

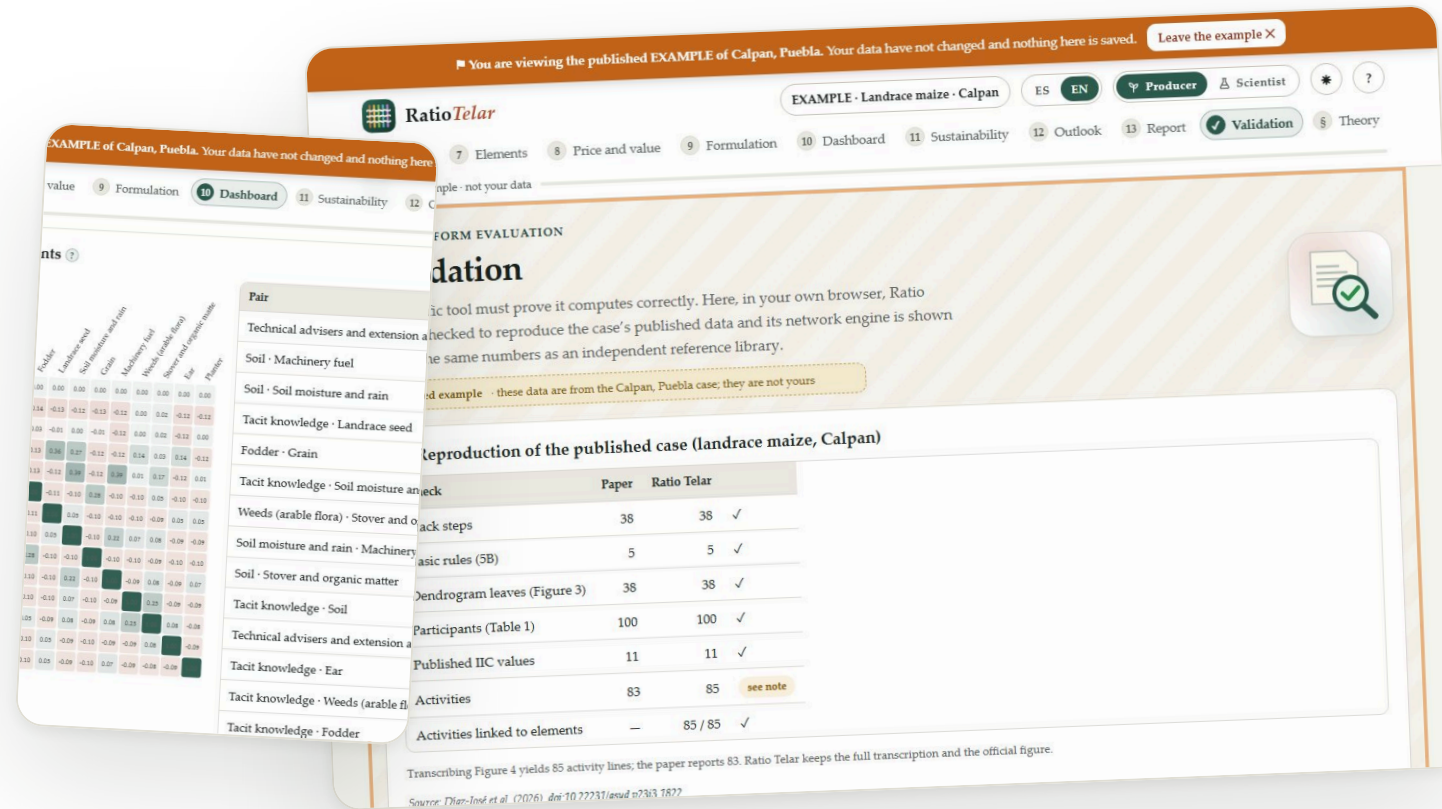


Local knowledge as a *complex adaptive system*: **model, equations and evidence**

Technical documentation of Ratio Telar for research and teaching: the data model, the weighted network and its statistics, the cladogram, the sustainability, regeneration and risk indices, the outlook, validation against NetworkX and SciPy, and how to reproduce every number.

1st edition · October 2026 · covers Ratio Telar 0.5.0
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For step-by-step use, see the Producer Guide.

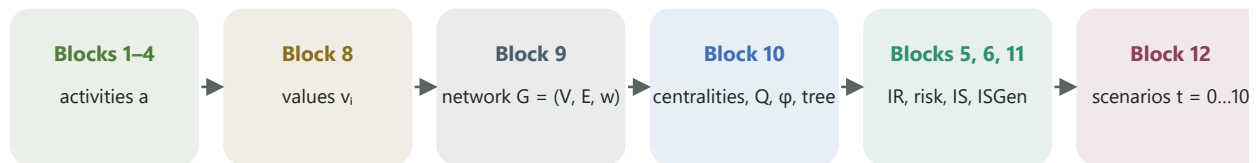


1	2	3	4	5	6	7	8	9	10	11	12	13
Crop	Region	Requirements	Management	Regeneration	Risks	Elements	Price and value	Formulation	Dashboard	Sustainability	Outlook	Report

P Scope, data provenance and conventions

Ratio Telar represents a crop or livestock farm as a complex adaptive system (Holland, 1995): its elements are nodes and its management activities, the links. On that network it computes centralities, communities, correlations and a cladogram; assesses sustainability, regeneration and risk; and projects scenarios at 2, 5 and 10 years. Everything runs in the browser, in a single HTML file with no external dependencies.

User or published-case data → model → indicators. Everything is recomputed when any input changes.



Every value keeps its origin: • published data · ♦ Ratio Telar reading · editable assumption · no data

FIGURE P.1 The computation flow. From activities to all other indicators.

Provenance of every value

LABEL	MEANING
● Dato publicado	Taken from a cited source: Díaz-José et al. (2026), Mojica Zárate (2017), INEGI (2020), CONABIO (2020), IPCC (2006, 2018, 2019), Zhao et al. (2017).
◆ Lectura de Ratio Telar	Rule, grouping or value proposed by the app (for example, activity–element links, impact profiles, class cut-offs). Editable.
Supuesto	Scenario parameter with no published basis (prices, costs, labour, risk reduction factors). Editable and flagged.
Sin dato	The value is not in the sources and was not entered by the user. The app does not impute it.

REFERENCE CASE	Landrace maize, San Andrés Calpan, Puebla (21026). 38 steps, 83 activities, 5 rules; 100 informants, 2022–2024.	ELEMENTS	63 in 10 categories, from the paper; those inferred from an activity are flagged.
TERRITORY	32 states, 2,478 municipalities, 54,357 localities (INEGI, 2020).	IMPLEMENTATION	Library-free JavaScript; one file built from <code>src/</code> with <code>armar.py</code> .

