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Landscape management among the Guarani of the Atlantic Forest of Misiones, Argentina: the case of the *Syagrus romanzoffiana* (Cham.) Glassman (Arecaceae) palm tree

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ABSTRACT

The study of the management practices that different Guarani settlements have carried out in the environment over time constitutes one of the objectives of ethnoecology and historical ecology as the way through which these communities obtain forest resources affects landscape settings. In this work, based on a local classification system of the ontogenic stages of the *pindo* palm tree *Syagrus romanzoffiana* (Cham.) Glassman (Arecaceae), we study the effects of traditional management practices on the unity of the *pindoty* landscape - plant communities with a high concentration of this species. We evaluated the degree to which two morphometric variables used in the measurements of woody tree species, diameter at chest height (DBH) and total height (H), explain the local classification. As a result, in the environment of four Guarani settlements (*Ita Piru, Kurupayty, Pindo Poty*, and *Yvyra Pepe Poty*), the production of edible larvae favors temporary changes in the *pindoty* landscape unit since it produces changes in *pindo* population's structure – (abundances by class size). In addition, we discuss some aspects of the *pindoty* units and their anthropogenic nature concluding that their evolution results from the Guarani cyclical cosmological conception.

Keywords: Indigenous Settlement; Population Structure; Traditional Classification; Vegetation Unit.

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SIGNIFICANCE STATEMENT

The studied Guarani system to recognize ontogenic stages of palm *S. romanzoffiana* (*pindo*) is based on the diameter at chest height (DBH) and total height (H) of the plant. In the structure of traditionally managed wild populations of *pindo*, we found a relationship between the intensity of management, the distance to the resource and the number of producer families. The study reveals a cultural landscape associated with the *pindo* cultural importance.

INTRODUCTION

Throughout time, different human activities have modified the environment; in America, evidence dates to about 10,000 years BP, more precisely to the Holocene period (Bonomo and Capeletti 2014; Levis et al. 2018) increasing particularly in the current period known as the Anthropocene (Gillings and Hagan Lawson 2014; Oldfield and Dearing 2003). In places where human populations have settled down, practices of use, management and domestication of resources remain reflected in modifications of the landscape units and in many cases, it is possible to speak of bio-cultural landscapes (Cassino et al. 2019). The study of the interactions between human populations and the management of their environment constitutes one of the main objectives of historical ecology (Armstrong et al. 2017; Szabó 2014) as well as of ethnoecology (Toledo and Barrera Bassols 2008). Several studies have shown that human perception of the environment and decisions on how to relate to it are based on biophysical and cultural factors (Cotton 1997; Fowler 1979).

In this study we start from the premise supported by historical ecology on the inexistence of pristine forests, as proposed by Balée (1998). Historical ecology does not consider humans simply as another animal in a complex web of organisms or as a species among many in an ecosystem within a system based on balance and process; rather, the human species can be understood as a keystone species (Balée and Erickson 2006).

When wild plant populations are managed *in situ*, even if transformations are not observed at first sight, there may be a system preluding agriculture, called "incipient forestry" (Casas et al. 1997). This type of management, which varies in intensity and effect, has an impact on the spatial distribution of resources and in the species composition of plant communities, including expansion or reduction of populations over time and changes in the complexity and heterogeneity of the landscape (Casas et al. 2016; Krapovickas 2010). Evidence suggests that this type of management has favored the development of hyper-dominant species among which there are a high number of palm species (Levis et al. 2017; Ter Steege 2013).

In general terms, to evaluate a forest status of conservation, floristic surveys are carried out where the structure of communities (richness, abundance and vital status of species, (mainly woody ones) is measured. However, historical evidence suggests that, despite their harmonious and functional appearance, it is unlikely that untouched environments exist to date (Stampella 2018). In this sense, it is proposed that species of cultural importance, potentially managed *in situ*, are included when surveying the structure of communities in order to analyze emerging information that the effect of past and current use and management could be reflecting (Araújo and Ferraz 2014; Levis et al. 2017).

The structure of woody populations in tropical forests can be mainly associated with three different curves, two of which are of interest in this study. Type I distribution curve, known as the inverted "J", is characterized by presenting the greatest number of individuals in small classes in relation to larger ones. This distribution pattern is typical of shade tolerant species with a natural rate of regeneration. Type II distribution curve characterizes species that show discontinuities in regeneration, usually interpreted as related to an alteration in populations which affected their development in the first stages. This pattern is typical of species in an ancient secondary succession (Peters 1996).

Arecaceae palm trees include numerous species with nutritional, medicinal, symbolic and economic importance in the daily lives of millions of people around the planet (Dransfield et al. 2008). In this sense, given their strait contact with man, it has been suggested that the presence and abundance of palm trees of recognized cultural importance is considered a potential indicator of anthropogenic landscapes (Balée 1993; Cassino et al. 2019; Clement 1988; Clement et al. 2010; 2015; Pereira Cruz et al. 2020; Rival 1998).

Among the Arecaceae, the two curves pointed by Peters (1996) are strongly related to the regeneration of populations and their development is affected by environmental changes – e.g. management- so, they can easily go from a Type I to Type II curve (Moraes et al. 2016). In landscape units managed by indigenous communities, it is proposed that the vertical structure of a vegetation unit is directly associated with the use and management applied to the populations in it; therefore, the study of abundances of each ontogenic stage can be useful to jointly evaluate the sustainability of its use (Dummel et al. 2011).

In general, in floristic studies of population structures, the number of individuals by size classes is used (DBH diameter at breast height ranges or total height) as indicators of the age of the individuals (e.g. Bernacci et al. 2008; Campos et al. 2017; Dummel et al. 2011; Moraes et al. 2016). However, in studies of palm tree populations the age of individuals is difficult to determine, so it is common to use growth or ontogenic stages as an estimation method (Freckleton et al. 2003; Moraes et al. 2016; Peters 1996; Svenning 2002; Souza and Martins 2005). A population growth stage can be defined as a series of successive morphologically recognizable states that occur and manifest themselves throughout their ontogeny (Gatsuk et al. 1980). In this way, an individual can be characterized in each period of its life not only by its chronological age but also by biological characteristics at a certain interval of its life or ontogenic stage (Bernacci et al. 2008).

In this context, the study of classifications within cultural groups provides valuable information related to its management of resources and contributes to understanding the functioning of biocultural ecosystems (Ferreira Júnior et al. 2016; Rist et al. 2010). Such is the case among the *Kayapó* of the Brazilian Amazon, in which they classify different sites or vegetation environments within the jungle (Posey 1985). Local cognitive processes operate at choosing a plant for a certain management and the elements of individual and local knowledge are conceptually ordered and denominated according to them (Berlin 1992). These local classifications have been referred to as "folk taxonomy" (Albuquerque et al. 2017) and underlie management decisions.

In this sense, in a recent study among the Guarani of the region a differential management of the development stages of the *pindo*, *Syagrus romanzoffiana* (Cham.) Glassman (Arecaceae) was observed to promote a differential production of edible larvae of three species of coleopterans (Dryophthoridae) (Araujo et al. 2018). As these operations involve the cutting of numerous individuals of *pindo* palms at different stages by each family group per season, they result in an activity that intervenes in the modeling of the landscape in general, and of *pindo* populations in particular. Although all the *pindo* specimens in the lands managed by the Guarani can be felled, the production of larvae is preferentially carried out in the vegetation units called *pindoty* – palm grove -which consist of plant communities with a large concentration of *pindo* individuals. Certain factors influence and shape management activities, for example, the species of larvae to be promoted (since each larval species proliferates in palms of different ontogenic stages and / or with different management of the stipe) (Araujo et al. 2018; Keller 2008a).

