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Investigación con Impacto Social

**2nd Inter-Conference Symposium (19-21 April, 2023)  
6to Congreso Regional de Economía Agraria and  
1st Latin-American Workshop on Productivity and Efficiency**

Stochastic frontier analysis, Production chains for white maize, sugar cane, cattle and milk: Production chains of white corn, sugar cane, cattle and milk.

**Session 5: [CP 2-1](#)  
April 19, 2023 15:00 to 17:00**



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# Stochastic frontier analysis, Production chains for white maize, sugar cane, cattle and milk.

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# Introduction

- The Food and Agriculture Organization of the United Nations (FAO) develops and uses food and agricultural decision-making tools that contribute to
  - eradicating poverty ([SDG 1](#)), and
  - ending hunger and ensuring access to healthy, nutritious and sufficient food for all ([SDG 2](#)).
- One of the ways in which FAO fulfils this commitment is through its Hand-in-Hand Initiative, which identifies for each agricultural product the microregions with the greatest productive opportunity and need — that is, those in which a high percentage of its population is in poverty and considers them priority areas.

# Objectives of this analysis

- **Define areas of intervention** where small innovations may allow small producers to catch up to their peers and larger farmers by helping them overcome the specific challenges they face.
- The framework states that there exists:
  - a **maximum or optimum level** of production that farmers can reach with the smaller innovations of their own and their peers (and hence become more **efficient**), and
  - an **upper bound** (which we call **potential**) that can be increased by larger investments in R&D with the support of governments, donors, and researchers.
- Hence, our **typology** considers this framework using the estimation of the production function.

# Production estimation

- According to Maruyama (2018) the two most commonly used methods to estimate the efficiency of production units are Data Envelopment Analysis (DEA- non parametric) (Charnes et al., 1978; 1981) and Stochastic Frontier Analysis (SFA - parametric) (Aigner, Lovell & Schmidt, 1977).
- “Both methods **measure efficiency** as the distance between observed and maximum possible (frontier) outcomes, but the key advantage of SFA for our purposes is that, unlike DEA, it allows to separate random noise in the error term from the actual efficiency score.”
- Agricultural activities are exposed and extremely sensitive to (negative and positive) random shocks such as droughts, variation in international prices, and SFA allows to separate efficiency and random noise.
- We use the Stata command **sfcross** from Belotti, Daidone, Ilardi & Atella (2013), which includes models from Greene (2003), Wang (2002), Cornwell, Schmidt, and Sickles (1990), Lee and Schmidt (1993), Kumbhakar (1990), Battese and Coelli (1995), Greene (2005)

