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Knowledge of the Yucatec Maya in seasonal tropical forest management: the forage plants

El conocimiento de los mayas yucatecos en el manejo del bosque tropical estacional: las plantas forrajeras

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Abstract. Indigenous knowledge and the millenary experience in management of natural vegetation on karstic landscapes are important aspects that should be considered in animal production in seasonal tropical environments. The aim of the present work was to make an inventory of native plants associated to soilscapes from seasonal tropical forests from the Yucatán Peninsula that are used as forage by Mayan people. The work was carried out in 27 Mayan communities on karst landscapes in the Yucatán Peninsula as a part of the "Ethnoflora Yucatanense" project of the Universidad Autónoma de Yucatán. Samples were taken of forage plants together with corresponding floristic and ethnobotanical information. Data were processed in EXCEL dynamic tables, grouped by plant family, geoforms and soils, life form and animal consumers. Results indicate that Mayan communities use 196 plant species as forage: 139 herbaceous, 17 shrubs, 35 trees and 2 palms. These plants are fed to cows, pigs, horses, lambs, turkeys, chickens, ducks and pigeons. The use of native forage plants may be an agricultural option both for rural communities and for intensive animal production on silvopastoral systems on karstic tropical landscapes from the Yucatán Peninsula.

Key words: forage trees, Maya culture, animal production, edible plants, legumes, tropical karst.

Resumen. El conocimiento indígena y la experiencia de milenios de años en el manejo de la vegetación natural en ambientes kársticos tropicales son aspectos importantes que deben ser considerados en la producción animal. El objetivo de este trabajo fue hacer un inventario de las plantas forrajeras nativas de los bosques tropicales estacionales de la península de Yucatán que son utilizadas por los mayas, incluyendo los paisajes edáficos en los que se encuentran las plantas, información que servirá de base para la planeación de las actividades agropecuarias. El trabajo se llevó al cabo en 27 comunidades indígenas mayas, como parte del proyecto "Etnoflora Yucatanense" de la Universidad Autónoma de Yucatán. Las muestras de plantas forrajeras se tomaron con información florística y etnobotánica. Los datos se manejaron mediante tablas dinámicas en Excel y fueron agrupados por familia florística, geoforma, forma de vida y por los animales que las consumen. Las comunidades mayas utilizan 196 especies de plantas para alimentar a los animales: 139 herbáceas, 17 arbustos, 35 árboles y dos palmeras. Las plantas forrajeras nativas son utilizadas para alimentar vacas, cerdos, caballos, corderos, pavos, pollos, patos y palomas. Las plantas forrajeras nativas pueden ser una opción de mejoramiento de la agricultura de temporal y también para la producción animal intensiva en sistemas silvopastoriles en los paisajes kársticos tropicales de la península de Yucatán.

Palabras clave: árboles forrajeros, cultura maya, producción animal, plantas comestibles, leguminosas, karst tropical.

Introduction

Mayan people have used their natural resources since the Preclassic period (approximately, between 2 000, some authors considering it could be 3 000, to 1 000 years B.C.) (Vargas, 2004). While studies about the Maya knowledge of plants (Barrera et al., 1976; Sosa et al., 1985; Flores et al., 2001; Arellano et al., 2003) and soils have been published (Bautista et al., 2003a; Bautista et al., 2005; Bautista and Zinck, 2010), studies made about forage plants are mainly focused on their chemical composition, animal consumption and plant productivity (Vargas et al., 1987; Mizrahi et al., 1998; Sosa et al., 2000; Solorio and Solorio, 2002; Sandoval et al., 2005; Zapata et al., 2009), without consideration of soils, geomorphic environments,

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geoforms and spatial aspects. For this reason, the Maya culture and its millenary knowledge provide an opportunity for studying the forage plants from seasonal tropical forest of karstic landscapes.

On the other hand, extensive cattle rising activities have been responsible for a large part of the deforestation of tropical and subtropical zones because of the conversion of forests in artificial grasslands. The gradual transformation of forests to pastures and agricultural lands has had negative ecological impacts, disturbing the functions of the karstic ecosystems, as well as altering and fragmenting the natural ecosystems (Harvey, 2001).

The expansion of pastures and the conservation of ecosystems are 2 incentives for the search of new forms of production in tropical karstic zones (Zapata et al., 2009; Castillo et al., 2010). Silvopastoral systems using wild plants are characterized by their biodiversity and by their amply demonstrated economic and environmental benefits, providing a possibility to improve the productivity and stability of land use systems (Giraldo et al., 1995; Solorio y Solorio, 2002; Llamas et al., 2004; Zapata et al., 2009). However, their establishment depends on availability of local knowledge and management of soils and plants, due to the fact that when exotic plants are used without any consideration for soils, the possibility of failure is increased.

Legume fodder trees are often planted, both within extensive grazing systems and in association with crops. However, the adoption of new agricultural systems has been slow because of the high costs of tree planting and management. Leptosols, Cambisols, Luvisols and Vertisols are the dominant soil groups in karstic areas, characterized by very fragmented soil-relief patterns and high spatial soil heterogeneity (Bautista et al., 2004b; Bautista et al., 2005; Bautista et al., 2011). In karstic areas with seasonal tropical climate, studies carried out on the identification of new forage plants other than grasses are commonly scarce, but highly relevant (Sosa et al., 2000), which makes it difficult to formulate appropriate planning strategies for agriculture, animal production and environmental preservation (NAS, 1979; NRC, 1989; Acosta et al., 1998; Flores, 2001; Flores, 2002).

The aim of the present work was to do an inventory of forage plants used by Mayan people from soilscapes in the Yucatán Peninsula, which could be used for designing silvopastoral systems for the karstic tropical zones.

Materials and methods

Study area. The Yucatán Peninsula is located in southeastern Mexico between 18º and 21º30' of northern latitude. It is a region of low relief with elevations generally being below 50 m a.s.l. (Bautista et al., 2005). The highest areas lay in the center of the peninsula, the elevation decreasing eastward and westward from there abruptly. The higher elevations correspond to the Ticul and Sayil hills located in the southern part of the state of Yucatán, with altitudes up to 250 m a.s.l. Four geomorphic environments with their respective soilscapes have been recognized in the Yucatán Peninsula, i.e. karstic (Leptosols, Cambisols, Luvisols, Vertisols), coastal (Arenosol, Regosols, Solonchacks, Histosols), fluvio-paludal (Gleysols, Solonchacks, Histosols), and tectono-karstic (Leptosols, Cambisols, Luvisols, Vertisols) with plains and hills as main geoforms (Bautista et al., 2011). The karstic environment can be subdivided in incipient, juvenile, mature with good drainage and mature with poor drainage. The northern coast is the driest area of the Yucatán Peninsula, with semi-arid climate of the subtypes BS_1(h') w and BS_0(h')w. On the island of Cozumel, the climate is of the warm humid subtype Am(f) with abundant winter rainfall. The rest of the Yucatán Peninsula has a warm subhumid climate with 3 subtypes of increasing moisture: Aw_0, Aw_1 and Aw_2. The driest areas are located in the west and the wetter areas in the east (García, 2004). Forest cover includes various types from tropical deciduous forest to tropical evergreen forest. In coastal and other low-lying areas, vegetation includes savannah, petenes (i.e. tropical forests on residual hills), mangroves, coastal dune scrub, sedge, cattail marshes and tular (Flores and Espejel, 1994).

In the Yucatán Peninsula there are 3 large areas dedicated to cattle raising; *1),* the eastern part of the state of Yucatán, with Leptosols having problems of effective depth, fertility, proliferation of weeds, besides the erratic midsummer rains (Bautista et al., 2011); *2),* the southwestern part of the state of Campeche, with Leptosols, Vertisols and Gleysols presenting serious problems of internal drainage, and *3),* the southwestern part of the state of Quintana Roo, with Leptosols, Gleysols and Vertisols with heavy soils with poor drainage. In these regions, the cattle density varies from 0.5 to 0.8 animals per hectare (Bautista et al., 2003b).