1

Data model

Activities, elements, value and impact: the inputs to every computation.

1.1 Activities and incidence

Each activity a belongs to a step p and, when there is a Stack, to a 5B rule. It has a type (traditional or innovated) and an element set E_a . The incidence matrix X (elements $\times$ activities) is 1 if the element takes part. Stack activities are questions: only those the user answers “yes” enter the computation; those answered “no” and unanswered ones stay out (nothing is preloaded). In the Calpan case the app activates 85 activities.

1.2 Element value

The user rates each element on four dimensions $k \in \{\text{economic, use, cultural, ecological}\}$, from 0 to 5, with weights $\omega_k \in [0, 3]$. Without a rating the structural value, relative participation, is used:

$$v_i = \sum_k \omega_k \cdot c_{ik} / \sum_k 5 \omega_k \quad \text{o bien} \quad v_i = n_i / \max_j n_j \quad (1)$$

where c_{ik} is the rating and n_i the number of activities element i takes part in.

1.3 Impact by compartment

Five compartments c : soil, water, atmosphere, vegetation and fauna. Each element has an impact profile (a Ratio Telar reading with its rationale); the activity’s impact is the clipped sum, or the value edited by the user:

$$s_{ac} = \min(2, \max(-2, \sum_{i \in E_a} \pi_{ic})) \quad (2)$$

2

The weighted network and its statistics

2.1 Network construction

Two elements are linked when they co-occur in an activity; the weight accumulates the geometric mean of their values over all shared activities, plus the structural ties documented in the paper (for example, local academia with the actors):

$$w_{ij} = \sum_{a: i, j \in E_a} \sqrt[3]{(v_i \cdot v_j)} \quad (3)$$

A zero value is replaced by 0.05 so the link is not cancelled. The “hide the omnipresent node” option excludes farmers (PM), who take part in almost every activity.

2.2 Centralities

MEASURE	DEFINITION IN THE APP
Weighted degree	$s_i = \sum_j w_{ij}$
Betweenness	Brandes (2001) with Dijkstra and length $1/w_{ij}$; unnormalised (Freeman, 1978).
Closeness	Inverse of mean $1/w$ distance to reachable nodes, scaled by the reachable fraction (Wasserman & Faust, 1994).
Eigenvector	Power iteration on the weighted matrix (200 iterations, max normalisation).
Clustering	Unweighted local coefficient; mean path and diameter by BFS (Watts & Strogatz, 1998).

2.3 Communities and modularity

Communities are detected with the Louvain method (Blondel et al., 2008), deterministic: local moves maximising ΔQ and aggregation, repeated until Q stops improving. Modularity (Newman, 2006):

$$Q = (1/2m) \sum_{ij} [w_{ij} - s_i s_j / 2m] \delta(c_i, c_j) \quad (4)$$

2.4 φ correlation

Pearson correlation between two elements' incidence vectors across the N activities (equivalent to the φ coefficient of a 2×2 table):

$$\varphi_{ij} = \sum_a (x_{ia} - \bar{x}_i)(x_{ja} - \bar{x}_j) / (N \sigma_i \sigma_j) \quad (5)$$

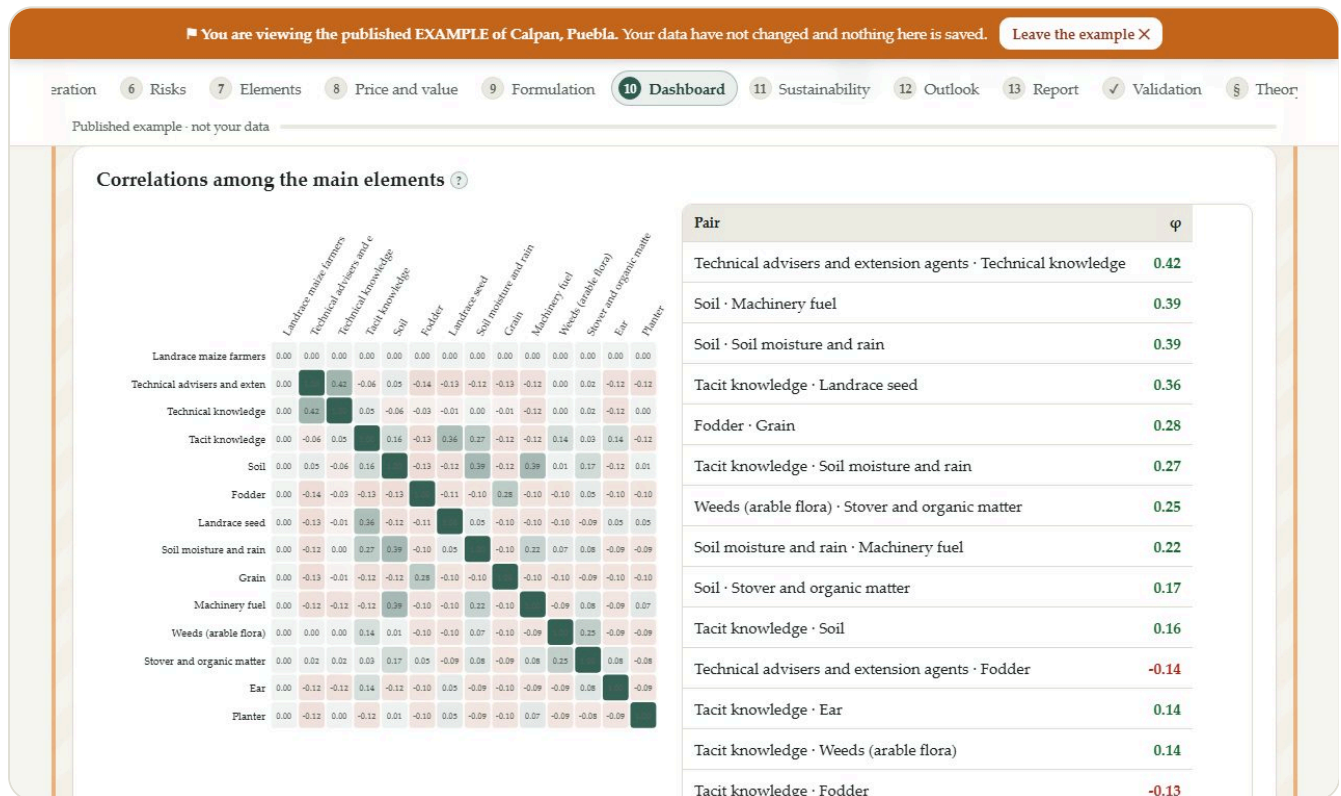


FIGURE 2.1 φ matrix of the 14 highest-degree elements (scientist view).