# Production Frontier

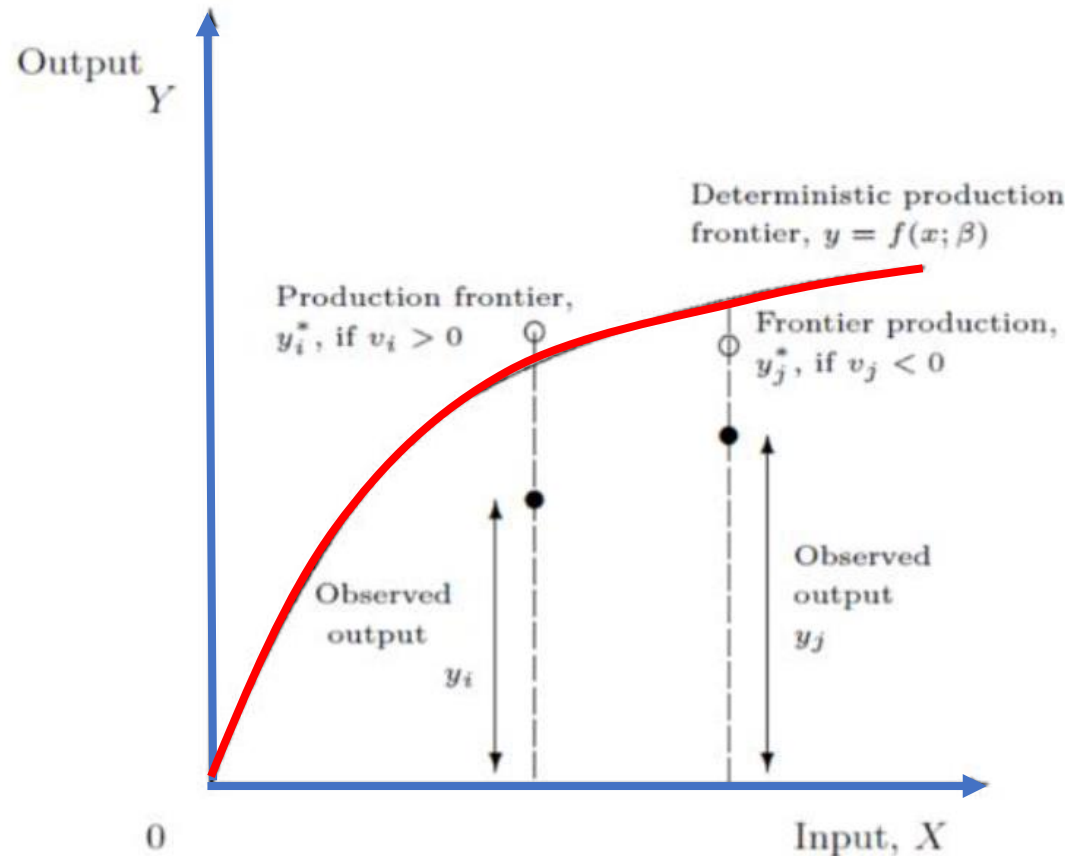
Consider the following SF model,

$$y_i = \alpha + \mathbf{x}'_i \boldsymbol{\beta} + \varepsilon_i, \quad i = 1, \dots, N \quad (1)$$

$$\varepsilon_i = v_i - u_i \quad (2)$$

$$v_i \sim \mathcal{N}(0, \sigma_v^2) \quad (3)$$

$$u_i \sim \mathcal{F} \quad (4)$$



Greene (1980), Belotti, Daidone, Ilardi, Atela (2013)

$v_i$  is a random error with zero mean, associated with random factors that are not under the control of the producer, and

$u_i$  is a non-negative random variable associated with factors that prevent the producer from being efficient.

$$TE_i = \frac{y}{y^*} = \frac{f(x; \boldsymbol{\beta}) \cdot e^{(v-u)}}{f(x; \boldsymbol{\beta}) \cdot e^{(v)}} = e^{-u}$$

Source: Maruyama (2018)

# Four Steps in this Analysis: 1

- **Stage 1. Collection and processing of statistical and geospatial data** from household surveys or production units.
- In the case of Mexico, the 2019 ENA was used, which collects data per unit of production.
- This data has to be processed in the micro lab of the National Statistical office (INEGI) in Mexico city.
- In the case of Mexico, the ENA 2019 is representative of the four subsectors considered (sugarcane, white corn, cattle and milk) at the state level .



# Four Steps in this Analysis: 2

- **Stage 2. Estimation of a stochastic frontier function** at producer level that includes the socio-economic characteristics of the producer and the unit of production. For this, three fundamental components are considered:
  1. The **frontier** function, which estimates a function of net income of the producer (or gross income when taxes or marketing margins are not available). As explanatory variables, the selling prices of the product and the prices of the main inputs are used. According to Maruyama *et al.* (2018) All inputs that are under the control of the producer must be used.
  2. The **inefficiency component**, which includes variables under producer control that impair efficiency (e.g. management variables, sociodemographic characteristics of the producer and his workers, adoption of available technologies, public or private support programs, short-term climatic conditions).
  3. The **component for random error**, which includes random factors beyond the producer's control. To correct for heteroscedasticity, scale variables are included over the unit of production, including farm size and number of livestock.

# Equation to be estimated

- The stochastic sales revenue frontier function is defined as:

$$y_i = f(p_i; \beta) \exp(v_i - u_i) \quad (1)$$

- where  $y_i$  represents sales revenue for the producer  $i$ ,
- $f(p_i; \beta)$  is a function of product prices  $p_i$  and parameters  $\beta$ ,
- $v_i$  is a random error with zero mean, associated with random factors that are not under the control of the producer, and
- $u_i$  is a non-negative random variable associated with factors that prevent the producer from being efficient.
- Factors of geographical areas such as rainfall, altitude, latitude or soil type are considered. These variables are introduced into the deterministic portion of the frontier, so that equation (1) becomes

# Equation to be estimated continue

Factors of geographical areas such as rainfall, altitude, latitude or soil type are considered. These variables are introduced into the deterministic portion of the frontier, so that equation (1) becomes

$$y_i = f(p_i, ZAE_i, CC_i; \beta) \exp(v_i - u_i) \quad (2)$$

Assuming a Cobb–Douglas production function, the normalized gross income frontier function estimated by maximum likelihood is:

$$\ln\left(\frac{y_i}{p}\right) = \delta_o + \sum_n \delta_n \left(\frac{p_n}{p}\right) + \sum_q \delta_q ZAE_q + \sum_q \delta_q CC_q + v_i - u_i \quad (3)$$

where:  $\frac{y_i}{p}$  is normalized gross income,  $\delta_o$  is a constant,  $\frac{p_n}{p}$  are the standard unit prices of products,  $ZAE_q$  is the proportion of land in a given administrative unit covered by a given land use,  $CC_q$  is a variable that captures long-term weather conditions,

- Eq. (3) is estimated using only the subsample of farmers participating in the market

# Four Steps in this Analysis: 3

- **Stage 3. Prediction.** At this stage, the estimated stochastic frontier coefficients are used to predict—at the level of the smallest administrative units available—agricultural potential, frontier, and levels of inefficiency. Subsequently, agricultural potentials and their efficiency levels in each region are extrapolated. For this, it is necessary to have information from an agricultural census (municipal representativeness) or a national survey (state or urban-rural representativeness).
- These data predict the potential and technical efficiency of each representative geographic area.

