Silvopastoral systems in the dry tropics of Mexico: A social-ecological approach

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Advantages of silvopastoral systems

- High quality forage
- N fixation
- Soil improvement
- Erosion control, moisture maintenance
- Shade, fences, other uses of trees
- Parasite control, carcass quality (Murgueitio 2011)

Study area: Adjacent communities to the Biosphere Reserve Chamela-Cuixmala, Jalisco (Pacific Coast)

Ecological features

Tropical, warm subhumid climate with high seasonality and inter and intra-annual variability. Mean annual rainfall 800 mm (340 – 1329). Mean annual temperature 24.6°C.

Topography: Plains and hilly terrains (11 and 89% respectively) < 300 masl. Shallow soils (<30 cm) with low nutrient content.

The region is relevant for conservation for its high biodiversity and endemism. The Biosphere Reserve has conserved forests and is surrounded by agricultural areas including secondary forests of different ages, primary forests, cultivated grasslands and few annual crops.

Forests cover between 70 - 80 % of the area and are highly resilient, but little is known about their conservation status.

Social and productive context

Beef livestock is the main economic activity in the region. It is family owned, under extensive management (< 2 LSU/ha), focused on breeding and sale of calves for fattening.

Silvopastoral management is traditional, using low technology and external inputs. Infrastructure consists in fences, small reservoirs and handling pens.

Farms go from 17 to 200 ha and herds from 15 to 150 animals. Water availability is variable and strongly determines stocking rate.

Market context

The main income of families comes from selling calves (4 to 60/family/year) to middlemen. Calves are then taken to feedlots outside the region.

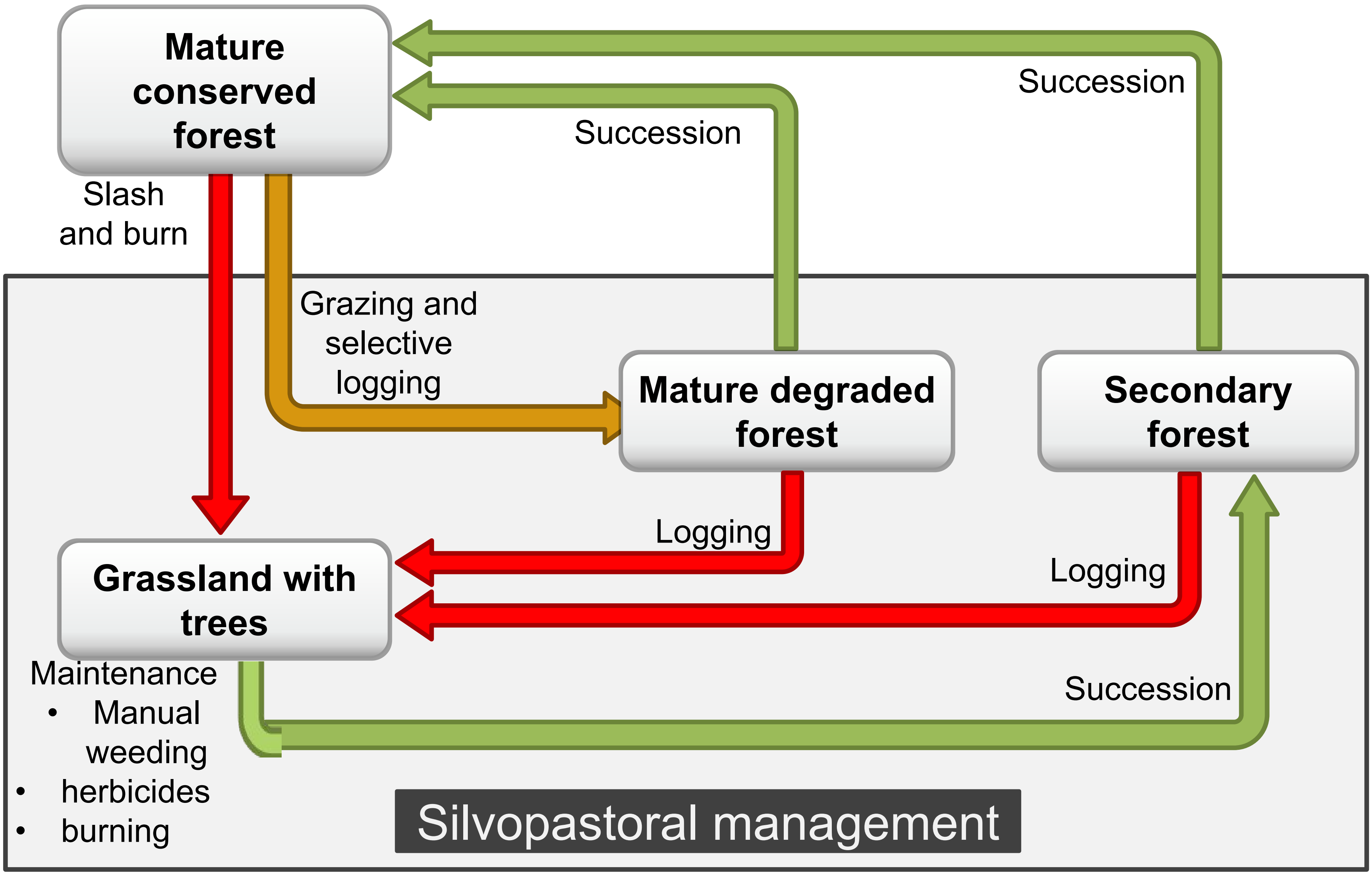
Middlemen prefer smaller animals in order to obtain higher profits. Thus, the price paid per kg drops after 240 kg. Prices are unstable and seasonal, but have increased over the last decade, which incentivises cattle production, as there are few other economic activities in the region.

Public policies

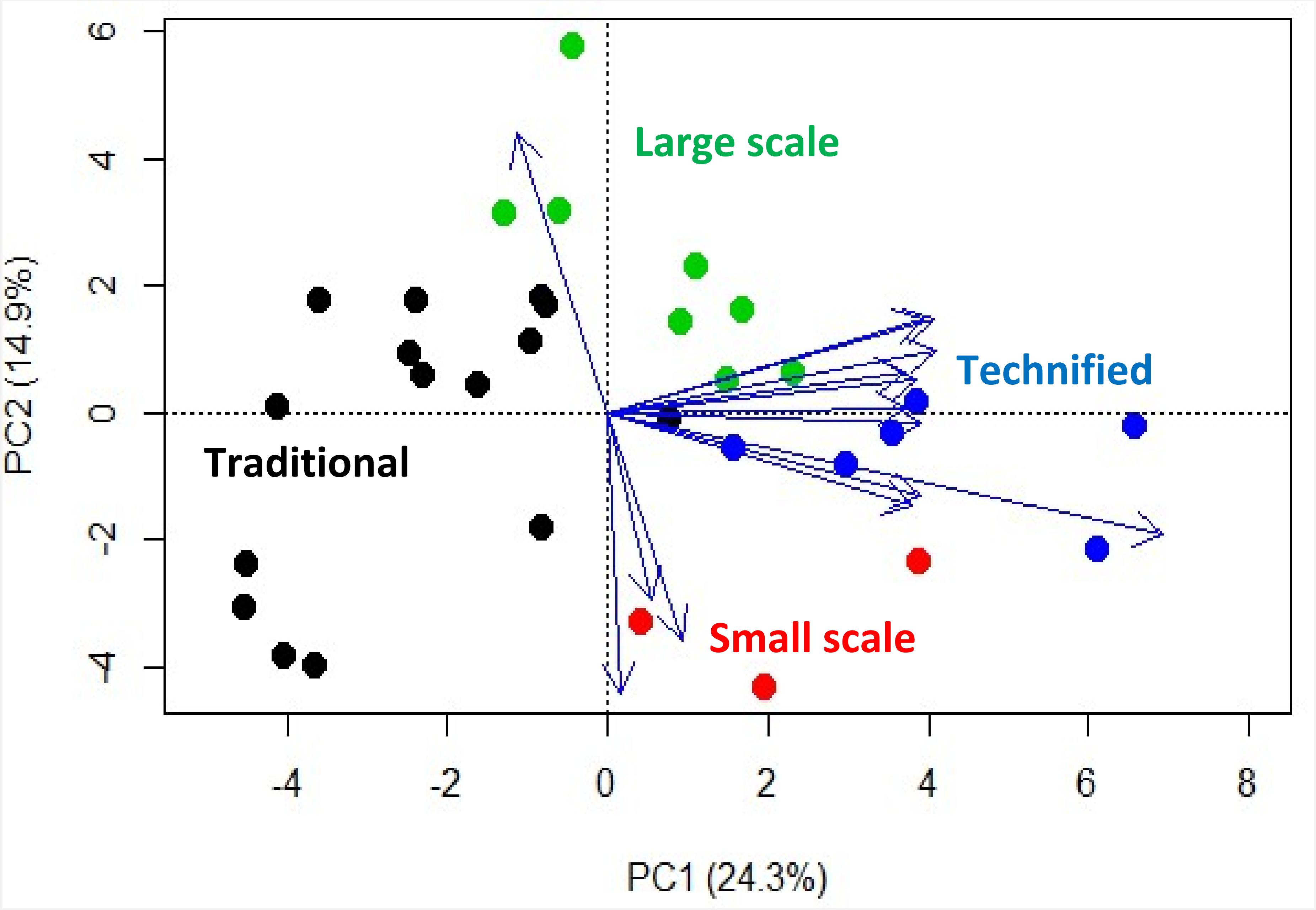
During the 1970s extensive cattle production was promoted through deforestation, credits, improved breeds and inputs. Small subsidies were given in the 2010s per livestock unit.

