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Mayan Homegardens in Decline: The Case of the Pitahaya (*Hylocereus undatus*), a Vine Cactus With Edible Fruit

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Abstract

Homegardens are small-scale agroforestry systems consisting of parcels of land on homesteads in which diverse plant species are cultivated in several strata, often integrating herbaceous, tree, vine, crop, and animal components. Among the vines in Mayan homegardens in Yucatán is the pitahaya (*Hylocereus undatus*), a cactus with edible fruit. We use this species as a model to identify changes in the level of knowledge and management of homegardens due to modernization (increased tourism, paved roads, and urban expansion) in order to propose conservation strategies. Structured interviews were carried out in 100 homegardens; information regarding economics, language, school attendance, and the distance to cities were gathered. Currently, pitahaya is mostly eaten as a sorbet, and women harvest its fruit more often than men do. It is the elderly who teach the next generations about the use and care of pitahayas. The model that best explained the level of knowledge and management about pitahaya included variables such as the location of homegardens; their distance to the nearest city; as well as language, gross domestic product, and school attendance rate of home gardeners. We found that there is less traditional knowledge about pitahayas when home gardeners have higher school attendance and that not only pitahayas but also homegardens near cities are being neglected. We suggest that conservation planning for pitahayas and homegardens should include education programs on their ecological, nutritional, and economic importance. Homegardens, whose owners have the highest level of knowledge about their management and biodiversity, should be interactively conserved, and the knowledge of home gardeners should be acknowledged.

Keywords

agroforestry systems, education and conservation, Mayan culture, loss of traditional knowledge, tropical conservation, Yucatán

Introduction

Small-scale agroforestry systems such as homegardens are components of diversified land systems that are invaluable for preserving biodiversity at the local and global levels (Gbedomon, Salako, Cossi Adomou, Kakaï, & Assogbadajo, 2017; Gbedomon et al., 2017; Scales & Marsden, 2008). Homegardens are small parcels of land surrounding homes in which diverse plant species are cultivated in several strata, often integrating herbaceous, tree, vine, crop, and animal components, and that are largely confined to the humid tropics (Kumar & Nair, 2004). Homegardens are repositories of plant genetic resources; they play a crucial role in the subsistence of local inhabitants and also function as centers for the domestication and conservation of crop wild relatives (Barbhuiya, Sahoo, & Upadhyaya, 2016). In addition, homegardens offer ecosystem services such as (a) food security and nutrition; (b) medicine; (c) livelihood; (d) places for the transmission of traditional knowledge and for cultural, symbolic, and ritual

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purposes; (e) recreation areas; and (f) a way to maintain social networks through gifts and reciprocity (Aguilar-Støen, Moe, & Camargo-Ricalde, 2009; Calvet-Mir et al., 2016; Furlan, Pochettino, & Hilgert, 2017; Lope-Alzina & Howard, 2012). There is a large number of studies on homegardens around the world from diverse perspectives. These studies reveal how homegardens differ in their biodiversity; the abundance of indigenous or exotic species; strata arrangement and management practices depending on where they are located; and on the ethnic group, economic level of their owners, and the gender that manages them (e.g., Aguilar-Støen et al., 2009; Akhter et al., 2010; Alayón-Gamboa & Gurri-García, 2008; Ávila et al., 2017; Caballero-Serrano et al., 2016; Haile, Lemenih, Senbeta, & Itanna, 2017; Larios, Casas, Vallejo, Moreno-Calles, & Blancas, 2013; Mellisse, Descheemaeker, Giller, Abebe, & van de Ven, 2018; Poot-Pool, Van Der Wal, Flores-Guido, Pat-Fernández, & Esparza-Olguín, 2012).

Among the most diverse homegardens in the world are those of Mesoamerica, which vary widely in their vertical and horizontal structure and also in their species composition (Montagnini, 2006). Within this region, in the Mayan domain, diverse indigenous communities, descendants of the ancient Maya, still manage homegardens that are frequently set up in several strata to exploit light availability efficiently (Aguirre-Dugua, Eguiarte, González-Rodríguez, & Casas, 2012; De Clerck & Negreros-Castillo, 2000; Gillespie, Knudson, & Geilfus, 1993; Martínez-Ballesté, Martorell, & Caballero, 2006). Furthermore, it has been documented that since the 16th and 17th centuries, the Mayan lowland orchards and homegardens have been crucial in the semi-intensive production of important crops such as cacao, annatto, and vanilla (Caso Barrera & Aliphat Fernández, 2006). Differences in the plant species composition of homegardens in central Yucatán have also been detected when comparing those on the outskirts of cities with those in isolated villages (Rico-Gray, García-Franco, Chemas, Puch, & Simá, 1990) or when there are differences in the economic stratification of their owners (Poot-Pool et al., 2012).

In recent decades, there have been social and economic changes on the Yucatán Peninsula caused by the increase in tourism, improved roadways, expanding urban centers, and the tendency to lose traditional knowledge by younger generations, and this is resulting in the transformation of Mayan homegardens (Caballero, 1992; Lope-Alzina & Howard, 2012; Martínez-Ballesté et al., 2006).

