



Food and Agriculture
Organization of the
United Nations

GLOBAL SYMPOSIUM ON SOIL INFORMATION AND DATA

MEASURE
MONITOR
MANAGE

NATIONAL ATLAS OF MEXICO 2022 THE ANTHROPOGENIC IMPACT ON THE SOIL

Carlos Omar Cruz-Gaistardo

September 25-28, 2024
Nanjing, China





HUMANITY'S CRITICAL PROBLEMS

- Exponential population growth
- Consumptions patterns

LEAD TO OTHER BIG PROBLEM

Ever-increasing soil degradation in pursuit of progress



SOIL CHANGES ON MEXICO 2000-2022

5 Mha deforested soils

0.8 Mha recent sealing or hypersalinity

2.1 Mha new accelerated soil erosion

What can we still recover?



The **National Atlas of Mexico** data and information aims to support public policies and community activities focused on reducing or reversing soil degradation.



Tijuana

Chihuahua

Monterrey

Culiacán

La Paz

Guadalajara

Tuxpan

Ciudad de México

Acapulco

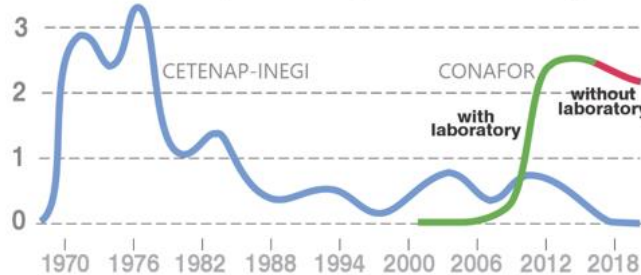
Tuxtla Gutiérrez

Mérida

>200,000 study sites depurated

Study sites in Mexico, 1968-2022

Thousands of soil profiles or conglomerates with drillings



LAMBERT CONICAL
PROJECTION
DATUM: ITRF2008
1:15,000,000
RESOLUTION: 10 m
160 km

2.0
0.5
0.1
MILLION
HECTARES



NATIONAL SOIL SURVEY

SOIL SURVEY SOURCES

- CETENAP-INEGI
1968 a 2022
- CONAFOR
2001-2022

SURVEY PERIODS: CETENAP (1968-1970), CETENAL (1970-1980), DETENAL (1980-1982), DGGTENAL (1982-1983) INEGI (1983-2022), CONAFOR (2001-2022).

SOURCE: CRUZ-GAISTARDO. NATIONAL ATLAS OF MEXICO 2022 (PRELIMINARY VERSION). INSTITUTE OF GEOGRAPHY. UNAM..
DATASETS: SOIL PROFILES CAPTURE SYSTEM FROM THE NATIONAL INSTITUTE OF STATISTICS AND GEOGRAPHY (INEGI). DATA SET OF DRILLING AND SOIL PROFILES BY THE NATIONAL FORESTRY COMMISSION (CONAFOR).