In recent years, regulations have become stricter regarding logging and fire in the buffer areas next to the Reserve. Some communities receive environmental services payments, destined to maintaining anti-fire trenches, cattle restriction areas and removal of sick or dead trees.

Forest management in the study area (Sánchez-Romero et al 2021)



Farm typology



Results

Technified

Traditional

Extensive

Intensive

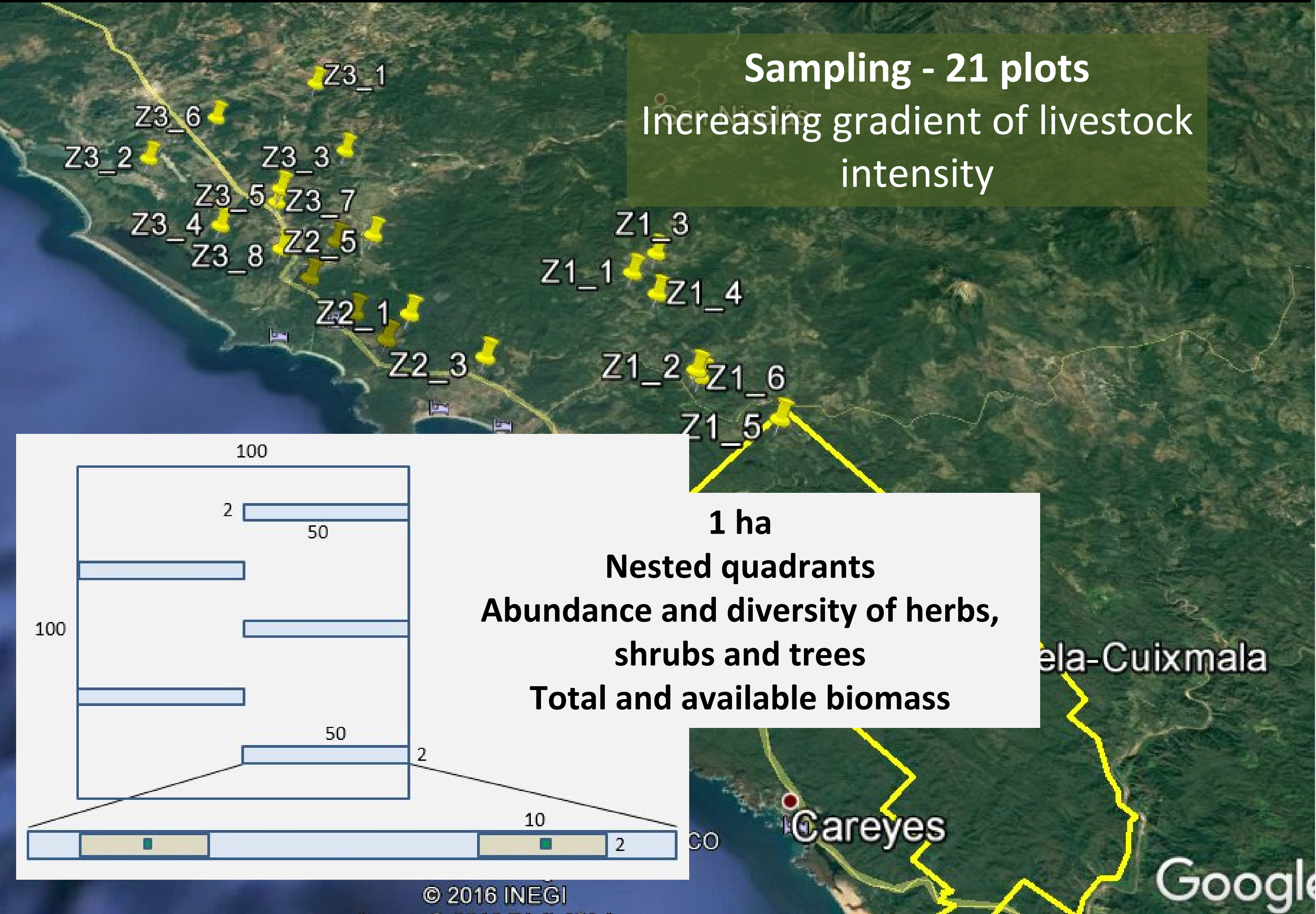
Technology / resource access	**Technified** (6)	**Traditional** (15)
Training	Yes	No
Machinery and tolos	High	Low
Access to water	High	Low
No. of animals	109 $\bar{X}$	52 $\bar{X}$
Crops (ha)	14 $\bar{X}$	1 $\bar{X}$
Feed supplementation	High	Low

forest / grassland	**Extensive** (8)	**Intensive** (3)
Forest proportion	52 – 90 %	8 – 9 %
Grassland proportion	3 – 43 %	73 – 84 %