Plant collection and data management. During the 1989-1999 period, 20 interviews were carried out in each of the 27 studied Mayan communities as a part of the "Ethnoflora Yucatanense Project" (EYP) of the Universidad Autónoma de Yucatán (UADY). Samples of forage plants were collected together with associated floristic and ethnobotanical information. Based on a survey designed within the EYP, it was possible to explore several information entries (data fields) on the use of the plants (life cycle, life form and reproduction, parts used, forms of use and handling), as well as information on the interviewees and their economic activities. Each record contained the following fields: common names (Mayan and common Castilian name), types of use (35 fields), potential uses, part used (14 fields), in the case of being of alimentary use for humans and animals the

form of preparation is described (16 fields), evaluation of the information (4 fields), form of reproduction (5 fields), flowering period (6 fields), period of leaf fall (6 fields), management degree (6 fields), management type (7 fields), source of material (11 fields), type of information source (9 fields), locality, municipality, state, interviewer, collection date and general observations (BADEPY-INIREB, 1985).

The information is completed with plant family, scientific name, life form (3 fields), the animal that consumes it (6 fields), geoforms and soilscapes in which the plant is located (Fig. 1) (Bautista et al., 2003b; Bautista et al., 2011), in accordance with the community in which the interview was carried out.

All the plants were collected during the 1989-1999 time period and were deposited in the herbarium of the Campus of Biological and Agricultural Sciences of the UADY. The botanical information was included in the "Ethnobotanical database of the Yucatán Peninsula" (BADEPY).

In addition, a bibliographic review was made in relation to the forage quality of native plants.

All plants were geographically located in the geomorphic environments, geoforms and soilscapes in which they were collected. Data on the scientific and Maya plant names, edible parts, life forms and consumption by domestic animals were managed in dynamic tables in EXCEL. Plant records may be grouped according to family, life form, geomorphic environment, geoforms, soilscapes or by animals consumption.

Results

A total of 196 plant species used as forage in the Yucatán Peninsula were detected, the families Fabaceae and Poaceae being the most represented (74 and 29 species respectively), followed by Convolvulaceae (8), Solanaceae (7), Asteraceae (6), Malphighiaceae (6), Malvaceae (6), Nyctaginaceae (5), Verbenaceae (5), Amaranthaceae (5) and other families with less than 5 species each (Fig. 2, Appendix 1).

The more widely distributed forage plants are: *Amaranthus spinosus* L.*, Carica papaya* L., *Viguiera dentata* (Cav). Sprengel *var. helianthoides* (Kunth) Blake, *Eleusine indica* (L.) Gaertn, *Panicum maximum* Jacq., *Paspalum notatum* Alain ex Flügge., *Leptochloa virgata* (L.) P. Beauv., *Celosia virgata* Jacq., *Olyra yucatana* Chase, *Acacia pennatula* (Schltdl. and Cham.) Benth., *Acacia riparia* Kunth and *Centrosema virginianum* (L.) Benth. (Table 1).

From the total 196 species of fodder plants recorded, 140 (71%) are herbs, 19 (10%) shrubs, 35 (18%) trees and 2 (1%) are palms (Fig. 2). This fact is important since 73% of the species are herbaceous and therefore, of rapid growth (annual). Herbaceous forage plants have potential use in silvopastoral systems, more so considering that the majority belong to the legume family (Fabaceae).

The stem, leaves, buds and flowers of the arborescent and shrubby forage species have a potential as animal food sources. Moreover, 33 of these perennial plant species are multipurpose trees having uses such as wood, firewood, shade, live fences, medicinal, etc.

The comparison of our results with data from 3 cattle zones of the Yucatán Peninsula showed that in the latter only 7 species of African grasses are used as forage plants: *Cynodon nlemfuensis* (African bermudagrass), *Hyparrhenia rufa* (jaragua grass), *Panicum maximun* (Guinea grass), *Pennisetum ciliare* (buffelgrass*), Pennisetum purpureum* (elephant grass), *Sorghum halepense* (Jhonson grass), *Stenotaphrum secundatum* (St. Agustin grass). These plants represent only 3.6% of the total of forage plants recorded in the present study, while

Table 1. Plants present in the largest number of soilscape

Species	*Geomorphologic landscapes*	*Part used*
Amaranthus spinosus L.	30,14,15,16,17,18,19	Fl, Fr, B
Carica papaya L.	7,8,9,129,13,30,14,15,28,16,17,18,4,19,20,21,10,11,22,23	St, Le, Fr
Viguiera dentata (Cav). Spreng. *var. helianthoides* (Kunth) S. F, Blake	30,15,17,18,4,19,20,21,10	Le
Eleusine indica (L.) Gaertn.	14,15,28,16,17,18,4	Le
Panicum maximum Jacq.	30,14,15,28,16,17,18,4,19	Le
Paspalum notatum Alain ex Flüggé.	30,14,15,28,16,17,18,4,19	Whole plant
Leptochloa virgata (L.) P. Beauv	7,8,9,1,29,13,30,14,15	Ap
Celosia virgata Jacq.	7,8,9,1,29,13,30,14,15,28,16,17,18	Le
Olyra yucatana Chase	7,8,9,1,29,13,30,14,15,28,16,17,18	Le
Acacia pennatula (Schltdl. and Cham.) Benth.	30,14,15,28,16,17,18,4,19	Le
Acacia riparia Kunth	30,14,15,28,16,17,18,4,19	Le
Centrosema virginianum (L.) Benth.	30,14,15,28,16,17,18	Whole plant

Le= leaf, Ap= aerial parts; Fl= flower; Fr= fruit, St= stem, B= bud; Se= seed.

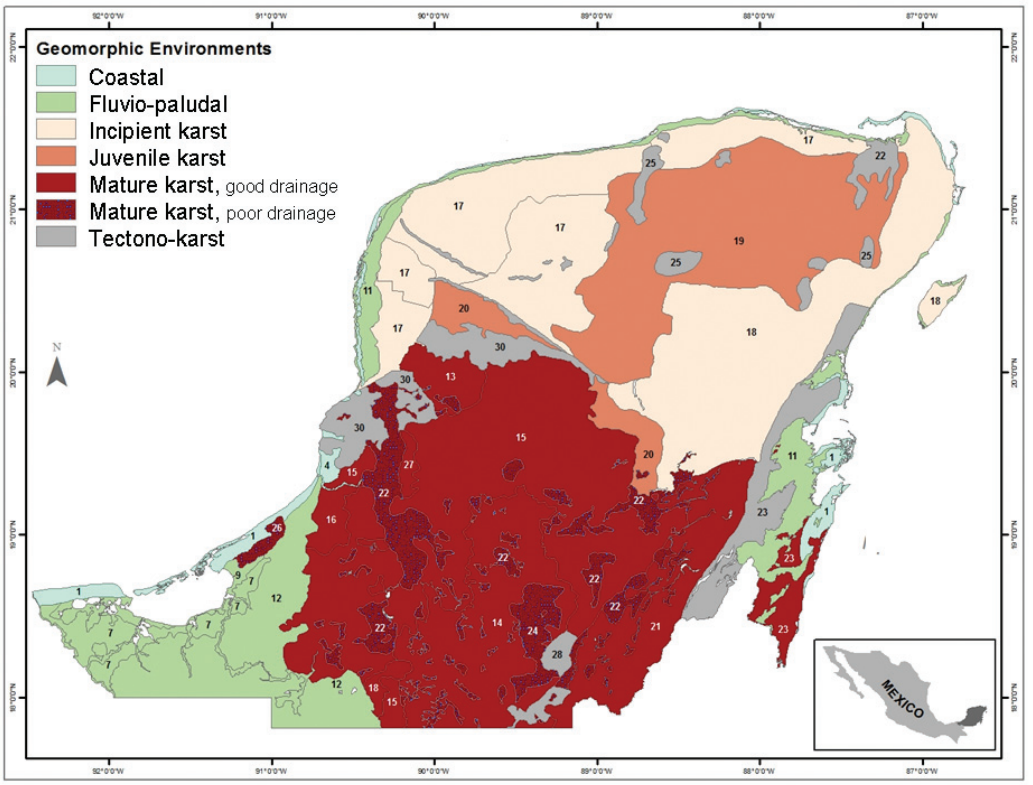

Figure 1. Study area. Geomorphic environments of the Yucatán Peninsula. Numbers correspond to geoforms (Appendix 1) and soilscapes (Table 4).