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print [list (BP-161)]
Landscape 10-12-220-0/02
Microbas RH14Ab
Microfor LS
Elevation 1506.5
Inclination 11.3
Direction VV
RockType OptDA
SoilForm residual
KopenC1 (A)C(w1)(w)
AATemper 20.9
TAPrecip 675.0
MMRadiat 497.0
SoilWRB Vrcru
AgricDro 0.5
AridityI 0.6
Informant NN
Vegetation No
LandUse TA
Crop/Spec Agave t.
Fallow No
Machine1 Subsoleo 60cm
Machine2 Rastra
Seeds Hijuelos 4 años
Crop den 31 (100m2)
FertiType Nitrato de Calcio
FertiQual 30g/planta
OrgFerti No
Pest/Dis Picudo del Agave
Agrochem Folidol M-50
CargoCap 2 ton
Restorat No
Financin No
Depth 64
StonesIn 0.2
StonesSu 0.1
Texture C (44 29 27)
Destruct 2.54-2.70
BulkDens 1.32
OrgancM 0.0
MulchLit 0.05
Munsell- 7.5YR 3/2
CIELab-h 38.68 13.64 34.73
CElectri 1.1
pH 6.2
CIC/PSB C3P4
CaCO3 0.0
SOCarbon 75.8
```

>2.2 million agricultural plots integrated

with environmental, management practices and laboratory data

SOIL BASELINES

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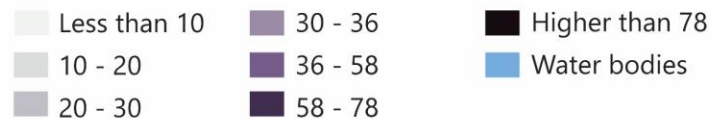
SOIL ORGANIC CARBON INDICATORS

National stock 9.9 Pg C 30 cm
National average 51.8 ± 38.4 Mg C ha
Range [0.5 – 465] Mg C ha

0.5 Mg.C.ha

SOIL ORGANIC CARBON

TONS PER HECTARE OF COS (SURFACE 30 CM)



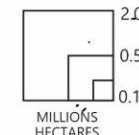