CALPAN

Full network: 61 nodes, 209 links, density 0.114, $Q = 0.038$ (4 communities). Without PM: 60 nodes, 158 links, $Q = 0.4496$ with 7 communities, mean clustering 0.5252 and mean path 2.9017. The highest betweenness without PM belongs to technical advisers, technical knowledge, tacit knowledge and soil.

3

METHOD

Nearest-neighbour cladogram

3.1 Network distance

The distance between two elements is the shortest-path length in the full network, with length $1/w_{ij}$ per link (the same metric as betweenness and closeness). The path may pass through any element even if the tree shows a subset (actors; actors and institutions; all). Pairs with no path get 1.15 times the largest observed distance.

$$d_{ij} = \min_{\text{camino } i \rightarrow j} \sum_{(u,v)} 1/w_{uv} \quad (6)$$

3.2 Single linkage and cophenetic correlation

Agglomerative hierarchical clustering by single linkage (Sneath, 1957; Sokal & Sneath, 1963): at each step the two groups with the closest pair of members merge, $D(A, B) = \min_{i \in A, j \in B} d_{ij}$. Tree fidelity is measured with Sokal and Rohlf's (1962) cophenetic correlation, the Pearson correlation between d_{ij} and the height at which i and j merge.

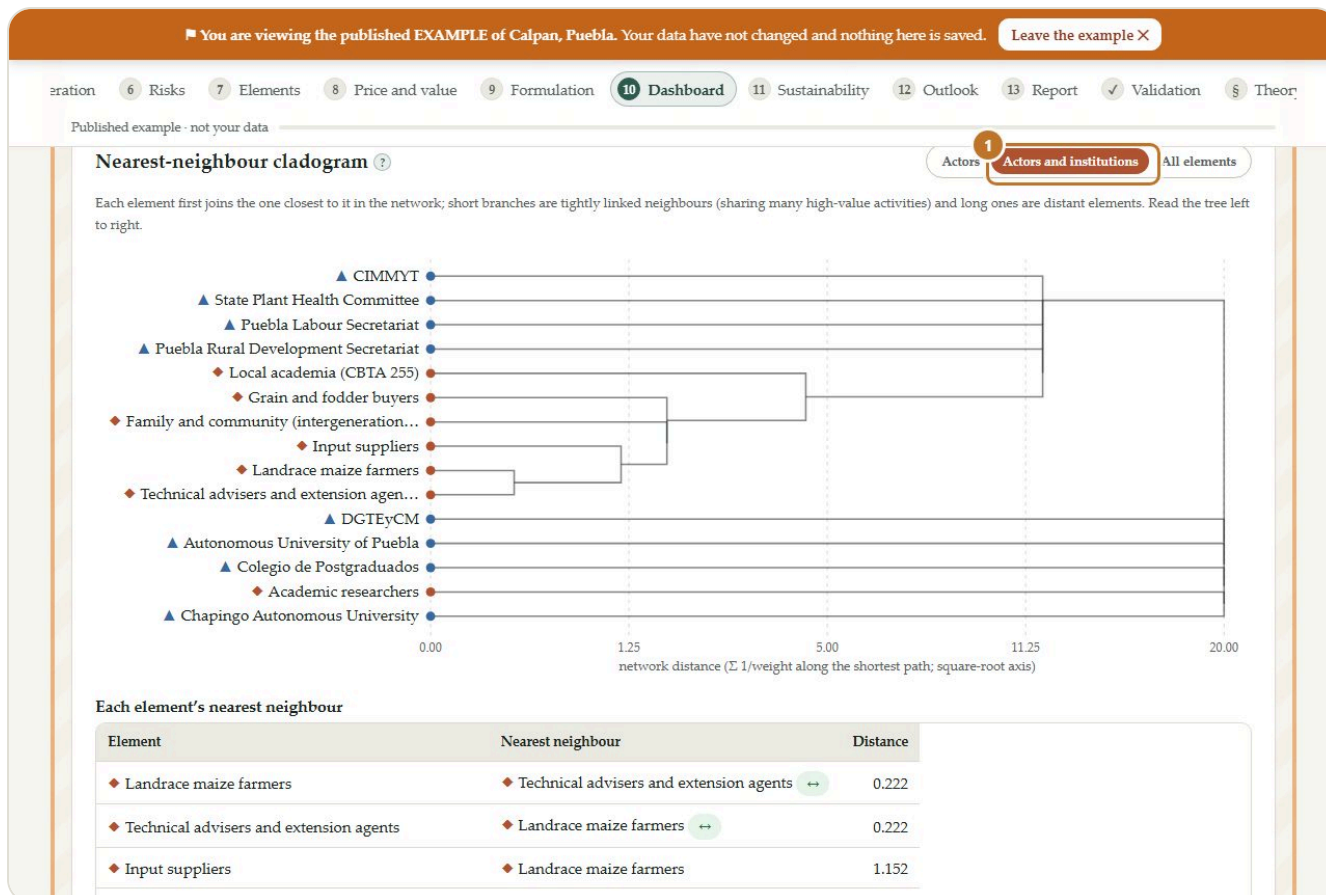


FIGURE 3.1 Calpan actors and institutions cladogram. Square-root axis; cophenetic correlation 0.853.

SUBSET	N	COPHENETIC R	Δ VS SCIPY
Actors	7	0.9917	1.1×10^{-16}
Actors and institutions	15	0.8526	1.0×10^{-15}
All elements	61	0.9103	2.1×10^{-15}

? WHY SINGLE LINKAGE?

Because it directly answers “who is whose nearest neighbour?”: each element’s first merge is with its nearest neighbour, and the tree matches the minimum spanning tree of the distances.

4

Sustainability, SDGs and carbon footprint

4.1 Activity sustainability index

$$IS_a = (1/5) \sum_c (s_{ac} + 2)/4 \in [0, 1] \quad (7)$$

0.5 is neutral. The system IS is the mean of its activities; it is also reported by step and by type (traditional or innovated). In Calpan: 0.51.

4.2 Sarandón's general index

Following Sarandón (2002), each dimension is expressed on 0–4 through sub-indicators; their translation into app data is a Ratio Telar reading:

DIMENSION	SUB-INDICATORS (0–4)	CALPAN
IK	A margin $4(I - C)/I$ · B distinct products (cap 4) · C $4(1 - \text{steps with external inputs/steps})$	3.11
IE	Mean of $(s_{ac} + 2)$ across activities and compartments	2.05
ISC	A rules with local knowledge · B rules with technical knowledge · C linked institutions	2.67

$$ISGen = (IK + IE + ISC)/3 ; \text{ sostenible si } ISGen > 2 \text{ y } \min(IK, IE, ISC) \geq 2 \quad (8)$$

In Calpan, ISGen = 2.61: sustainable. The margin (IK-A) stays as no data until income and costs are entered; IK averages the available sub-indicators.