Impact of livestock intensity on dry tropical forest vegetation and soils

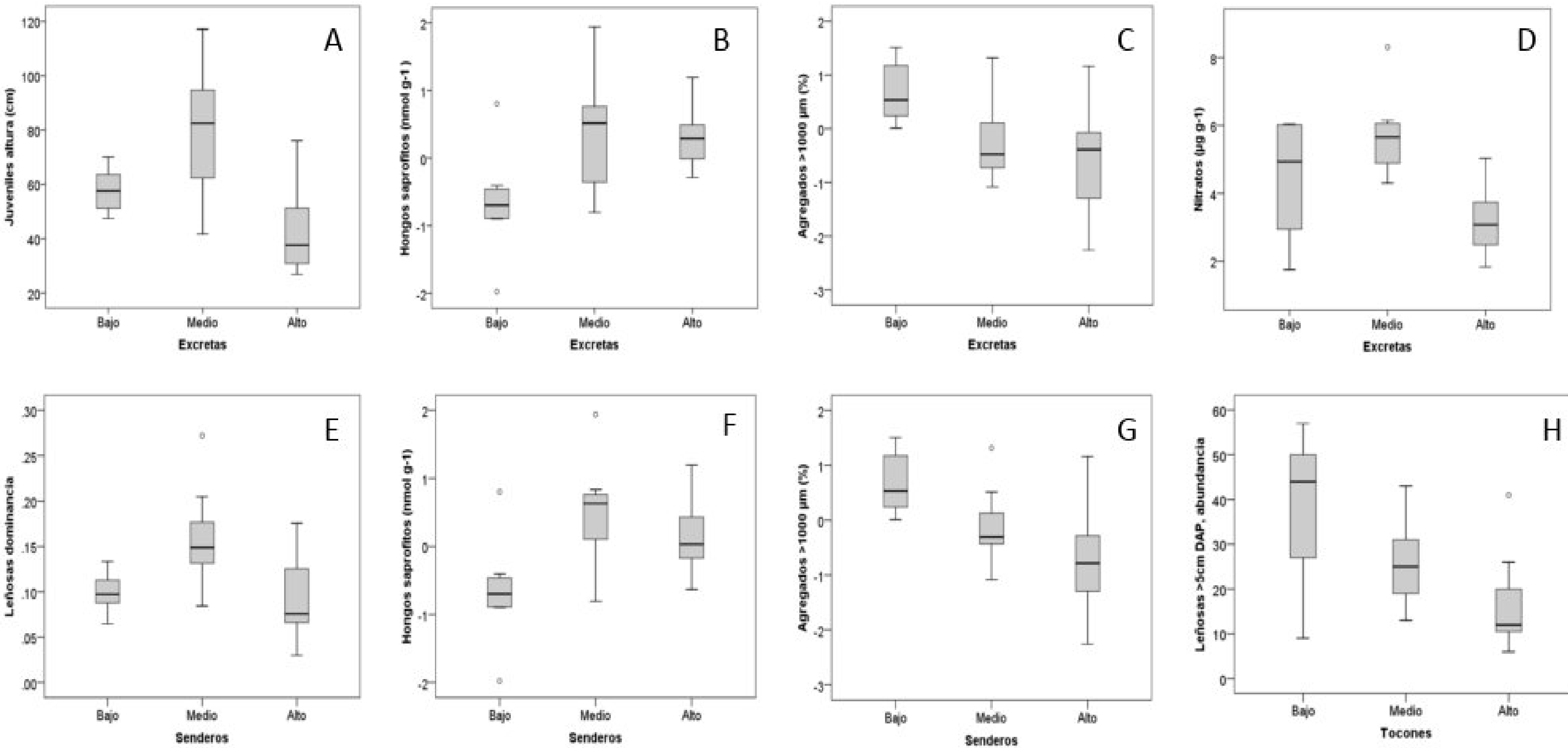
	Componentes	Variables evaluadas
Vegetation	Established vegetation, woody sp 💿 1cm BHD (11)	• BHD, height • Abundance and richness, BHD 💿 1cm, 1-5cm, >5cm • Diversity, dominance
	Regeneration vegetation, juveniles (8)	• Height, diameter, base are, canopy cover • Abundance and richness • Diversity, dominance
	Disponibilidad de forraje (3)	• Forage trees and shrubs: Abundance, forage • Herbs: forage
Soil	Fertility (4)	• Organic matter • Nitrates, ammonia, ortophosphates
	Structure and hydric capacity	• Apparent density • Stable aggregates: Micro (< 250 µm), macro (250-1000, > 1000 µm) • Field capacity
	Microbiota (8)	• Total microbiota • Bacteria: Total, Gram +, Gram –, Actinobacteria • Fungi: Total, mycorrhizal, saprotrophyc
	Cover (3)	• Herbs: Total, palatable, non palatable
	Chemical (1)	• pH

Methods



Sampling - 21 plots
Increasing gradient of livestock intensity

1 ha
Nested quadrants
Abundance and diversity of herbs, shrubs and trees
Total and available biomass



Effects of three levels of livestock (dung patches, paths, cut trees) on vegetation and soil variables. Only variables with significant differences are shown (*p*< 0.05).

Sánchez Romero, 2021

FORAGE POTENTIAL OF WOODY SPECIES

16 species were selected based on the number of mentions in 32 interviews and two workshops with farmers (total ≈ 70)

Abundance in 21 sampling sites (Sánchez-Romero et al, 2021b)

Which trees do we want?

- Nutritive quality
- Forage yield
- Resistance to drought, fire, pests
- Seed production season
- Easiness of management (direct planting, pruning)

Biomass (kg DM/tree) and nutritive quality of leaves (g kg^{-1} DM)

Species	Biomass	DM (g kg^{-1} FM)	CP	CF	Ashes	Fat	CH
Acacia macracantha	0.2 ± 0.3	474.3 ± 49.4	164.0 ± 13.0	106.3 ± 35.8	92.0 ± 16.8	49.1 ± 9.1	589.4 ± 31.5
Apoplanesia paniculata	0.05 ± 0.06	464.1 ± 47.8	177.5 ± 17.9	107.7 ± 43.3	106.3 ± 5.4	24.5 ± 3.9	584.0 ± 52.4
Caesalpinia caladenia	0.1 ± 0.1	389.7 ± 39.9	90.1 ± 25.2	150.6 ± 21.5	114.9 ± 23.5	40.2 ± 9.3	604.2 ± 37.4
Caesalpinia coriaria	0.5 ± 0.6	562.4 ± 42.1	111.3 ± 30.4	147.6 ± 16.8	64.0 ± 14.0	26.8 ± 4.5	650.5 ± 42.0
Caesalpinia platyloba	0.2 ± 0.1	362.0 ± 51.3	171.3 ± 10.8	136.7 ± 44.7	79.1 ± 11.5	28.0 ± 6.1	585.6 ± 36.3
Caesalpinia sclerocarpa	0.04 ± 0.04	506.8 ± 69.0	111.0 ± 13.9	93.2 ± 15.8	76.6 ± 06.3	31.9 ± 8.9	646.9± 147.4
Cordia elaeagnoides	0.3 ± 0.5	331.7 ± 76.7	167.8 ± 11.0	97.8 ± 23.1	147.1 ± 13.8	30.2 ± 4.2	557.1 ± 34.0
Guazuma ulmifolia	0.6 ± 0.8	448.9 ±120.5	127.8 ± 7.8	127.4 ± 41.9	112.8 ± 11.1	38.8 ± 6.9	593.0 ± 51.3
Hura polyandra *	9.9 ± 15.5	387.4 ± 54.5	103.3 ± 27.3	197.4 ± 17.5	102.9 ± 87.3	33.0 ± 3.3	484.8 ± 86.1
Leucaena lanceolata	0.07 ± 0.07	358.2 ± 75.4	206.5 ± 33.9	150.7 ± 13.9	86.5 ± 9.1	61.7 ± 17.9	498.3 ± 34.0
Lonchocarpus mutans	0.07 ± 0.06	543.8 ± 61.1	237.7 ± 24.0	165.6 ± 12.3	106.3 ± 13.0	29.5 ± 7.7	461.0 ± 31.0
Piranhea mexicana	0.1 ± 0.2	249.1 ± 38.5	131.2 ± 4.9	205.4 ± 31.0	58.1 ± 9.8	31.6 ± 4.9	569.0 ± 47.6
Spondias purpurea	0.1 ± 0.1	845.5 ± 67.4	128.3 ± 9.3	148.9 ± 44.9	129.3 ± 22.5	31.2 ± 8.3	562.2 ± 33.8
Promedio	1.0 ± 5.0	457.3 ±151.9	148.1 ± 46.6	141.7 ± 45.2	98.0 ± 36.6	33.0 ± 3.3	567.9 ± 81.2