NOTE: THE VALUES OF ORGANIC MATTER (MOS) OBTAINED BY THE TOTAL DRY COMBUSTION METHOD MAY HAVE A SIGNIFICANTLY HIGHER PRECISION RESPECT TO THE VALUES OBTAINED BY WET COMBUSTION METHOD (WALKLEY BLACK) ESPECIALLY IN SOILS WITH MORE THAN 6% MOS OR WITH MORE THAN 10% CALCIUM CARBONATES.

SOURCE: CRUZ, ETCHEVERS Y GALLARDO. NATIONAL ATLAS OF MEXICO 2022. INSTITUTO DE GEOGRAFÍA. UNAM



DATASETS: VALUES OF DEPTH, STONENESS, BULK DENSITY AND ORGANIC MATTER OF THE SOIL HORIZONS (INEGI 1968-2020). CONGLOMERATES FROM THE NATIONAL FOREST AND SOIL INVENTORY (FIELD DATA 2004-2020), LABORATORY DATA 2015-2016). STUDY SITES OF THE WORLD SOIL CONGRESS (INEGI-NRCS, 1994) AND THE NATIONAL CONGRESSES OF SOIL SCIENCE. SOIL DATASETS OF THE NATIONAL GEOLOGICAL SERVICE (SGM), UNAM, UACH, UNICACH, ECOSUR, INIFAP, COLPOSY UAAAN.

LAMBERT CONICAL
PROJECTION
DATUM: ITRF2008
1:15,000,000
RESOLUTION: 250 m
160 km



465 Mg.C.ha

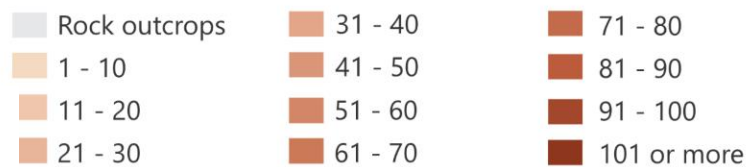


SOIL DEPTH INDICATORS

National average 49 ± 25 cm
 Rainfed soils 58 ± 24 cm
 Irrigated soils 75 ± 20 cm

SOIL DEPTH

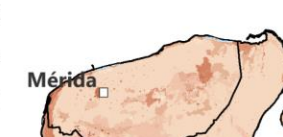
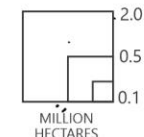
UNITS IN CENTIMETERS



SOURCE: CRUZ-GAISTARDO. NATIONAL ATLAS OF MEXICO 2022 (PRELIMINARY VERSION). INSTITUTE OF GEOGRAPHY, UNAM.

DATASETS: SOIL PROFILES CAPTURE SYSTEM (INEGI). LABORATORY DATA FROM SAMPLES OBTAINED BY CONAFOR AND ANALYZED BY INIFAP (TORREON-TEPIC), ECOSUR (SAN CRISTOBAL DE LAS CASAS), AND THE POSTGRADUATE COLLEGE (MONTECILLO-VILLAHERMOSA). LABORATORY DATA OBTAINED AND ANALYZED BY THE FACULTY OF HIGHER STUDIES OF ZARAGOZA AND THE UNIVERSITY OF SCIENCES AND ARTS OF CHIAPAS.