In this article, we focus on a cactus from the vine stratum in Yucatecan homegardens, the pitahaya (*Hylocereus undatus*) (Figure 1(a)). These are planted over trees or over the stone walls that delimit homegardens (Figure 1(b)). This hemi-epiphytic species produces colorful, edible fruit that is rich in carotenes and lycopenes and beneficial to health. They are eaten directly by the inhabitants of the region, sold locally, and even

Figure 1. (a) Homegarden in Xuilub, Yucatan. (b) Pitahaya plants over a small stone wall in Xiulub. (c) Pitahaya fruits.

cultivated on larger scales (Ortiz-Hernández & Carrillo-Salazar, 2012) (Figure 1(c)). Pitahaya has been cultivated for centuries in Mayan homegardens owing to its edible fruit and their curative properties (De Clerck & Negreros-Castillo, 2000). Moreover, its fruit is used by the Maya to treat gastric and enteric diseases (Blanco & Thiagarajan, 2017). Pitahayas are increasingly cultivated around the world not only for their edible, decorative fruit, but also because they can be used as thickening agents and natural colorants in the food industry (Ortiz-Hernández & Carrillo-Salazar, 2012).

We selected the pitahaya as a model for understanding the effects of modernization on Yucatecan homegardens because it can be considered an indicator species in these agroforestry systems. On one hand, there are numerous ancient and current records of their presence in the Maya domain, with *Hylocereus undatus* among the species subjected to human selection in the Mayan lowlands before 3400 BC and currently one of the species that characterize homegardens on the Yucatán Peninsula (Colunga-García Marín & Zizumbo-Villarreal, 2004). On the other hand, we chose pitahaya because globally it is becoming an increasingly important crop. Nearly all of the fruit sold in markets comes from extensive farmlands around the world and some of them are located in the Yucatán. Here, we evaluate whether the use, knowledge, or management of *Hylocereus undatus* varies according to the proximity of homegardens to urban centers or with the economic stratification of owners. We also evaluate whether there are any differences in pitahaya management by those who speak Mayan and those who do not. Our study aims to respond the following questions: Is management and knowledge of pitahaya declining in localities adjacent to urban centers? Knowledge and management are declining in areas with higher income and in localities with improved roadways? Do Mayan speakers possess the highest level of knowledge about how to manage pitahayas?

Methods

Study Area

The study area comprised municipalities in the state of Yucatán, Mexico, located in the north of the Yucatán Peninsula, bordering Campeche to the southwest and Quintana Roo to the east and southeast and the Gulf of Mexico to the north and west (Figure 2). The capital city Mérida is the largest, with approximately half of the population of the state (900,000 inhabitants); other important cities are Progreso, Tizimín, and Valladolid (Figure 2). Yucatán has a large indigenous population: Approximately 550,000 inhabitants speak Maya, and 14 of every 100 people do not speak Spanish. Approximately 55% of the population has completed primary school (National Institute of Statistics and Geography, INEGI, www.inegi.org.mx). The geographic isolation of the Yucatán Peninsula has allowed ancient Mayan traditions such as housing (thatched huts), dressing (*huipiles*), occupation (farming), language (Mayan), and religion (deities associated with agriculture, *chacs* or rain gods) to continue to present day.

We visited 100 homegardens, where pitahayas had previously been reported, located in 11 municipalities in the state of Yucatan taking into account the different geographic, ethnic, and economic areas (Figure 2(a)) (De Clerck & Negreros-Castillo, 2000; Cuanalo de la Cerda & Guerra Mukul, 2008; Lope-Alzina & Howard, 2012; Poot-Pool et al., 2012; Rico-Gray et al., 1990). The homegardens studied included areas with differences in gross domestic product (GDP), distance to cities, proximity to different types of roads, and areas with Mayan and non-Mayan speakers.

Data

To estimate the distance to the nearest urban center and the main access roads to every homegarden studied, a map was plotted with the homegardens locations (Figure 2(b)). Socioeconomic data (number of Mayan speakers and economic level of inhabitants) for each municipality were considered as well (Figure 2(c) and (d)). The data were compiled from the National Institute of Statistics and Geography (www.inegi.org.mx). The type of house was also noted, that is, whether the homeowner lived in a traditional Mayan house with a roof made of palm leaves (Figure 3(a)) or house built entirely of bricks (Figure 3(b)).

Structured interviews were conducted, which covered (a) how pitahayas are cultivated, (b) their uses, and (c) management. There were questions regarding the number of pitahaya plants in the homegarden and the number of fruit they produce, the amount of management they receive, the economic use of plants, the way in which the fruit is consumed and whether they have any additional uses, who instructed the person who was answering the questions on the management and use of pitahaya plants, the origin of the pitahaya plants, and whether fruits are sold (Table S1 includes the questionnaire). Interviews were carried out from March to August 2017. Informants were recruited by visiting homegardens during different times of the day, conducting the interview with the young person or adult working or living in the homegarden. Direct observation of the type of house, the gender of the homegardener, the language spoken, and the type of clothing worn was made. In addition, the general condition of each homegarden was noted (whether plants or animals were partially removed, contained garbage, etc.).