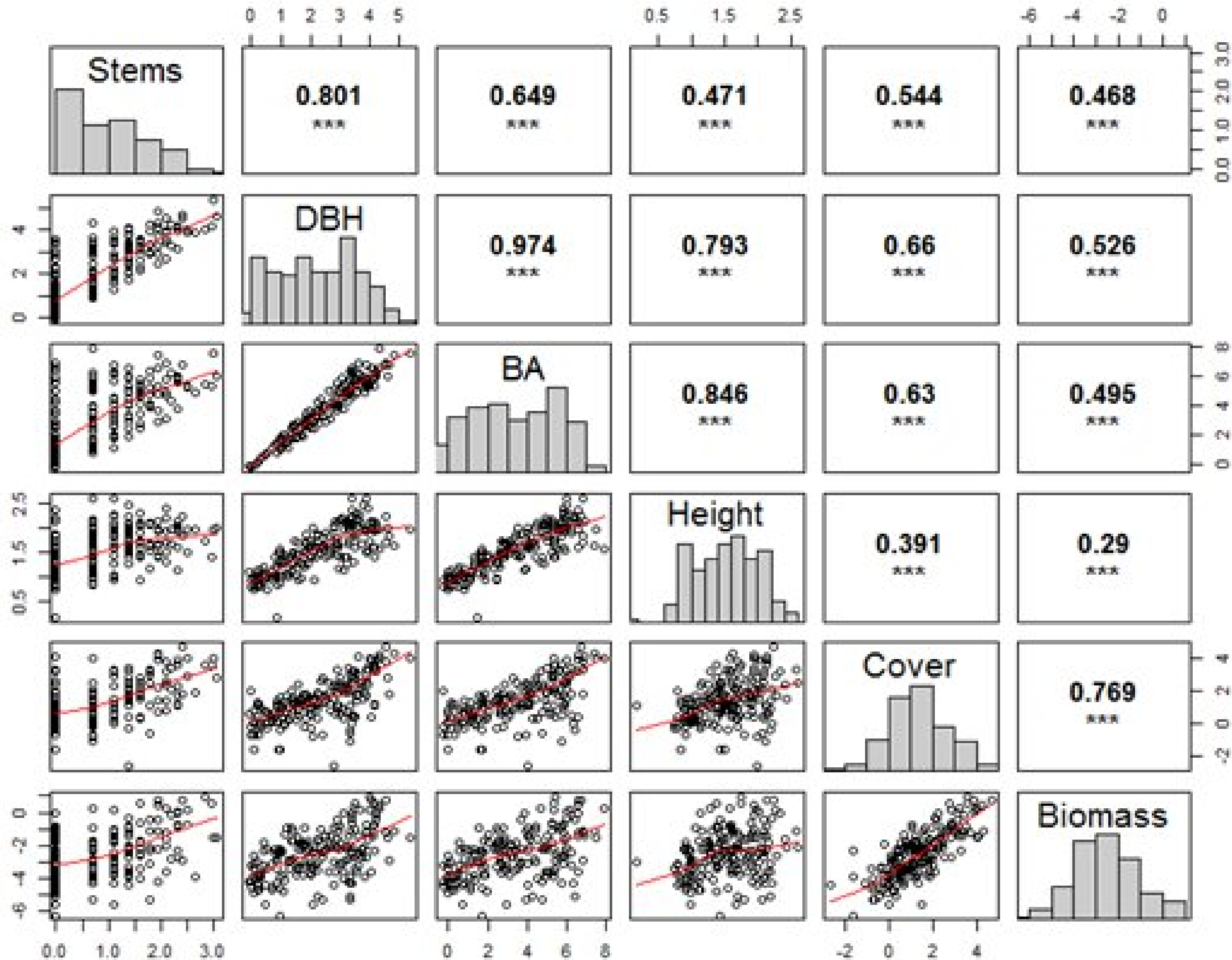
Biomass (kg DM/tree) and nutritive quality of fruits (g kg^{-1} DM)

Species	Biomass	DM (g kg^{-1} FM)	CP	CF	Ashes	Fats	CH
Acacia macracantha	1.9 ± 2.7	507.6 ± 86.6	167.5 ± 20.9	77.6 ± 12.8	190.7 ± 39.9	9.2 ± 1.6	492.9 ± 45.8
Caesalpinia caladenia	0.2 ± 0.4	550.9 ± 233.6	79.8 ± 45.1	81.9 ± 20.7	163.3 ± 57.3	18.9 ± 8.7	587.5 ± 63.0
Caesalpinia coriaria	1.0 ± 1.4	720.0 ± 128.1	68.5 ± 14.9	137.7 ± 67.7	138.9 ± 40.4	7.7 ± 4.1	582.4 ± 97.5
Caesalpinia eriostachys	3.9 ± 5.9	545.8 ± 122.7	104.0 ± 17.7	86.8 ± 30.5	191.2 ± 38.4	26.0 ± 13.4	537.2 ± 40.4
Caesalpinia platyloba	1.5 ± 1.6	877.8 ± 55.4	122.2 ± 22.3	75.1 ± 18.4	226.7 ± 30.1	47.9 ± 24.4	445.5 ± 48.2
Caesalpinia sclerocarpa	0.8 ± 1.0	919.4 ± 94.5	68.0 ± 14.8	59.3 ± 24.6	170.2 ± 33.4	4.5 ± 1.7	624.9 ± 37.7
Gliricidia sepium	0.6 ± 0.8	346.5 ± 35.7	119.5 ± 39.3	70.2 ± 13.3	184.7 ± 31.4	27.2 ± 9.9	535.6 ± 38.2
Guazuma ulmifolia	4.4 ± 6.2	443.3 ± 143.9	80.5 ± 22.9	59.1 ± 8.8	203.1 ± 50.5	23.0 ± 6.7	557.0 ± 52.9
Leucaena lanceolata	0.5 ± 0.8	985.9 ± 401.1	202.6 ± 92.4	104.3 ± 44.3	179.5 ± 88.1	24.9 ± 12.5	425.9±114.9
Senna mollissima	0.2 ± 0.3	504.1 ± 207.7	122.6 ± 15.2	81.5 ± 18.7	194.8 ± 20.5	28.6 ± 69.8	515.8 ± 71.1
Spondias purpurea	3.5 ± 6.7	283.0 ± 52.7	81.9 ± 22.7	49.0 ± 16.6	216.4 ± 38.9	32.4 ± 12.7	561.1 ± 66.7
Promedio	1.7 ± 3.7	617.8 ± 283.8	110.1 ± 54.1	79.8 ± 36.9	187.3 ± 50.2	22.7 ± 25.7	534.1 ± 85.9