LAMBERT CONICAL
 PROJECTION
 DATUM: ITRF2008
 1:15,000,000
 RESOLUTION: 100 m
 160 km



Tijuana

SOIL BULK DENSITY INDICATORS

National avg	$1.27 \pm 0.33 \text{ Mg.m}^{-3}$
Mineral soils	$[0.65 - 1.84] \text{ Mg.m}^{-3}$
Organic soils	$[0.25 - 0.85] \text{ Mg.m}^{-3}$

1.84 Mg.C.ha

SOIL BULK DENSITY

ESTIMATED VALUE IN TONS PER CUBIC METER

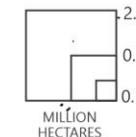
Less than 0.90	1.31 - 1.40
0.91 - 1.17	1.41 - 1.50
1.18 - 1.24	More than 1.50
1.25 - 1.30	Water bodies



SOURCE: CRUZ, CASTORENA Y ETCHEVERS. NATIONAL ATLAS OF MEXICO 2022 (PRELIMINARY VERSION). INSTITUTE OF GEOGRAPHY, UNAM.

DATASETS: (1) DATASETS ON TEXTURE, SHAPE, AND DEGREE OF COMPACTION OF THE SOIL STRUCTURE (INEGI, 1968-2020). (2) CALIBRATION SITES OF BULK DENSITY (CONAFOR-REDLABS: INIFAP COAHUILA-NAYARIT, COLPOS MONTECILLO-VILLAHERMOSA, INEGI AND ECOSUR, 2015-2016). STUDY SITES OF THE WORLD SOIL CONGRESS (NRCS-INEGI, 1994).

LAMBERT CONICAL
PROJECTION
DATUM: ITRF2008
1:15,000,000
RESOLUTION: 900 m
160 km



0.25 Mg.C.ha

0.65 Mg.C.ha



SOIL CHANGE FACTORS

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Tijuana

SOIL DEFORESTATION 2000-2021

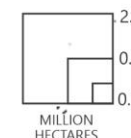
National Forest Baseline 2000 46.5 Mha
National lost 10.8 % forest baseline 2000
Gross lost 256 k ha yr (0.5% f-baseline)