# Four Steps in this Analysis: 4

- **Stage 4. Preparation of typology maps of agricultural territories.**

At this stage, three classification criteria are used:

1. productive potential
2. productive efficiency and
3. territorial poverty.

Each criterion is labeled into a category (low, medium, or high).

- This uses an approach whereby the 33rd and 67th percentiles divide the distribution into three-thirds.
- The combination of the three criteria and labels results in the typological classification described in Diagram 1.

# Diagram 1. Classification of typology in microregions.



	Poverty	Potential	Efficiency
Critical condition with moderate opportunities	High	Low	High/Medium/Low
Average poverty with moderate opportunities	Medium	Bajo	High/Medium/Low
Low priority	Low	Bajo	High/Medium/Low
High priority	High	Medio/Alto	Medium/Low
Medium priority with high opportunities	Medium	Medio/Alto	Medium/Low
Low priority with high opportunities	Low	Medio/Alto	Medium/Low
High performance	Low	Medio/Alto	High

**Priority**, which describes a region's degree of *urgency* for investments in development, *agricultural (income) potential*, which establishes the maximum agricultural income smallholders in a region can attain if performing at maximum capacity, *agricultural (income) efficiency*, which describes how much of the potential described above is attained by farmers in a region under current conditions.

Source: Authors' elaboration based on Maruyama et al. 2018

## In summary the production frontier is estimated using the following data

For each product, the production frontier is estimated with current inputs, for example:

- Soil / Irrigation
  - Workers (age, sex, education, salary, etc.)
  - Seeds / Livestock
  - Fertilizers / Pesticides
  - Supports / Credit
  - Technology / machinery
  - And considering market access variables in km, weather, climatic variables rainfall, need for irrigation, etc.
1. The gap between what is produced and the potential is calculated.
  2. The level of poverty of municipal welfare is taken into account.
  3. Typology is formed considering efficiency, potential and poverty

# DATA

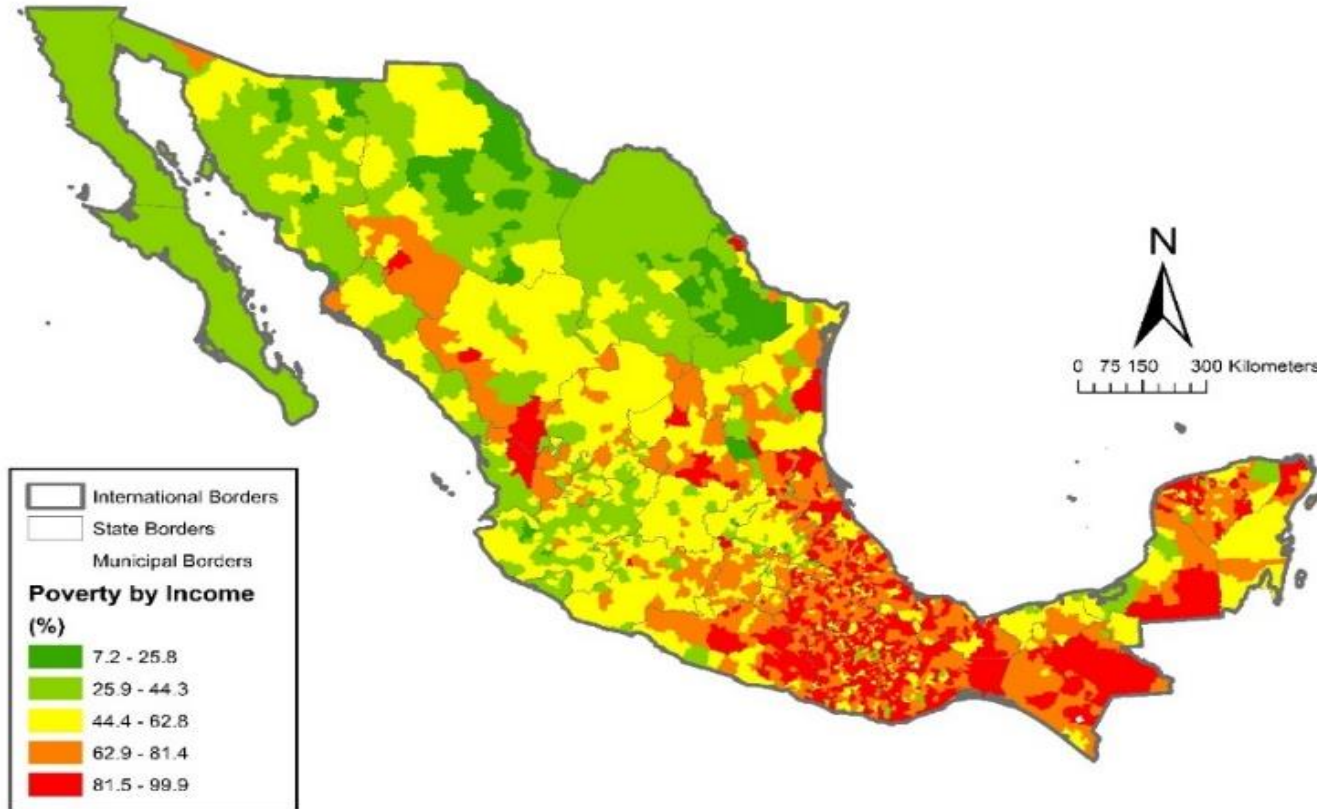
MICRODATA FROM THE NATIONAL SURVEY OF AGRICULTURA 2019 (THE MOST RECENT)