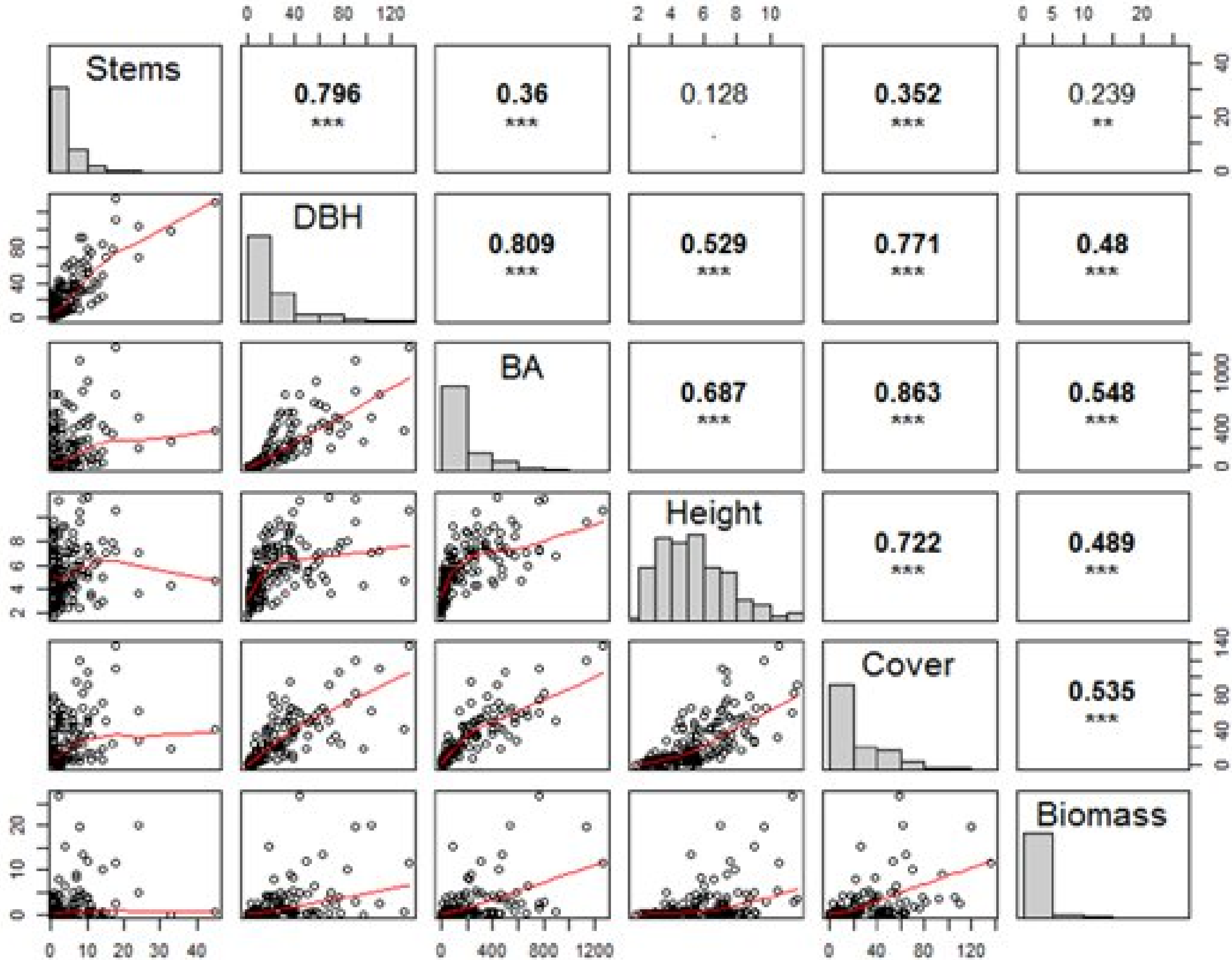
Structural attributes

Species	BHD (cm)	Height (m)	Base area (cm^2)	Canopy cover (m^2)	Stems (no.)
Acacia macracantha	20.30 ± 22.81	5.51 ± 2.16	107.23 ± 141.32	18.36 ± 24.65	4.35 ± 3.69
Apoplanesia paniculata	14.54 ± 18.74	4.57 ± 2.49	62.62 ± 106.25	4.78 ± 4.92	4.27 ± 3.92
Caesalpinia caladenia	9.56 ± 8.77	3.78 ± 1.44	36.86 ± 48.19	7.68 ± 8.53	2.73 ± 2.10
Caesalpinia coriaria	43.62 ± 35.60	4.93 ± 1.56	335.80 ± 511.25	26.23 ± 22.09	9.47 ± 10.12
Caesalpinia eriostachys	26.94 ± 27.01	5.61 ± 1.95	170.02 ± 196.50	24.50 ± 20.39	5.63 ± 5.64
Caesalpinia platyloba	14.60 ± 15.65	4.82 ± 1.92	75.23 ± 95.99	11.35 ± 11.69	3.29 ± 2.99
Caesalpinia sclerocarpa	24.60 ± 17.60	6.52 ± 2.41	241.72 ± 183.68	27.34 ± 27.86	2.88 ± 2.24
Cordia elaeagnoides	22.81 ± 24.24	6.28 ± 3.58	270.63 ± 337.03	9.56 ± 13.14	2.69 ± 1.78
Gliricidia sepium	19.74 ± 22.79	4.56 ± 2.55	97.72 ± 205.75	15.13 ± 21.66	6.00 ± 4.11
Guazuma ulmifolia	33.65 ± 35.77	5.37 ± 2.10	257.79 ± 347.23	31.25 ± 40.15	5.97 ± 5.07
Hura polyandra	21.88 ± 18.34	6.70 ± 3.51	598.78 ± 836.66	77.80 ± 103.28	1.25 ± 0.68
Leucaena lanceolata	11.12 ± 10.27	5.20 ± 1.74	72.60 ± 113.37	9.04 ± 11.99	2.31 ± 2.35
Lonchocarpus mutans	21.11 ± 26.29	5.49 ± 2.08	81.15 ± 125.64	3.40 ± 4.10	5.60 ± 5.01
Piranhea mexicana	14.50 ± 11.99	6.28 ± 2.35	151.86 ± 198.97	4.60 ± 5.38	2.00 ± 1.37
Senna mollissima	6.83 ± 9.18	4.18 ± 1.28	29.37 ± 60.41	2.89 ± 2.60	1.73 ± 1.33

Correlation coefficients: foliage



Correlation coefficients: fruits



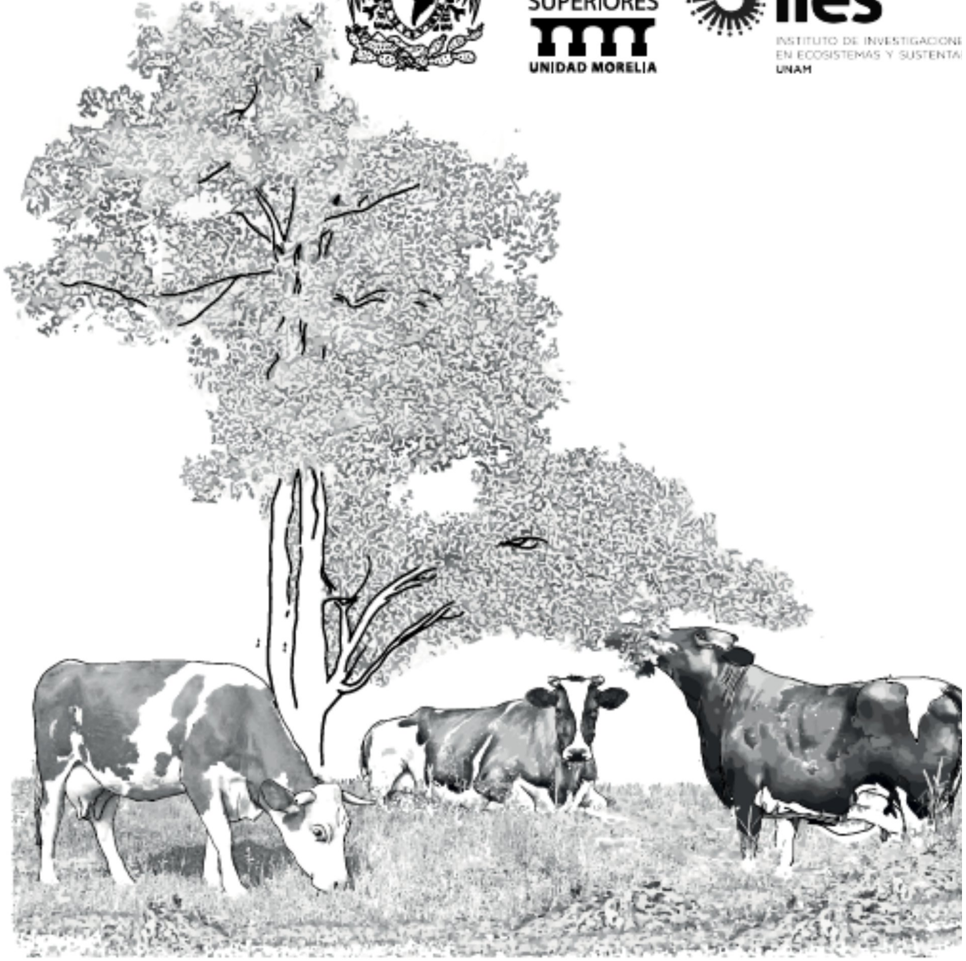
Allometric equations (Chave et al 2014)

$$\log(B_i) = \beta_0 + \beta_H \log(H_i) + \beta_{BA} \log(BA_i) + \beta_{cov} \log(C_i) + \beta_s \log(S_i) + \beta_{sp} Sp_i + \varepsilon_i$$