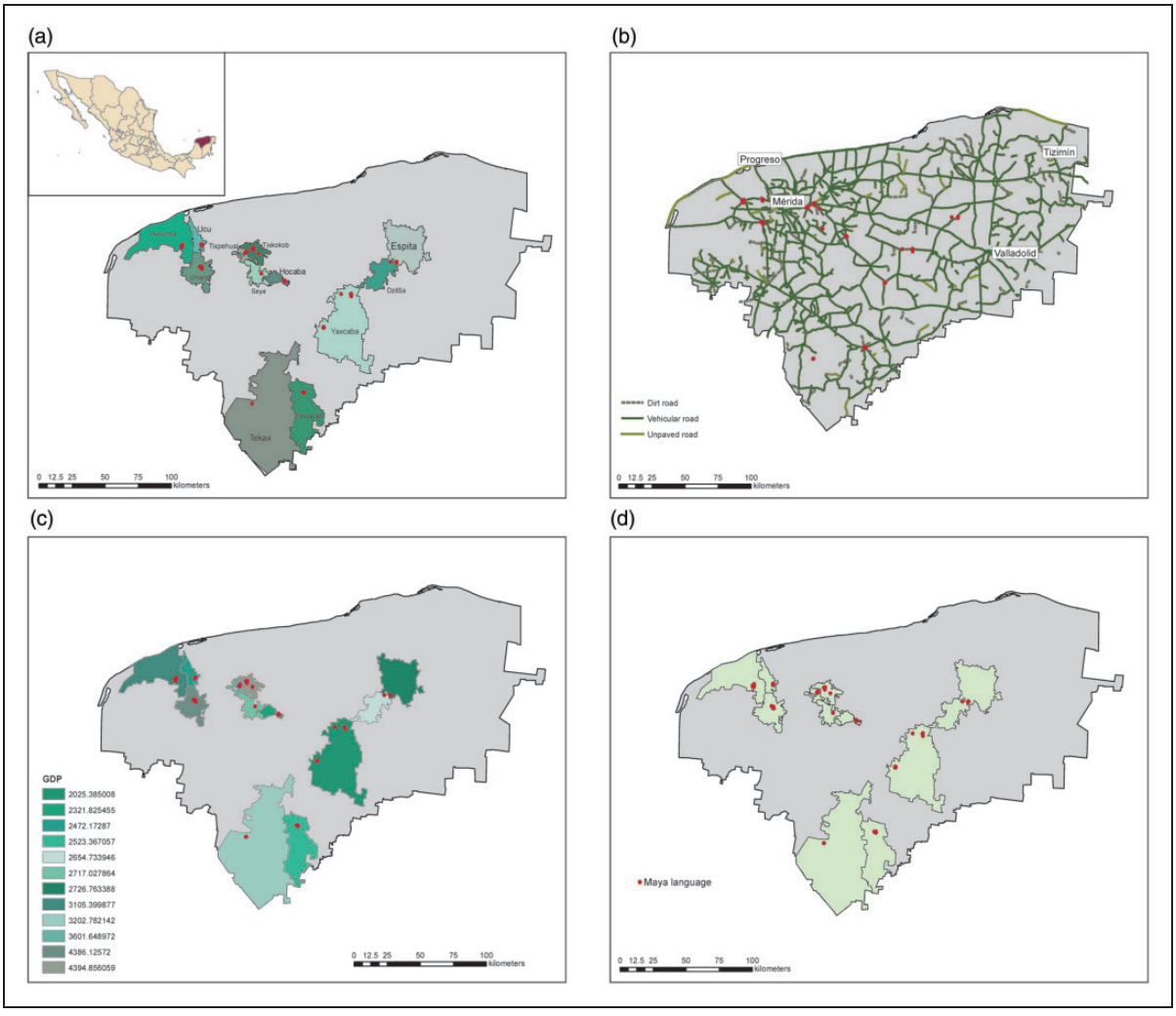

Figure 2. Maps of (a) locations of the homegardens studied, (b) map with the homegardens studied overlaid on a roadmap, (c) gross domestic product of municipalities, and (d) Maya language in the municipalities of the homegardens studied (data from the National Institute of Statistics and Geography, www.inegi.gob.mx).

Data Analysis

The variable "level of knowledge per homegarden" was defined as the number of questions answered in each interview which is a proxy to assess the level of knowledge utilized in ethnobotany. This proxy is recommended to avoid subjectivity (e.g., Saynes-Vásquez, Vibrans, Vergara-Silva, & Caballero, 2016). A critical review was carried out for every answer to identify synonyms and remove faults prior to analyses. We used a set of generalized linear models and a theoretical informatics approach based on the bias-corrected Akaike's information criterion (AICc) to examine the extent to which the level of knowledge was related to the independent variables. Numerical variables were latitude, number of indigenous languages in the municipality, number of Maya speakers in the municipality, school attendance rate, and distance to the nearest city. Categorical variables were age (15–25, 25–35, 35–45, 45–55, 55–65, and >70 years), sex (male or female), Maya speaker (yes or no), and use of traditional clothing (yes or no) (see Table S2). These sets of models aimed to describe the pattern of distribution of the response variables, namely, the level of knowledge. In addition, we used several two-way and three-way interactions as explanatory variables in these models. As a result, we came up with 31 plausible models with different combinations of these variables. The response variable did not follow a normal distribution and shows underdispersion; thus, we chose a generalized Poisson distribution error structure for the models of knowledge level with the "vglm" function of the R package "VGAM" version 1.0–6 (Yee, 2015). This function is potentially useful for underdispersion modeling (Consul & Famoye, 2006). We estimated maximum likelihood, AICc

Figure 3. Houses in studied homegardens in the Yucatan, Mexico. (a) Traditional house with a roof made of palm leaves in Xiulub and (b) a brick house in Umán.

values, and a D^2 for each model in order to select the best model that explained the response variable. All analyses were run in R 3.5 (R Core Team, 2018).

Results

Uses

Of the 100 interviews conducted, only 77 had a sufficient number of answers to carry out analyses. The following results are based on those interviews.