POVERTY MEASURES AT MUNICIPAL LEVEL 2020 (AVAILABLE EVERY 5 YEARS)

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# The Poverty is taken from CONEVAL



Source : Ortega, Molina, Flores, Guzmán (2023) using wellbeing poverty line with data from CONEVAL, 2021.

## Variables included in the estimation of the boundary function

Variable	Production of white corn	Production of sugar cane	Production of cattle	Production milk
Gross income	Annual income from the sale of white maize	Quarterly revenue from the sale of sugarcane	Annual revenue from the sale of cattle	Quarterly revenue from milk sales
Producer level pricing	Price per tone of the last sale of white corn	Price per ton of the last sale of sugar cane	Price of the last sale of cattle	Price per liter of milk sold
Agro-ecological zones (CHIRPS, USGS)	Proportion of land in forest, pasture, seasonal or continuous cultivation or no agricultural use	Proportion of land in forest, pasture, seasonal or continuous cultivation or no agricultural use	Proportion of land in forest, pasture, seasonal or continuous cultivation or no agricultural use	Proportion of land in forest, pasture, seasonal or continuous cultivation or no agricultural use
	Proportion of land suitable for seasonal or continuous agriculture with mechanized tillage, animal or manual traction	Proportion of land suitable for seasonal or continuous agriculture with mechanized tillage, animal or manual traction	Proportion of land suitable for seasonal or continuous agriculture with mechanized tillage, animal or manual traction	Proportion of land suitable for seasonal or continuous agriculture with mechanized tillage, animal or manual traction
	Irrigation requirement according to medium type	Irrigation requirement according to medium type	Irrigation requirement according to medium type	Irrigation requirement according to medium type
Weather conditions	Altitude, latitude and longitude measurement	Altitude, latitude and longitude measurement	Altitude, latitude and longitude measurement	Altitude, latitude and longitude measurement
	Average monthly rainfall for the period 2000-2020	Average monthly rainfall for the period 2000-2020	Average monthly rainfall for the period 2000-2020	Average monthly rainfall for the period 2000-2020
Distance-transfer time	Distance and minimum time to locations, airports, borders and seaports	Distance and minimum time to locations, airports, borders and seaports	Distance and minimum time to locations, airports, borders and seaports	Distance and minimum time to locations, airports, borders and seaports

Source: Ortega, Molina, Flores, Guzmán (2023) using microdata from ENA-2019, CHIRPS, USGS, and INEGI