Model	Equation	R^2
Foliage, general	$B = 0.02614 \times C^{0.83826}$	0.5914
Foliage, specific	$B_{sp} = e^{-3.64+\beta sp} \times C^{0.83826}$	0.6813
Fruits, general	$B = 0.00576 \times C^{0.6250} \times H^{1.6087}$	0.5222
Fruits, specific	$B_{sp} = e^{-3.755+\beta sp} \times C^{0.55158} \times BA^{0.55130}$	0.6547
Foliage, *H. polyandra*	$B = 0.01289301 \times BA^{1.01000}$	0.9156

B – biomass, C – canopy cover, H – height

BA – base area S – stems Sp – species ε_i - std dev



Prácticas silvopastoriles en el trópico seco
Guía para ganaderos

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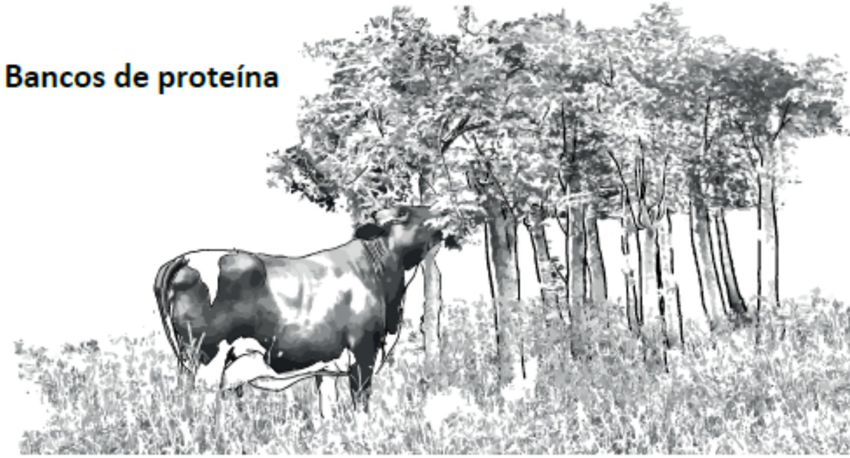
Francisco Mora Ardila, Gabriela Romo Díaz

3. Bancos de proteína



Los bancos de proteína son pequeñas áreas dentro de los potreros sembradas con árboles forrajeros y asociadas con pasturas o cultivos circundantes. El ganado puede pasar pequeños periodos al día ramoneando en estas zonas. También se pueden utilizar mediante la técnica de "corte y acarreo", es decir, cortar forraje de los bancos evitando el sobre ramoneo y llevándolo a donde esté el ganado. Su función principal es la producción de altas cantidades de forraje fresco, principalmente de plantas leguminosas (de la familia del frijol, haba, guaje) y otras especies de crecimiento rápido. El arreglo de los árboles lo podemos realizar en fila, cuadro o tres bolillo.

Ventajas

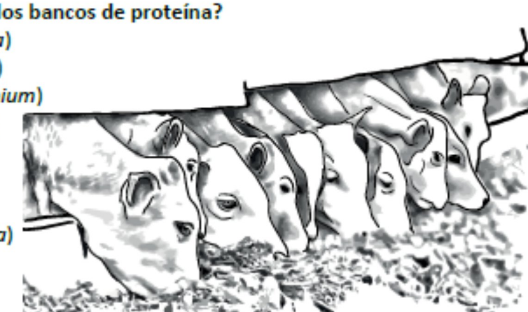
- El espacio se aprovecha de mejor manera que en otras plantaciones.
- Existe mayor disponibilidad de forraje de alta calidad para el ganado.

Es importante considerar que:

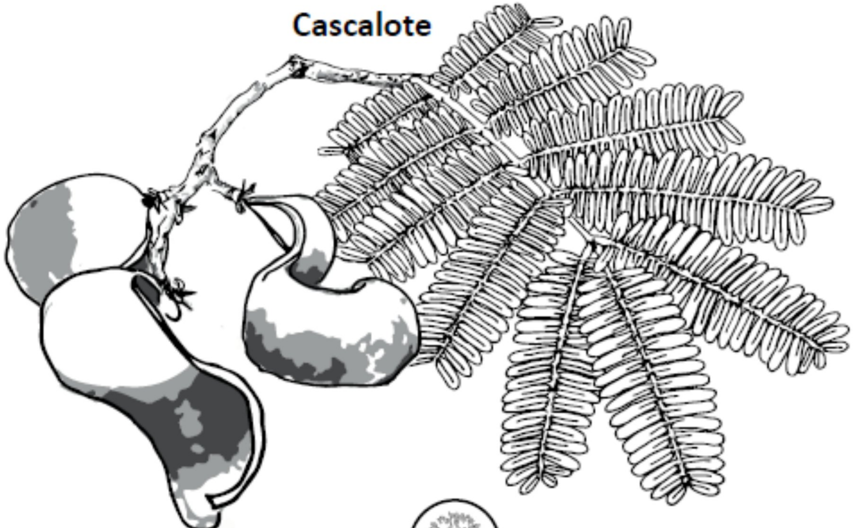
- Se requiere mano de obra, si el suelo es pobre hay que aplicar abonos para su establecimiento.
- Se debe cercar el espacio y esperar a que los arbolitos crezcan de 6 meses a 3 años para evitar daños por el ganado.

¿Qué árboles podemos plantar en los bancos de proteína?

- Guaje (*Leucaena leucocephala*)
- Guajillo (*Leucaena lanceolata*)
- Cacahuananche (*Gliricidia sepium*)
- Guácima (*Guazuma ulmifolia*)
- Moringa (*Moringa oleifera*)
- Senna (*Senna sp*)
- Nopal (*Opuntia sp*)
- Cascalote (*Caesalpinia coriaria*)



Cascalote



Caesalpinia coriaria.

Forraje (frutos y hojas), sombra, poste, cerco vivo, leña, medicinal (en humanos para problemas de riñón y en ganado para heridas, como desparasitante interno y externo del ganado: se puede bañar a la vaca con agua de la vaina molida; con esto se neutraliza a la garrapata por lo que ésta ya no puede comer y cae muerta), ornamental y ritual.

Tallo, corteza, hojas y frutos.

Se reproduce por semilla. Para preservarlas hay que almacenarlas en recipientes herméticos hasta por 10 años y colocar en un lugar fresco o en refrigeración.
Su germinación puede adelantarse remojando la semilla en agua tibia durante tres minutos, escurrirla y ponerla a secar al sol. La semilla germina de tres a 20 días después de la siembra. Las plantitas requieren al menos 15 semanas en el plantero.

Febrero a abril.

Febrero a junio.

Termita comején.

