Coq-Huelva et al., 2017; Whitten, 1978). One explanation for the absence of mythical values could be found in the influence of religion: the majority of Kichwa consider themselves catholic Christians (Holt et al., 2004), and it appears that this causes traditional mythical believes to erode, or even to be considered taboo (Allison, 2010). Personal observations during the fieldwork were in accordance with this: on one occasion a young Kichwa man said that he did not want to participate in certain ceremonial acts anymore, because these were “not allowed” by the church. Similarly, an elderly Kichwa man said that there are still a lot of *wiriwiris* (spirits) and *diablos* (devils) in the forest, but that “they don’t show themselves so often anymore because we are all Christians nowadays”. Additionally, as with agroecological values, it might be that our findings regarding mythical values are greatly affected by gender: as many of the rituals and cultural taboos in *chakras* are known specifically to women (Allison, 2010), such factors might have eluded our attention. However, and perhaps most importantly, it is possible that mythical aspects regarding *chakra* cultivation are not well understood by the authors, as a deeper level of comprehension of Kichwa culture might be necessary for these to become visible. Our method of directly asking the interviewees about mythical values presupposes that such cultural elements can be expressed in a western way of knowing the world, which might not be the case (Sharp, 2008; Spivak, 1988).

Concludingly, our findings thus suggest that essentially only those trees that have a direct utilitarian value are managed in *chakras*, whereas agroecological and mythical values related to Kichwa cosmovision seem to play a negligible role in the management of trees and palms. However, further ethnographic research that takes gender into account and which is more embedded in Kichwa culture is needed to ascertain the absence of mythical and agroecological values in the management of trees and palms, and if these values vary among communities.

4.2.2. External factors driving management of trees and palms

Several external factors were found that drive the management of tree and palm species in *chakras*. Firstly, in Santa Rita an externally initiated restoration programme had incited the Kichwa to plant trees in their *chakras*. In several *chakras* in this community a large fraction of *Cedrelinga cateniformis* trees was present, which had been planted ten years ago with the help of an NGO. Though the NGO had only been active in the community for a limited amount of time, without following up on the programme, the Kichwa in Santa Rita now widely planted and transplanted seeds of *C. cateniformis* trees, as well as several other species, both in nurseries as well as directly in their *chakras*. Interviewees explained that previous generations hardly planted and transplanted timber species in this manner, but that it was now common practice as the trees could be sold for a lot of money.

A second external factor that played an important role in shaping the management of trees and palms was the marketability of tree species. Several people in Santa Rita mentioned that they had recently started to manage tree species that they hardly managed before, because timber buyers were now purchasing new types of wood. This shows that market integration can lead to an increase in the number of species that are being managed. Though there are conflicting reports on the effect of market integration on *chakra* diversity (Perreault, 2005), some studies suggest that market access can lead to a diversification of crops (Perreault, 2005; Torres et al., 2018). Our results suggest that the same holds true for marketable tree species and potentially palms.

A third external factor is the influence of crop cooperatives. In both Santa Rita and Nueva Libertad the majority of households that cultivated cash crops, such as *T. cacao* and *I. guayusa,* were associated with a single cooperative, so that at regular times in the year the harvest in the community would be collected and sold. The cooperatives had a lot of influence in the management of *chakras*: they provided the growers with fertilisers and agronomists would visit the *chakras* to inform the Kichwa of improvements that could be made in the growing conditions of crops. On a few occasions interviewees stated that the number of trees in *chakras* was either increased, for the cultivation of *T. cacao*, or decreased, in *I. guayusa* cultivation, based on the request of the cooperative's visiting agronomists. It was not clear to us how freely such advises were, but these findings do imply that external advice or requests from commercial partners can have a great influence on *chakra* management.

These three observations thus show that several external factors can change the management practices of palms and trees by the Kichwa. This helps to explain a general pattern observed in the communities. Though we expected to see clear differences in the measured variables between the three Kichwa communities, reflecting their varying access to markets, this was not the case (Table 3). The data does however show a trend, in which Lupino, the community with the least access to markets, has a lower tree and palm density, basal area and average DBH compared to Santa Rita and Nueva Libertad (Fig. 2, Table 3). These findings can be explained in part by a scarcity of forest resources, leading to an increased management of trees and palms (section 4.2.1), but also by the three above mentioned observations. These show that market integration can induce external factors, leading to different management of palms and trees, which in turn can cause changes in the density and basal area of trees and palms in *chakras*.

