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Pineapple agoforest in El Cerro, Villa de Purificación, Jalisco. Photo: Jesús Juan Rosales-Adame

Pineapple cultivation under tree canopies of ancestral agroforests in Mexico

Jesús Juan Rosales-Adame and Judith Cevallos-Espinosa

> ***"The Indian pineapple or matzatli (Nahuatl word from Mesoamerica), is a plant which grows in warm regions and hilly places in these territories of the New World."***
>
> Translated from *La Historia Natural de la Nueva España*, 1571

Introduction

Pineapple (*Ananas comosus* var. *comosus* [L.] Merr.) is widely known. Due to its shape and popularity, it is considered the king of tropical fruits, and its production and consumption place it at the top of the world's acceptance rankings (Botella and Smith 2008). Despite this, the average consumer knows very little about its origin and production methods. The species is native to South America, particularly the Amazonian rainforests. There it was domesticated, diversified and disseminated millennia ago by local populations, as they did with other plant species, animals and ecosystems (Coppens d'Eeckenbrugge et al. 2011; Levis et al. 2018). In various regions of the continent, including Mesoamerica, the management of landscapes by local cultures generated primary agroecosystems that were probably

Weed and bush clearing with a *casanga*. Photo: Jesús Juan Rosales-Adame

indistinguishable from native forests or jungles (González-Jácome 2016). However, over time they developed productive management systems, some of which have recently become known as agroforests.

Agroforests, also known as modified forests or forest agroecosystems, are systems where human beings have managed the composition of the plants (native and introduced) according to their needs, but preserved the structural characteristics and ecological processes and functions that exist in ecosystems considered natural (Moreno Calles et al. 2016). In Mexico, these agroforestry systems include cocoa plantations, coffee plantations, multi-strata home gardens, *te'lom* (a Huastec agroforestry system, where the forest is managed and agriculture is included), silvopastoral systems and pineapple agroforests (Rosales-Adame and Cevallos-Espinosa et al. 2019; Fisher-Ortiz et al. 2020).

Pineapple agroforests are a form of land use where woody species (trees and shrubs) of the subdeciduous tropical forest (STF) have been associated with a *criollo* or *castilla* (*roja Española* complex) variety of pineapple since ancestral times (at least three centuries, but possibly millennia). This was long before the introduction of the improved varieties in the early 20th century that now dominate the national pineapple market (Rosales-Adame et al. 2016).

Pineapple is cultivated in Mexico under two production models. The conventional model is characterized by intensive monoculture, use of improved varieties, pest and disease control and chemical fertilization. This model relies on the elimination of biodiversity and has important negative implications from an environmental and human health point of view. The other production model is an agroforestry or "ecological" approach (Rosales-Adame et al. 2016). It is characterized by maintaining and respecting the natural forest cover of the region and including a significant investment in terms of ecological energy (higher light use efficiency due to several layers of foliage) and biological cultivation (manual labour with small tools rather than use of phytochemicals, and incorporation of litter from tree canopies). The pineapple variety grown in agroforestry is quite shade tolerant. It grows on sites with tree cover similar to or greater than that found in shaded coffee and cocoa systems; its canopy cover ranges from 75% to 88% of natural forest cover.

Shaping the pineapple agroforest

The Indigenous and mestizos inhabitants of the Pacific slope of Mexico, particularly in the west-central region in the states of Jalisco and Nayarit, have managed, conserved and treasured this agroecosystem for years. Agroforestry has also been practised in the state of Guerrero, where it is known as mountain pineapple.

This agroecosystem is almost unknown at the national and international level, despite its benefits in terms of sustainability, resilience and conservation of agrobiodiversity, and its role in the preservation of native

Photo 2. A pineapple agroforest in Jalisco.
Photo: Jesús Juan Rosales-Adame

diversity in marginalized areas of Mexico. Pineapple is deliberately associated with forest components only once, at planting, and is self-perpetuating (with management), which means that costs are low. Management is extensive, with minimal use of inputs and machinery, but with maximal use of traditional knowledge and local technologies, such as curved machetes or *casangas* , and harvesting baskets or *petacas*.

Pineapple agroforests are found in the lowlands of humid tropical regions, from flat land to steep slopes, at altitudes of 60 to 850 masl, and sometimes higher. Although pineapple is the most important crop, the system also yields about 20 other products that strengthen food sovereignty and self-sufficiency for the owners. This includes fruits (avocados, *mamey* (*Pouteria sapota*), bananas); coffee; wood for tools; and fodder. Goods are harvested or collected throughout the year, providing a regular source of food; some of them are traded in local and regional markets when there are surpluses. Pineapple production is seasonal and coincides with the rains (June to September). Timber production is not an objective. However, recently some timber species have been harvested, with negative impacts on the agroforest. A similar situation is observed with the deforestation of areas surrounding agroforests, which generates stress due to the edge effect when the temperature increases and the area dries out. The rural exodus of young people is another increasingly common problem.