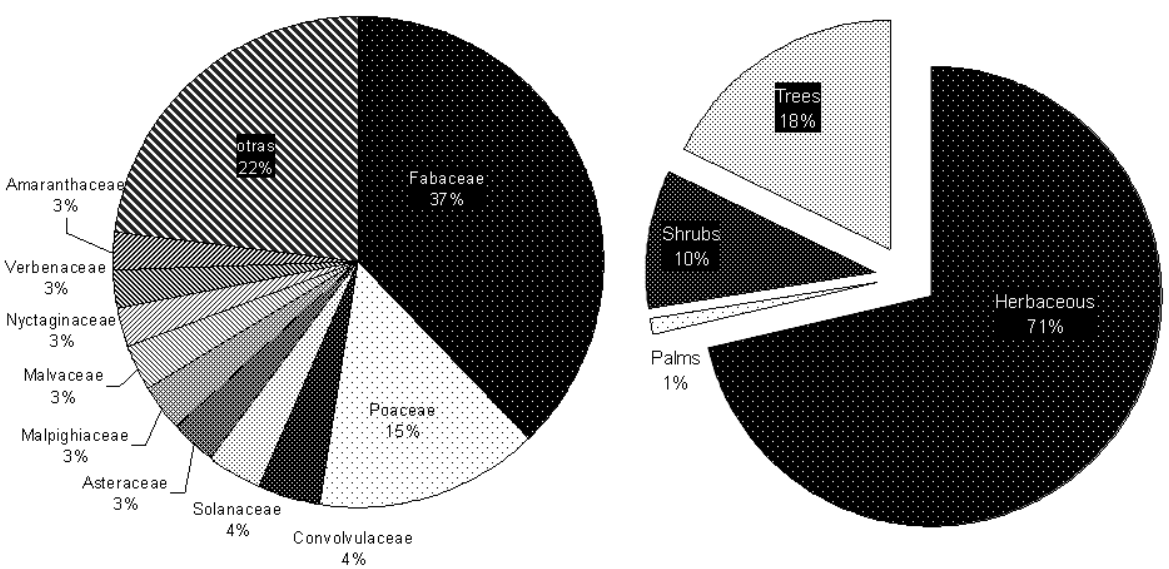

Figure 2. Percentage of forage plants species by family.

a great diversity of forage plants are used in the raising of backyard animals, especially in the north of the Yucatán Peninsula including part of the sisal, fruit tree and *milpera* zones (Barrera et al., 1976; Sánchez, 1993; Acosta et al., 1998; Flores, 2001; Flores, 2002).

Forage species used by Mayan communities. In the production of bovines, 25 arboreal species and 10 species of shrubs and 1 palm (*Sabal mexicana)* were found to have a potential for use in silvopastoral systems. Forage tree species are: *Carica papaya, Pithecellobium dulce, Acacia gaumeri, Piscidia piscipula, Lysiloma latisiliquum, Acacia pennatula, Sesbania grandiflora, Brosimum alicastrum, Bursera simaruba, Colubrina arborescens, Leucaena leucocephala, Lonchocarpus guatemalensis, Diphysa carthagenensis, Ficus cotinifolia, Guazuma ulmifolia, Lonchocarpus hondurensis, Vitex gaumeri, Lonchocarpus yucatanensis, Byrsonima bucidaefolia, Colubrina greggii, Duranta repens, Jacaratia mexicana, Swartzia cubensis, Lonchocarpus rugosus* and *Pithecellobium saman*. Forage shrub species are: *Acacia riparia, Dalbergia glabra, Tithonia diversifolia, Acacia collinsii, Bunchosia glandulosa, Malpighia punicifolia, Neomillspaughia emarginata, Senna undulada, Tithonia rotundifolia* and *Calliandra houstoniana*. Plants with a wider distribution are shown in figure 3. The chemical quality reported for some forage plants is presented in table 2.

The arboreal species with potential use as forage for porcine livestock are: *Bursera simaruba, Leucaena leucocephala, Enterolobium cyclocarpum, Byrsonima crassifolia, Ficus yucatanenses, Psidium guajava, Simarouba glauca, Byrsonima bucidaefolia, Jacaratia mexicana, Swartzia cubensis, Ziziphus yucatanensis, Artocarpus communis* and *Pithecellobium saman*. In addition, *Bursera simaruba* presents high ecological importance values in 12 and 26 year old fallows. Forage shrub species are: *Bauhinia divaricada*, *Sesbania emerus, Piper auritum, Bunchosia glandulosa, Malpighia lundellii* and *Malpighia glabra*. *Bauhinia divaricata, Bunchosia glandulosa, Sesbania emerus* and *Piper auritum* are woody forage plants consumed by pigs (Fig. 4).

Mayan knowledge includes 29 species of herbaceous and woody forage plants consumed by goats, of these species, those having a wider distribution (5 soilscapes o more) are: *Acacia gaumeri, Leptochloa virgata, Olyra yucatana, Panicum maximum, Acacia riparia, Lasiacis divaricata, Gouinia guatemalensis, Panicum hirsutum, Wissadula amplissima, Gayoides crispa* and *Leucaena leucocephala.* The preference displayed by goats for consumption of tree species is in the following order: *Brosimum alicastrum> Lysiloma latisiliquum> Piscidia piscipula> Acacia pennatula* (Alonso-Díaz et al., 2008).

The 5 most important plants used by the Maya communities for domestic animal consumption were: *Carica papaya*, *Chloris virgata, Leptochloa virgata, Olyra yucatana, Desmodium procumbens, Rhynchosia yucatanensis* and *Byrsonima bucidaefolia* with presence on 21, 9, 9, 9, 3, 2, and 2 soilscapes respectively.

The most important plants used by the Mayan people to feed rabbits are: *Paspalum vaginatum, Boerhavia caribaea, Chaetocalyx scandens, Cracca greenmanii, Cracca panamensis* and *Crotalaria cajanifolia.*

One hundred and twenty-seven species of plants were reported as appropriate for feeding equines, of these, the most widely distributed in the studied soilscapes are: *Carica papaya, Pithecellobium dulce, Celosia virgata, Lysiloma latisiliquum, Piscidia piscipula, Chloris virgata, Leptochloa virgata, Olyra yucatana, Panicum maximum, Acacia riparia, Viguiera dentate, Eleusine indica, Lasiacis divaricata, Amaranthus dubius, Gouinia guatemalensis, Panicum hirsutum, Paspalum vaginatum, Senna occidentalis, Sida acuta, Sorghum halepense, Wissadula amplissima, Sesbania grandiflora, Brachiaria fasciculata, Gayoides crispa, Waltheria americana, Ximenia americana, Zea mays, Dalbergia glabra, Brosimum alicastrum, Bursera simaruba, Colubrina arborescens* and *Lonchocarpus guatemalensis* (5 o more soilscapes)

The Mayan people use 39 forest plants for feeding poultry, of these, those found in 5 or more soilscapes studied are: *Acacia gaumeri,Celosia virgata, Paspalum notatum, Amaranthus spinosus, Eleusine indica, Lasiacis divaricata, Amaranthus dubius, Hyptis suaveolens, Sida acuta, Amaranthus hybridus, Brachiaria fasciculata, Zea mays* and *Leucaena leucocephala.*

Discussion

Arellano et al. (2003) estimated that the flora of the Yucatán Peninsula includes 2 200 species, based on that number, 8.6% of the flora is used by Mayan communities as forage, largely for feeding backyard animals including equine, bovine and porcine livestock and poultry.

Some authors such as Standley (1930), Sousa and Cabrera (1983) and Sosa et al. (1985) consider the Fabaceae to be the family having the most abundant number of species in the flora of the Yucatán Peninsula. It is noteworthy that legumes are amply recognized as being important forages for use to improve animal production (NAS, 1979; NRC, 1989).