SOURCE: CRUZ-GAISTARDO, GONZALEZ-MURGUIA, FARRERA-SARMIENTO ET AL. NATIONAL ATLAS OF MEXICO 2022 (PRELIMINARY VERSION). INSTITUTE OF GEOGRAPHY. NATIONAL AUTONOMOUS UNIVERSITY OF MEXICO.

DATASETS: GLOBAL FOREST CHANGE 2000-2021, CORRECTED AND UPDATED WITH INFORMATION FROM THE GOVERNMENT OF NORWAY (GN-UNDP-FAO), OBTAINED THROUGH NATIONAL PHOTO INTERPRETATION AT A SCALE OF 1:20,000, AND WITH INFORMATION FROM THE CRITICAL FOREST CHANGE PROJECT (CFC 2000-2022), OBTAINED THROUGH PHOTO INTERPRETATION OF STRATEGIC AREAS AT 1:10,000 SCALE, NUMERICAL DATA ANALYSIS AND PHOTOGRAPHIC REVIEW OF THE NATIONAL FORESTRY AND SOIL INVENTORY OF THE NATIONAL FORESTRY COMMISSION (CONAFOR 2004-2018).

LAMBERT CONICAL
PROJECTION
DATUM: ITRF2008
1:15,000,000
RESOLUTION: 100 m
160 km



Mérida

2000-2021

DEFORESTATION FACTOR OF CHANGE IN SOILS

TYPE OF DEFORESTATION

- | | |
|---|---|
| ■ Loss of dense tree strata | ■ Tree strata in balance |
| ■ Loss of shrub and tree strata | ■ Non-tree strata |





Industrial loss
38.9% deforestation
(11 k biggest parcels)

18,600
TREES/YEAR/PARCEL



Community loss
8.5% deforestation
(300 k smallest parcels)

60
TREES/YEAR/PARCEL



0.0028% yr⁻¹ SOC National Stock

It is being lost only due to deforestation



SOIL HUMAN IMPACTS

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STRONG/EXTREME SALINIZATION

Agricultural soils	427 k ha
Rainfed soils	28 k ha
Irrigated soils	399 k ha (93.7%)