In Jalisco, the oldest agroforest has a current area of about 15 ha, while in Nayarit it covers approximately 950 to 1,000 ha. In both states, there are also fragments (relicts) of agroforests in other sites.

Left: Close-up of a pineapple in Villa Purificación, Jalisco; Right: pineapple fruit harvesting baskets in Nayarit, Mexico.
Photos: Jesús Juan Rosales-Adame

About 70 species of woody plants are maintained in these agroecosystems, most of them native and a few domesticated. All the woody species are important, above all, for providing shade. However, the species that measure the highest on the importance value index (IVI) are *parota* or *guanacastle* (*Enterolobium cyclocarpum*) and *cuapinol* or *guapinol* (*Hymenaea courbaril*) which have forage, food (animal and human), timber and nitrogen-fixing values (Table 1). IVI measures how dominant a species is in a certain forest area.

Table 1. Importance value index (IVI) of pineapple agroforests in west-central Mexico

Species	Family	Importance value index (IVI)					
		R	C	V	Z	P	A-C
Astronium graveolens	*Anacardiaceae*	0	0	0	2.86	0	4.62
Mangifera indica [a]	*Anacardiaceae*	2.92	1.98	4.63	2.77	0	2.33
Spondias mombin	*Anacardiaceae*	0	0	0	8.48	1.3	0
Annona reticulata	*Annonaceae*	0	0	1.67	0	0	0
Thevetia ovata	*Apocynaceae*	0	0	2.22	0	0	0
Dendropanax arboreus	*Araliaceae*	0	0	6.68	0	0	0
Acrocomia aculeata	*Arecaceae*	0	0	4.61	0	0	0
Attalea cohune	*Arecaceae*	5.85	0	0	0	0	0
Sabal rosei	*Arecaceae*	0	0	1.26	0	0	2.26
Tabebuia donnell-smithii	*Bignoniaceae*	**59.67**	0	0	0	0	0
Tabebuia palmeri	*Bignoniaceae*	0	0	2.70	0	0	0
Tabebuia rosea	*Bignoniaceae*	3.12	3.16	4.96	1.34	5.63	1.18
Cochlospermum vitifolium	*Bixaceae*	0	1.45	0	0	0	0
Bourreria superba	*Boraginaceae*	0	0	2.91	1.25	0	0
Bursera simaruba	*Burseraceae*	4.68	1.51	14.64	3.91	2.50	0
Calophyllum brasiliense	*Calophyllaceae*	0	0	1.33	3.80	3.12	0
Carica papaya	*Caricacaceae*	1.67	0	0	0	0	0
Couepia polyandra	*Chrysobalanaceae*	0	0	14.38	0	8.18	2.22
Licania retifolia	*Chrysobalanaceae*	0	1.79	8.36	2.22	1.86	3.79
Clethra hartwegii	*Clethraceae*	0	11.17	7.51	6.27	0	0
Sloanea terniflora	*Elaeocarpaceae*	0	0	0	0	2.19	0
Gymnanthes sp.	*Euphorbiaceae*	0	0	1.17	0	0	0
Acacia polyphilla	*Fabaceae*	0	0	2.46	0	0	8.15
Andira inermis	*Fabaceae*	1.45	0	0	0	0	0
Ateleia pterocarpa	*Fabaceae*	8.85	0	3.87	0	0	0
Bauhinia ungulata	*Fabaceae*	0	1.38	0	2.39	0	0
Enterolobium cyclocarpum	*Fabaceae*	**107.45**	0	0	0	0	0
Gliricidia sepium	*Fabaceae*	0	0	3.44	0	0	4.10
Hymenaea courbaril	*Fabaceae*	0	**111.20**	**62.27**	**74.76**	**154.28**	**195.79**
Inga laurina	*Fabaceae*	**24.83**	1.57	0	**31.59**	4.51	0
Inga vera subsp. eriocarpa	*Fabaceae*	0	9.17	1.36	6.93	0	3.28
Lonchocarpus salvadorensis	*Fabaceae*	0	3.83	**15.10**	6.93	**25.40**	**12.68**
Platymiscium trifoliolatum	*Fabaceae*	0	1.37	12.27	6.62	17.41	3.83
Quercus aristata	*Fagaceae*	0	1.28	0	**15.46**	0	0

cont. Table 1.