López et al. (2008) found that some species such as *Galactia multiflora, Psychotria nervosa, Macroptilium atropurpureum, Acalypha villosa, Cecropia obstusifolia, Piscidia piscipula, Trophis racemosa, Chaetocalyx scandens, Dalbergia glabra, Guazuma ulmifolia, Spondias*

Table 2. Reported chemical quality of forage plants native to the Yucatán Peninsula

CP %	*ADF %*	*IVDMD (%)*	*NDF %*	*LIG*	*Author*
Leucaena leucocephala					
28.0	24	*	31	*	Mizrahi et al., 1998
18.0	*	*	*	*	Ramírez and Solorio, 1997
20.3	*	*	30.9	68	Norton, 1994
26.9	*	*	38.3	99	Nsahlai et al., 1995
26.7	23.9	53.6	39.5	10.8	Sandoval et al., 2005
24.6	19.3		44.0	10.2	López et al., 2007, Ortega et al., 2009
24	*	*	42.34		Zapata et al., 2009
Lysiloma latisiliquum					
13	33	*	42.8	*	Mizrahi et al., 1998
21.3	21.2	37.3	41.8	11.6	Sandoval et al., 2005
12.5	25.8	15.6	38.0	14.4	Alonso-Díaz et al., 2008
12.4	25.3		39.8	5.0	Alonso-Díaz et al., 2009
Gliricidia sepium					
20.5	23.36	*	36	*	Mizrahi et al., 1998
150	212	*	231	55	Norton, 1994
275	357	*	272	94	Nsahlai et al., 1995
Piscidia piscipula					
13.95	25.07	37.43	40.88	11.91	Sandoval et al., 1999
14	33	*	44	*	Mizrahi et al., 1998
14.6	28.7	50.3	46	*	Roshetko, 1998
38.5	28.9	47.9	48.1	14.8	Sandoval et al., 2005
12.7	31.2	16.1	45.4	16.1	Alonso-Díaz et al., 2008
15.7	*	*	49.5		Zapata et al., 2009
13.3	29.6	*	42.0	14.9	Alonso-Díaz et al., 2009
Acacia pennatula					
10	*	30.89	*	*	Mizrahi et al., 1998
13.5	22.0	18.2	32.3	11.0	Alonso-Díaz et al., 2008
13.6	20.1	*	32.2	10.2	Alonso-Díaz et al., 2009
Bursera simaruba					
13.2	23.9	*	40.5	*	Mizrahi et al., 1998
12.6	26.7		44.8	12.2	López et al., 2007
Pithecellobium dulce					
24	*	*	*	*	Mizrahi et al., 1998
Acacia gaumeri					
20	24	*	45	*	Mizrahi et al., 1998
Enterolobium ciclocarpum					
22	*	68.8	*	*	Mizrahi et al., 1998
168	*	*	*	*	Norton, 1994
250	*	*	*	*	Nsahlai et al., 1995
Caesalpinia gaumeri					
15	24	*	38	*	Mizrahi et al., 1998
Panicum maximum					
6	48	*	80	*	Mizrahi et al., 1998
Gymnopodium floribundum					
14	25	*	47	*	Mizrahi et al., 1998
Guazuma ulmifolia					
15	31	43.5	44	*	Mizrahi et al., 1998
15.5	*	*	57	*	Solorio et al., 2000
14.7	31.4	*	*	*	Vargas et al., 1987
15.5	25.9	53.5	42.6	10.7	Sandoval et al., 2005
12.1	31.8		50.8	11.8	López et al., 2007

Table 2. Continues

CP %	*ADF %*	*IVDMD (%)*	*NDF %*	*LIG*	*Author*
Desmanthus virgatus					
115	195	*	256	91	Norton, 1994
Sesbania grandiflora					
206	*	*	244	81	Norton, 1994
348	*	*	371	81	Nsahlai et al., 1995
Brosimum alicastrum					
12.9	29.8	*	45.8	*	Sandoval et al., 1999
13.2	*	*	*	*	Solorio et al., 2000
14.2	26	*	37.4	6,4	Santos and Abreu, 1995
28.8	*	*	*	*	Yerana et al., 1978
16.9	28.8	69.5	36.0	6.8	Sandoval et al., 2005
15.1	27.4	52.3	42.4	5.9	Alonso-Díaz et al., 2008
13.7	27.0		49.6	5.6	Alonso-Díaz et al., 2009
Bauhinia divaricata					
16.97			49.25		Zapata et al., 2009

CP= crude protein; ADF (%)= acid detergent fiber; IVDMD (%)= *in vitro* digestibility of dry mass; NDF= neutral detergent fiber; LIG= lignine; *= data not reported.

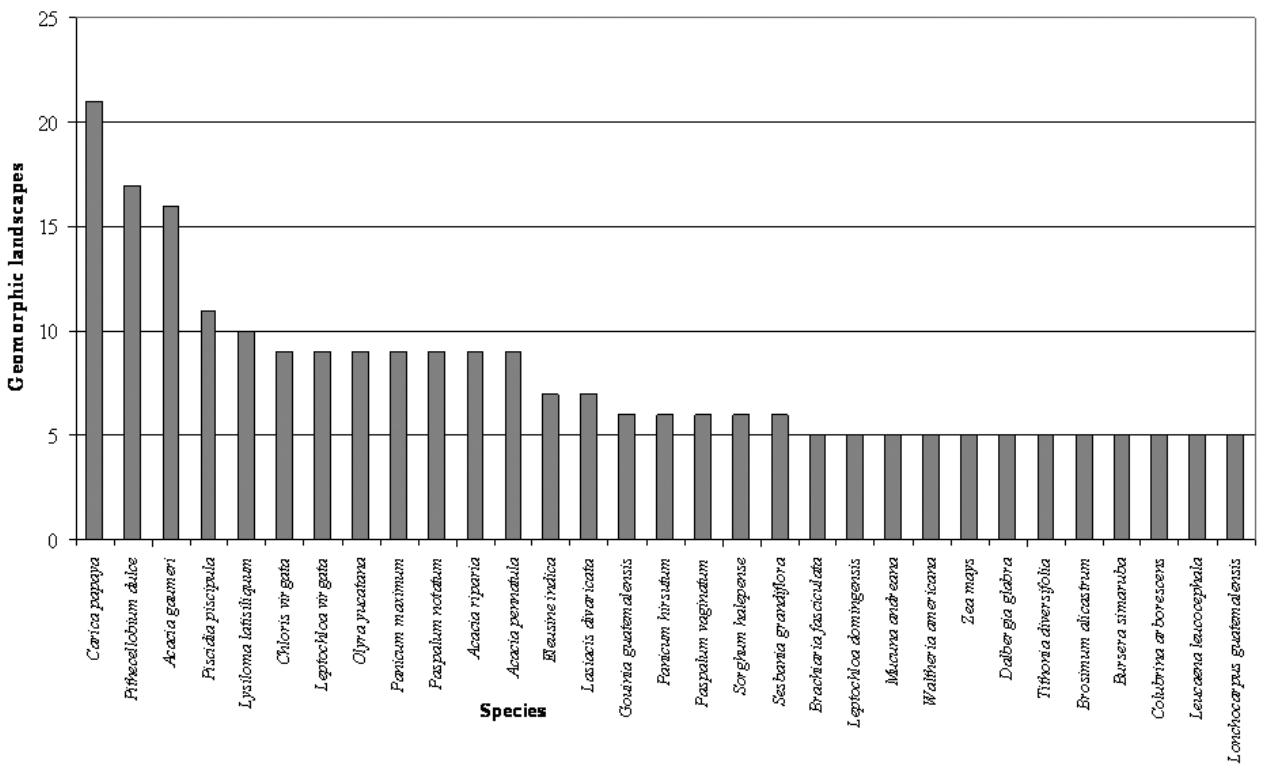

Figure 3. Number of geoforms with major forage plants used by Mayan people for feeding cattle. Total number of plants, 172.

mombin and *Ampelocissus erdvendbergiana* have potential as protein sources in tropical ruminant diets; however, these plants also have antinutritional compounds such as phenols. Currently, Mayan people use the non-legume species *Brosimum alicastrum* and *Guazuma ulmifolia* as forage sources for bovines (Sosa et al., 2004). Local producers in the study zone consider *Bursera simaruba, Sesbania grandiflora, Lonchocarpus guatemalensis, Acacia pennatula, Lysiloma latisiliquum, Gliricidia sepium* and *Acacia gaumeri* to be good quality forage plants

Table 3. Geomorphic environments, geoforms and soilscapes in the Yucatán Peninsula (following Bautista et al., 2011)