SALINIZATION AND SODIFICATION OF THE SOIL

Critical zone of salinization and sodification

▲ Soils with pH greater than 10 and sodium saturation of 100%

SALINITY OR
NATURAL SODICITY

Strong

Moderate or light

Not saline and not sodium

Water bodies

ANTHROPOGENIC SALINIZATION
OR SODIFICATION

Intense on strongly saline or sodic soils

Intense on moderately saline or sodic soils

Intense on basic, slightly saline, or sodic soils

Light or moderate on basic, non-saline, and non-sodic soils



SOURCE: CRUZ, LOBO Y GALLARDO. NATIONAL ATLAS OF MEXICO 2022 (PRELIMINARY VERSION). INSTITUTE OF GEOGRAPHY. NATIONAL AUTONOMOUS UNIVERSITY OF MEXICO.

DATASETS: (a) INFORMATION ON SOIL PROFILES FROM INEGI 1968-2021. (b) ALPHANUMERIC INFORMATION ON THE QUALITY OF GROUNDWATER AND INFORMATION ON WETLANDS IN MEXICO (INEGI, 2001 AND 2018). (c) INFORMATION SYSTEM OF AGRICULTURAL PARCELS REGISTERED IN THE PROCAMPO PROGRAM (SAGARPA, 2017). (d) GUIDES FOR THE DETERMINATION OF WATER REQUIREMENTS (Kc) OF CROPS (STUDY 56, FAO, 2000). (e) INFORMATION SYSTEM ON DEFORESTATION AND LAND USE CHANGES OBTAINED BY PHOTO INTERPRETATION IN THE CRITICAL FOREST CHANGE PROJECT (2000-2023). (f) SALINITY AND SODICITY VARIABLES AND THRESHOLDS ESTABLISHED BY THE WORLD REFERENCE BASE FOR SOIL RESOURCES (IUSS-FAO, 2014).

LAMBERT CONICAL
PROJECTION
DATUM: ITRF2008
1:15,000,000
RESOLUTION: 100 m
160 km

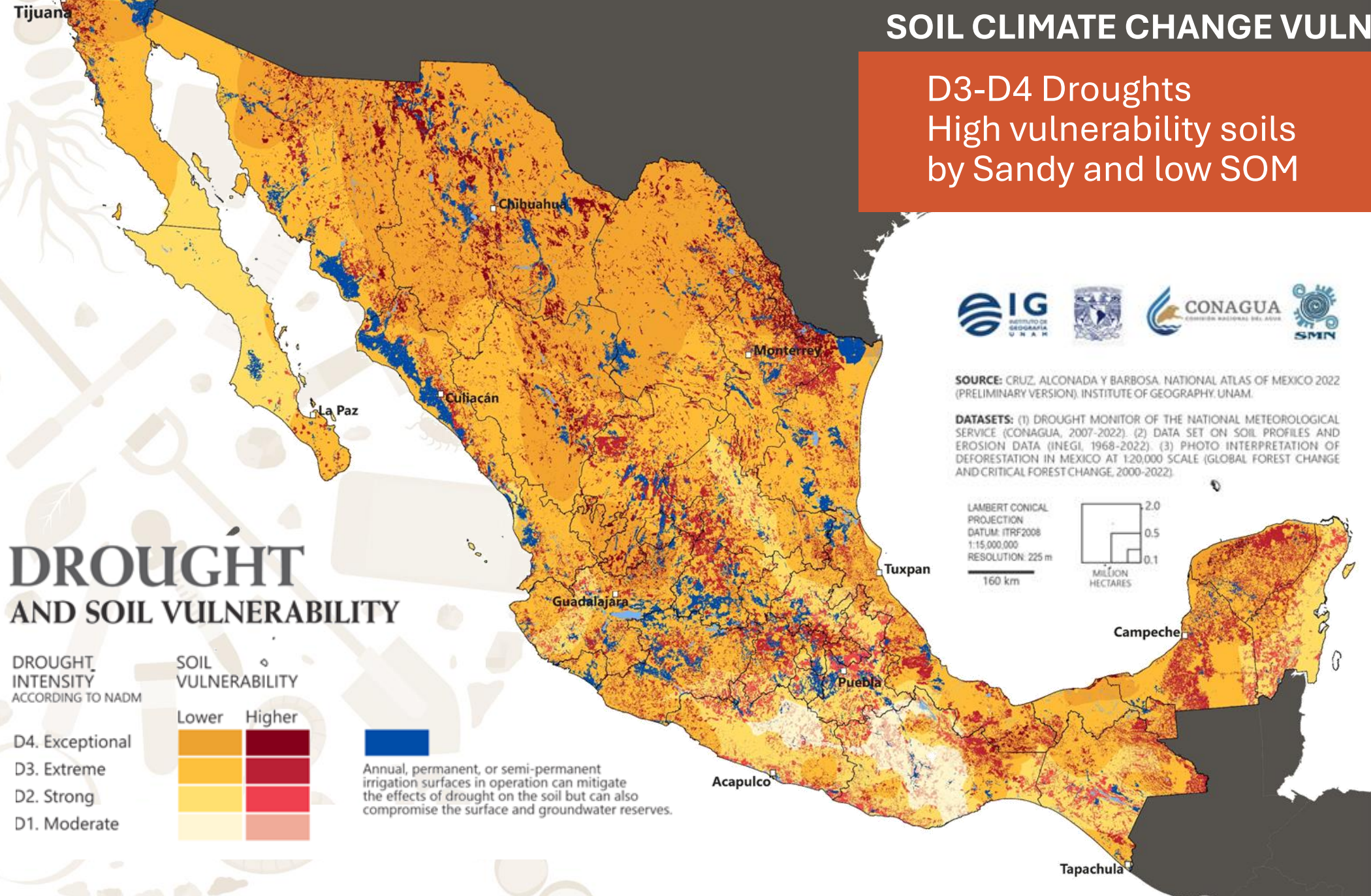
2.0
0.5
0.1