Baja.

Sí.

Media.

Tolerancia a la salinidad: sí.

Este árbol puede alcanzar hasta 12 metros de altura. No fija nitrógeno y a menudo produce troncos múltiples desde la base. Crece bien en las orillas de ríos y lugares que se inundan.

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Pilot of the FAO Tool for Agroecology Performance Evaluation (TAPE) in Mexico

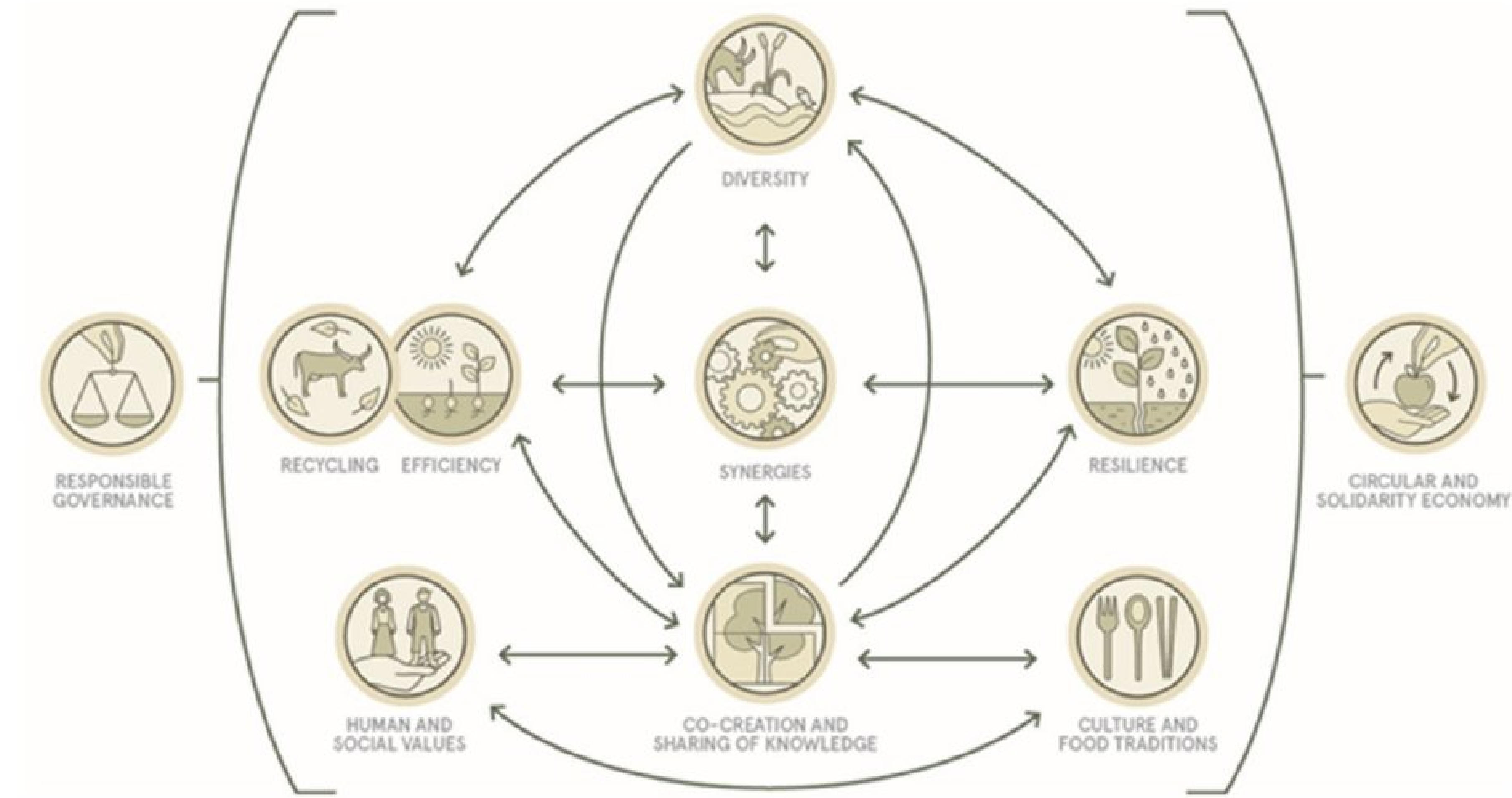
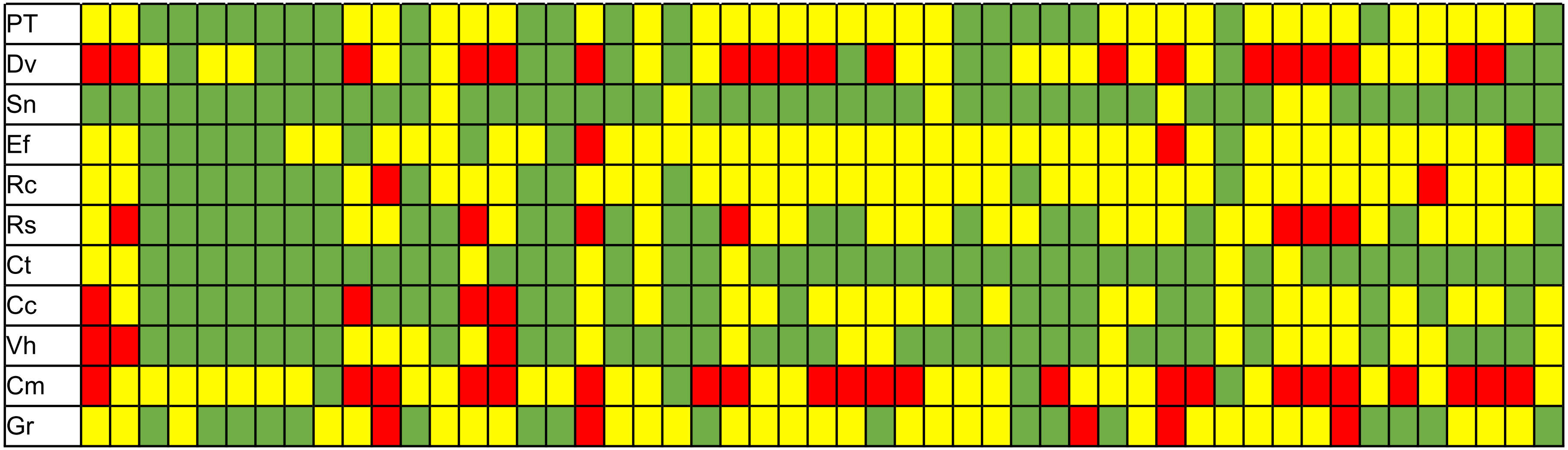