The most frequent use of pitahayas is as edible fruit, either eaten directly or in drinks by adding water or prepared as a sorbet. Only a few people mentioned its medicinal use to treat kidney diseases (Figure 4(a)). In response to the question, how do you think pitahaya consumption or culture has changed over the years? most people said that "the fruit used to be more common" (29%) and "it used to be more common in homes" (5%) (Figure S1). Grandparents and parents were the ones who taught others how to prepare pitahayas for consumption (Figure S2).

Management and Consumption

Pitahayas are mainly harvested by women (58%). It was the grandparents who mainly taught the practices of cultivating and taking care of pitahaya plants (14), followed by parents (12) and mothers (4) (Figure 4(b)). The main problem affecting pitahaya production is predation by fauna: different birds eat the fruit (Figure S3), as do insects such as ants and lice, and even marsupials-like possums (Figure S3). Most of the homegardens were laid out around traditional Mayan houses with a roof made of palm leaves (52), while for others (16), the houses were made of brick; and in some homegardens, some rooms were made of brick with roofs made of palm leaves (9). In only 15 of the homegardens studied were more than 10 pitahaya plants being grown. Most of the pitahaya plants had been obtained via exchange, as a gift, by buying plants, or by collecting plants in the wild (43 homegardens). Often the source of plants was spontaneous germination (20 homegardens) and some home gardeners did not recall how the pitahaya plants had been brought to their homegardens (14). The majority of home gardeners do not take care of their pitahaya plants (41), the others (36) provide care such as adding fertilizer, watering, or weeding the plants. Approximately 87% (68) of home gardeners consume the fruits produced in their gardens, with only a few (9) selling fruits to their neighbors or to merchants.

Knowledge

The highest level of knowledge about the pitahaya was found in Xuilub (a town far from Merida) and the lowest level was found in Umán, an urbanized part of the city of Mérida) ($p = .047$) (Figure 5(a)). The majority of home gardeners in all of the homegardens sampled do not take care of their pitahayas (Figure 5(b)).

The model that best explained the level of knowledge included the location of the homegardens studied, latitude, age, sex, Maya speaker, use of traditional clothes by the people interviewed, the number of Maya speakers in the municipality of the homegardens studied, school attendance rate, GDP, and distance to the nearest city with an AICc = 404.892, ΔAICc (next best) = 1.2, ΔAICc (worst) = 146.1 (Table 1). This model explained a large part of the variance in the level of knowledge (generalized linear model $D^2 = 0.93$). Less traditional knowledge was found where the school attendance rate

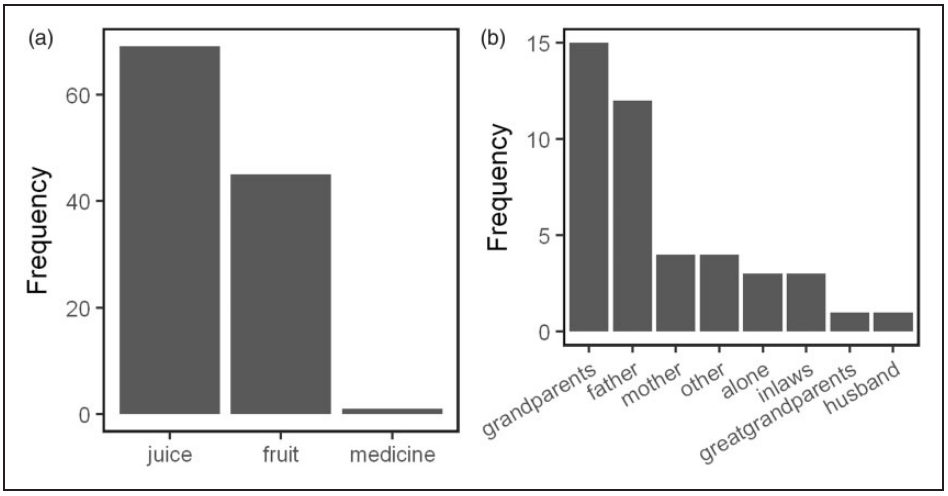

Figure 4. Graphs of (a) the main uses of pitahaya fruits and (b) the people who teach others how to use and manage pitahayas.

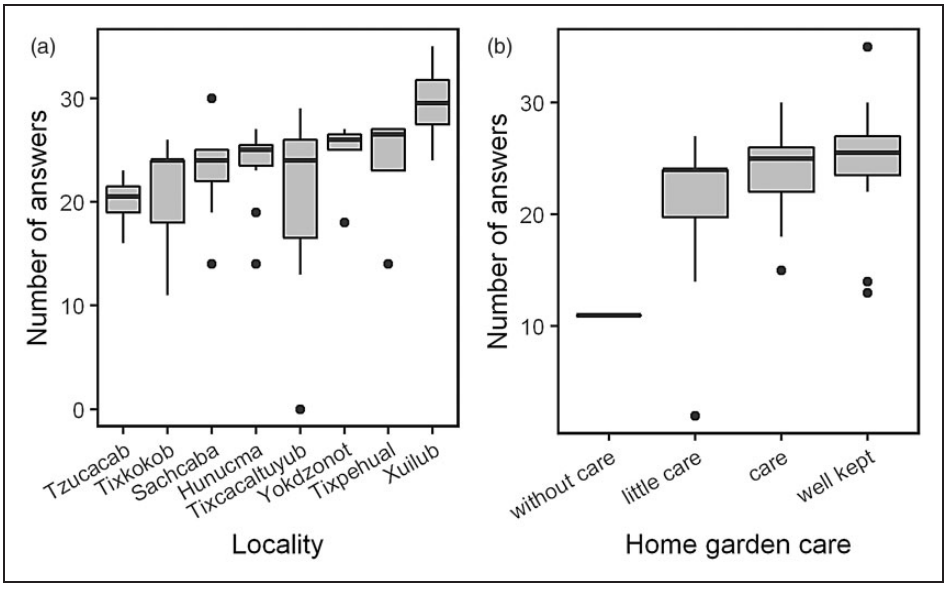

Figure 5. Number of answers to the structured interviews per (a) locality and (b) degree of care of pitahayas.