MILLION
HECTARES



SOIL CLIMATE CHANGE VULNERABILITY

D3-D4 Droughts
High vulnerability soils
by Sandy and low SOM

156 M ha
24 M ha
14 M ha



EROSION, POVERTY AND MIGRATION

383k

emigrants
per year

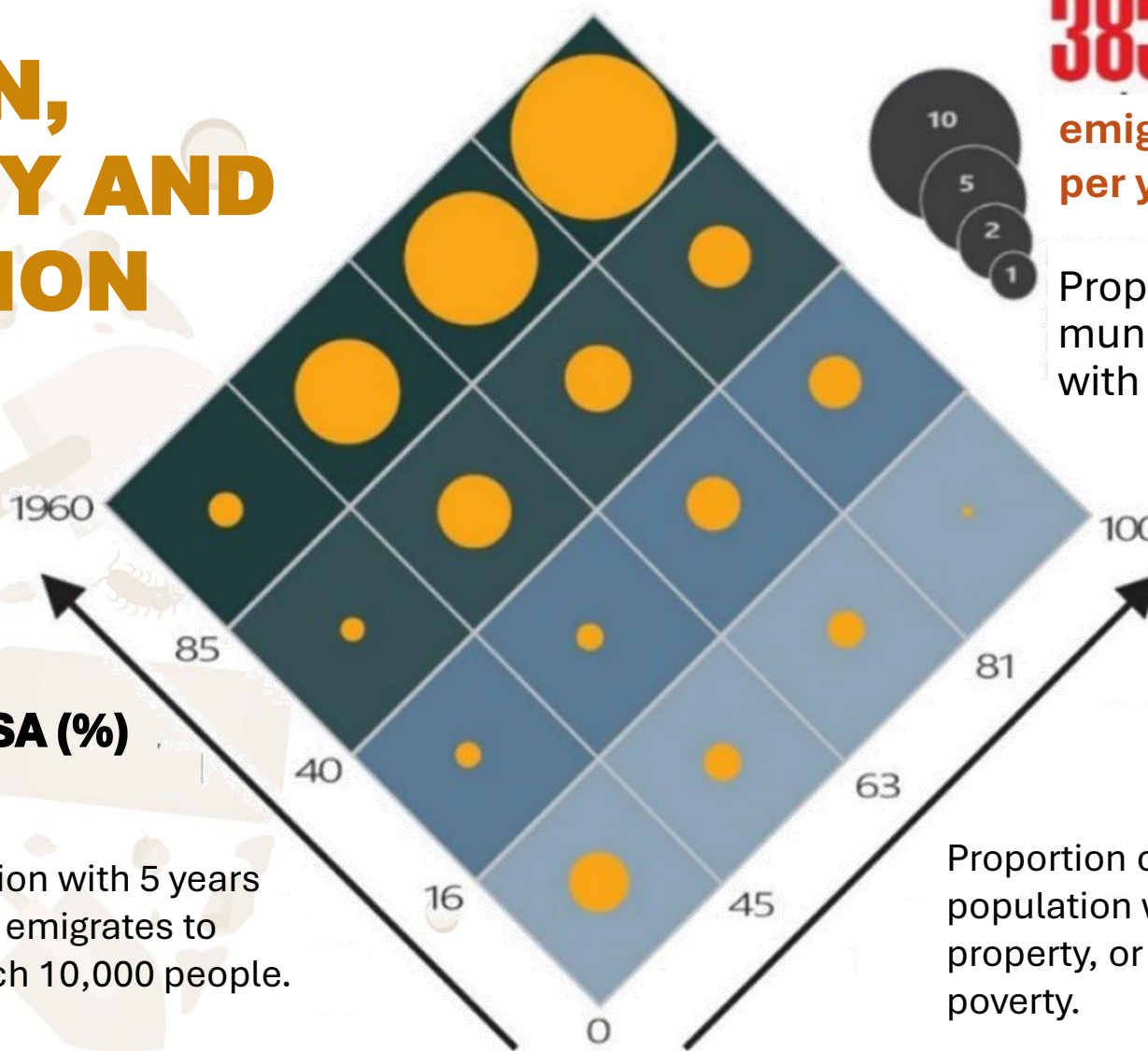
Proportion of
municipal surface
with total erosion

**Largest rural
emigration to USA (%)**

Population with 5 years
or more emigrates to
USA each 10,000 people.

**Highest rural
poverty (%)**

Proportion of the total
population with food,
property, or satisfaction
poverty.



Tijuana

Chihuahua

Monterrey

La Paz

Culiacán

Guadalajara

Ciudad de México

Tuxpan

Tuxtla Gutiérrez

Huatulco

RECOVERING FEDERAL PROGRAMS

Growing Life Budget
Area of recovering
Farmers involved

1,500 M USD yr
1.1 M ha
441 k

PRESERVING THE FUTURE OF SOIL

FOREST AND SOIL PRESERVATION, CONSERVATION
AND RESTORATION ZONES IN MEXICO

Unprotected

Protected

Soils with higher MOS content

Soils with dense tree strata

Soils with the agro-forestry restoration
of the Sembrando Vida Program

Soils associated with the
conservation of Strategic Wetlands

ANP-ADVC
Conservation Areas

Areas with Payments
for Environmental Services

Soil Conservation Works and Practices
on Slopes and Erosion Gullies in 2022



BIENESTAR



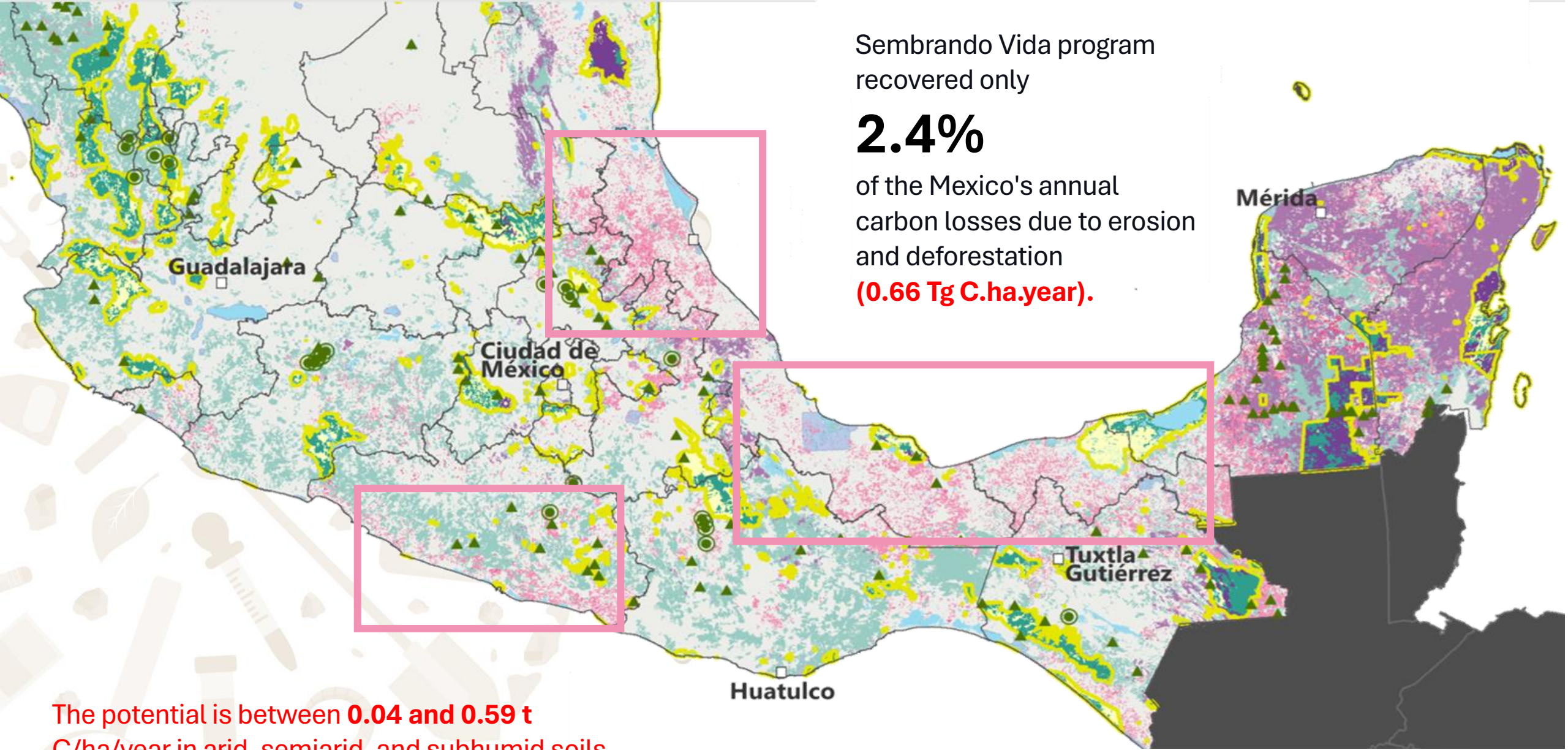
SOURCE: CRUZ-GAISTARDO, MARTINEZ-DE ANDA Y GONZALEZ-MURGUIA NATIONAL ATLAS OF MEXICO 2022 (PRELIMINARY VERSION). INSTITUTE OF GEOGRAPHY OF THE NATIONAL AUTONOMOUS UNIVERSITY OF MEXICO.