4.3 SDG attainment

For each SDG the available evidence is averaged: environmental (mean of $(s_{ac} + 2)/4$ over the linked compartments: SDGs 2, 6, 12, 13 and 15) and structural (activities with technical knowledge or advice, SDG 4; linked institutions, SDG 17; margin, SDGs 1 and 8). Without evidence, “no data”. The compartment–SDG mapping is a Ratio Telaar reading. In Calpan 7 of the 17 have evidence.

4.4 Carbon footprint per hectare

$$\text{CO}_2\text{e} = 2.68 D + N (0.010 + 0.11 \times 0.010 + 0.24 \times 0.011) \times \frac{44}{28} \times 273 + 0.20 U \times \frac{44}{12} \quad (9)$$

D : litres of diesel; N : kg of N applied; U : kg of urea. IPCC default factors (2006; 2019 refinement): EF_1 , $\text{FracGASF} \times \text{EF}_4$ and $\text{FracLEACH} \times \text{EF}_5$; $\text{N}_2\text{O GWP}_{100} = 273$ (AR6, Forster et al., 2021). Divided by yield it gives kg CO_2e per tonne.

5

METHOD

Regeneration index

Eight ordinal indicators $s_k \in \{0, \dots, 4\}$ group the four USDA-NRCS soil health principles (minimal disturbance, soil cover, diversity, living roots) and the processes the regenerative agriculture literature adds (livestock integration, fewer synthetic inputs, organic matter; Newton et al., 2020; Schreefel et al., 2020), plus the Stack's local knowledge.

$$IR = \sum_{k=1}^8 s_k / 32 \in [0, 1] \quad (10)$$

5.1 Suggested-value rules

INDICATOR	RULE (RATIO TELAR READING)	CALPAN
Minimal tillage	n activities with plough, subsoiler or harrow (decisions excluded): 0→4, 1→3, 2→2, 3→1, ≥5→0	1 (n = 4)
Soil cover	2 if there are stubble activities with positive soil impact; otherwise 1	2
Diversity	species by system (milpa 3, MIAF 4...): 1→0, 2→1, 3→2, 4→3, ≥6→4	2
Living roots	3 if the system has perennials; otherwise 2	2
Livestock integration	3 with animals; 2 if fodder is produced; otherwise 0	2
Fewer synthetics	$\text{round}(4 (1 - S / (S + B)))$	0 (S = 16, B = 1)
Organic matter	1, 2 or 3 by residue-returning activities (0, 1, ≥2), +1 with soil testing	4
Local knowledge	$\min(4, \text{round}(8 f))$, f = share of activities with tacit or cultural knowledge, family or own seed	2 (f = 0.19)

With the suggested values, $IR = 15/32 = 0.469$ (47, conventional). Classes: < 0.25 degrading; 0.25–0.49 conventional; 0.50–0.74 regenerative transition; ≥ 0.75 regenerative. Trajectory is measured as ΔIR from a saved baseline and, with soil tests, as $\Delta\%$ organic matter.

You are viewing the published EXAMPLE of Calpan, Puebla. Your data have not changed and nothing here is saved. [Leave the example X](#)

Home 1 Crop 2 Region 3 Requirements 4 Management 5 **Regeneration** 6 Risks 7 Elements 8 Price and value 9 Formulation 10 D

Published example - not your data

The eight regeneration knobs

1 Minimal tillage 1 · Low

✓ Confirmed by you

0 1 2 3 4

How many machinery or plough passes move the soil each cycle? Fewer passes, less erosion and more soil life.

Suggested: 1 - 4 tillage activities practised

[Clear my answer](#)

Soil covered all year 2 · Medium

✓ Confirmed by you

0 1 2 3 4

How many months a year is the soil covered by crop, stubble, mulch or green manure?

Suggested: 2 - stubble is left or incorporated; adjust to months of cover

[Clear my answer](#)

Species diversity 2 · Medium

✓ Confirmed by you

0 1 2 3 4

How many species are grown or raised together in the unit (including trees and animals)?

Suggested: 2 - 3 species according to the chosen system

[Clear my answer](#)

Living roots as long as possible 2 · Medium

✓ Confirmed by you

0 1 2 3 4

How many months a year are there living plants on the plot (crop, cover crop, trees, pasture)?

Suggested: 2 - single-cycle crop; adjust to months with living plants

[Clear my answer](#)

Animals integrated into the system 2 · Medium

✓ Confirmed by you

0 1 2 3 4

Are there animals grazing stubble, providing manure or living in the unit?

Suggested: 2 - fodder is produced for animals

[Clear my answer](#)

Fewer synthetic agrochemicals 0 · None

✓ Confirmed by you

0 1 2 3 4

What share of input activities uses synthetic agrochemicals versus bio-inputs?

Suggested: 0 - 16 activities with agrochemicals and 1 with bio-inputs

[Clear my answer](#)

Organic matter and residues 4 · Very high

✓ Confirmed by you

0 1 2 3 4

Are stubble, manure or compost incorporated, and is soil organic matter measured?

Suggested: 4 - 6 activities returning residues to soil; with soil testing

[Clear my answer](#)

Local knowledge and own seed 2 · Medium

✓ Confirmed by you

0 1 2 3 4

How much does management rely on tacit and cultural knowledge, own seed selection and the family?

Suggested: 2 - 19 % of activities use local knowledge or own seed

[Clear my answer](#)

FIGURE 5.1 The eight indicators with their suggested value and reason.

6

METHOD

Risk and adaptive capacity

Nineteen hazards h in six categories. Each has likelihood P_h and impact I_h on 1–5 (5×5 matrix; IEC 31010:2019, within the ISO 31000:2018 process) and a control $c_h \in \{0, 1, 2, 3\}$. Following the IPCC (2014) framework, risk depends on the hazard and on vulnerability, which adaptive capacity reduces:

$$r_h = P_h I_h (1 - 0.4 CA)(1 - 0.15 c_h) ; \quad \text{índice} = \sum_h r_h / 25H \quad (11)$$

$$CA = \text{mean}(\text{IR}, \text{IK}_B/4, \text{ISC}_B/4, \text{ISC}_C/4) \quad (12)$$

The 0.4 and 0.15 factors are Ratio Telar assumptions. Levels of r : ≤ 4 low, 5–9 medium, 10–15 high, ≥ 16 very high. Suggested values derive from the trend scenario (warming, costs, price, labour) and the share of activities with purchased inputs or local knowledge; the rest stays at 3.

6.1 Hazard catalogue

Each hazard is linked to the Stack elements that transmit it; the link is a Ratio Telar reading and is used to show risk in the Elements and Dashboard blocks.