In this work, a Guarani classification is presented on different microenvironments or landscape units. It analyzes in depth the effect of the set of traditional practices related to the use and promotion of the development of edible larvae of Curculionidae (Dryophthoridae) on the palm structure. It also analyzes the local form of classification of the different ontogenic stages that operate at recognizing and selecting the plants to be cut and evaluates the intensity of palm tree cuttings and their effect on the structure of the managed populations. In this way, the questions shaping this work are: What morphometric variables do the Guarani observe when classifying an individual ontogenic stage? and How does the intensity of management affect the *pindo* populations in each village? The population structure of the vegetation units of each palm grove managed in four Guarani settlements is analyzed. We expected to find populations with different structures under different intensity of management scenarios. Intensity was measured as the number of family groups that manage each *pindoty*, the number of individuals felled in each ontogenic stage -according to the food preferences of the inhabitants- by annual cycle, the extension of the *pindoty* and the accessibility to the palm grove (measured in travel time to the resource)

MATERIAL AND METHODS

Framed into this scheme of anthropogenic or biocultural forests (plant formations under the intervention of human practices) and in the impossibility of counting with reference material - virgin forest - for comparison, the present investigation was developed in four Guarani settlements, each one constituting an independent case: *Ita Piru, Kurupayty, Pindo Poty*, and *Yvyra Pepe Poty* (Figure 1).

The *Ita Piru* village is located on provincial route No. 15 within the Guarani Multiple Use Reserve (RUMG). The *Kurupayty* community (population of the *Kurupa'y* tree, *Parapiptadenia rigida* (Benth.) Brenan) is located about twelve kilometers from the Paraíso neighborhood, Municipality of San Pedro, it settled in the area in 2017. The *Pindo Poty* village (flower of the *pindo* palm tree) is located in the northeast extreme of the Papel Misionero Natural and Cultural Reserve. And the *Yvyra Pepe Poty* (flower of the *Holocalyx balansae* Micheli, tree) settlements are located on the edge of provincial route No. 20, within the department of San Pedro.

The information was obtained during 14 trips made in the forest around the settlements between 2015 and 2019 during short stays, one to four days in each village. For the ethnobotanical aspects, different methodological approaches were used. Through participant observation, walking in the wood and semi-structured interviews (Albuquerque et al. 2014; Bernard 2000; Guber 2006) the different locally recognized vegetation units were delimited. In total, nine participant observation and walkings in the wood were carried out (4 in *Ita Piru* village, 2 in *Kurupayty*, 2 in *Pindo Poty* and 1 in *Yvyara Pepe Poty* village). In addition, a total of 13 semi-structured interviews were conducted (4 in *Ita Piru* and 3 in *Kurupayty*, *Yvyara Pepe Poty* and *Pindo Poty*, respectively). The participants were selected by the cacique - traditional leader - of each village, considered by the communities as a specialist in the activity. In *Ita Piru* and *Kurupayty* communities the field work was carried out under the supervision of the chief himself.

In the interviews, the local criteria to define the

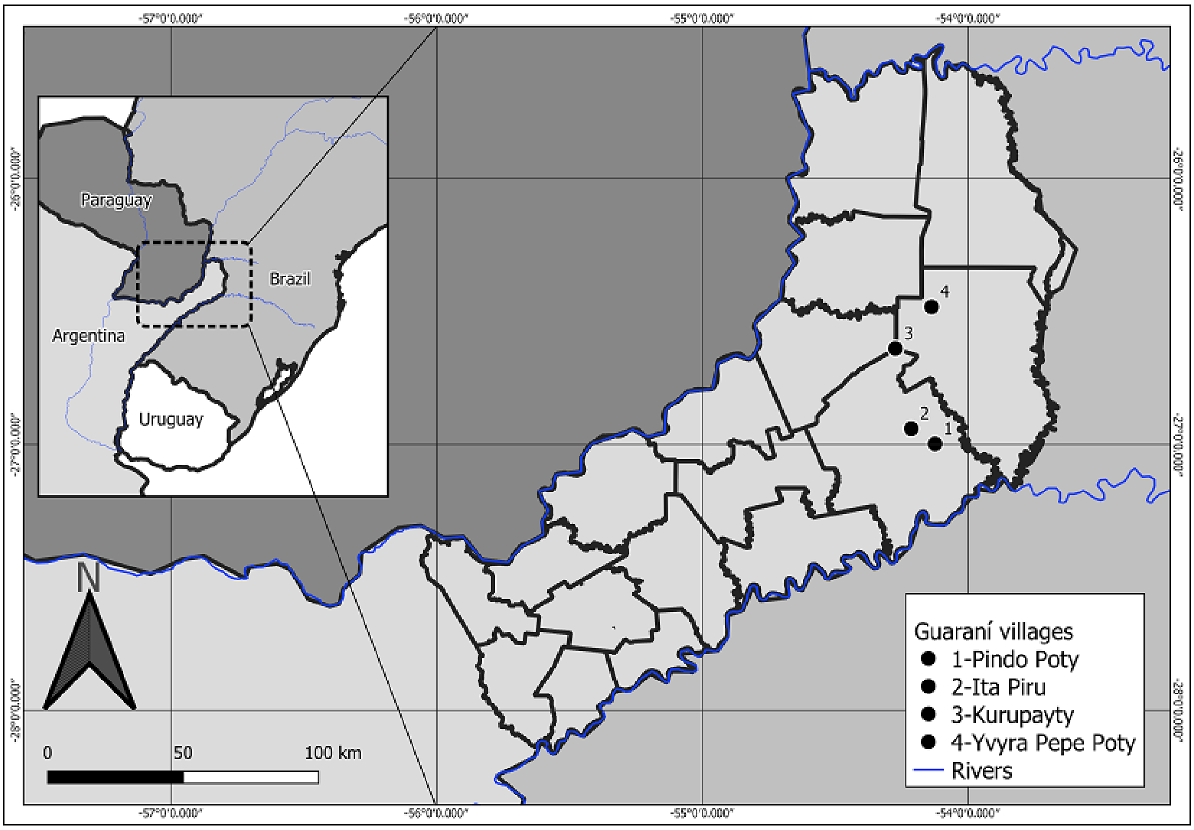

Figure 1. Geographic location of the visited Guarani settlements.

ontogenic stage - folk taxonomy - and the intensity of management of each stage in each village were specially investigated. In all cases, prior oral informed consent was requested (ISE 2016) and the corresponding research permit was obtained before the provincial regulatory body (Permit No. 069/14 -and successive renewals- to Norma Hilgert, General Directorate of Ecology and Environmental Quality, MEyRNR and subsequent renovations).

In order to evaluate the *pindo* population structure with local collaborators, 20 m wide transects with variable length were established in each community according to the size of the managed vegetation units – *pindoty* -. A total of 12,000 m^2 of surface were surveyed in the *Ita Piru* village, 5,200 m^2 in *Kurupayty*, 6,400 m^2 in *Pindo Poty* and 7,600 m^2 in *Yvyra Pepe Poty*, comprised of six managed areas (two in *Ita Piru*, two in *Kurupayty* and one in *Pindo Poty* and *Yvyra Pepe Poty*. Poty. All the managed areas in each settlement were analyzed. The variables measured were: diameter at breast height (DBH), total height (H), and growth -or ontogenic- stages. Within the same transect to evaluate the species shoots, we recorded the number of juvenile individuals that have not reached the minimum height to be measured. In each village, the ontogenic stage of the measured specimens was defined by a local inhabitant designated by the chief of each village (according to the local or emic perspective). The intensity of management (or intensity of palm cutting) was estimated for each stage of *pindo* development per village. Then, the relationship between the number of domestic units in each village and the number of palm trees felled by ontogenic stage during an annual breeding cycle per domestic units was analyzed.

To assess the degree to which the morphometric variables explain the local classification, ANOVA was used with prior verification of the assumptions of normality and homogeneity of variances through the Shapiro-Wilk and Levene tests respectively. Also, a comparison analysis of means of a Tukey test was performed following that proposed by Dummel et al. (2011) in their study on the comparison of the vertical structure of a fraction of native forest in the province of Misiones). The R Core Team (2013) software was used to process the relayed data.