ID	*Geomorphic Environments/ Geoforms*	*Soilscapes*
	Coastal	
1	Undulating plain	RG/SC
2	Undulating plain	AR/RG
3	Plain	AR/RG/SC
4	Plain	LP/RG
5	Plain	AR/RG/SC
6	Plain	SC/RG
	Fluvio-paludal	
7	Plain	SC/GL
8	Plain	GL/SC
9	Plain	SC
10	Plain	SC/GL/HS
11	Plain	SC/HS/GL
12	Plain	GL/LP/CM
26	Plain	GL/SC
	Incipient Karst	
17a	Horizontal Plain	LPnt/LPli
17b	Horizontal Plain	LP/CM
17c	Horizontal Plain	LP/LV
17d	Horizontal Plain	LPrz/LPli/CM
17e	Horizontal Plain	LP
18	Subhorizontal Plain	LPrz/LPli
	Juvenile karst	
19	Rolling Plain	LP/CM/LV
20	Rolling Plain	LP/CM
	Mature karst with good drainage	
13	Hills	LP/NT
14	Hills	LP/VR
15	Hills	LP/VR/GL
16	Hills	CM/LP/LV
21	Plain	LP/VR/GL
27	Plain	VR/PH/LP
	Mature karst with poor drainage	
22	Plain	GL/LP
24	Plain	VR/GL/LP
	Tectono-karstic	
22a	Plain	LPrz/LPgl/HS
23	Plain	LP/VR
25a	Lagoon	Water
25b	Grouped sinkholes	LP/CM
28	Aligned hills	LP/CM/LV
29	Aligned hills	LP/CM
30	Aligned hills	LP/CM/NT

(Ayala and Sandoval, 1995; Mizrahi et al., 1998; Solorio and Solorio, 2002; Llamas et al., 2004). In particular, *Bauhinia divaricata* and *B. glandulosa* are present in the natural vegetation in 12-year-old fallows, where they have high ecological importance values (Mizrahi et al., 1998). *Bauhinia divaricata* has the potential to be used in silvopastoral systems in seasonal tropical forests due to its coppicing capacity after pruning, thus forage can be produced during the dry season (Zapata et al., 2009). The recent karstic plain (ID 17) is dominated by Nudilithic Leptosols, Lithic Leptosols and Hyperskelethic Leptosols having low effective depth, low retention of humidity and a scarce amount of fine earth (Table 3). Leptosols present extreme restrictions for plant growth (Bautista et al., 2003a,b; Bautista et al., 2011), however, most of the recorded forage species (140 plants) are present in this karstic plain with Leptosols, which constitutes an opportunity for the design of silvopastoral systems under these particularly unfavorable conditions.

Goats select the quality of the forage they eat, preferentially consuming plants with the highest *in vitro* apparent dry matter (DM), digestibility (IVDMD) and *in vitro* gas production (IVGP) (Alonso-Díaz et al., 2008). However, further studies are required in order to evaluate the quality of the remaining 56 plants.

Considering that the state of Yucatán is the fourth largest pork producer in the country, and given the local relevance of the meat, the results of the present work could be used for the elaboration of nutritional supplements, thus diminishing the import of forage, principally by the use of *Bursera simaruba, Jacaratia mexicana*, *Swartzia cubensis, Bunchosia glandulosa, Sesbania emerus* and *Piper auritum.*

A large amount of herbaceous plant species is used for feeding livestock and poultry in the Mayan communities, which constitutes another opportunity for further research on the chemical, physical and biological characteristics of these plants, as well as their agronomic properties and their assimilation by animals. Also, since most herbaceous plants grow during the rainy season when forage is abundant, future studies must be focused on the conservation of the forage quality of these species in order to used during the dry season.

On the other hand, in the Yucatán Peninsula soils are highly heterogeneous, Leptosols, Cambisols, Luvisols, Vertisols and Gleysols being distributed in patches (Table 4) (Bautista et al., 2005; Zapata et al., 2009; Bautista et al., 2011). Therefore it is important to know soil distribution in order to design agricultural management practices that are appropriate for each soilscape for forage plants.

The design of silvopastoral systems considering forest management will allow for reducing tree establishment costs while also achieving meat and milk production from the beginning and in a continuous way.

The knowledge of Mayan people should be considered in the design of new agricultural programs of the region, especially in the cattle area. However, knowledge of the Mayan communities about the use of seasonal tropical forest plants as forage sources generates new research questions: What is the chemical quality of plants? What might be the problems generated by antinutritional compounds? What plants respond best to pruning? How does the quality and quantity of fodder vary in response to soil and climatic factors?

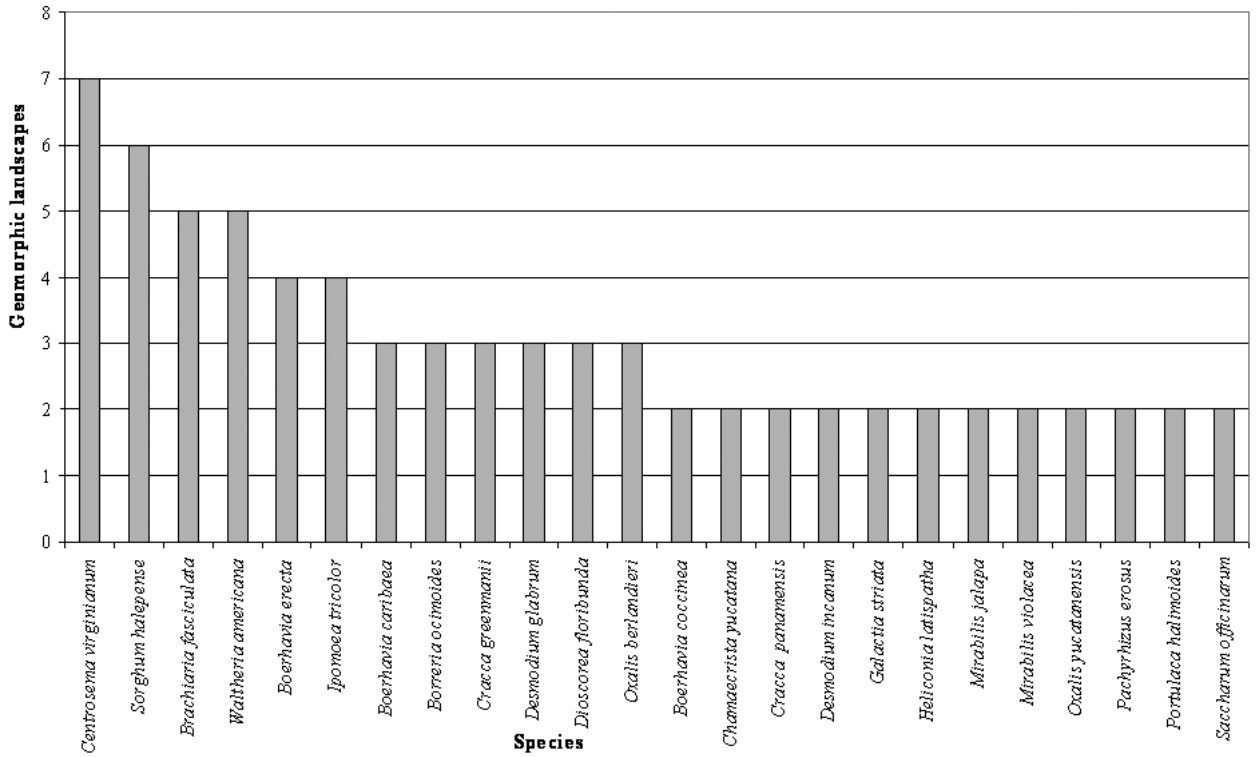

Figure 4. Number of geoforms with major forage plants used by Mayan people for feeding pigs. Total number of plants, 107.

The present study is an example of the inclusion of the knowledge (*corpus and praxis*) of the Mayan people for the generation of natural resource productive strategies as new silvopastoral systems. However, to achieve sustainability goals it is also necessary to include the Maya cosmovision (*kosmos)*, i.e., the respect for nature, and the concept that land occupants are not the "real" landowners.

The results of the present study allow for concluding that on the karstic tropical landscapes of the Yucatán Peninsula the Mayan people manage 196 forage plants, mostly from the Fabaceae and Poaceae families.

Mayan traditional knowledge on forage plants includes the edible parts and the consumption by domestic animals. This knowledge can be used to improve animal production systems. In this study we include geographic location, geomorphic environment, geoforms and soilscapes of the fodder plants.

Knowledge of the Mayan people about the use of tropical seasonal forest forage plant species provides us with valuable information that could be used to improve existing forms of livestock and poultry production, as well as the design of new practices suited for particular combinations of landscape components (e.g., relief, aquifers, soils and climate), such as those present in the karstic soilscapes of the Yucatán Peninsula.