CATEGORY	HAZARDS	LINKED ELEMENTS
Climatic (6)	Drought or late rains · frost · hail · heavy rain or flooding · heatwave · cyclones and hurricanes	HUM, CLIMA, ENSO, CICL, MJO
Biological (3)	Pests · diseases · resistant or invasive weeds	PLAGA, ARV, HERB
Market (3)	Price fall · rise in input and service costs · middlemen or no buyer	PRECIO, COMP, GRANO, COSTOS, FERTG, PI, TRANS
Social (3)	Labour shortage and no succession · loss of local knowledge · insecurity or theft	PM, FAM, KTAC, KCUL
Institutional (2)	Withdrawal of programmes and support · tenure conflicts	AT, SDR
Natural resources (2)	Erosion and fertility loss · water scarcity	SUELO, HUM

6.2 Suggested-value rules

HAZARD	RULE
Drought, heatwave	$P = 4$ if trend warming is ≥ 0.2 °C per decade; otherwise 3
Input cost rise	$P = 4$ if trend cost grows ≥ 2 %/yr; $I = 1 + \text{round}(4 \min(1, 2f_s))$, f_s = share of activities with purchased inputs
Labour	$P = 4$ if $g_L \leq -1.5$ %; 3 if $g_L < 0$; otherwise 2
Price fall	$P = 4$ if the trend price falls; otherwise 3
Knowledge loss	$I = 1 + \text{round}(4 \min(1, 2f_k))$, f_k = share of activities with tacit, cultural or family knowledge
All others	$P = 3, I = 3$ (moderate; adjust to the locality)

The user can switch off a hazard that does not apply (it leaves H) or overwrite P, I and control; the app flags which values were adjusted.

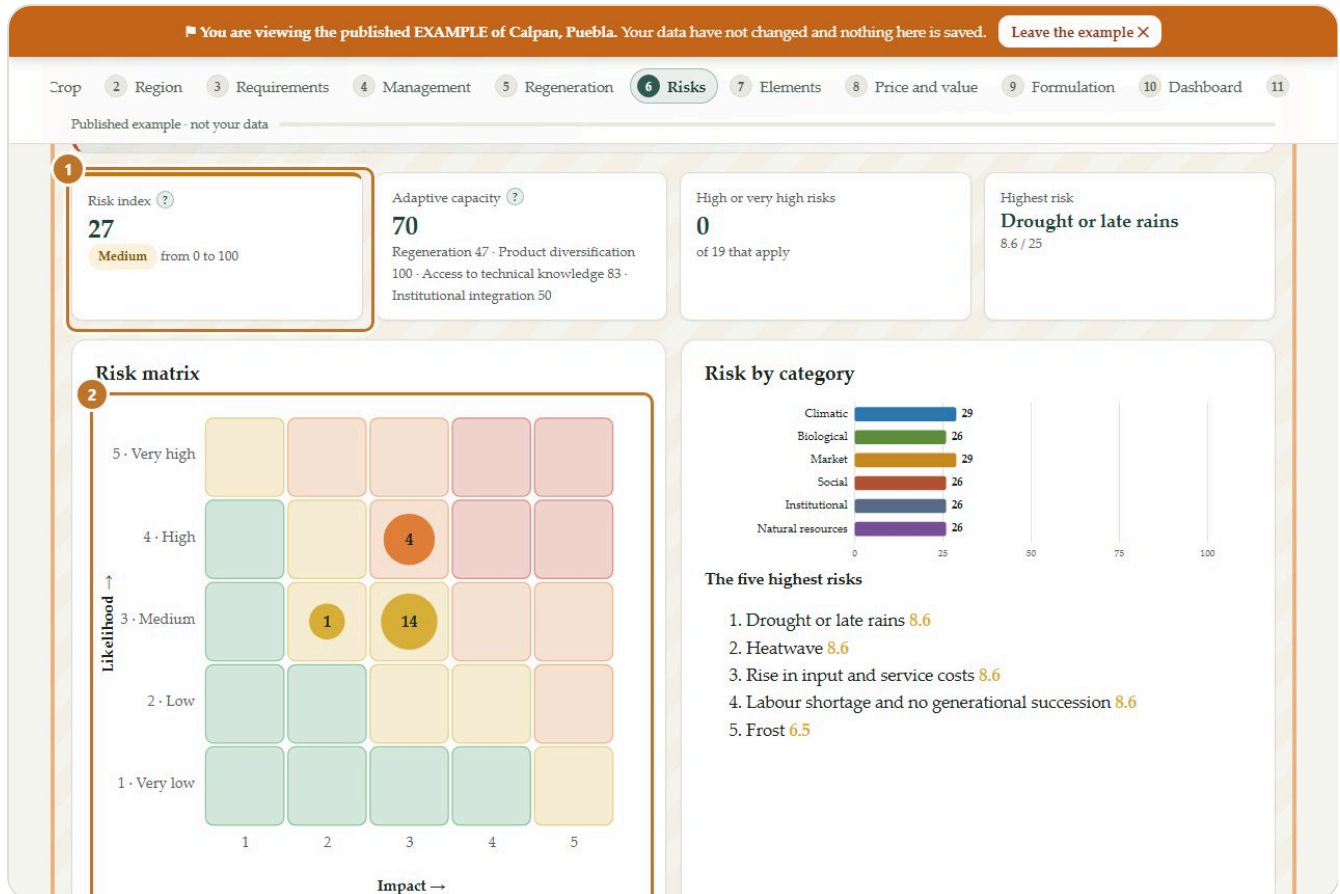


FIGURE 6.1 Calpan risk index and matrix. Index 27, CA = 0.701.



CALPAN

$CA = (0.47 + 1.00 + 0.83 + 0.50)/4 = 0.70$. The four highest hazards (drought, heatwave, input cost rise, labour shortage) have $P = 4$, $I = 3$ and $r = 12 \times 0.72 = 8.6$.

7

METHOD

Scenario model

Three exploratory scenarios (Godet & Durance, 2011) are simulated year by year, $t = 0 \dots 10$. Adoption of innovated activities follows a logistic curve (Rogers, 2003) starting from the current share a_0 :

$$A(t) = a_0 + (A_{\text{m}\acute{\text{a}}\text{x}} - a_0) [\sigma(t - t_{50}) - \sigma(-t_{50})] / [1 - \sigma(-t_{50})] \quad (13)$$

$$Y(t) = 100 [1 + \beta \Delta T t/10] \cdot (1 - p(t) L_{\text{ef}}) / (1 - p_0 L_{\text{ef}}) \cdot [1 + e_Y(A - a_0)] \cdot [1 - 0.5 \text{d}\acute{\text{e}}\text{f}(\text{icit})(t)] \quad (14)$$

$$L_{\text{ef}} = L_{\text{ext}}(1 - 0.5 \text{IR}_0) ; \quad \text{IR}(t) = \text{IR}_0 + 0.5 (1 - \text{IR}_0)(A - a_0) \quad (15)$$

β : yield change per $^{\circ}\text{C}$ (maize -7.4% , wheat -6.0% ; Zhao et al., 2017; -4.9% assumed for others); ΔT : warming per decade (0.1, 0.2 and 0.3°C ; IPCC, 2018 likely range); $p(t)$: extreme-year probability, linear from p_0 to p_{ext} . Price and cost grow at constant rates; available labour declines at rate g_L and required labour falls with adoption. Risk at t recomputes (11) with $P_{\text{climate}} + 5(p(t) - p_0)$ and CA with $\text{IR}(t)$. The 0.5 coefficients are assumptions.