RESULTS

Landscape in local perception

The classification of forest landscapes is presented according to the local perceptions of the Guarani, the analysis of this classification reveals the way in which these environments are perceived in their own culture. In the areas used in the surroundings of the settlements, they recognize different sites -or landscape units- and name them according to environmental (edaphic types, topography, and water availability) biological (composition and abundance of species of plant communities) and utilitarian-cultural criteria (food, medicinal, ornamental, religious and recreational uses/ presence of sacred spaces and availability of key resources). According to the Guarani, in general terms, a landscape unit is named after one of the outstanding micro-environmental characteristics observed in it. Among them, the most common traditional use sites identified by local people are:

Ka'aguy ete or "true forest", a mature managed forest without alteration of the upper canopy woody structure and with a "clean" understory - without dense reeds and lianas-, large trees are also possible; it is one of the appropriate sites for hunting wildlife activities (Figure 2 A).

Ka'aguy yvyty or "stony forest", a type of forest whose main distinctive characteristic is the presence of rocky outcrops -loose stones- on the ground. It corresponds to forest sites where large stones are easily seen on the surface. This environment is usually common on steep slopes or rugged topography (Figure 2 B).

Ka'aguy pyau or "young forest", a vegetation unit made up of a "secondary forest" without large trees typical of the mature forest. This type of environment is found in areas where ancient villages settled in the past. *Karai Tataendy*, an elderly inhabitant from *Ita Piru* village relates that his grandfather lived in a *Ka'aguy pyau* landscape unit near his village about 80 years ago. These environments result from the successional state of the vegetation after the abandonment of the settlement (Figure 2 C and D).

Ka'aguy karape or "low forest", the special characteristic of this environment is a low tree stratum, mainly due to shallow soils and rocky outcrops on the surface. These sites are characterized by the abundance of species such as *yvyra ovy*, - *Helietta apiculata* Benth. (Rutaceae) - and *ñangapiri*, - *Eugenia uniflora* L. (Myrtaceae) - which makes them favorable environments for collecting edible fruits and hunting wild animals in the fruiting period (Figure 2 E and F).

Takuaty or "reed forest" is an area dominated by the *takuapi* - the *Merostachys claussenii* Munro (Poaceae) reed -. It is an appropriate unit to collect basic supplies for the elaboration of handicrafts and baskets. In addition, it is one of the areas adequate to make openings and install new slashes for agriculture as the *takuapi* species is considered an indicator of deep edaphic types (Figure 3 A and B).

Chachindy or "chachi jungle", is an environment where fern trees called *chachi* predominate - *Cyathea atrovirens* (Langsd & Fisch) Domin (Cyatheaceae) - (Figure 3 C and D).

Y akã or "stream", represents watercourses - streams- with marginal floristic composition adapted to the abundance of humidity. The streams are appropriate sites to carry out ancestral fishing with ichthyotoxic plants and are also used by families as recreational sites in the hot seasons (Figure 3 E and F).

Y upa or swamp (or marsh), is a waterlogged area where water accumulates easily on the surface. The Guarani use these sites to collect ornamental plants that proliferate in these environments, mainly orchids and bromeliads for trade. The margins of these landscapes are favorable areas to install hunting traps built to hunt animals such as *kochi*, *Tayassu pecari*, mbore, *Tapirus terresis*, and *kapii*, *Hydrochoerus hydrochaeris*, which frequent these areas. (Figura 4 A and B).

Kokue or "chacra", an area of agricultural cultivation, corresponds to the peridomestic space near the houses. In these managed environments, main traditional crops like cassava, corn, sweet potatoes, peanuts, beans, and others are planted (Figure 4 C and D).

Finally, *Pindoty* or "palm grove", a vegetation unit with abundance of *pindo*, *S. romanzoffiana*; the *pindo* is a palm tree of great importance in the nutritional and symbolic life of local communities. Palm groves are appropriate sites to settle in the villages (Figure 4 E and F), in addition, these sites are used to hunt wild animals, as well as to collect edible fruits in the fruiting period. These areas are the most suitable environments to carry out the promotion of the rearing of coleopterans edible larvae of (Dryophthoridae).

Local classification of the stages of the *pindo*

In this work, we surveyed the classification system traditionally used to characterize and identify the different ontogenic stages of the *pindo* put into practice when selecting the plants to be felled according to the species of larvae to be promoted. The use of local names to denote five different age classes were recorded: *pindo tay* (palm that begins to exist) "seedling"; *pindo yky* (tender palm) "juvenile"; *pindo yky* guachu (large tender palm) "pre-adult"; *pindo pyau* (young palm) "young adult", and *pindo tuja* (old palm) "old adult".

When analyzing to what degree the morphometric variables explain the local classification, it is observed that the total height (H) is one of the general criteria of differentiation among classes. Significant differences were found in all stages (Figure 5 center). We also observed significant differences in relation to

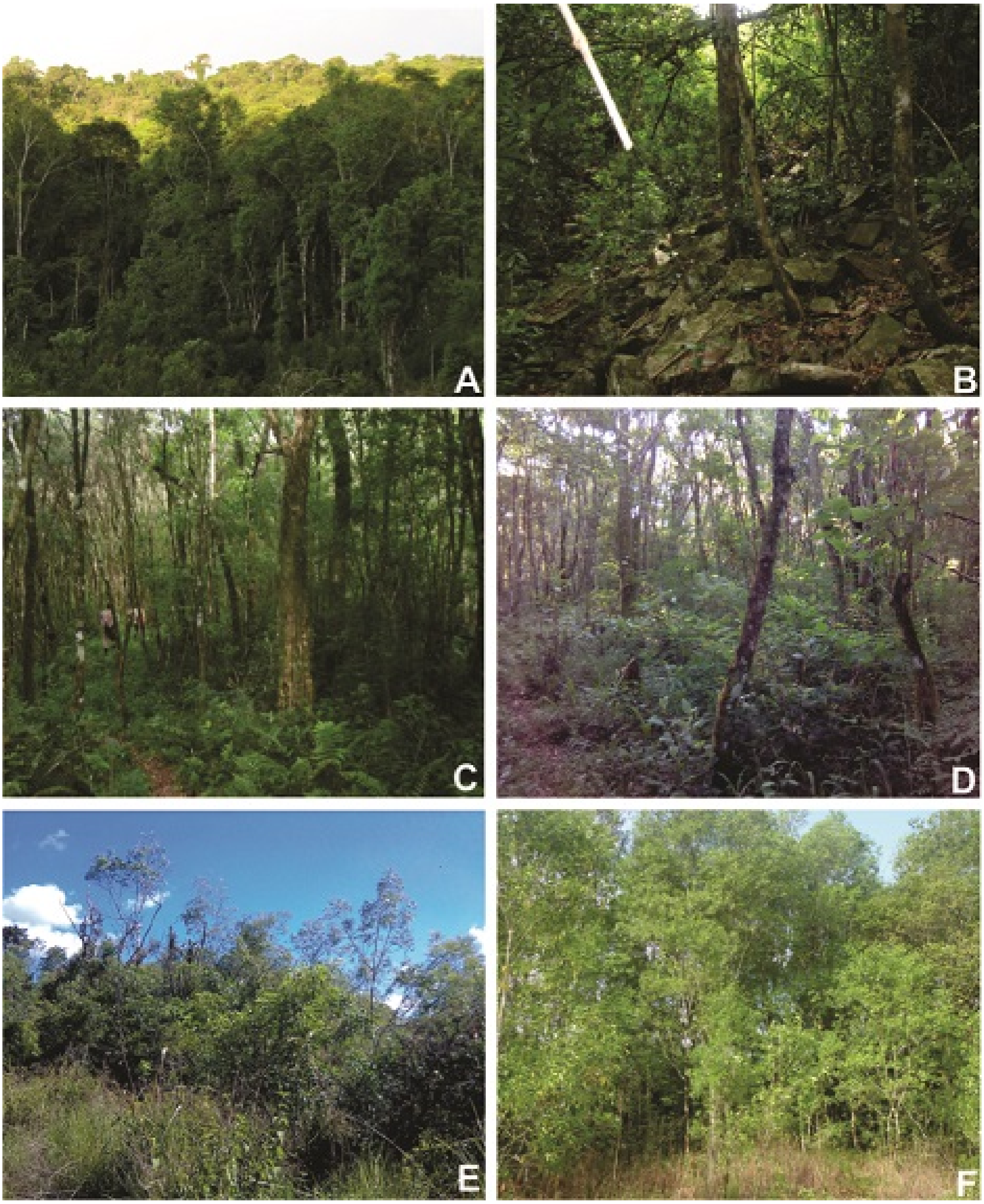

Figure 2. Landscapes recognized by the Guarani of the province of Misiones, Argentina. A: Marginal view of *Ka'aguy ete*. B: *Ka'aguy yvyty* surface stone outcrops. C and D: *Ka'aguy pyau* environment. E and F: *Ka'aguy karape* environment.

the diameter at breast height (DBH) for juvenile, pre-adult and young adult ontogenic stages while no differences were observed between the young and old adult stages (Figure 5 left).