Species	Family	Importance value index (IVI)					
		R	C	V	Z	P	A-C
Quercus glaucescens	*Fagaceae*	0	9.11	0	2.90	0	0
Carya illinoinensis	*Juglandaceae*	0	0	2.91	0	0	0
Cinnamomum sp.	*Lauraceae*	0	**24.76**	0	3.59	0	**15.17**
Persea americanaa [a]	*Lauraceae*	3.78	1.74	0	0	8.76	0
Persea hintonii	*Lauraceae*	0	3.37	0	11.82	0	5.47
Byrsonima crassifolia	*Malpighiaceae*	0	1.42	0	2.77	0	0
Heteropterys laurifolia	*Malpighiaceae*	0	0	1.15	0	0	0
Malpighia sp.	*Malpighiaceae*	0	5.93	0	2.65	0	0
Guazuma ulmifolia	*Malvaceae*	1.84	0	5.78	0	0	0
Trichospermum insigne	*Malvaceae*	0	7.20	12.90	0	0	0
Miconia sp.	*Melastomataceae*	0	18.51	3.32	0	0	0
Cedrela odorata	*Meliaceae*	**19.21**	0	1.77	5.45	9.15	0
Guarea glabra	*Meliaceae*	0	0	0	0	0	1.86
Trichilia americana	*Meliaceae*	2.17	0	0	0	0	0
Brosimum alicastrum	*Moraceae*	7.49	0	8.43	2.76	2.40	0
Ficus cotinifolia	*Moraceae*	0	0	16.31	4.90	0	0
Trophis racemosa	*Moraceae*	0	1.66	0	0	0	0
Musa cavendishiia [a]	*Musaceae*	0	5.53	0	0	0	0
Eugenia sp.	*Myrtaceae*	0	2.73	**17.30**	11.34	2.40	11.53
Psidium sartorianum	*Myrtaceae*	4.22	0	2.26	**19.99**	0	0
Piper tuberculatum	*Piperaceae*	1.66	0	0	0	0	0
Coccoloba barbadensis.	*Polygonaceae*	0	0	1.28	0	0	0
Myrsine juergensenii	*Primulaceae*	0	1.87	0	5.49	0	0
Coffea arabicaa [a]	*Rubiaceae*	7.30	13.20	2.17	**25.27**	0	0
Citrus aurantifoliaa [a]	*Rutaceae*	1.66	0	1.10	0	0	0
Citrus limona [a]	*Rutaceae*	1.72	0	0	0	2.12	0
Citrus sinensisa [a]	*Rutaceae*	3.45	0	0	0	0	0
Casearia arguta	*Salicaceae*	0	0	5.63	0	0	3.23
Xylosma flexuosum	*Salicaceae*	0	0	1.28	0	0	0.00
Xylosma sp.	*Salicaceae*	0	0	1.11	0	0	0
Cupania dentata	*Sapindaceae*	0	3.34	**28.13**	**14.90**	**31.77**	5.76
Pouteria sapota	*Sapotaceae*	**14.62**	0	0	0	0	0
Sideroxylon sp.	*Sapotaceae*	0	1.43	0	0	0	0
Cecropia obtusifolia	*Urticaceae*	1.66	11.32	3.29	1.23	0	0
Citharexylum sp.	*Verbenaceae*	0	0	0	0	0	3.86

R = La Rinconada (Jalisco); C = Cordón del Jilguero; V = El Venado; Z = El Zopilote; P = Puerta de Platanares; A-C = Acatán de las Piñas-El Cantón (Nayarit). See Rosales-Adame et al. (2014).

[a] Domesticated species incorporated into the agroforest to provide fruit.

Bold numbers indicate higher IVI values. IVI is calculated as relative frequency plus relative density plus relative dominance.

Tree density ranges from 130 to 850 individuals per ha depending on locality (Table 2). The subdeciduous tropical forest (STF) is the main forest type providing shade, but pineapple agroforests are also found in low-elevation deciduous *Quercus* forests and in vegetation assemblages with coffee. The richness (number of different species) and diversity (Shannon's diversity index) of woody species are similar to and in some cases higher than those recorded in shaded coffee systems in Central America (Costa Rica and Nicaragua), and in native lowland rainforests and montane cloud forests of the region.