7.1 Price, cost, labour and sustainability

$$Pr(t) = 100 (1 + g_P)^t ; \quad C(t) = 100 (1 + g_C)^t (1 - s_C \Delta A) ; \quad \text{rel} = 100 (Pr \cdot Y/100) / C \quad (16)$$

$$L_d(t) = (1 + g_L)^t ; \quad L_n(t) = 1 - r_L \Delta A ; \quad \text{d}\acute{\text{e}}\text{f}(\text{icit}) = \max(0, L_n - L_d) / L_n \quad (17)$$

$$IS(t) = IS_{\text{trad}} (1 - A) + IS_{\text{inn}} A \quad (18)$$

$\Delta A = A(t) - a_0$, and it is 0 when there are no innovated activities. If the user entered income I_0 and cost C_0 per hectare (Block 8), net income is $I_0 (Pr \cdot Y/100)/100 - C_0 C/100$.

7.2 Default parameters

PARAMETER	DESIRABLE	TREND	UNDESIRE	BASIS
g_P real price (%/yr)	+1	0	-1.5	assumption
g_C real cost (%/yr)	+1	+2	+4	assumption
ΔT (°C per decade)	0.1	0.2	0.3	IPCC (2018)
p_{ext} extreme year by year 10	0.12	0.18	0.25	assumption
g_L labour (%/yr)	-0.5	-1.5	-3	assumption
A_{max} maximum adoption	0.9	0.5	0.15	assumption
t_{50} half-adoption year	4	6	9	Rogers (2003)

Common to the three scenarios: $p_0 = 0.10$; $L_{\text{ext}} = 30$ % loss in an extreme year; adoption effect on yield $e_Y = 10$ %, on cost $s_C = 5$ % and on required labour $r_L = 15$ %. All are editable assumptions in the Block 12 assumptions table.

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6 Risks 7 Elements 8 Price and value 9 Formulation 10 Dashboard 11 Sustainability 12 Outlook 13 Report Validation Theory

Published example - not your data

Assumptions per scenario

1 **Variable** **Desirable (potentials)** **Trend** **Undesired** **Basis** 2 [Reset to defaults](#)

Real product price (% per year)	1	0	-1.5	♦ RATIO TELAR READING
Real input and service cost (% per year)	1	2	4	♦ RATIO TELAR READING
Warming (°C per decade)	0.1	0.2	0.3	♦ IPCC (2018)
Probability of an extreme year by year 10 (drought, frost, cyclone)	0.12	0.18	0.25	♦ RATIO TELAR READING
Available family labour (% per year)	-0.5	-1.5	-3	♦ RATIO TELAR READING
Maximum innovation adoption (0-1)	0.9	0.5	0.15	♦ RATIO TELAR READING
Year half of adoption is reached	4	6	9	♦ ROGERS (2003)

Common assumptions

Yield change per +1 °C (%)	Current probability of an extreme year	Yield loss in an extreme year (%)
-7.4	0.1	30
♦ Zhao et al. (2017), Landrace maize	♦ Assumption	♦ Assumption
Extra yield with full innovation adoption (%)	Cost saving with full adoption (%)	Labour saving with full adoption (%)
10	5	15
♦ Assumption	♦ Assumption	♦ Assumption

Labour and prices vary by region: check the assumptions against INEGI's Agricultural Census and ENOE, and SIAP prices for your municipality.

FIGURE 7.1 Assumptions table with its basis: IPCC, Rogers or assumption.

CALPAN, T = 10 (TODAY = 100)	DESIRABLE	TREND	UNDESIRE
Yield	96	90	82
Gross income ÷ cost	96	74	48
Available labour	95	86	74
Risk index (0-100)	28	28	29

8

METHOD

Territory and map

States, municipalities and localities come from INEGI's Geostatistical Catalogue and 2020 Population and Housing Census, with population, altitude and coordinates. Regions are Banco de México's (North, North-central, Central and South). Outlines are from Natural Earth (public domain). To place each locality on the map a projection was fitted:

$$x = 32.355 (\lambda + 102) \cos^{0.4375} \varphi + 514.57 ; \quad y = -34.346 \varphi + 1122.86 \quad (19)$$

95.4 % of localities fall inside their state outline; the point is approximate.

9

EVIDENCE AND USE

Validation

9.1 Reproduction of the published case

The app checks that the loaded case matches the paper: 38 steps and 5 rules, 38 leaves in the Figure 3 dendrogram, 100 Table 1 participants and 11 published knowledge-intensity values.

You are viewing the published EXAMPLE of Calpan, Puebla. Your data have not changed and nothing here is saved. [Leave the example X](#)

RatioTelar EXAMPLE · Landrace maize · Calpan ES EN 🔧 Producer 🔬 Scientist ⚙️ ?

6 Risks 7 Elements 8 Price and value 9 Formulation 10 Dashboard 11 Sustainability 12 Outlook 13 Report **✓ Validation** § Theory

Published example · not your data

— PLATFORM EVALUATION

Validation

A scientific tool must prove it computes correctly. Here, in your own browser, Ratio Telar is checked to reproduce the case's published data and its network engine is shown to give the same numbers as an independent reference library.

Published example - these data are from the Calpan, Puebla case; they are not yours

1 · Reproduction of the published case (landrace maize, Calpan)

Check	Paper	Ratio Telar	
Stack steps	38	38	✓
Basic rules (5B)	5	5	✓
Dendrogram leaves (Figure 3)	38	38	✓
Participants (Table 1)	100	100	✓
Published IIC values	11	11	✓
Activities	83	85	see note
Activities linked to elements	—	85 / 85	✓

Transcribing Figure 4 yields 85 activity lines; the paper reports 83. Ratio Telar keeps the full transcription and the official figure.

Source: Díaz-José et al. (2026). doi:10.22231/asud.n23i3.1822

FIGURE 9.1 The app's validation block.