Likewise, the spatial relationship distribution of the different DBH and H, classified by ontogenic stages has been plotted as complementary data (see Figure 6. The graph presents the distribution in geo-

Figure 3. A and B: *Takuaty*, site dominated by the *M. claussenii* reed. C and D: *Chachindy* environment with abundance of tree ferns E and F: *Y akã*, stream.

metric shapes for both variables and a trend line representing the relationship between the two continuous variables. The graph shows the grouping of individuals for each stage.

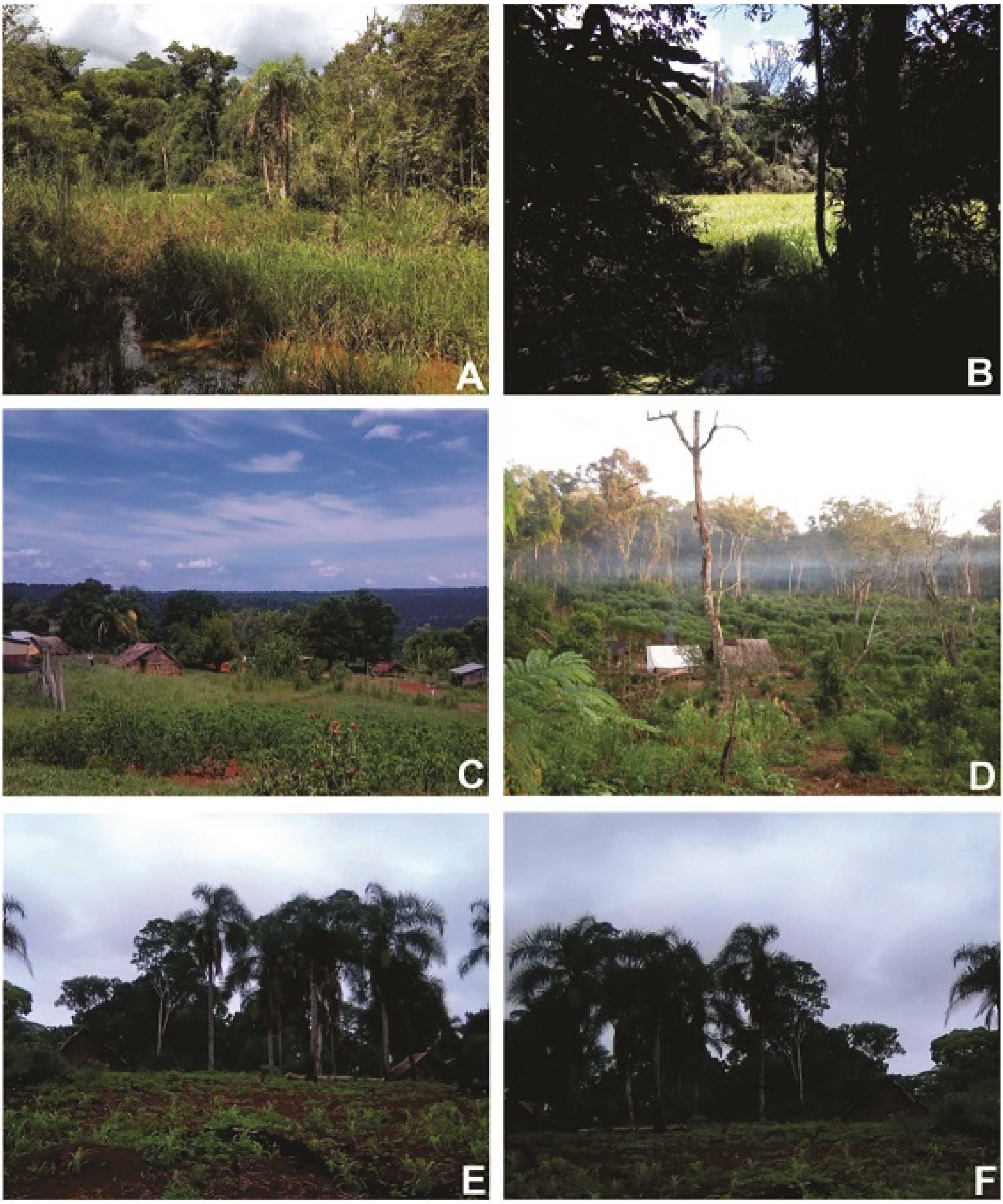

Figure 4. A and B: *Y upa* swamp, a waterlogged area. C: Settlement of the *Pindo Poty* village. D: Peridomestic and agricultural site in *Ita Piru* village. E: Village settled in *pindoty* in the Yabotí Biosphere Reserve. F. Agricultural cultivation area with traditional houses in the background

Population structure of the palm tree *S. romanzoffiana*

As mentioned before, to promote the breeding of edible larvae of coleopterans (family: Dryophthoridae) some standing specimens in different ontogenic stages are selectively and differentially felled. The specimens intentionally cut are those corresponding to the pre-adult, young adult and old adult stages.

Figure 7 shows the population structure of the

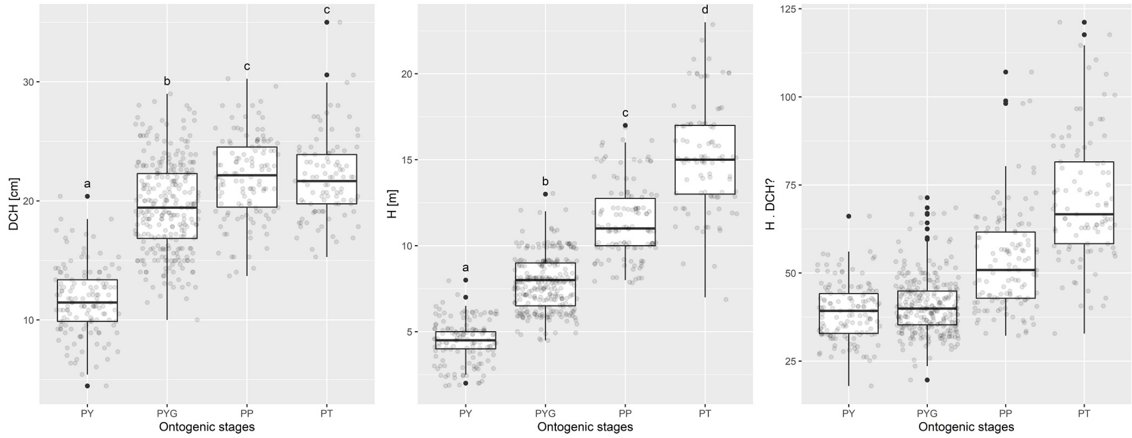

Figure 5. Vertical structure of *pindo* populations in Guarani villages. References: PY: *pindo yky*; PYG: *pindo yky* guachu; PP: *pindo pyau*; PT: *pindo tuja*. Comparison of means by ontogenic stage for DBH (left) and H (center). Different letters indicate significant differences ($p < 0.05$).