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Appendix 1. Forage plant list order by family with ethnobotanical data and animal consumers

Plant species	*Maya name*	*Geomorphologic landscapes*	*Life form*	*Used part*	*Animal consumer*
Amaranthaceae					
1. *Amaranthus dubius* Mart. ex Thell	Chak te'es	29,13,15,17,18,7	H	Fl, Fr, B	PO, HO
2. *Amaranthus greggii* S. Watson	Te'es	15,17,18,4	H	Fl, Fr, B	PO
3. *Amaranthus hybridus* L.	Te'es	29,13,15,17,18	H	Fl, Fr, B	PO
4. *Amaranthus spinosus* L.	K'i'ixtes	30,14,15,16,17, 18,19	H	Fl, Fr, B	PO
5. *Celosia virgata* Jacq	Xtees	7,8,9,1,29,13,30,14,15,28,16,17,18	H	Le	PO
Asteraceae					
6. *Calea urticifolia* (Mill.) DC.	Xikin	17,19	H	Le, B	GO
7. *Tithonia diversifolia* (Hemsl.) A. Gray	Chak su'um	15,17,18,4,19	S	Le	HO, CO
8. *Tithonia rotundifolia* (Mill.) S.F. Blake	Tsuum	17,19	S	Le	HO, CO
9. *Viguiera dentata* (Cav.) Spreng.	Thá	30,17,18,4,19,20,21,10	H	Le	HO
10. *Wedelia hispida* Kunth	Sajum	17,19	H	Le, B	HO
11. *Zexmenia hispida* (Kunth) A. Gray	Chacksink	17,19	H	Le	GO
Araceae					
12. *Xanthosoma yucatanense* Engl.	Kukut mak'al	4,19	H	St	PI
Bromeliaceae					
13. *Ananas sativus* Schult. and Shult. f.	Salbay	19	H	Ca	CO
Burseraceae					
14. *Bursera simaruba* (L.) Sarg.	Chaka'	7,8,9,1,5	T	Le, B	HO, CO, PI
Caricaceae					
15. *Carica papaya* L.	Chich puut	7,8,9,1,29,13,30,14,15,28,16,17,18,4,19, 20,21,10,11,22,23	T	St, Le, Fr	HO, CO, DA
16. *Jacaratia mexicana* A. DC.	Puut ch'iich	17,18	T	St, Le, Fr	HO, CO, PI
Convolvulaceae					
17. *Ipomoea carnea* Jacq.	Chok' o kaat	23	H	Le, B	HO, CO
18. *Ipomoea crinicalyx* S. Moore	Is ak'il	30,17,18,19	H	Ap	HO, CO
19. *Ipomoea nil* (L.) Roth	Tso' ots k'abil	14,17,18,19	H	Ap	HO, CO
20. *Ipomoea tricolor* Cav.	Uulum ja'	14,17,18,4	H	Ap	PI
21. *Merremia aegyptia* (L.) Urb.	Ka'ak	18,19	H	Ap	HO, CO
22. *Merremia cissoides* (Lam) Hallier f.	K'i'ix lool aak	23	H	Ap	PI
23. *Quamoclit coccinea* (L.) Moench	Xkaal p'uul	30,15,17,19	H	Ap	GO, CO
24. *Quamoclit hederifolia* (L.) G. Don	Chak lool	17,18,19	H	Le, B	HO, CO
Cucurbitaceae					
25. *Cucurbita mixta* Pangalo	Xka'	14,17,18,19	H	Fr	PO, HO
26. *Cucurbita moschata* Duchesne	K'uum	14,17,18	H	Fr	HO, CO, PO
27. *Cucurbita pepo* L.	Ts'ol	30,15,17	H	Fr	PO
28. *Ibervillea millspaughii* (Cogn.) C. Jeffrey	Tu'ka'anil	14,15,17,19	H	Le	GO, HO
Dioscoriaceae					
29. *Dioscorea floribunda* Martens and Galeotti	Makal'k'uuch	15,17,18	H	St	HO, PI
Fabaceae					
30. *Acacia collinsii* Saff.	Subin	17,18,4,19	S	Le	HO,CO,GO
31. *Acacia gaumeri* Black	Boxcatxim	4,6,7,910,11,14,15,16,17,18,19,22,23, 29,30	T	Le	CO,GO,PO
32. *Acacia pennatula* (Schltdl. and Cham.) Benth.	Chimay	30,14,15,28,16,17,18,4,19	T	Le	CO, C
33. *Acacia riparia* Kunth	Yaax. katsin	30,14,15,28,16,17,18,4,19	S	Le	HO,CO,GO
34. *Aeschynomene americana* L.	Kabal pich	17,18,4,19	H	Le	HO,GO,PO
35. *Aeschynomene fascicularis* Schltdl. and Cham.	Kabal pich	17,18,4,19	H	Le	HO,CO,GO
36. *Bauhinia divaricata* L.	Ps'unibtook'	30,14,15,28,16, 17	S	Le, St	PI
37. *Bauhinia herrerae* (Britton and Rose) Standl. and Steyerm.	K'ibix	15,19	S	Le	HO

Appendix 1. Continues.

Plant species	*Maya name*	*Geomorphologic landscapes*	*Life form*	*Used part*	*Animal consumer*
38. *Caesalpinia pulcherrima* (L) Sw.	Chak sikin	17	S	Le, Fr	PO
39. *Cajanus bicolor* DC.	*	17	H	Le, Fr	CO
40. *Calliandra belizensis* (Britton and Rose) Standl.	Kabul	21,1	H	Le, B	CO
41. *Calliandra houstoniana* (Mill.)Standl.	Xa'ax	14	S	Fl, Le	HO, CO
42. *Canavalia ensiformis* (L.) DC.	*	17	H	Le	CO, PI
43. *Centrosema angustifolium* (Kunth) Benth.	*	17,4,19,24	H	Ap	HO,CO,GO
44. *Centrosema galeotti* Fantz	Libcho'	17,18,4,19	H	Ap	HO,CO,GO
45. *Centrosema plumieri* (Turpin ex Pers.) Benth	Libcho'	17,18	H	Ap	HO, CO, C
46. *Centrosema sagittatum* (Humb. and Bonpl. ex Willd.) Brandegee	Libcho'	17,18,4	H	Ap	HO, CO
47. *Centrosema schottii* (Mllsp.) K. Schum.	Bu'ul beech'	17,18,4	H	Ap	HO,CO,GO
48. *Centrosema virginianum* (L.) Benth.	Bu'ul ak'	30,14,15,28,16,17,18	H	Complete	PI
49. *Chaetocalyx scandens* (L.) Urb.	K'ayab yuk	30,14,28	H	Le, St	HO, RA
50. *Chamaecrista diphylla* (L.) Greene	Kaanlol xiw	17,18,4	H	Le, Fr	CO
51. *Chamaecrista glandulosa* (L.) Greene*	Misib kok	17,18	H	Ap	HO, CO
52. *Chamaecrista nictitans* (L.) Moench	Canlol xiw	17,18	H	Ap	HO, CO
53. *Chamaecrista yucatana* Britton and Rose	Tamarindo xiw	17,28	H	Le	HO, PI
54. *Cracca greenmanii* Millsp.	Chi'ikam t'u'ul	17,18,4	H	Le	HO, PI, RA
55. *Cracca panamensis* Fydb.	Jak'che'	17,18	H	Le	HO, CO, PI, RA
56. *Crotalaria cajanifolia* Kunth	*	17	H	Le, B	CO, RA
57. *Crotalaria incana* L.	K'iinil ooch	10,22,23	H	Le, B	HO, CO
58. *Crotalaria retusa* L.	*	30,15,28,16	H	Ap	PO, CO
59. *Dalbergia glabra* (Mill.) Standl.	Aj muk	17, 19,20,1,21	S	Ap	HO, CO
60. *Desmodium distortum* (Aubl.) J.F. Macbr.	Kintaj	17,18,4,19	H	Le	HO, CO
61. *Desmodium glabrum* (Mill.) DC.	Kiintaj	19,20,1	H	Le	HO, CO, PI
62. *Desmodium incanum* DC.	K'iintaj	17,18	H	Le	HO, PI
63. *Desmodium procumbens* (Mill.) Hitche.	K'iintaj	17,18,4	H	Ap	DA, HO
64. *Desmodium tortuosum* (Sw.) DC.	Bu'ul ka'aax	17,18	H	Le	HO
65. *Desmanthus virgatus* (L.) Willd.	Bu'ul ka'aax	17,18,4	H	Ap	HO,CO,GO
66. *Diphysa carthagenensis* Jacq.	Ka'an lol	17,18,4,19	T	Le	HO, CO
67. *Enterolobium cyclocarpum* (Jacq.) Griseb.	Piich	17,18,4,19	T	Fr	HO, PI, PO
68. *Galactia striata* (Jacq.) Urb.	Bu'ul baach	17,18	H	Ap	HO, PI
69. *Gliricidia sepium* (Jacq.) Kunth.	Sak ya'ab	17,18	T	Fr	PO
70. *Indigofera indica* Lam.	Cho'oy	17,1	H	Ap	HO
71. *Leucaena leucocephala* (Lam.) De Wit	Waaxin	30,14,17,18,19	T	Le, Fr	PO,GO, PI
72. *Lonchocarpus guatemalensis* Benth.	Ja'abin	14,15, 28,16,17	T	Le	HO, CO
73. *Lonchocarpus hondurensis* Benth.	Ya'ax ja'abin	1,17,18,4	T	Le	HO, CO
74. *Lonchocarpus rugosus* Benth.	Choy che'	17	T	Le	CO
75. *Lonchocarpus yucatanensis* Pittier	Ba'al che'	17,18,4	T	Le	CO
76. *Lysiloma latisiliquum* (L.) Benth	Tsalam	4,14,15,16,17,18,19,20,23,30	T	Le	CO,HO
77. *Macroptilium atropurpureum* (Moc. and Sessé ex DC.) Urb.	Bu'ul cho'	29,17,4,19	H	Le	PO, CO
78. *Macroptilium lathyroides* (L.) Urb.	Bu'ul ch'o'	17	H	Ap	
79. *Mucuna andreana* Micheli.	Ich kejj	14,15,28,16,17	H	Ap	CO
80. *Nissolia fruticosa* Jacq.	Box ac	17,18	H	Ap	HO
81. *Pachyrhizus erosus* (L.) Urb.	Chiikam	17,18	H	Ap	PI
82. *Phaseolus lathyroides* L.	Bu'ul ch' o	17	H	Ap, Fr	CO, PI
83. *Piscidia piscipula* (L.) Sarg.	Ja'abin	4,7,11,14,15,16,17,18,19,23,30	T	Le	CO,HO
84. *Pithecellobium saman* (Jacq.) Benth.	Algarroba	17	T	Fr	CO, PI