# Variables included in the estimation of inefficiency

White corn production	Sugar Cane production	Production of cattle	Milk production
<b>Inefficiency</b>			
Organization: The number of organizations you belong to.	Organization: The number of organizations you belong to.	Organization: number of organizations you belong to.	Organization: The number of organizations you belong to.
Property and assets: number of facilities, information technology, type of seed used, use of manure and type of water.	Property and assets: number of facilities, information technology, type of seed used, use of manure and type of water.	Property and assets: number of facilities, information technology, type of seed used, type of water used, land management, number of cattle facilities, type of beef.	Property and assets: number of facilities, information technology, type of seed used, type of water, number of facilities for bovine use.
Machinery: depreciated number of tractors, number of machines and average years used	Machinery: depreciated number of tractors, number of machines and average years used.	Machinery: depreciated number of tractors, number of machines and average years used.	Machinery: depreciated number of tractors, number of machines and average years used.
Agricultural management: agricultural area under cultivation, irrigation or temporary division and land in irrigation distance.	Agricultural management: agricultural area under cultivation, irrigation or temporary division, rest, land in irrigation distance, source of water for irrigation and cause of crop loss.	Agricultural management: agricultural area in temporary and irrigation.	Agricultural management: irrigated agricultural area.
Adoption of technologies: sensor sorter, technical assistance, pesticides and fertilizers.	Technology Adoption: Sensor Classifier, Technical Support, Pesticides and Fertilizers.	Adoption of technologies: care to deworm, grazing, genetic treatment, technical assistance and use of fire.	Adoption of technologies: care to deworm, grazing, genetic treatment, technical assistance and use of fire.
Characteristics of the worker: number of workers, salary received.	Characteristics of the worker: number of workers, salary received.	Characteristics of the worker: number of workers, salary received.	Characteristics of the worker: number of workers, salary received.
Characteristics of the producer: sex, age, experience, dialect ability, time spent and dependents in the dwelling.	Characteristics of the producer: sex, age, experience, dialect ability, time spent and dependents in the dwelling.	Characteristics of the producer: sex, age, experience, indigenous ethnicity, dialect capacity, time spent and dependents in the home.	Characteristics of the producer: sex, age, experience, indigenous ethnicity, time spent and dependents in the dwelling.
Supports: beneficiary of social programs, type of support program received and support in older adults.	Supports: beneficiary of social programs, type of support program received and support in older adults.	Supports: beneficiary of social programs, type of support program received and support in older adults.	Supports: beneficiary of social programs, type of support program received and support in older adults.
Problem: number of problems faced by the producer.	Problem: number of problems faced by the producer.	Problem: number of problems faced by the producer.	Problem: number of problems faced by the producer.
Financing: amount of credit accepted.	Financing: amount of credit accepted.	Financing: amount of credit accepted.	Financing: amount of credit accepted.
Corruption: Unauthorized Government Spending and 2015 Government Corruption Classifier.	Corruption: Unauthorized Government Spending and 2015 Government Corruption Classifier.	Corruption: Unauthorized Government Spending and 2015 Government Corruption Classifier.	Corruption: Unauthorized Government Spending and 2015 Government Corruption Classifier.
Accessibility: type of buyer.	Accessibility: type of buyer.	Accessibility: type of buyer.	
Care and preparation: agricultural production certificates, actions against environmental change.	Care and preparation: agricultural production certificates, actions against environmental change.		

Source: Ortega, Molina, Flores, Guzmán (2023) using data from ENA-2019, *INEGI and Ajzenman, N. 2021.*

# Variables included in the estimation of the random error

White corn production	Sugar Cane production	Production of cattle	Milk production
<b>Random error</b>			
Surface area of the property in m <sup>2</sup>	Surface area of the property in m <sup>2</sup>	Surface area of the property in m <sup>2</sup>	Surface area of the property in m <sup>2</sup>
Standard deviation of monthly rainfall over the period 2000-2020	Standard deviation of monthly rainfall over the period 2000-2020	Standard deviation of monthly rainfall over the period 2000-2020	Standard deviation of monthly rainfall over the period 2000-2020
		Total number of cattle.	Total number of cattle.

Source: Ortega, Molina, Flores, Guzmán (2023)

# Estimation results

Using sfcross with exponential distribution fo the error term

```
sfcross $ING $PRICES $LANDCOVER $CLIMATE , d(exp) cluster(cve_mun)  
u($USIGMA_1 $USIGMA_2 $USIGMA_3) v($VSIGMA)
```