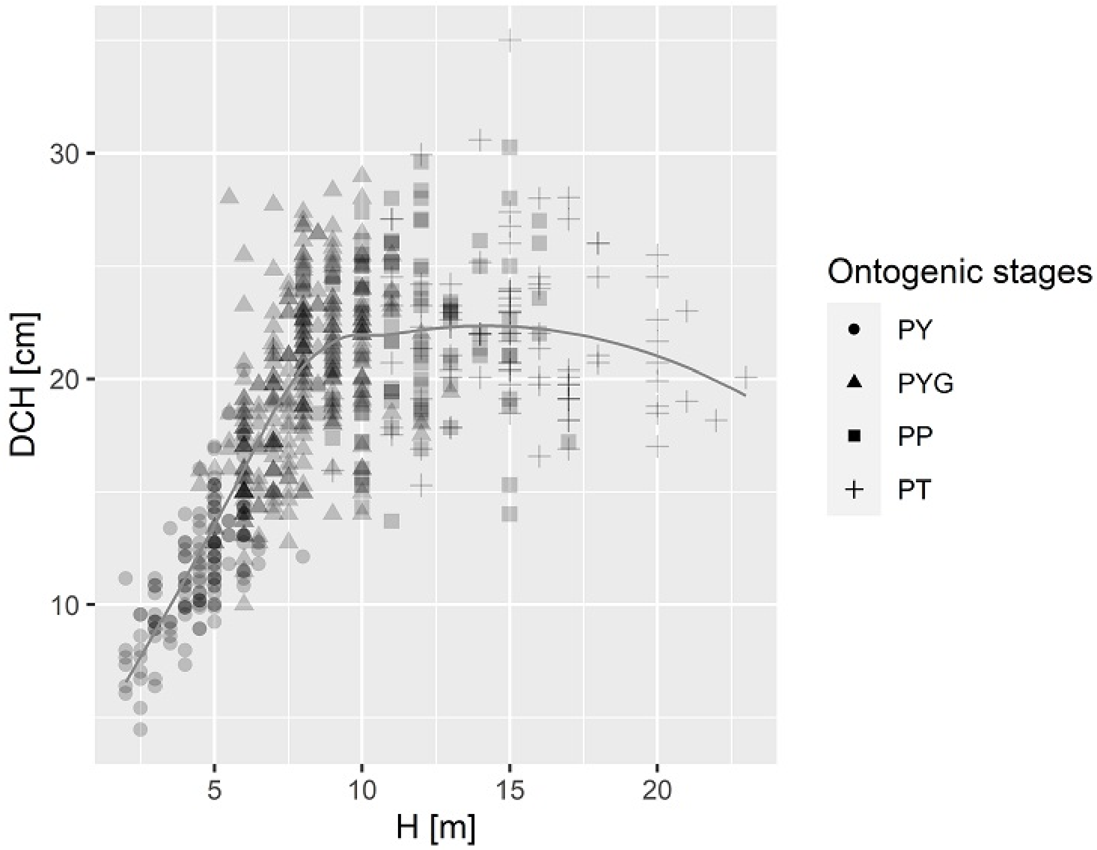

Figure 6. Distribution of diameter at breast height (DBH) in relation to total height (H) by ontogenic stages.

palm groves managed in each village. The results reveal a moderately conserved structure (with respect to that estimated without management) in *Ita Piru, Kurupayty* and *Yvyra Pepe Poty* settlements with an approximation to the inverted "J" pattern. On the contrary the population distribution pattern in the palm grove of *Pindo Poty* village shows discontinuous changes.

In the *Ita Piru* village, a practically typical inverted "J" is observed (Figure 7) with a lack of specimens in the young adult stage (32 individuals) and 48 individuals estimated per hectare in the young adult

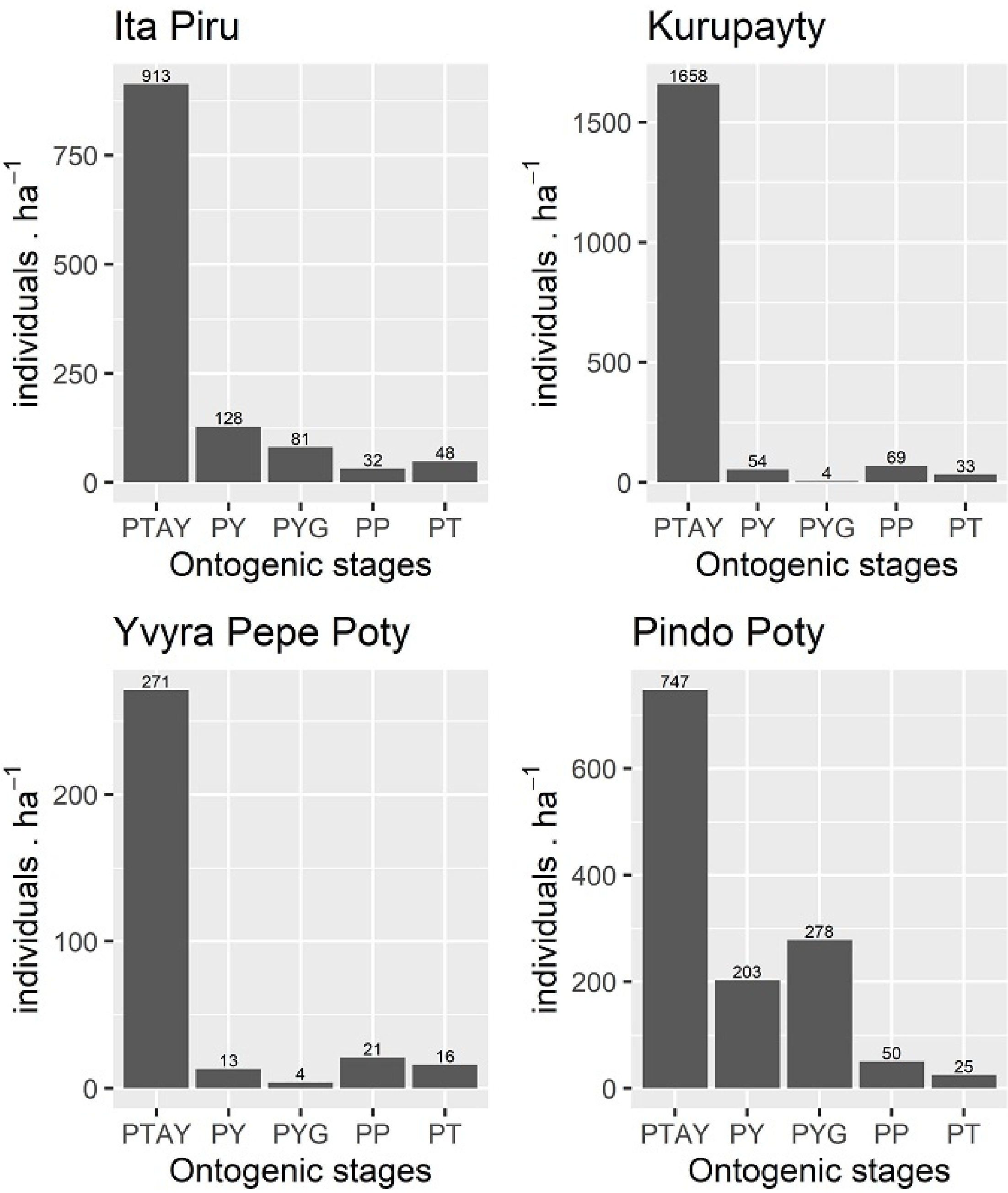

Figure 7. Palm grove population distribution pattern in four Guarani villages: *Ita Piru, Kurupayty, Yvyra Pepe Poty* and *Pindo Poty,* (values estimated in one hectare). References: PTAY: *pindo tay* "seedling"; PY: *pindo yky* “juvenile”; PYG: *pindo yky* guachu “pre-adult”; PP: *pindo pyau* "young adult"; PT: *pindo tuja* “old adult”.

one. This distribution responds exactly to the intensity of management registered by domestic units (see Table 1). In addition, we surveyed 2 *pindoty* patches. In Figure 8 the current settlement area of the village can be observed.