9.2 Network engine against NetworkX

TEST	MAXIMUM DIFFERENCE
Krackhardt (1990) kite: betweenness, closeness, clustering, eigenvector, mean path	< 0.00005
Maize network without PM (60 nodes, 158 links): weighted betweenness	0
Partition Q (0.4496), mean clustering (0.5252), mean path (2.9017)	0

For reference, NetworkX's randomised Louvain (seed 1) finds a 5-community partition with $Q = 0.4422$; Ratio Telar's (7 communities, $Q = 0.4496$) has higher modularity.

9.3 Cladogram against SciPy

Merge heights and cophenetic correlation for the three subsets match `scipy.cluster.hierarchy.linkage(method='single')` and `cophenet` (SciPy 1.18) on NetworkX distances with differences below 10^{-14} (chapter 3 table).

10

EVIDENCE AND USE

Reproducibility and export

10.1 Code and tests

bash

```
git clone https://github.com/hectortecumshe-ai/RatioTelar
cd RatioTelar
python armar.py                # arma index.html desde src/
python pruebas/verificar_red.py # red frente a NetworkX
python pruebas/verificar_clado.py # cladograma frente a SciPy
```

10.2 Data for analysis

Block 13 exports to CSV the activities (with their five impacts and IS), nodes (value, participation, neighbours, weighted degree, betweenness, closeness, eigenvector, clustering, community), links (weight and number of activities), calendar, SDGs and cladogram (merges and nearest neighbours). [Save project](#) produces a JSON with the full state, which reproduces any result.

10.3 Deep links

The address accepts #block/view/language, for example .../RatioTelar/#tablero/cien/en. This guide's screenshots were taken this way, automatically.

10.4 Published case and user data

Since version 0.5.0 the app starts blank. The Calpan case is loaded only in an **example mode** that is never saved (`estadoCalpan()`: maize, milpa, Calpan, sowing on day 79 and all 85 activities answered "yes"); with it the full network reproduces the values in this guide (61 nodes, 209 links; without PM, $Q = 0.4496$). In a user project, the structural ties documented in Calpan enter only if they touch an element of the user's activities, and Figure 4 date windows are not used as the user's dates. Suggested regeneration and risk values count in the index, flagged as provisional, until the user confirms them. Project files carry `formato: 2`; older ones are converted on opening.

10.5 Scope and limits

- The only case with a documented Stack is Calpan landrace maize; other crops are documented with user data.

- Activity–element links, impact profiles, the SDG mapping, regeneration rules and risk factors are Ratio Telar readings, flagged and editable.
- Scenarios are not forecasts; their value lies in comparing explicit assumptions.
- SIAP municipal crop production will be added when its open-data service is available.

You are viewing the published EXAMPLE of Calpan, Puebla. Your data have not changed and nothing here is saved. [Leave the example](#) ×

RatioTelar EXAMPLE · Landrace maize · Calpan ES EN [Producer](#) [Scientist](#) * ?

6 Risks 7 Elements 8 Price and value 9 Formulation 10 Dashboard 11 Sustainability 12 Outlook 13 Report ✓ Validation **§ Theory**

Published example · not your data

FOUNDATIONS

Theoretical framework

The ideas behind Ratio Telar: complex adaptive systems, local knowledge, integrated strategic management, networks, regeneration, risk, foresight and sustainability.

Published example these data are from the Calpan, Puebla case; they are not yours

▼ The complex adaptive system

A complex adaptive system consists of heterogeneous agents that interact locally, learn and adapt; patterns no agent designed emerge from those interactions (Holland, 1995). A milpa or a farm is one: farmers, seeds, soil, water, knowledge, institutions and markets feeding back each cycle. García (2006) proposes studying them as organised wholes whose elements cannot be separated, and Morin (1990) as what is “woven together” (complexus), the root of this suite line’s name.

► Order, chaos and resilience

► The local knowledge stack

► Integrated Strategic Management and environmental rationality

► Networks and statistics

► Regeneration and risk

FIGURE 10.1 Theoretical framework inside the app, with its bibliography.

11

Worked example: Calpan by hand

Every number in this chapter can be redone with a calculator and matches what app 0.4.0 shows.

11.1 Regeneration

$$IR = (1 + 2 + 2 + 2 + 2 + 0 + 4 + 2) / 32 = 15 / 32 = 0.469 \quad (10)$$

Class: conventional (0.25–0.49). Raising “fewer synthetics” from 0 to 2 and “tillage” from 1 to 2 would take IR to $18/32 = 0.56$, in transition.

11.2 Adaptive capacity and drought risk

$$CA = (0.469 + \frac{4}{4} + 3.\frac{33}{4} + \frac{2}{4}) / 4 = (0.469 + 1.00 + 0.833 + 0.50) / 4 = 0.7005 \quad (12)$$

$$r_{\text{sequía}} = 4 \times 3 \times (1 - 0.4 \times 0.7005) \times (1 - 0.15 \times 0) = 12 \times 0.7198 = 8.64 \quad (11)$$

Medium level (5–9). With the 19 hazards active, $\Sigma r / (25 \times 19) = 0.273$: index 27. Partial control ($c = 2$) of drought would lower its r to $8.64 \times 0.70 = 6.05$.

11.3 Sarandón general index

$$ISGen = (3.11 + 2.05 + 2.67) / 3 = 2.61 > 2 \text{ y } \min = 2.05 \geq 2 \Rightarrow \text{sostenible} \quad (8)$$

The ecological dimension (2.05) is the closest to the threshold: it is the main lever, and it matches the low “fewer synthetics” score in IR.

11.4 Trend scenario at 10 years

In the Calpan base case there are no active innovated activities, so $a_0 = 0$ and $\Delta A = 0$ throughout.

TERM	COMPUTATION	VALUE
Climate	$1 - 0.074 \times 0.2 \times 10/10$	0.9852
Effective loss	$30 \times (1 - 0.5 \times 0.469)$	22.97 %
Extreme year	$(1 - 0.18 \times 0.2297) / (1 - 0.10 \times 0.2297)$	0.9812
Available labour	$(1 - 0.015)^{10}$	0.8597
Shortfall factor	$1 - 0.5 \times (1 - 0.8597)$	0.9299
Yield Y	$100 \times 0.9852 \times 0.9812 \times 0.9299$	89.9
Cost C	100×1.02^{10}	121.9
Income ÷ cost	$100 \times (100 \times 0.899) / 121.9$	73.7

The app reports 90 and 74, these values rounded. Risk at 10 years is 28: climate likelihood rises $5 \times (0.18 - 0.10) = 0.4$ points, but adaptive capacity does not change because there is no adoption.

11.5 Carbon footprint (illustrative example)

Hypothetical values, not from Calpan: 60 L of diesel and 100 kg of N per hectare, all as urea (217 kg; 46 % N).

$$2.68 \times 60 + 100 \times 0.01374 \times 44/28 \times 273 + 0.20 \times 217 \times 44/12 = 160.8 + 589.4 + 159.1 = 909 \text{ kg CO}_2\text{e/ha} \quad (9)$$

$0.01374 = 0.010 + 0.11 \times 0.010 + 0.24 \times 0.011$. With 3 t of grain per hectare this is 303 kg CO₂e per tonne. Fertiliser N₂O contributes almost two thirds.