Appendix 1. Continues.

Plant species	*Maya name*	*Geomorphologic landscapes*	*Life form*	*Used part*	*Animal consumer*
85. *Pithecellobium dulce* (Roxb.) Benth	D'siuche'	4,6,7,8,9,11,13,15,16,17,18,19,20,27,29,30,36	T	Le	CO.HO,WF
86. *Prosopis juliflora* (Sw.)DC.	Box ka'atsim	22,23	T	Le	HO
87. *Rhynchosia minima* (L.)DC.	Libch'o	17,18,19	H	Ap	PO, HO
88. *Rhynchosia swartzii* (Vail.) Urb.	Mejen beech	17,18	H	Ap	HO,CO,GO
89. *Rhynchosia yucatanensis* Grear	Libcho'	17,28	H	A, B	HO, DO
90. *Senna atomaria* (L.) H.S. Irwin and Barneby	Kaanlol	17,18,4,19	H	Le, B	HO, CO
91. *Senna occidentalis* (L.) Link.	Bataban	30,14,15,28,16, 17	H	Le, Fr	HO
92. *Senna pallida* (Vahl) H.S. Irwin and Barneby	kaalol	17,18	H	Le	CO
93. *Senna undulata* (Benth.) H.S. Irwin and Barneby	Bu'ul kaax	17,18	S	Le	CO, HO
94. *Sesbania emerus* (Aubl.) Urb.	Kaanbal piich	14.15,28,16,17	S	Le	PI
95. *Sesbania grandiflora* (L.) Pers.*	Pico flamenco	17,18,4,19,20,21	T	Le	CO, HO
96. *Stizolobium niveu* (Roxb.) Kuntze	Xpiika bu'ul	17	H	Le, St	HO, CO
97. *Stizolobium pruriens* (L.) Medik.	Chi'ikam	17,18,4	H	St, Le	HO, CO
98. *Stylosanthes hamata* (L.) Taub.	Chiichi bej	30,16	H	Ap	HO, CO
99. *Swartzia cubensis* (Britton and P. Wilson) Standl.	K'attaal oox	18,4	T	Le, Fr	CO, PI
100. *Tephrosia cinerea* (L.) Pers.	Ix buul	17,18	H	St, Le	PI
101. *Vigna elegans* (Piper) Maréchal, Mascherpa and Stainier	*	17	H	Le, Fr	CO, PI
102. *Vigna unguiculata* (L.) Walp.	Nux xpeelon	17	H	Le, Fr	CO, PI
103. *Vigna vexillata* (L.) A. Rich.	*	17	H	Le, Fr	CO, PI
Iridaceae					
104. *Cipura paludosa* Aubl.	Kukut ch' com	30,14,21	H	Bulb	HO, CO
Labiatae					
105. *Hyptis suaveolens* (L.) Poit.	Cholte xnuuk	17,18,4,19,20,21	H	Le	PO
106. *Ocimum micranthum* Willd.	Kakaltun	17,18,4,19	H	Le	GO
Malpighiaceae					
107. *Byrsonima bucidaefolia* Standl.	Sak paj	17,6	T	Fr	CO, PI
108. *Byrsonima crassifolia* (L.) Kunth	Chi'	17,18,4	T	Fr	HO, PI
109. *Malpighia glabra* L.	Box'wayarkte'	17	S	Fr	HO, PI
110. *Bunchosia glandulosa* (Cav.) DC.	Siipche'	17,19	S	Le, Fr	CO, PI
111. *Malpighia lundellii* C.V. Morton.	Wayakte'	19,21	S	Fr	PI, HO
112. *Malpighia punicifolia* L.	Uste'	17,19	S	Le, Fr	HO,CO, WF
Malvaceae					
113. *Anoda cristata* (L.) Schltdl.	Sakte'	14,16,17,18	H	Le	HO
114. *Abutilon gaumeri* Standl.	Kan jool	4,19	H	Le	HO
115. *Gayoides crispa* (L.). Small	Sakte'	30,14,16,17,18	H	Ap	HO,GO
116. *Sida acuta* Burm.f.	Chichibej	30,15,14,17,23, 19	H	Ap	HO, PO
117. *Sida rhombifolia* L.	Chichib tux'	17,18,4,19	H	Le	HO,GO
118. *Wissadula amplissima* (L.) R. E. Fr.	Sak xiw	16,30,14,17,18, 19	H	Ap	HO,GO
Moraceae					
119. *Artocarpus communis* J.R. Forst. and G. Forst.	*	17	T	Fr	PI
120. *Brosimum alicastrum* Sw.	Ox'	14,17,30, 18,4	T	Le, Se, Fr	HO, CO
121. *Ficus cotinifolia* Kunth	Ju'um	17,18,4,19	T	Le, Fr	HO, CO
122. *Ficus yucatanenses* Standl.	Akum	17,18,4	T	Fr	PI
Musaceae					
123. *Heliconia latispatha* Benth.	Platanillo	17,18	H	Ap	HO, CO, PI
124. *Musa paradisíaca* L.	*	17	H	St, Le, Fr	HO, CO, PI, PO
125. *Musa sapientum* L.	*	17	H	St, Le, Fr	HO, CO, PI

Appendix 1. Continues.