In the *Kurupayty* village, the population distribution of the palm grove observed presents slight changes, after the seedling, the second most abundant stage is the young adult one with 69 individuals, the third in the juvenile stage (54) and a lack of specimens in the pre-adult stage (Figure 7). The village was established in its present location in 2017. Figure 9 shows 2 registered *pindoty* vegetation patches, approximately 300 meters apart, the village does not show in the image due to its recent settlement. Forest crops can be seen on the right margin of the main

Table 1. Management intensity (number of family units and number of specimens in each ontogenic stage felled by season / year) and estimated area of the palm grove.

Village	Distance[1]	Producer families (domestic units)	Palm grove area (ha.)	Average plants felled in a season		
				Pre-adult	Young adult	Old adult
Ita Piru	1.5	3	6.5	15	30	9
Kurupayty	1	2	2	10	20	6
Pindo Poty	3.5	7	4.5	35	70	21
Yvyra Pepe Poty	1	10	6.5	50	100	30

1 Distance to the palm groves, walking time (hours).

Figure 8. *Teko'a Ita Piru*, management of the *pindoty*, surface without vegetation corresponds to the patches of the current village settlement.

image.

In the *Yvyra Pepe Poty* village, the second highest abundant is on the young adult stage with 21 individuals, followed by the old adult with 16 estimated specimens, these values are higher than those of juvenile and pre-adult ones (Figure 7). The settlement without vegetation cover and the measured *pindoty* patch are also recorded in the image (Figure 10).

The most important difference in the estimated population structure is observed in the *Pindo Poty* village where the pre-adult stage is in second place with 278 individuals and the juvenile stage in third

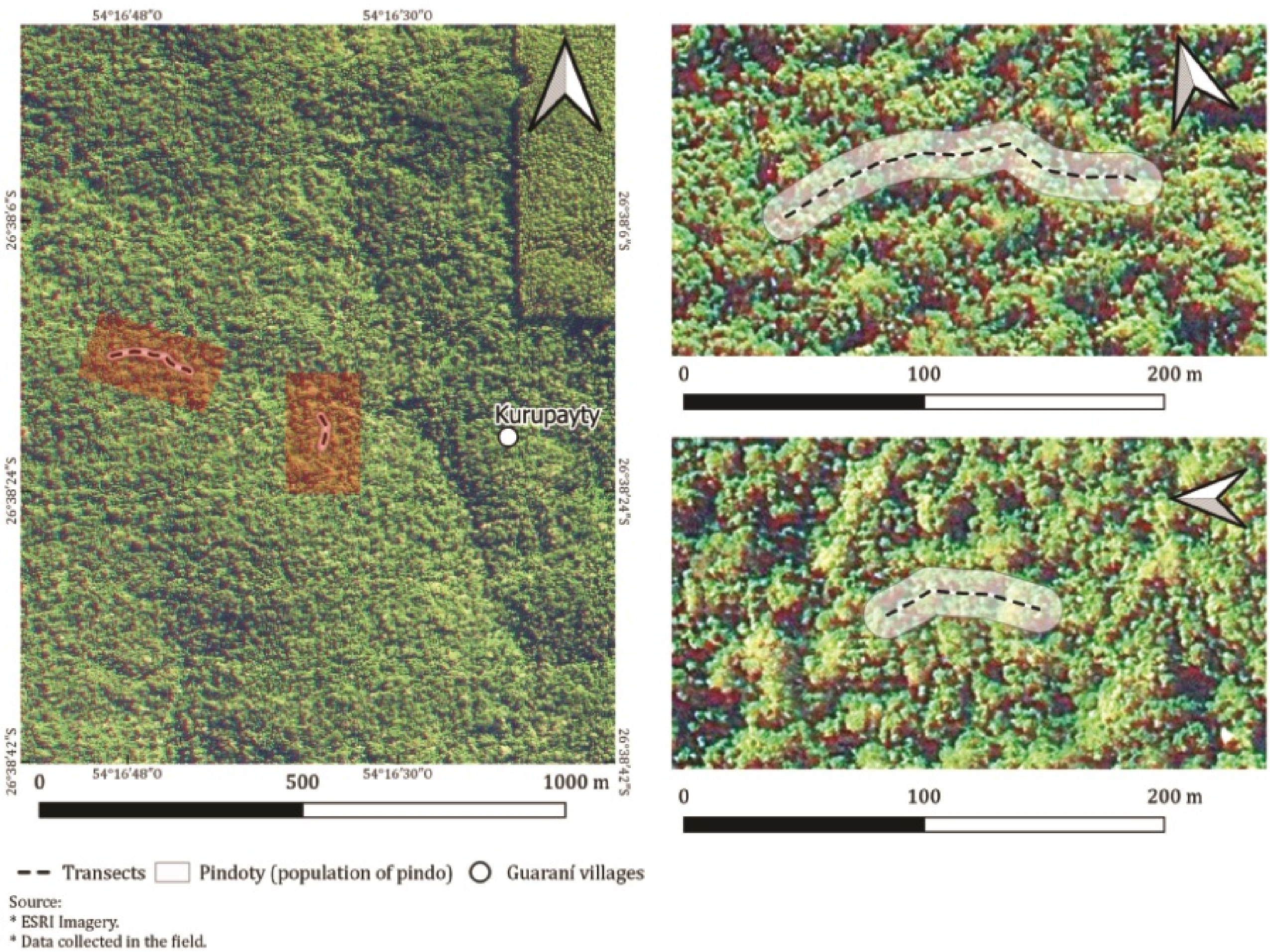

Figure 9. *Teko'a Kurupayty*, management of the *pindoty* and recent village settlement; forest cultivation can be seen in the main image.

place with 203 specimens (Figure 7). The settlement of the village and the transect in which the palm grove was measured were surveyed in the cartography (Figure 11).

Management intensity of the palm groves

According to the interviewed local inhabitants, in the promotion of larvae - on average 5 specimens are knocked down in the pre-adult, 10 in the young adult and 3 in old adult stage per household. Considering the number of domestic units and the relationship with the number of plants that are felled by ontogenic stages, the number of individuals felled per year is estimated (number of individuals / year and by ontogenic stage) (see Table 1).

DISCUSSION

In accordance with that proposed by Cotton (1997), who states that biophysical, sociological, spiritual and idiosyncratic aspects are involved in the perception of the environment, our observations show a detailed local knowledge of the environment and a set of different aspects considered in the conceptual organization of landscape units. Likewise, when analyzing the way these landscape units are named, a complex series of factors is involved. Most of the names assigned describe biophysical aspects whicht differs from that observed in local communities in semi-arid environments in Brazil, where local classifications of the forests correspond purely with utilitarian characteristics (Da Silva et al. 2016) but agrees with the multidimensionality observed in neighboring areas among multicultural groups (Stampella 2018; Zamudio and Hilgert 2016). In the same way, the different landscape vegetation units perceived in our region were