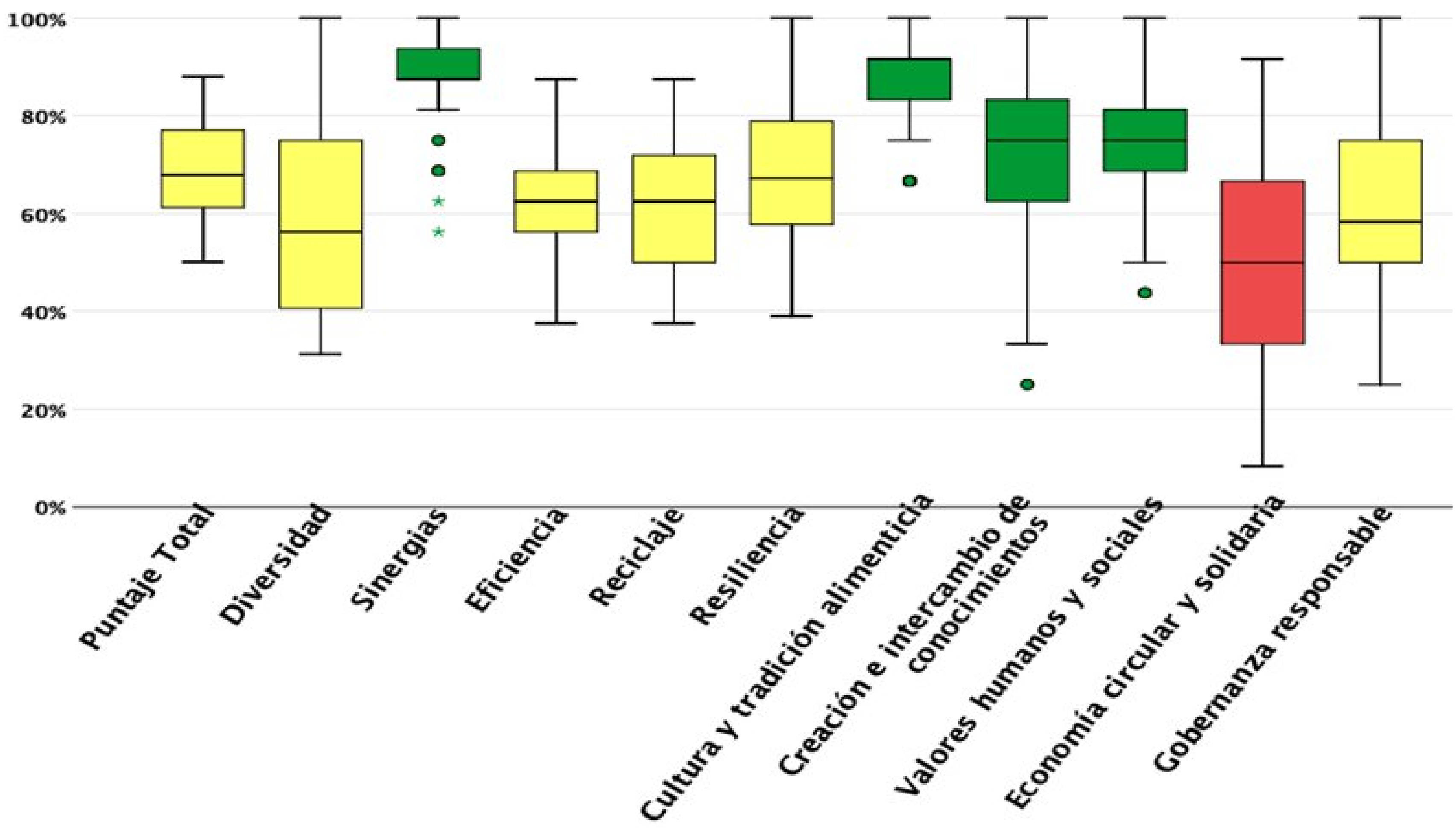
FIGURE 2 | The 10 Elements of Agroecology (FAO, 2018a).

Characterization of agroecological transitions



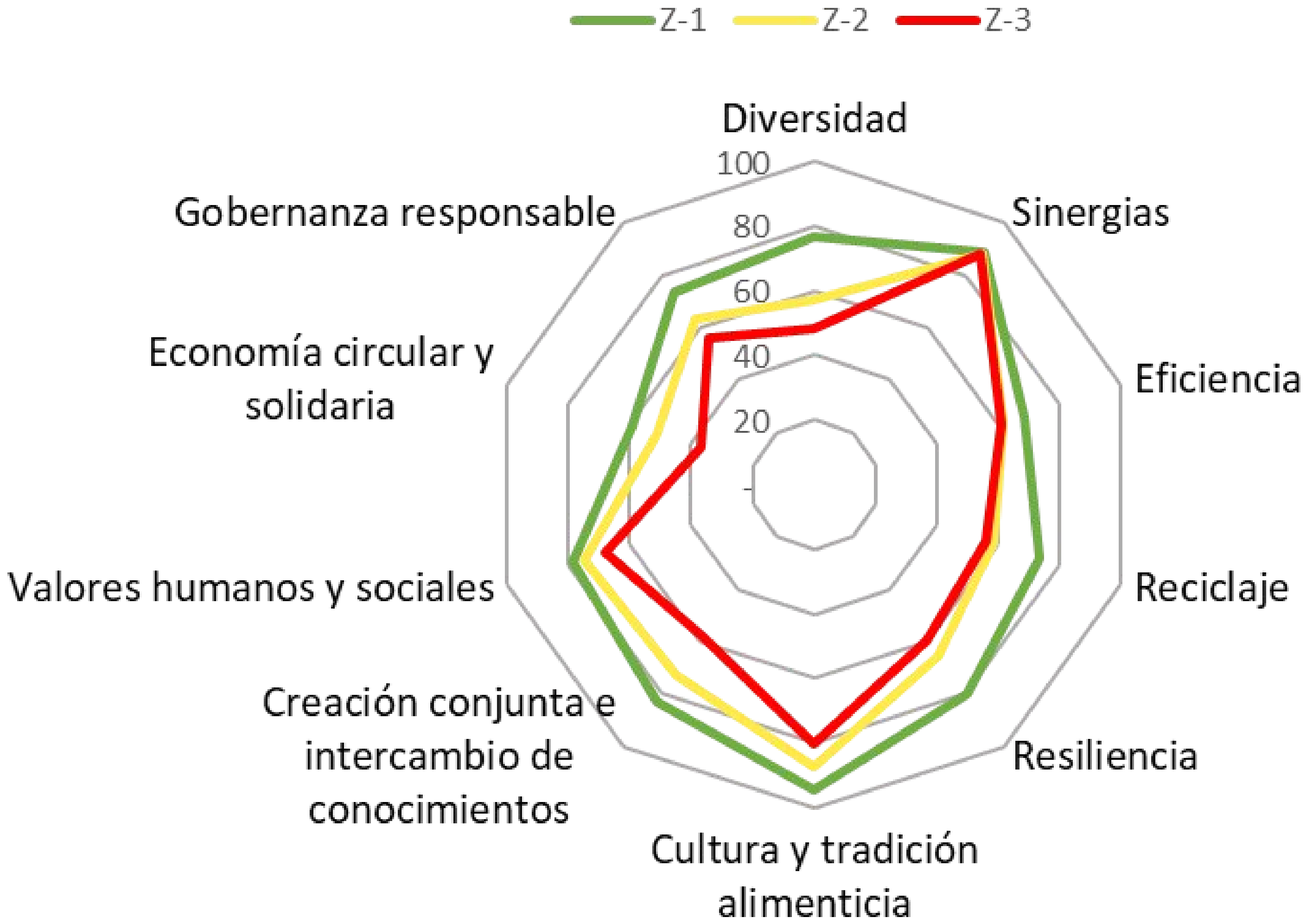
PT – Total points, Dv - Diversity, Sn - Synergies, Ef - Efficiency, Rc - Recycling, Rs - Resilience, Ct – Food culture and traditions, Cc – Knowledge co-creation and exchange, Vh – Human and social values, Ec – Circular and solidarity economy, Gr – Responsible governance.

Total points 50 - 88% (average 68). Out of 51 farms, 31 were between 50 – 70% and 20 above 70%, although with high variability.



100%
80%
60%
40%
20%
0%
Puntaje Total
Diversidad
Sinergias
Eficiencia
Reciclaje
Resiliencia
Cultura y tradición alimenticia
Creación e intercambio de conocimientos
Valores humanos y sociales
Economía circular y solidaria
Gobernanza responsable

Tipology by agroecological zones



Z1 plains, Z2 hills, Z3 mixed

A proposal for the design of biodiverse SP landscapes

Sánchez Romero and González Esquivel, 2022 (adapted from Arroyo et al., 2020)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