in the municipality is higher. There was a negative correlation (−0.35) between the level of knowledge and school attendance rate (Figure 6(a)). The level of knowledge followed a linear pattern, with a decrease toward more northern latitudes (Table 1; Figure 6(b)). The higher the number of Maya speakers per municipality, the higher the level of knowledge is (Figure S4).

Discussion

The Yucatán Peninsula is one of the areas where pitahayas have been cultivated in homegardens for centuries, and more recently on both a small scale and also in large, well-established plantations (Caso Barrera & Aliphat Fernández, 2006; Ortiz-Hernández & Carrillo-Salazar, 2012). Thus, *Hylocereus undatus* offers a good model for understanding the effects of modernization in the Yucatan on homegardens.

Regarding changes in the way pitahayas are consumed, our results indicate that instead of eating the pitahaya, currently the fruit is more commonly used in drinks, that is, blended with water, and sometimes this drink is frozen. Our interviewees revealed that the fruit is still eaten by the inhabitants of the Yucatan.

The traditional fruit has been found to help nourish families that have a low economic income (Ferdous, Datta, Anal, Anwar, & Khan, 2016). Therefore, we suggest that in elementary, secondary, and high school,

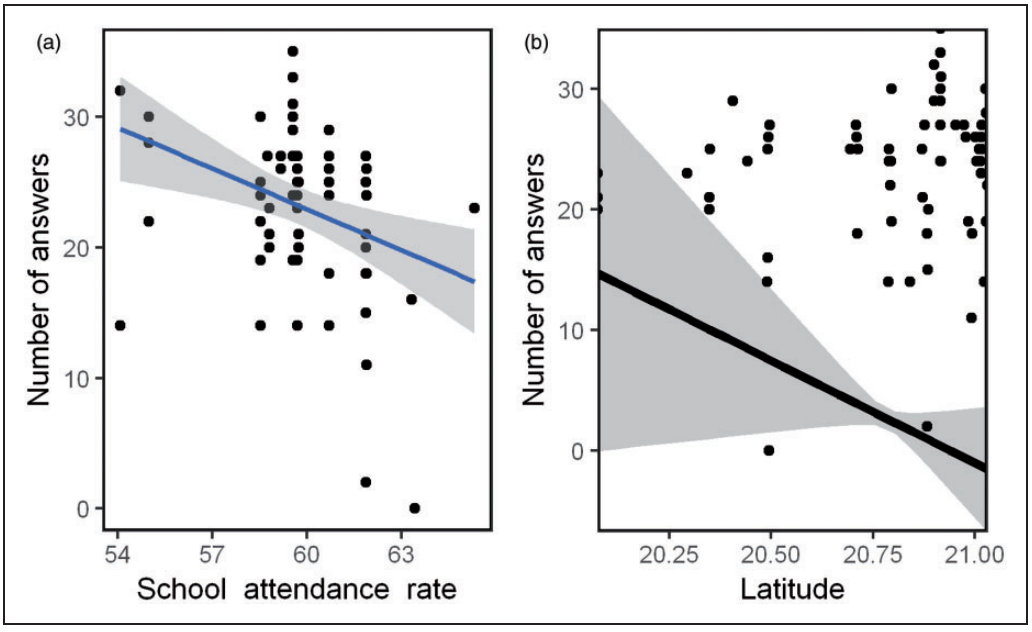

Figure 6. Analyses modeled with (a) school attendance rate and (b) latitude.

Table 1. Parameter Estimates From the Generalized Linear Model.

	Estimate	Standard error	χ^2 value	*p*
(Intercept)	413.197	95.880	4.310	<.001***
Hunucma	10.715	2.046	5.237	<.001***
Nenelá	1.445	1.768	0.817	.414
Sachcaba	8.394	1.728	4.859	<.001***
Tixcacaltuyub	1.894	1.372	1.381	.167
Tixkokob	12.065	2.287	5.275	<.001***
Tzucacab	−4.899	2.677	−1.830	.067
Ucú	12.104	2.274	5.323	<.001***
Xuilub	9.164	1.672	5.481	<.001***
Latitude	−18.924	4.490	−4.214	<.001***
Age (25–35)	5.089	1.337	3.807	<.001***
Age (35–45)	4.349	1.130	3.850	<.001***
Age (45–55)	2.915	0.803	3.630	<.001***
Age (55–65)	1.769	0.484	3.652	<.001***
Age (>70)	0.335	0.136	2.462	.014*
Sex: male	0.070	0.081	0.867	.386
Speaks Maya: low	0.038	0.061	0.618	.537
Speaks Maya: yes	0.084	0.078	1.071	.284
Traditional clothes	−0.173	0.098	−1.758	.079**
Number of languages in the municipality	0.928	0.193	4.803	<.001***
Number of Maya speakers in the municipality	0.010	0.001	5.572	<.001***
School attendance rate in the municipality	−0.412	0.088	−4.662	<.001***
Proximity to the nearest city	−2.924	0.415	−7.044	<.001***