4.3. Implications for research and policy

This research has three important implications for future research and conservation policies. Firstly, researchers and policy makers should define clearly what type of *chakra* is studied or advocated for. We found differences between the communities as to what was perceived to be a *chakra*, with people in Lupino adhering to much stricter definitions than people in the other two communities. Similarly, some authors define *chakras* as a type of agroforestry (e.g. Coq-Huelva et al., 2017; Torres et al., 2015), whereas *chakras* have also been described as monocultures of *M. esculenta*, with hardly any trees (Allison, 2010). Correspondingly, extensive variation was found in this study in both the density and the basal area of the tree and palm assemblages among *chakras*, as indicated by the high standard deviations for these variables within communities (Table 3). Consequently, it is hard to formulate a definition of *chakra* that embodies all the variation found amongst *chakras,* and that integrates the Kichwa understanding of this concept. Our current definition is that *chakra* is a term that describes a wide range of cultivation practices used by Kichwa people to cultivate short-lived crops together with trees and palms that differ largely in number and size. As trees and palms are pivotal to the environmental and social benefits of *chakras* (e.g. Arévalo, 2009; Torres et al., 2015), it is important to acknowledge these differences among *chakras* and to clearly distinguish the type of *chakra* that is advocated for.

Secondly, this research shows that *chakra* management should not be assumed to be inherently sustainable. The Kichwa manage trees and palms mainly for utilitarian values, and agroecological and mythical values seem to play a very limited role. The Kichwa thus do not necessarily aim to create ecologically sustainable *chakras*, which is contrasting to what has previously been assumed (Coq-Huelva et al., 2017; Vera-Vélez et al., 2019). While indigenous peoples are often thought of as living in harmony with nature, with an intrinsic tendency to conserve their natural environment (Redford, 1991), such assumptions should not be carelessly made, as they tend to hinder prudent considerations regarding sustainable livelihoods and environments (Raymond, 2007). The understanding that mainly economic and utilitarian values drive the management of trees and palms in *chakras* is of crucial importance for effective communication between governments, NGO's, the Kichwa and other stakeholders involved. This in turn is essential for the conservation of forests owned by the Kichwa as well as the improvement of their livelihoods.

Thirdly, this research shows that market integration and external influences from the government, NGOs and agronomists can lead to management practices that conserve trees and palms in *chakras*. By linking conservation of trees and palms to the wider services they provide, for example as a way of generating revenue from ecotourism, the protection of these species has the potential to improve the livelihoods of the Kichwa whilst simultaneously creating an ecologically sustainable form of food production (Jarrett et al., 2017; Porro et al., 2012).

5. Conclusion

We found that the Kichwa manage trees and palms more extensively, and use different management practices, than generally assumed, which is mainly driven by utilitarian values. Three important implications arise from this research: 1) future research should acknowledge and adequately address the large variation that exists among *chakras*, especially regarding their differences in number and size of trees and palms; 2) trees and palms in *chakras* should not be assumed to be managed inherently sustainably; 3) the understanding that economic and utilitarian considerations induce active management of palms and trees in *chakras* can lead to effective conservation policies.

Authors' contributions

Robin Bredero zur Lage: Conceptualisation; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Writing – original draft. Marielos Peña-Claros: Conceptualisation, Formal analysis, Supervision; Writing – review & editing. Montserrat Rios: Resources; Supervision; Writing – review & editing.

Declarations

Ethics approval and consent to participate

This research was conducted in accordance with the Code of Ethics of the International Society of Ethnobiology. Informed consent to participate in the study was given by the presidents of the three researched communities as well as by the collaborators of this study.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data on which this research is based can be found here: https://data.mendeley.com/datasets/wgxv5g22dz/1.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.envdev.2023.100855.

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