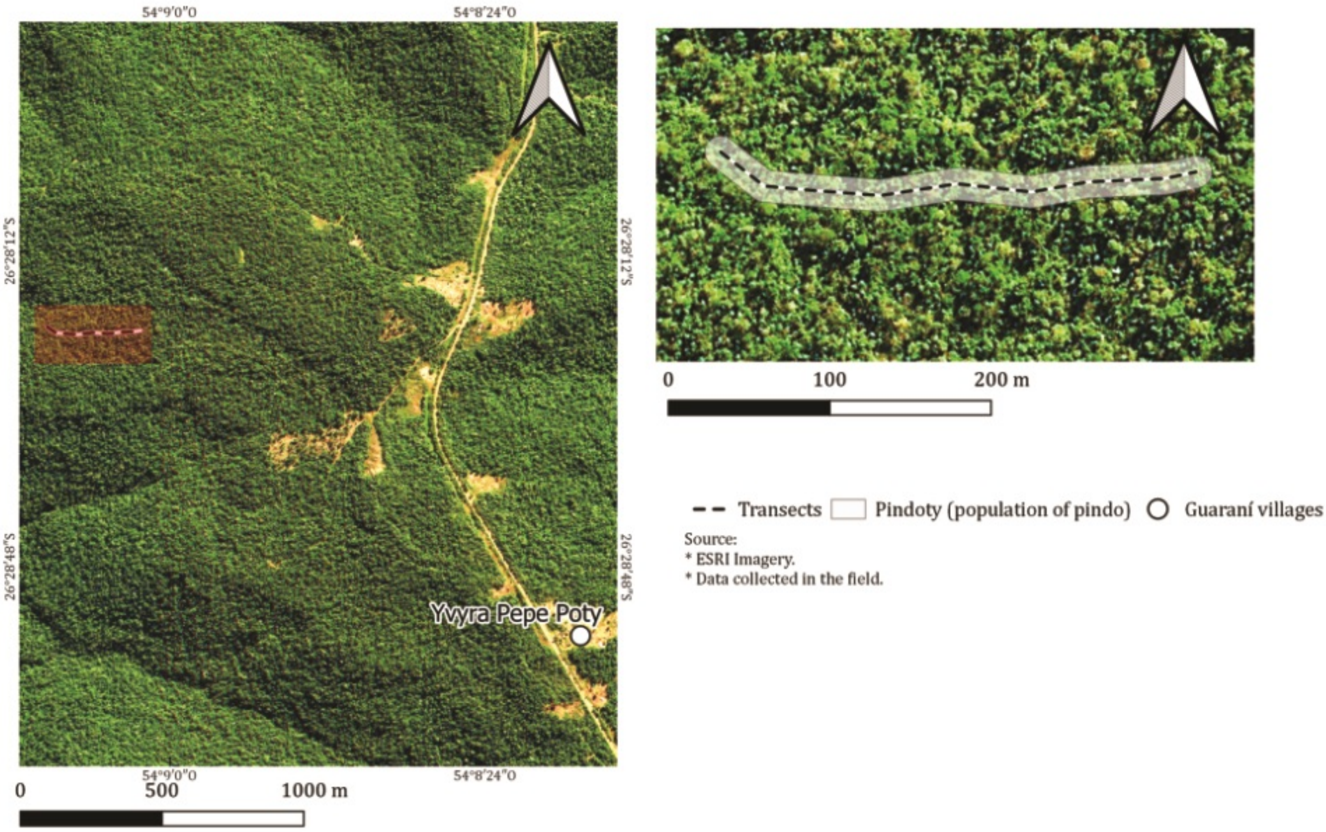

Figure 10. *Teko'a Yvyra Pepe Poty*, area without vegetation, different family units, and highlighted *pindoty*.

similar to those recorded by Pirondo and Keller (2015) in a community of guaranitic descent in the wetlands of northeast Corrientes province, where the denomination of the environments was assigned according to the abundance of certain vegetal species. This supports the idea that the environment constitutes a dynamic space resulting from the collective and temporal construction of cultural groups (family unit, settlement). On the other hand, the variations in species population in each environment can be considered as a result of the construction of different niches of use (Lamas et al. 2018). An exhaustive study of each of the recognized landscape units is pending, since at present we delve particularly into the *pindoty*.

In relation to the local classification of the stages of the *pindo* classes (or ontogenic stages) defined locally, they correlate with indicators of height and DBH, in coincidence with those utilized by ecologists in studies of floristic communities (e. g. Bernacci et al. 2008; Campos et al. 2017; Dummel et al. 2011; Moraes et al. 2016). Given that in the identification of individuals of different ontogenic stages, the local population "only observes" - i.e. does not carry out any measurement-, it is very likely that the observed characteristics are the sum of multiple factors not included in our measurements. This again highlights the complexity of the elements involved in local classifications, as pointed out on numerous occasions (Berlin 1992; Cotton 1997, among many others) and the importance of ethnobiology in recording the local holistic perspective (Keller 2008b).

With respect to the *pindo* population trend, our results are similar to those found for the DBH/ H population behavior of the palm *Elaeis guinnensis* Jacq. by Tan et al. (2014). In the ecology of plant communities in intra- and inter-specific competition, it is possible that the old adult palms had grown under conditions of great competition for light (sunlight) which demanded a height extension resulting in a decrease of the DBH diameter in relation to the total height

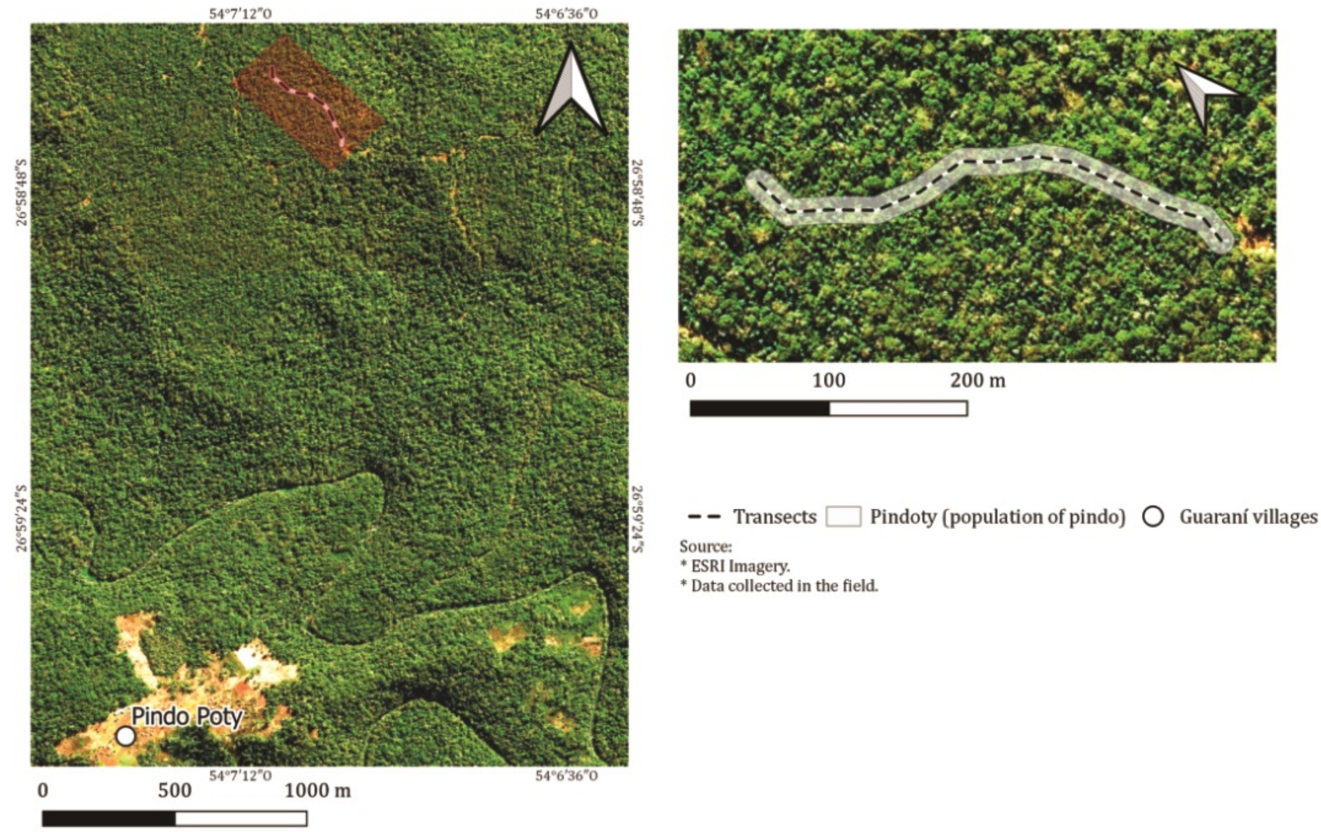

Figure 11. *Teko'a Pindo Poty*, management of the Guarani territory, area without vegetation cover (peridomestic and agricultural spaces).

(Yang et al. 2019). Another study suggests that the decrease in DBH in senile adult palm trees may be related to a physiological variation produced after the first flowering and fruiting which generates a loss of vegetative vigor and a reduction in the meristematic activity of the apex (Guzmán et al. 2017).