Note. The parameters link knowledge level to geographic and social explanatory variables, along with the latitudinal gradient for Yucatán, Mexico. Estimates are on the standardized scale ± standard error. Significant estimates are marked with an asterisk (*$p \leq .05$, **$p \leq .01$ and ***$p < .001$).

lectures and seminars be given on issues related to food and nutrition in order to come up with strategies to protect and use the traditional fruits obtained from homegardens. There should be interactive activities such as collecting recipes and recording medicinal uses that take into account changes in food patterns among immigrants and cultural groups, food availability, family traditions, health issues, their use in traditional

celebrations, and economics. Moreover, the role of the elderly in the transmission of knowledge and the management of the produce from homegardens should be acknowledged and promoted, working in a multilingual environment and using resources available in the community. For pitahaya, there is plenty of information on the current and potential uses of its fruit and its nutritional value, so it would be advantageous to incorporate this information into the classes and into interactive horticultural practices.

Our results also revealed that women harvest pitahaya fruits more than men do. This coincides with reports of women actively participating in agrosystem management in surrounding homesteads in other parts of the world. For instance, traditional ecological knowledge of small agrosystems is curated by women in India (Singh, Rallen, & Padung, 2013), and another example is the work on coffee plantations done by women on family farms in Colombia (Bravo-Monroy, Potts, & Tzanopoulos, 2016). Moreover, it has been observed that homegardening in Latin America, particularly in Mayan Mesoamerica, is a reputable way for women to contribute to the home economy and demonstrate their specialized knowledge and expertise (Howard, 2006).

It is well known that elderly people instruct family members the management practices of plants and animals present in the homegarden (Galhena, Freed, & Maredia, 2013). Elderly women have been considered "living encyclopedias" in biocultural knowledge systems because they play a crucial role in teaching their family biodiversity-related traditional knowledge (Singh et al., 2013). Our results suggest that grandparents and even grand-grandparents taught the next generations about the use and care of pitahayas.

Our analysis suggests that people living in cities close to large urban centers in the Yucatan, such as Mérida, are no longer taking care of pitahayas (or homegardens in general). We observed that homegardens in these areas had been decimated and were being used as garbage dumps. This has also been observed for the knowledge and management of papaya in Yucatecan homegardens, where owners of homegardens in cities or small towns close to Mérida worked in the city and did not spend time taking care of homegardens (Moo-Aldana et al., 2017).

The most significant variables affecting the level of knowledge about pitahaya were location, latitude, number of spoken languages in the municipality, number of Maya speakers in the municipality, school attendance rate, and proximity to cities. There is less traditional knowledge when home gardeners have higher school attendance. Thus, for the homegardens in the municipality of Espita—located far from main cities and has mostly Mayan speakers and lower school attendance—we found the highest level of knowledge of all our homegardens. This should be taken into account to propose homegarden conservation planning: The areas with the most biodiverse, best conserved, and best cared for homegardens with Mayan owners should be protected.

Implications for Conservation

We suggest that the value of small agrosystems such as homegardens be taught at least in elementary, secondary, and high school. Direct, practical courses need to be implemented stressing the importance of homegardens for the ecosystem services they provide, as repositories of biodiversity, for food security and nutrition, as places for the transmission of traditional knowledge, and for cultural, symbolic, and ritual purposes.

Our observations during the interviews suggest that not only pitahayas but also homegardens are being neglected. Homegardens are abandoned, particularly in locations near Mérida or Umán or where roads have been improved. Previously, concern about the loss of homegardens has been expressed in many countries, with a diversity of solutions proposed. Among the recommendations for conserving homegardens is the creation of flexible government institutions that are able to provide solutions within social–ecological systems to contribute to the long-term maintenance of homegardens using a biocultural conservation approach (Berkowitz & Medley, 2017; González-Cruz, García-Frapolli, Casas, & Dupuy, 2015). Another solution is to recognize and incorporate knowledge and practices of elderly women into local level planning for the sustainable conservation of homegardens or small agrosystems (Singh et al., 2013). It has also been suggested that the diversity of homegardens be evaluated and legally protected (Fernandes & Malézieux, 2014; van der Wal & Bongers, 2013). Furthermore, not only should the biodiversity be evaluated but also the genetic resources in homegardens, including primitive varieties and wild relatives in order to propose conservation strategies (Galluzzi, Eyzaguirre, & Negri, 2010).

Abandoning homegardens only adds to the risks posed by climate change, which will influence the capacity of owners to manage their homegardens. Therefore, measures are needed to mitigate the negative effects of this type of external factor on these agrosystems (Abdul-Razak & Kruse, 2017; Das & Das, 2015).

In summary, we propose the following measures to preserve the biodiversity and knowledge that Yucatecan home gardeners possess: (a) include practical courses on horticulture in the homegardens of the locality in elementary, secondary, and high school, in which elderly people participate; (b) give lectures and informal talks to students and to the public in general to increase awareness about the importance of homegardens; (c) involve

government institutions in the long-term maintenance of homegardens, perhaps paying home gardeners for the environmental services provided by their homegardens; and (d) support research to document the biodiversity, wild relatives, and genetic data found in Yucatecan homegardens.

Conservation approaches for homegarden systems make multidisciplinary studies involving botanists, ecologists, geneticists, anthropologists, and sociologists possible. A better understanding of the factors that affect homegarden composition and management is needed in order to propose conservation planning designed to maintain homegardens and preserve traditional knowledge.