Technical glossary

Brandes algorithm <i>Brandes (algoritmo)</i>	Exact betweenness computation in $O(nm + n^2 \log n)$ for weighted networks (Brandes, 2001).
Adaptive capacity (CA) <i>Capacidad adaptativa (CA)</i>	Mean of regeneration and three Sarandón sub-indicators (diversification, technical knowledge, institutional integration), on 0–1.
Cophenetic correlation <i>Correlación cofenética</i>	Pearson correlation between original distances and the tree's merge heights (Sokal & Rohlf, 1962).
Single linkage <i>Enlace simple</i>	Agglomerative clustering in which the distance between groups is that of their closest pair of members (Sneath, 1957).
Exploratory scenario <i>Escenario exploratorio</i>	Possible future built on explicit assumptions, with no assigned probability (Godet & Durance, 2011).
GWP100 <i>GWP100</i>	100-year global warming potential; 273 for N_2O (AR6).
Incidence <i>Incidencia</i>	Binary elements $\times$ activities matrix: 1 if the element takes part in the activity.
Ratio Telar reading <i>Lectura de Ratio Telar</i>	Value, rule or grouping proposed by the app and not published in the source; it is flagged and editable.
Louvain <i>Louvain</i>	Community detection method maximising modularity through local moves and aggregation (Blondel et al., 2008).
Modularity (Q) <i>Modularidad (Q)</i>	Fraction of weight within communities minus that expected at random (Newman, 2006).
Foresight <i>Prospectiva</i>	Discipline building possible futures to guide present decisions (Berger; de Jouvenel; Godet).
Local knowledge stack <i>Stack de conocimiento local</i>	Layered structure of farming knowledge: rules, steps and activities (Díaz-José et al., 2026).

Structural value <i>Valor estructural</i>	An element's relative participation in activities, used as default value.
Eigenvector centrality <i>Vector propio</i>	Centrality proportional to that of neighbours; obtained by power iteration.

B

References, how to cite and legal page

1. Blondel VD, Guillaume J-L, Lambiotte R, Lefebvre E. 2008. Fast unfolding of communities in large networks. *Journal of Statistical Mechanics* P10008.
2. Brandes U. 2001. A faster algorithm for betweenness centrality. *Journal of Mathematical Sociology* 25(2): 163–177.
3. CONABIO. 2020. Razas de maíz de México. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad.
4. Díaz-José O, Mojica-Zárata HT, Díaz-José J, Vilaboa-Arróniz J. 2026. El conocimiento agrícola local: el stack del maíz criollo en Calpan, Puebla. *Agricultura, Sociedad y Desarrollo* 23(3). <https://doi.org/10.22231/asyd.v23i3.1822>
5. Forster P, et al. 2021. The Earth's energy budget, climate feedbacks, and climate sensitivity. En: *Climate Change 2021: The Physical Science Basis*. Cambridge University Press.
6. Freeman LC. 1978. Centrality in social networks: conceptual clarification. *Social Networks* 1(3): 215–239.
7. Godet M, Durance P. 2011. *La prospectiva estratégica para las empresas y los territorios*. Dunod/UNESCO.
8. Hagberg AA, Schult DA, Swart PJ. 2008. Exploring network structure, dynamics, and function using NetworkX. *Proceedings of the 7th Python in Science Conference*: 11–15.
9. Holland JH. 1995. *Hidden order: how adaptation builds complexity*. Addison-Wesley.
10. IEC. 2019. IEC 31010:2019 Risk management — Risk assessment techniques.
11. INEGI. 2020. Censo de Población y Vivienda 2020; Catálogo Único de Claves Geoestadísticas.
12. IPCC. 2006, 2019. Guidelines for National Greenhouse Gas Inventories, vol. 4, y su refinamiento de 2019.
13. IPCC. 2014. Summary for Policymakers. En: *Climate Change 2014: Impacts, Adaptation, and Vulnerability*. Cambridge University Press.
14. IPCC. 2018. Summary for Policymakers. En: *Global Warming of 1.5 °C*.
15. ISO. 2018. ISO 31000:2018 Risk management — Guidelines.
16. Krackhardt D. 1990. Assessing the political landscape: structure, cognition, and power in organizations. *Administrative Science Quarterly* 35(2): 342–369.
17. Mojica Zárata HT. 2017. *Modelo y procedimiento para la gestión estratégica integrada de los recursos naturales en territorios áridos con orientación agroproductiva*. Tesis doctoral, Universidad Central

«Marta Abreu» de Las Villas.

18. Newman MEJ. 2006. Modularity and community structure in networks. *PNAS* 103(23): 8577–8582.
19. Newton P, Civita N, Frankel-Goldwater L, Bartel K, Johns C. 2020. What is regenerative agriculture? *Frontiers in Sustainable Food Systems* 4: 577723.
20. Rogers EM. 2003. *Diffusion of innovations*, 5.^a ed. Free Press.
21. Sarandón SJ. 2002. El desarrollo y uso de indicadores para evaluar la sustentabilidad de los agroecosistemas. En: Sarandón SJ (ed.), *Agroecología: el camino hacia una agricultura sustentable*. Ediciones Científicas Americanas: 393–414.
22. Schreefel L, Schulte RPO, de Boer IJM, Schrijver AP, van Zanten HHE. 2020. Regenerative agriculture – the soil is the base. *Global Food Security* 26: 100404.
23. Sneath PHA. 1957. The application of computers to taxonomy. *Journal of General Microbiology* 17(1): 201–226.
24. Sokal RR, Rohlf FJ. 1962. The comparison of dendrograms by objective methods. *Taxon* 11(2): 33–40.
25. Sokal RR, Sneath PHA. 1963. *Principles of numerical taxonomy*. W. H. Freeman.
26. Virtanen P, et al. 2020. SciPy 1.0: fundamental algorithms for scientific computing in Python. *Nature Methods* 17: 261–272.
27. Wasserman S, Faust K. 1994. *Social network analysis: methods and applications*. Cambridge University Press.
28. Watts DJ, Strogatz SH. 1998. Collective dynamics of ‘small-world’ networks. *Nature* 393: 440–442.
29. Zhao C, et al. 2017. Temperature increase reduces global yields of major crops in four independent estimates. *PNAS* 114(35): 9326–9331.

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App: [hectortecumshe-ai.github.io/RatioTelar](https://github.com/hectortecumshe-ai/RatioTelar)
Code: github.com/hectortecumshe-ai/RatioTelar

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