Plant species	*Maya name*	*Geomorphologic landscapes*	*Life form*	*Used part*	*Animal consumer*
Myrtaceae					
126. *Psidium guajava* L.	Pichi	17,18,19	T	Fr	PI
Nyctaginaceae					
127. *Boerhavia caribaea* Jacq.	Chakil xiw	17,4,22	H	Ap	PI, PO, RA
128. *Boerhavia coccinea* Mill.	*	17,4	H	Ap	PI, PO
129. *Boerhavia* erecta L.	Sak xiw	17,18,6,19	H	Ap	PI, PO
130. *Mirabilis jalapa* L.	Tutsuy xiw	17,18	H	Ap	PI, PO
131. *Mirabilis violacea* (L.) Heimerl	Pak'umpak	17,18	H	Ap	PI, PO
Olacaceae					
132. *Ximenia americana* L.	Napalche	30,14,15,17,18	H	Ap	HO
Orchidaceae					
133. *Oncidium ascendens* Lindl.	Ajoche'	14,15,28,17	H	Le	HO, CO
134. *Catasetum integerrimum* Hook.	Chiit ku'uk	19,4	H	Le	HO
Oxalidaceae					
135. *Oxalis berlandieri* Torr.	*	17,18,4	H	Ap	HO, PI
136. *Oxalis yucatanensis* (Rose) Standl.	Ch'oj chak'am	17,4	H	Ap	HO, PI
Palmae					
137. *Bactris balanoidea* (Oerst.) H. Wendl.	Jawate'	6,21,24	P	Fr, Se	HO, PI
138. *Sabal mexicana* Mart.	Bon xa'an	15,28,16,17	P	Fr, Se, Le	HO, PI, CO
Passifloraceae					
139. *Passiflora foetida* L.	Poch'il	17,4	H	Ap	HO, CO
Piperaceae					
140. *Piper auritum* Kunth	Makulam	17,29,6	S	Le	HO, PI
Poaceae					
141. *Aristida ternipes* Cav.	Chak su'uk	8,15	H	Ap	CO
142. *Brachiaria fasciculata* (Sw.) Parodi	K'aan chiim	15,28,16,17,18	H	Ap	HO, CO, PI, PO
143. *Cenchrus brownii* Roem. and Schult.	X'mul	17,18,4,19	H	Ap	CO
144. *Cenchrus pilosus* Kunth	Xmul	7,15,10	H	Ap	CO
145. *Cynodon dactylon* (L.) Pers.	K'an suk	15,17,19	H	Ap	HO, CO
146. *Chloris virgata* Sw.	Ne'ex nuxib	7,8,9,1,29,13,30,14,15	H	Ap	HO, CO
147. *Digitaria ciliaris* (Retz.) Koeler	*	15,17,19	H	Le	HO, CO
148. *Digitaria insularis* (L.) Fedde	Nej boob	13	H	Ap	HO, CO
149. *Eleusine indica* (L.) Gaertn.	Yook maas	11,15,28,16,17,18,4	H	Le	HO,CO,PO
150. *Eragrostis ciliaris* (L.) R. Br.	Sak su'uk	15,17,19	H	Le	HO, CO
151. *Gouinia guatemalensis* (Hack.) Swallen	Chak su´uk	15,28,16,17,18, 19	H	Le	HO,CO,GO
152. *Lasiacis divaricata* (L.) Hitch.	Siit	15,17,18,19, 30, 25, 36	H	Le	HO,CO,GO, PO
153. *Leptochloa domingensis* (Jacq) Trin	*	15,28,16,17,18	H	Le	CO
154. *Leptochloa virgata* (L.) P. Beauv.	Chac zuuc	7,8,9,1,29,13,30,14,15	H	Le	HO, CO, GO, DA
155. *Olyra yucatana* Chase	Ya'ax tok	7,8,9,1,29,13,30,14,15	H	Le	HO, CO, GO, DA
156. *Panicum bartlettii* Swallen	*	17	H	Le	HO, GO
157. *Panicum hirsutum* Sw.	*	15, 16,17,18,4,19	H	Ap	HO,CO,GO
158. *Panicum maximum* Jacq.	*	30,14,15,28,16,17,18,4,19	H	Le	HO,CO,GO
159. *Panicum trichoides* Sw.	*	8,15	H	Ap	HO, CO
160. *Paspalum caespitosum* Flüggé	*	15,17,19	H	Ap	HO, CO
161. *Paspalum notatum* Flüggé	*	30,14,15,28,16,17,18,4,19	H	Complete	CO, PO
162. *Paspalum vaginatum* Sw.	*	30,14,15,28,16, 17	H	Complete	HO, CO, RA
163. *Pennisetum ciliare* L. Link	*	15,17,19	H	Ap	HO, CO
164. *Pennisetum purpureum* Schumach.	*	8,15	H	Le,St	HO, CO
165. *Saccharum officinarum* L.	*	29,15	H	St	HO, PI, CO
166. *Spartina spartinae* (Trin.) Merr. ex Hitchc.	Ko'axol ek'	8,15	H	Ap	HO, CO
167. *Sorghum bicolor* (L) Moench	*	18	H	Le, St	HO, PI, CO

Appendix 1. Continues.

Plant species	*Maya name*	*Geomorphologic landscapes*	*Life form*	*Used part*	*Animal consumer*
168. *Sorghum halepense* (L.) Pers.	Ak'il su'uk	15,28,16,17,18, 19	H	Ap	HO, CO, PI
169. *Zea mays* L.	Naal	16,17,18,4,19	H	Complete	PO, HO,CO
Polygonaceae					
170. *Neomillspaughia emarginata* (H.Gross) S.F. Blake	Sajiitsa'	17,19	S	Le	HO, CO
Portulacaceae					
171. *Portulaca halimoides* L.	Ts'ayoch	17,12	H	Ap	PI
172. *Portulaca oleracea* L.	Kabal'chunup	17,19,18	H	Ap	PO
173. *Talinum triangulare* (Jacq.) Willd.	Xukul	17	H	Ap	PI
Rhamnaceae					
174. *Colubrina arborescens* (Mill.) Sarg.	Xlu'um che'	30,14,15,17,18	T	Le	HO, CO
175. *Colubrina greggii* S. Watson	Box ooch	17,18	T	Le	HO, CO
176. *Ziziphus yucatanensis* Standl.	*	14,17	T	Fr	PI
Rubiaceae					
177. *Borreria ocimoides* (Burm. f.) D. C.	Sac sajum	17,18,4	H	Le	GO, HO
178. *Borreria verticillata* (L.) G. Mey.	Sac sajum		H	Le	GO, HO
Simaroubaceae					
179. *Simarouba glauca* D. C.	Pa'asaak'	17,18,4	T	Le, Fr	PI
Solanaceae					
180. *Physalis pubescens* L.	Pajab kaan	17,18	H	Ap	PO
181. *Solanum americanum* Mill.	Xtu'ja'abil	17,19	H	Fr	PO
182. *Solanum hirtum* Vahl.	Put balaam	14,17,18	H	Fr	HO
183. *Solanum niidepannum* Dunal	Uukuch	14,18	H	Le	PO, PI
184. *Solanum torvum* Sw.	Che'eliik	17,18,4	H	Le	HO
185. *Solanum umbellatum* Mill.	Uk'uche	17,18,4	H	Le, B	HO
186. *Solanum verbascifolium* L.	Toom paap	17,18	H	Le, B	HO
Sterculiaceae					
187. *Guazuma ulmifolia* Lam.	Piixoy	17,18,19,6	T	Le, Fl, Fr	CO
188. *Waltheria americana* L.	Sak xiw	17,18,4,19,10	H	Le	HO, CO, PI
Tiliaceae					
189. *Corchorus siliquosus* L.	Chi'ichibe	17	H	Le	PI
Ulmaceae					
190. *Trema micrantha* (L.) Blume	Sak piixoy	14,17,18	T	Fr	PO
Verbenaceae					
191. *Callicarpa acuminata* Kunth	Puk'in	17,18	S	Le	WF
192. *Duranta repens* L.	Jonbonil che'	17,18	T	Fr	HO,CO, PO
193. *Lantana camara* L.	Ich cho'	17,18,4	H	Le	HO,CO
194. *Vitex gaumeri* Greenm.	Yax nilk	17,18,4,19	T	Le, Fr	HO,CO, WF
195. *Petrea volubilis* L.	Oop tsimiin	17	H	Le	HO,CO
Zygophyllaceae					
196. *Kallstroemia maxima* (L.) Hook. and Arn.	Xukul	17	S	Ap	PO

* without Maya name; S= shrub; T= tree; H= herb; P= palm; Le= leaf, Ap= aerial parts; Fl= flower; Fr= fruit, St= stem, B= buds; Se= seed; HO= horse; CO= cow; PI= pig; GO= goat; RA= rabbit; PO= poultry; WF= wild fauna; DA= domestic animals.