Table 2. Richness, diversity and structure of woody vegetation in pineapple agroforests

Locality	Plot	Veg	D ind. ha^{-1}	BA m^2 ha^{-1}	AH (m)	S	H´
La Rinconada	El Cerro	STF–Coffee	260	73.2	18	6	1.28
	El Grande	STF–Coffee	310	72.0	11	9	1.84
	El Mamey	STF–Coffee	370	48.6	11	9	1.82
	El Morado	STF–Coffee	350	61.2	13	10	1.85
	Las Guámaras	STF–Coffee	190	35.0	16	5	1.02
Cordón del Jilguero	Campo de Fútbol	STF	200	21.9	13	3	0.39
	C. Salas	STF–Coffee	720	16.1	8	10	1.31
	F. Alemán	STF-*Quercus*	460	14.6	7	12	2.07
	Rodolfo	STF	200	18.2	11	5	1.40
	Los Chinos	STF–Coffee	640	30.0	7	13	1.92
El Venado	Los Zapotillos II	STF	240	20.1	11	3	0.54
	Los Zapotillos	STF	130	17.7	13	3	0.54
	M. Rosales	STF	470	36.5	10	18	2.42
	C. Cruz	STF–Coffee	800	28.2	9	15	1.94
	El Paranal	STF	850	21.8	7	24	2.72
El Zopilote	El Limón	STF–Coffee	510	21.4	12	13	2.20
	El Panteón	STF–*Quercus*	410	29.3	6	12	2.05
	P. Venado	STF	610	15.0	5	7	1.14
	P. Rosales	STF–Coffee	550	30.3	8	17	2.11
	R. Rosales	STF–Coffee	440	16.0	7	8	1.51
Puerta de Platanares	C. Ayón	STF	280	20.5	11	6	1.59
	E. Alemán	STF	230	22.4	12	5	1.21
	Exiquio	STF	180	21.0	15	3	0.73
	Puerteña	STF	380	29.5	8	8	1.25
	German	STF	250	32.1	10	6	1.67
Acatán de las Piñas-El Cantón	El Abril	STF	330	25.9	13	9	1.31
	Las Correras	STF	410	11.7	9	5	0.61
	P. Galana	STF	390	17.7	9	13	2.22
	Los Llanitos	STF	240	16.3	14	2	0.29
	Joel Rivera	STF	210	18.3	13	4	0.78

Veg = vegetation type; D = density; BA = basal area; AH = average height; S = species richness; H' = Shannon index. See Rosales-Adame et al. (2014). STF = subdeciduous tropical forest.

Agroforest work basically consists of removing weeds, bushes, branches and fallen trunks and preparing for harvesting. The density of adult pineapple plants varies according to the site, ranging from 8,700 to more than 25,300 per ha, while juvenile individuals range from 2,600 to 8,000 per ha. The production volume reaches 6.5 to 7 metric tonnes per ha per year, which is about 10% of what is harvested from improved, full-sun modern varieties. This low yield is compensated for by very low handling costs. Fruits are generally small but of outstanding quality. The plant is twice the height of the improved varieties and has thorns on the leaves and crown of the fruit. Pests and disease are minimal, due to the biodiversity of the system.

Cost to establish pineapple agroforests

Very little is known about the costs of establishing these agroforests. Information provided by producers in 2015 indicated that the maintenance cost was between MXN (Mexican peso) 12,740 and 17,200 per ha, depending on the region, in addition to the time and use of inputs, if required. The plots can be rented for a lump sum, depending on the condition and area. Production costs, updated for the year 2023, are estimated in Table 3.

Table 3. Estimated cost per ha in MXN (Mexican pesos) of establishing pineapple agroforests in Mexico, 2023

Item	Jalisco			Nayarit		
	No.	Cost	Subtotal	No.	Cost	Subtotal
Land preparation (hand labour wages)	15	400	6,000	15	300	4,500
Seed (pineapple plant shoots) including freight	10,000	[a]4.50	45,000	10,000	1.00	10,000
Labour for sowing seedlings	15	400	6,000	15	300	4,500
Labour for fence rehabilitation	4	400	1,600	4	300	1,200
Fuel for work on the plot	15	100	1,500	15	100	1,500
Total			**60,100**			**21,700**

[a] The cost of seed for Jalisco is higher because of the transfer from Nayarit.

Conclusions

Pineapple agroforests were the area's first ecological, sustainable and resilient systems and they have been cultivated to maintain the conservation of native vegetation and agrobiodiversity. The production of this tropical fruit on the Mexican Pacific coast was practised centuries before the establishment of today's prevailing conventional production model.

The considerations presented in this article are useful to decision-makers at the political level to value, defend, conserve and promote the maintenance of this ancestral form of agroforestry.

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Author affiliations

Jesús Juan Rosales-Adame, Departamento de Ecología y Recursos Naturales, Centro Universitario de la Costa Sur, Universidad de Guadalajara (jesus.radame@academicos.udg.mx)

Judith Cevallos-Espinosa, Departamento de Ecología y Recursos Naturales, Centro Universitario de la Costa Sur, Universidad de Guadalajara (jcevallo@cucsur.udg.mx)