When interpreting the population structures found in the managed *pindoty* of the four settlements, we observed a large number of individuals in the juvenile stage which suggests that at present the availability of fruits has not diminished. However, juvenile populations are affected by tree borer beetles (*Strategus surinamensis-hirtus*, of the Dynastidae family) which may explain the decrease in the abundance of specimens in the following stages (Fig. 7). These beetles enter the base of the palm and move to the apical bud producing the death of the specimens (Lourenção et al. 1999).

In the four Guarani villages (*Ita Piru, Kurupayty, Pindo Poty*, and *Yvyra Pepe Poty*) where the population structures of the *pindoty* were evaluated, we observed two types of distribution curves, a type I distribution curve in *Ita Piru, Kurupayty, Yvyra Pepe Poty* villages) and a type II in *Pindo Poty*. With these results, we consider that different management intensities (estimated number of individuals felled per year, and the number of individuals / year by ontogenic stage), as well as the distance to each palm grove from the settlement, are factors that model the structure of the populations. We conclude that palm groves that approach the Type I distribution curve (*Ita Piru, Kurupayty*, and *Yvyra Pepe Poty* villages) are associated with *in situ* population management; whereas in the *Pindo Poty* community, the Type II population distribution curve suggests it was formed from an old settlement; the difficult access to the palm grove (a three-hour-walk) could explain why it is not used.

Distribution curves of the Type I population structure have been recorded in four species of palms from Tumupasa, in Bolivia (*asaí, Euterpe precatoria* Mart;

copa, Iriartea deltoidea Ruiz & Pav; *chima, Bactris gasipaes* Kunth; *jatata, Geonoma deversa* (Poit.) Kunth (Moraes et al. 2016). This type of population structure has also been found in managed landscapes in the *Attalea speciosa* Mart. ex Spreng. tree of the northeast region of Brazil (Campos et. al. 2017). However, the Type II population distribution trend was found in a similar way for the *marfil* palm, *Phytelephas tenuicaulis* (Barfod) AJ Hend (Moraes et al. 2016).

Specifically, when observing the population distribution pattern of the palm grove in the *Ita Piru* village from the point of view of the estimated trend curve, the lower estimated number of young adult specimens could result from the fact that it is the most used stage for promoting the rearing of coleopterans edible larvae. However, for the *pindoty* of the *Kurypayty* and *Yvyra Pepe Poty* settlements, the pre-adult stage is already affected, with or without very few specimens, which may cause insufficient recruitment to supply the following classes and keep populations in balance. The observed gaps at the pre-adult stage in *Kurypayty* and *Yvyra Pepe Poty* villages cannot be explained only by the cutting of individuals for the promotion of edible larvae, as the larvae mainly produced in this stage (*Metamasius hemipterus* L., ycho'i) are neither the most appreciated nor the most promoted (Araujo et al. 2018). But, if we add cutting pressure at this stage as a result of the consumption of the apical bud -*pindo ruã*- (Araujo et. al. 2020), it is possible to state that the alteration of the population structure responds to anthropic factors. Populations without specimens in the younger ontogenic stages indicate the structure has been altered, probably by over-exploitation of some of the older stages as observed in managed palms populations in Colombia (Bernal and Galeano 2013).

Kurupayty is a small and relatively new village (established in 2017) therefore, a Type I population distribution pattern was expected, however, there is a reduction of individuals in the pre-adult stage. Probably, the currently managed *pindoty* was used in the past by other neighboring settlements not addressed in this work, which may have caused the decrease in individuals. Likewise, the low number of individuals in the pre-adult stage in *Yvyra Pepe Poty* can be associated to the easy access to the *pindoty*, together with the density of families and the resulting high intensity of management (10 households) suggesting a current overuse in this ontogenic stage. In contrast to the density found in the pre-adult stage in *Kurupayty* and *Yvyra Pepe Poty* village, in *Pindo Poty* this stage is the second with the largest number of individuals, with a distribution pattern that approximates to the Type II curve. This type of distribution could be explained by a lack of seed production of the reproductive specimens during a certain period (Peters 1996). The high number of individuals found at this stage contrasts with the intensity of management usually recorded in the rest of the settlements, it would indicate the underuse of the resource in the village. It is possible that this change in the distribution and abundance of the *pindoty* reflects that it was formed from an ancient settlement, as suggested by Levis et al. (2018) with reference to the formation of domesticated palm groves. Furthermore, the difficult access to the palm grove (a three-hour-walk) could explain why it is not used.

Given the temporal changes in the population distribution of the species studied, and taking into account other studies, the results suggest that human intervention– e.g.. management techniques, can exert modifications in the ecological groups of plants, and the populations can change from a Type I to a Type II pattern and vice versa (Moraes et al. 2016). This population mismatch occurs particularly in opportunistic species, which can be pioneers in microhabitats, as those generated by humans. In such circumstances, their diasporas find a new niche and an explosion of renewals is generated there. But after several years, a structure with many adults and low production of shoots is formed due to the low availability of light, food, water resources, etc., from that niche to continue producing them. Such changes in population ecological behavior at different successional stages after disturbances were proposed for the Paraná pine, *Araucaria angustifolia* (Bertol.) Kuntze (Araucariaceae) in several studies carried out in the Atlantic Forest region (Bortoncello 2008; Paludo et al. 2009; Souza 2020). In general, to determine the impact of the use of the resource in the short term, it is necessary to carry out periodic measurements and determine the dynamics of the populations in each settlement incorporating other factors that may affect distribution patterns (palm grove size, socio-economic characteristics, other productive activities, and access to other resources as welfare programs of government agencies, and NGOs).

However, when considering the cyclical management of the Guarani territory (Noelli et al. 2019), collection activities are fundamental, since they favor the germination of *pindo* seeds through *in situ* consumption and dispersal of the fruits as well as indirect cultivation causing an increase in population densities. In this sense, Crivos et al. (2007) indicate that these environments can be considered modified spaces in different phases of transformation as a consequence of human intervention.

This supports the idea that the environment constitutes a dynamic space resulting from the collective and temporal construction of cultural groups (family unit, settlement). The variations in species population in each environment can be considered as a result of the construction of different niches of use (Lamas et al. 2018)., In his study among the *Kayapó* of the Amazon, Posey (1985) states that landscape units are considered as patches, where the management practices carried out tend to increase the concentration of useful species. The *pindoty* surveyed here can be considered as special sites for resources accumulation, similar to the spaces called "islands of resources" in the Amazon regions. It has been pointed out that these environments are subject to an itinerant form of landscape management along many years in order to ensure availability for generations to come (Keller 2008b; Posey 1985).

CONCLUSION

In this study we found local classifications of the different landscapes perceived by the Guarani of Misiones, Argentina. The vernacular nominations of each landscape unit are strongly associated with the dominant plant species, such as palm trees, reeds, and ferns, although sometimes topographic and water aspects are also taken into account. At the same time, each landscape unit is related to the utility of each environment. In relation to the local classification of ontogenetic stages, we found that locally observed factors correlate with diameter at breast height (DBH) and total height (H) which suggests that height is one of the differentiation criteria of the size of individuals, but that there are probably other contextual elements that have not been made explicit by the inhabitants.

We emphasize that the management of wild populations by the Guarani is comparable to the typical management systems of the Amazonian tribes, which responds to management / abandonment. Likewise, the cyclical use and abandonment of different spaces could be considered practices that could foster the formation of anthropogenic palm groves in the long term. Cycles that link to each other result in the constant manipulation of the environment and in the formation of the Guarani biocultural landscape.

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DATA AVAILABILITY

The data used to support the findings of this study are available from the corresponding author upon reasonable request.

CONFLICT OF INTEREST

The author has no conflicts of interest to declare.

CONTRIBUTION STATEMENT

Conceptualization, methodology review and funding acquisition were done by JJA, NIH and HK. JJA conducted all interviews together with local people, made the data curation, and writing of original draft. JJA and JLR made the formal analysis. All authors contributed in the editing and read and approved the final manuscript.

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