DATASETS: (a) NATURAL PROTECTED AREAS PROGRAM AND VOLUNTARILY AREAS FOR CONSERVATION PROGRAM, CONANP, 2022. (b) REGISTRY OF PRODUCERS OF THE SEMBRANDO VIDA PROGRAM. WELFARE SECRETARY, AUGUST 2022. (c) WETLANDS OF INTERNATIONAL IMPORTANCE. RAMSAR, 2022. (d) SUPPORT PROGRAM FOR SUSTAINABLE FOREST DEVELOPMENT: COMPONENT III FOREST RESTORATION OF MICRO WATERSHEDS AND COMPONENT IV PAYMENTS FOR ENVIRONMENTAL SERVICES. CONAFOR, 2021-2023. (e) MAP OF THE ORGANIC MATTER CONTENT OF MEXICO. UNAM, 2022. (f) MAP OF DEFORESTATION IN MEXICO. UNAM, 2021. (g) LETTER OF LAND USE AND VEGETATION SERIES VII. INEGI, 2020.

LAMBERT CONICAL
PROJECTION
DATUM: ITRF2008
1:15,000,000
RESOLUTION: 100 m
160 km

2.0
0.5
0.1
MILLION
HECTARES





Sembrando Vida program recovered only

2.4%

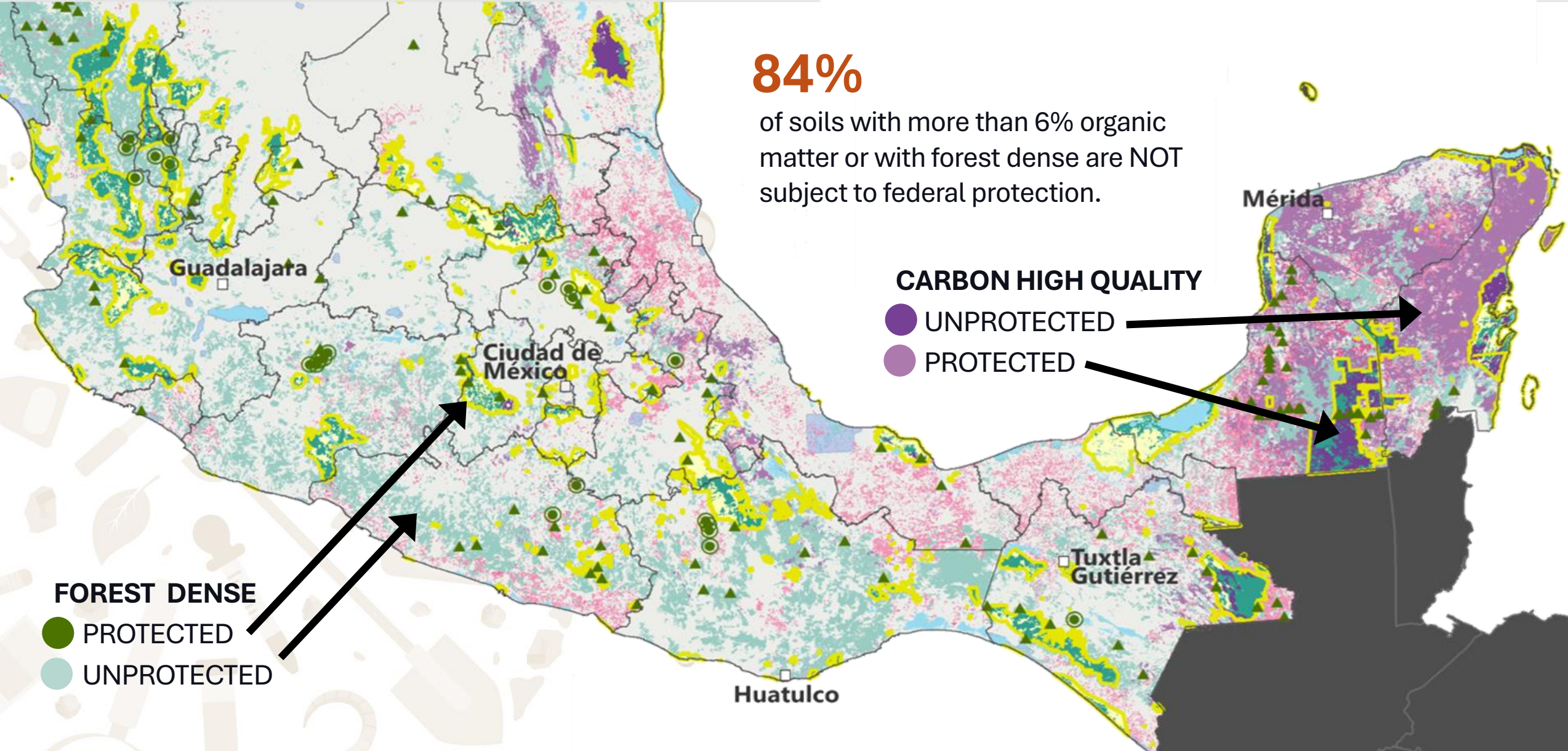
of the Mexico's annual carbon losses due to erosion and deforestation
(0.66 Tg C.ha.year).

The potential is between **0.04 and 0.59 t C/ha/year** in arid, semiarid, and subhumid soils.



84%

of soils with more than 6% organic matter or with forest dense are NOT subject to federal protection.



FINAL COMMENT

The best time to save our soil from degradation... was yesterday!

Today, there are other options. Now, we must redefine the progress word.

Since my opinion the solution is education with data quality and universal access to information.

THANK YOU