Dependent Variable White Corn Income			Dependent Variable White Corn Income		
Variables	Coefficient	Standar Error	Variables	Coefficient	Standar Error
<i>Inputs X - arcsinh (annual revenue or agricultural sales)</i>			<i>Inefficiency u</i>		
arcsinh (Precio de venta (imp.))	1.308***	(0.0514)	arcsinh (Conteo organizaciones pertenecientes)	-0.0178	(0.175)
arcsinh (Precio de herbicida (imp.))	0.00170	(0.00116)	arcsinh (Superficie con cultivos anuales)	0.0183	(0.512)
arcsinh (Precio de fungicida (imp.))	-0.000740	(0.000694)	arcsinh (Superficie agrícola temporal)	-0.00295	(0.327)
arcsinh (Precio de insecticida (imp.))	0.00186	(0.00116)	arcsinh (Superficie agrícola temporal jugo o hume)	-0.0748	(0.0982)
arcsinh (Precio de fertilizantes (imp.))	6.57e-05*	(3.71e-05)	arcsinh (Superficie agrícola riego)	0.00406	(0.459)
arcsinh (Prop. tierra bosques)	-0.0168	(0.0962)	arcsinh (Numero depreciado de tractores)	0.0424	(0)
arcsinh (Prop. tierra pastizales)	-0.0101	(0.0732)	arcsinh (Años promedio maquinaria)	-0.0562	(0.240)
arcsinh (Prop. tierra cultivos estacionales)	-0.0895	(0.187)	arcsinh (Conteo de máquinas)	-0.205	(0.359)
arcsinh (Prop. tierra sin uso agrario)	0.00553	(0.0707)	arcsinh (Capacidad de carga transporte)	-0.201	(1.037)
arcsinh (Prop. tierra cultivos continuo)	-0.132	(0.134)	arcsinh (Suma anual de sueldos y jornales)	0.0666***	(0.0244)
arcsinh (Tiempo min. localidad 100km)	-0.244	(0.161)	arcsinh (Conteo trabajadores)	-0.0499	(0.168)
arcsinh (Tiempo a aeropuertos)	0.233**	(0.111)	arcsinh (Conteo usos de estiércol)	-0.353**	(0.158)
arcsinh (Tiempo a puertos marítimos)	0.103	(0.0956)	arcsinh (Conteo de IT)	-0.108	(0.122)
arcsinh (Tiempo a frontera)	0.0396	(0.0765)	arcsinh (Edad del productor)	0.122	(0.238)
arcsinh (Req. riego medio)	-0.0113	(0.0149)	arcsinh (Años de experiencia productor)	0.102	(0.0661)
arcsinh (Tierra apta agr. mecanizada continua)	-0.00702	(0.0127)	arcsinh (Promedio horas dedicadas)	0.00277	(0.105)
arcsinh (Tierra apta agr. tracción animal continua)	-0.0315*	(0.0172)	arcsinh (Dependientes econ. en la vivienda)	-0.0670	(0.113)
arcsinh (Tierra apta agr. manual continua)	0.00975	(0.0147)	arcsinh (Conteo de instalaciones)	-0.312	(0.318)
arcsinh (Tierra no apta para agricultura)	0.00944	(0.0120)	arcsinh (Gasto gub. no autorizado 2015 )	0.0137	(0.115)
arcsinh (Tierra apta agr. manual estacional)	0.0777*	(0.0418)	Cat. certificado para agricultura orgánica	-0.247	(1.078)
arcsinh (Tierra apta agr. mecanizada estacional)	-0.217*	(0.115)	Cat. certificado de buenas prácticas agrícolas.	-0.0879	(0.384)
arcsinh (Tierra apta agr. tracción animal estacional)	0.0298	(0.0367)	Cat. adquisición de ambos certificados.	0.297	(0.399)
arcsinh (Prom. mensual precipitación 2000-2020)	-0.244	(0.217)	Cat. cambio de cultivo por prob. ambientales	-0.200	(0.178)
arcsinh (Altitud)	-0.222**	(0.0885)	Cat. cambio de siembra por prob. ambientales	-0.265**	(0.116)
arcsinh (Latitud)	-0.757	(0.544)	Cat. ambos cambios de cultivo y siembra	-0.268**	(0.117)
arcsinh (Longitud)	-12.71**	(5.839)	Cat. cultivo de Temporal	-0.294	(1.088)
<i>Random error v</i>			Cat. tipo de semilla mejorada	-0.359	(0.357)
arcsinh (Num. terrenos o parcelas)	0.158	(0.113)	Cat. tipo de semilla certificada	-0.344*	(0.196)
arcsinh (Superficie total)	0.252	(0.264)	Cat. tipo de semilla transgénica	-0.141	(0.831)
arcsinh (Desv. est. mensual de precipitación 2000-20	-0.867	(0.789)	Cat. comprador SEGALMEX	0.297	(0.939)
Observaciones	18,381		Cat. comprador intermediario	1.463***	(0.542)
			Cat. comprador consumidor directo	0.684	(0)
Source: Ortega-Díaz, Molina, Flores Guzman (2023) using ENA2019.			Cat. comprador central de abastos	0.425	(0.938)