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Authors' Note

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Declaration of Conflicting Interest

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References

Abdul-Razak, M., & Kruse, S. (2017). The adaptive capacity of smallholder farmers to climate change in the Northern Region of Ghana. *Climate Risk Management*, *17*, 104–122.

Aguilar-Støen, M., Moe, S. R., & Camargo-Ricalde, S. L. (2009). Home gardens sustain crop diversity and improve farm resilience in Candelaria Loxicha, Oaxaca, Mexico. *Human Ecology*, *37*, 55–77.

Aguirre-Dugua, X., Eguiarte, L. E., González-Rodríguez, A., & Casas, A. (2012). Round and large: Morphological and genetic consequences of artificial selection on the gourd tree *Crescentia cujete* by the Maya of the Yucatan Peninsula, Mexico. *Annals of Botany*, *109*, 1297–1306.

Akhter, S., Alamgir, M., Sohel, M. S. I., Rana, M. P., Ahmed, S. M., & Chowdhury, M. S. H. (2010). The role of women in traditional farming systems as practiced in homegardens: A case study in Sylhet Sadar Upazila, Bangladesh. *Tropical Conservation Science*, *3*, 17–30.

Alayón-Gamboa, J. A., & Gurri-García, F. D. (2008). Home garden production and energetic sustainability in Calakmul, Campeche, Mexico. *Human Ecology*, *36*, 395–407.

Ávila, J. V. D. C., Mello, A. S. D., Beretta, M. E., Trevisan, R., Fiaschi, P., & Hanazaki, N. (2017). Agrobiodiversity and in situ conservation in quilombola home gardens with different intensities of urbanization. *Acta Botanica Brasilica*, *31*, 1–10.

Barbhuiya, A. R., Sahoo, U. K., & Upadhyaya, K. (2016). Plant diversity in the indigenous home gardens in the Eastern Himalayan Region of Mizoram, Northeast India. *Economic Botany*, *70*, 115–131.

Berkowitz, B. N., & Medley, K. E. (2017). Home gardenscapes as sustainable landscape management on St. Eustatius, Dutch Caribbean. *Sustainability*, *9*, 1310.

Blanco, L., & Thiagarajan, T. (2017). Ethno-botanical study of medicinal plants used by the Yucatec maya in the northern district of Belize. *International Journal of Herbal Medicine*, *5*, 33–42.

Bravo-Monroy, L., Potts, S. G., & Tzanopoulos, J. (2016). Drivers influencing farmer decisions for adopting organic or conventional coffee management practices. *Food Policy*, *58*, 49–61.

Caballero, J. (1992). Maya homegardens: Past, present and future. *Etnoecológica*, *1*, 35–54.

Caballero-Serrano, V., Onaindia, M., Alday, J. G., Caballero, D., Carrasco, J. C., McLaren, B., & Amigo, J. (2016). Plant diversity and ecosystem services in Amazonian homegardens of Ecuador. *Agriculture, Ecosystems & Environment*, *225*, 116–125.

Calvet-Mir, L., Riu-Bosoms, C., González-Puente, M., Ruiz-Mallén, I., Reyes-García, V., & Molina, J. L. (2016). The transmission of home garden knowledge: Safeguarding biocultural diversity and enhancing social–ecological resilience. *Society & Natural Resources*, *29*, 556–571.

Caso Barrera, L., & Aliphat Fernández, M. (2006). Cacao, vanilla and annatto: Three production and exchange systems in the Southern Maya lowlands, XVI-XVII centuries. *Journal of Latin American Geography*, *5*, 29–52.

Colunga-GarcíaMarín, P., & Zizumbo-Villarreal, D. (2004). Domestication in Maya lowlands. *Economic Botany*, *58*(Supplement), S101–S110.

Consul, P. C., & Famoye, F. (2006). *Lagrangian probability distributions*. Boston, MA: Birkhauser.

Cuanalo de la Cerda, H. E., & Guerra, M. (2008). Homegarden production and productivity in a Mayan community of Yucatan. *Human Ecology*, *36*, 423–433.

Das, T., & Das, A. K. (2015). Conservation of plant diversity in rural homegardens with cultural and geographical variation in three districts of Barak Valley, Northeast India. *Economic Botany*, *69*, 57–71.

De Clerck, F. A., & Negreros-Castillo, P. (2000). Plant species of traditional Mayan homegardens of Mexico as analogs for multistrata agroforests. *Agroforestry Systems*, *48*, 303–317.

Ferdous, F., Datta, A., Anal, A. K., Anwar, M., & Khan, A. S. M. M. R. (2016). Development of home garden model for

year-round production and consumption for improving resource-poor household security in Bangladesh. *NJAS-Wageningen Journal of Life Sciences*, *78*, 103–110.

Fernandes, P., & Malézieux, P. (2014). Changes in the structure of agroforestry systems according to family life cycles: The example of home gardens in Haiti. *Bois et Forets Des Tropiques*, *69*, 87–120.

Furlan, V., Pochettino, M. L., & Hilgert, N. I. (2017). Management of fruit species in urban home gardens of Argentina Atlantic Forest as an influence for landscape domestication. *Frontiers in Plant Science*, *8*, 1690.

Galhena, D. H., Freed, R., & Maredia, K. M. (2013). Home gardens: A promising approach to enhance household food security and wellbeing. *Agriculture & Food Security*, *2*, 8.

Galluzzi, G., Eyzaguirre, P., & Negri, V. (2010). Home gardens: Neglected hotspots of agro-biodiversity and cultural diversity. *Biodiversity and Conservation*, *19*, 3635–3654.

Gbedomon, C. R., Salako, K. V., Cossi Adomou, A. C., Kakaï, G. R., & Assogbadajo, A. E. (2017). Plants in traditional home gardens: Richness, composition, conservation and implications for native biodiversity in Benin. *Biodiversity and Conservation*, *26*, 3307–3327.

Gbedomon, R. C., Salako, V. K., Fandohan, A. B., Rodrigue Idohou, A. F., Kakäi, G., & Assogbadjo, A. E. B. (2017). Functional diversity of home gardens and their agrobiodiversity conservation benefits in Benin, West Africa. *Journal of Ethnobiology and Ethnomedicine*, *13*, 66.

Gillespie, A. R., Knudson, D. M., & Geilfus, F. (1993). The structure of four home gardens in the Petén, Guatemala. *Agroforestry Systems*, *24*, 157–170.

González-Cruz, G., García-Frapolli, E., Casas, A., & Dupuy, J. M. (2015). Responding to disturbances: Lessons from a Mayan socio-ecological system. *International Journal of the Commons*, *9*, 831–850.

Haile, G., Lemenih, M., Senbeta, F., & Itanna, F. (2017). Plant diversity and determinant factors across smallholder agricultural management units in Central Ethiopia. *Agroforestry Systems*, *91*, 677–695.

Howard, P. L. (2006). Gender and social dynamics in swidden and homegardens in Latin America. In: B. M. Kumar & P. K. R. Nair (Eds), *Tropical homegardens* (pp. 159–182). Dordrecht, Netherlands: Springer.

Kumar, B. M., & Nair, P. R. (2004). The enigma of tropical homegardens. *Agroforestry Systems*, *61*, 135–152.

Larios, C., Casas, A., Vallejo, M., Moreno-Calles, A. I., & Blancas, J. (2013). Plant management and biodiversity conservation in Náhuatl homegardens of the Tehuacán Valley, Mexico. *Journal of Ethnobiology and Ethnomedicine*, *9*, 74.

Lope-Alzina, D. G., & Howard, P. L. (2012). The structure, composition, and functions of homegardens: Focus on the Yucatán Peninsula. *Etnoecológica*, *9*, 17–41.

Martínez-Ballesté, A., Martorell, C., & Caballero, J. (2006). Cultural or ecological sustainability? The effect of cultural change on *Sabal* palm management among the lowland Maya of Mexico. *Ecology and Society*, *11*, 27.

Mellisse, B. T., Descheemaeker, K., Giller, K. E., Abebe, T., & van de Ven, G. W. (2018). Are traditional home gardens in southern Ethiopia heading for extinction? Implications for productivity, plant species richness and food security. *Agriculture, Ecosystems & Environment*, *252*, 1–13.

Moo-Aldana, R. D., Munguía-Rosas, M. A., Serralta, L. P., Castillo-Burguete, M. T., Vega-Frutis, R., & Martínez-Natarén, D. (2017). Can the introduction of modern crop varieties in their centre of origin affect local ecological knowledge? A case study of papaya in the Yucatan Peninsula. *Human Ecology*, *45*, 367–375.

Montagnini, F. (2006). Homegardens of Mesoamerica: Biodiversity, food security, and nutrient management. In B. M. Kumar & P. K. R. Nair (Eds), *Tropical homegardens* (pp. 61–84). Dordrecht, Netherlands: Springer.

Ortiz-Hernández, Y., & Carrillo-Salazar, J. A. (2012). Pitahaya (Hylocereus spp.): A short review. *Comunicata Scientiae*, *3*, 220–237.

Poot-Pool, W. S., Van Der Wal, H., Flores-Guido, S., Pat-Fernández, J. M., & Esparza-Olguín, L. (2012). Economic stratification differentiates home gardens in the Maya village of Pomuch, México. *Economic Botany*, *66*, 264–275.

R Core Team. (2018). *R: A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from http://www.R-project.org/

Rico-Gray, V., García-Franco, J. G., Chemas, A., Puch, A., & Simá, P. (1990). Species composition, similarity, and structure of Mayan homegardens in Tixpeual and Tixcacaltuyub, Yucatan, Mexico. *Economic Botany*, *44*, 470–487.

Saynes-Vásquez, A., Vibrans, H., Vergara-Silva, F., & Caballero, J. (2016). Intracultural differences in local botanical knowledge and knowledge loss among the Mexican Isthmus Zapotecs. *PloS ONE*, *11*(3), e0151693.

Scales, B. R., & Marsden, S. J. (2008). Biodiversity in small-scale tropical agroforests: A review of species richness and abundance shifts and the factors influencing them. *Environmental Conservation*, *35*, 160–172.

Singh, R. K., Rallen, O., & Padung, E. (2013). Elderly Adi women of Arunachal Pradesh: "Living encyclopedias" and cultural refugia in biodiversity conservation of the Eastern Himalaya, India. *Environmental Management*, *52*, 712–735.

van der Wal, H., & Bongers, F. (2013). Biosocial and bionumerical diversity of variously sized home gardens in Tabasco, Mexico. *Agroforestry Systems*, *87*, 93–107.

Yee, T. (2015). *Vector generalized linear and additive models: With an implementation in R*. New York, NY: Springer.