Dependent Variable Sugar Cane Income					
Variables			Variables		
	Coefficient	Standar Error		Coefficient	Standar Error
<i>Frontera - arcsinh (Ingreso anual por ventas agrícolas)</i>			<i>Ineficiencia</i>		
arcsinh (Precio de venta (imp.))	1.824***	(0.0191)	arcsinh (Coteo organizaciones pertenecientes)	0.0108	(0.0854)
arcsinh (Precio de herbicida (imp.))	0.154	(0.256)	arcsinh (Superficie con cultivos anuales)	0.193**	(0.0822)
arcsinh (Precio de fungicida (imp.))	0.202	(0.148)	arcsinh (No siembra por descanso)	0.295***	(0.0790)
arcsinh (Precio de insecticida (imp.))	-0.287	(0.209)	arcsinh (Superficie agrícola temporal)	-0.401***	(0.106)
arcsinh (Precio de fertilizantes (imp.))	0.112	(0.320)	arcsinh (Superficie agrícola temporal jugo o humedad)	0.0203	(0.0731)
arcsinh (Prop. tierra bosques)	-0.102	(0.193)	arcsinh (Superficie agrícola riego)	-0.528***	(0.113)
arcsinh (Prop. tierra pastizales)	3.351***	(1.240)	arcsinh (Numero depreciado de tractores)	0.648	(0.560)
arcsinh (Prop. tierra cultivos estacionales)	-0.525***	(0.194)	arcsinh (Años promedio maquinaria)	0.0906	(0.0848)
arcsinh (Prop. tierra sin uso agrario)	-0.118	(0.101)	arcsinh (Coteo de máquinas)	-0.308*	(0.175)
arcsinh (Prop. tierra cultivos continuo)	-0.606***	(0.208)	arcsinh (Capacidad de carga transporte)	-0.170***	(0.0605)
arcsinh (Tiempo min. localidad 100km)	0.492***	(0.146)	arcsinh (Suma anual de sueldos y jornales)	-0.0292**	(0.0115)
arcsinh (Tiempo a aeropuertos)	0.0540	(0.127)	arcsinh (Coteo trabajadores)	0.0426	(0.0433)
arcsinh (Tiempo a puertos marítimos)	-0.303**	(0.150)	arcsinh (Coteo usos de estiércol)	0.125	(0.0835)
arcsinh (Tiempo a frontera)	-0.548***	(0.137)	arcsinh (Coteo de IT)	-0.0262	(0.0781)
arcsinh (Req. riego medio)	-0.0105	(0.0206)	arcsinh (Edad del productor)	0.0377	(0.0937)
arcsinh (Tierra apta agr. mecanizada continua)	-0.0839***	(0.0245)	arcsinh (Años de experiencia productor)	-0.107***	(0.0386)
arcsinh (Tierra apta agr. tracción animal continua)	-0.0213	(0.0306)	arcsinh (Promedio horas dedicadas)	0.0320	(0.0504)
arcsinh (Tierra apta agr. manual continua)	0.0507	(0.0391)	arcsinh (Dependientes econ. en la vivienda)	-0.114**	(0.0568)
arcsinh (Tierra no apta para agricultura)	-0.0410	(0.0276)	arcsinh (Coteo de instalaciones)	-0.0414	(0.111)
arcsinh (Tierra apta agr. manual estacional)	-0.107***	(0.0302)	arcsinh (Gasto gub. no autorizado 2015 )	0.0168	(0.219)
arcsinh (Tierra apta agr. mecanizada estacional)	-0.00828	(0.0536)	Cat. certificado para agricultura orgánica	-0.0195	(0.302)
arcsinh (Tierra apta agr. tracción animal estacional)	-0.0266	(0.0338)	Cat. certificado de buenas prácticas agrícolas.	-0.00668	(0.184)
arcsinh (Prom. mensual precipitación 2000-2020)	-0.0177	(0.241)	Cat. adquisición de ambos certificados.	0.465**	(0.234)
arcsinh (Altitud)	-0.117***	(0.0393)	Cat. cambio de cultivo por prob. ambientales	-0.121	(0.147)
arcsinh (Latitud)	-1.639**	(0.811)	Cat. cambio de siembra por prob. ambientales	0.102	(0.0971)
arcsinh (Longitud)	-10.34***	(2.202)	Cat. Cambio de cultivo y siembra por prob. amb.	0.193	(0.135)
<i>Error aleatorio</i>			Cat. cultivo de Temporal	0.796***	(0.260)
arcsinh (Num. terrenos o parcelas)	0.0353	(0.0493)	Cat. perdida debido a manejo de cosecha	-0.150	(0.106)
arcsinh (Superficie total)	0.356***	(0.0660)	Cat. perdida por selección de producto	-0.187	(0.153)
arcsinh (Desv. est. mensual de precipitación 2000-2020)	-0.0625	(0.125)	Cat. perdida durante el transporte	-0.254	(0.219)
Observaciones	7,884		Cat. perdida durante el empaque	-0.274	(0.580)
			Cat. perdida durante el almacenamiento	-0.558*	(0.318)
Source: Ortega-Díaz, Molina, Flores Guzman (2023) using ENA2019.			Cat. perdida por plagas	-0.159	(0.155)
			Cat. comprador SEGALMEX	-0.139	(0.671)
			Cat. comprador intermediario	3.888***	(0.501)

Dependent Variable Cattle Income					
Variables	Coefficient	Standar Error	Variables	Coefficient	Standar Error
<i>Frontera - arcsinh (Ingreso anual por ventas agrícolas)</i>			<i>Ineficiencia</i>		
arcsinh (Precio de venta (imp.))	1.416***	(0.0315)	arcsinh (Conteo organizaciones pertenecientes)	0.177***	(0.0526)
arcsinh (Prop. tierra bosques)	-0.148*	(0.0839)	arcsinh (Superficie agrícola temporal)	-0.0482***	(0.0174)
arcsinh (Prop. tierra pastizales)	0.0593	(0.0491)	arcsinh (Superficie agrícola temporal jugo o humedad)	-0.0270	(0.0393)
arcsinh (Prop. tierra cultivos estacionales)	0.0505	(0.111)	arcsinh (Superficie agrícola riego)	-0.0898***	(0.0300)
arcsinh (Prop. tierra sin uso agrario)	0.0236	(0.0418)	arcsinh (Numero depreciado de tractores)	0.796***	(0.266)
arcsinh (Prop. tierra cultivos continuo)	-0.129	(0.101)	arcsinh (Años promedio maquinaria)	-0.00115	(0.0237)
arcsinh (Tiempo min. localidad 100km)	0.0528	(0.0445)	arcsinh (Conteo de máquinas)	0.00308	(0.0450)
arcsinh (Tiempo a aeropuertos)	-0.00676	(0.0494)	arcsinh (Capacidad de carga transporte)	-0.300***	(0.0394)
arcsinh (Tiempo a puertos marítimos)	0.0263	(0.0424)	arcsinh (Suma anual de sueldos y jornales)	-0.0165***	(0.00551)
arcsinh (Tiempo a frontera)	-0.107**	(0.0462)	arcsinh (Conteo trabajadores)	-0.0731***	(0.0264)
arcsinh (Req. riego medio)	-0.00530	(0.00960)	arcsinh (Conteo usos de estiércol)	-0.0969	(0.167)
arcsinh (Tierra apta agr. mecanizada continua)	0.0443***	(0.0121)	arcsinh (Conteo de IT)	-0.181***	(0.0349)
arcsinh (Tierra apta agr. tracción animal continua)	0.0109	(0.0108)	arcsinh (Edad del productor)	-0.429***	(0.0979)
arcsinh (Tierra apta agr. manual continua)	0.0291**	(0.0144)	arcsinh (Años de experiencia productor)	-0.0801**	(0.0318)
arcsinh (Tierra no apta para agricultura)	0.00835	(0.00942)	arcsinh (Promedio horas dedicadas)	-0.00294	(0.0305)
arcsinh (Tierra apta agr. manual estacional)	0.00925	(0.00987)	arcsinh (Dependientes econ. en la vivienda)	-0.100***	(0.0329)
arcsinh (Tierra apta agr. mecanizada estacional)	-0.0217	(0.0201)	arcsinh (Conteo de instalaciones)	-0.0388	(0.0377)
arcsinh (Tierra apta agr. tracción animal estacional)	0.0301	(0.0185)	arcsinh (Conteo de instalaciones bovinas)	-0.299***	(0.0352)
arcsinh (Prom. mensual precipitación 2000-2020)	0.0525	(0.0765)	arcsinh (Gasto gub. no autorizado del 2015 )	-0.0144	(0.0719)
arcsinh (Altitud)	-0.0386**	(0.0169)	Cat. manejo por persona moral	-3.262***	(0.474)
arcsinh (Latitud)	1.286***	(0.276)	Cat. manejo por gobierno	-1.407**	(0.561)
arcsinh (Longitud)	1.234	(0.759)	Cat. manejo por otro organismo	-2.638***	(0.538)
<i>Error aleatorio</i>			Cat. cambio de cultivo por prob. ambientales	0.153**	(0.0773)
arcsinh (Num. terrenos o parcelas)	-0.00964	(0.0234)	Cat. cambio de siembra por prob. ambientales	0.146***	(0.0447)
arcsinh (Superficie total)	0.000397	(0.0145)	Cat. ambos cambios de cultivo	0.209***	(0.0563)
arcsinh (Existencia total de reses)	0.544***	(0.0237)	Cat. desparasitación interna	-0.350***	(0.0717)
arcsinh (Desv. est. mensual de precipitación 2000-2020)	-0.282***	(0.0671)	Cat. desparasitación externa	-0.104	(0.0956)
Observaciones	20,459		Cat. ambos tipos de desparasitación	-0.433***	(0.0675)
			Cat. pastoreo con pasto incluido	0.0215	(0.0495)
			Cat. pastoreo con pasto inducido	-0.186**	(0.0858)
			Cat. pastoreo con ambos	-0.122*	(0.0664)
Source: Ortega-Díaz, Molina, Flores Guzman (2023) using ENA2019.			Cat. mejoramiento genético	-0.313***	(0.0884)



Dependent Variable Milk Income								
Variables			Coefficient	Standar Error		Variables	Coefficient	Standar Error
<i>Frontera - arcsinh (Ingreso anual por ventas agrícolas)</i>						<i>Inefficiency u</i>		
arcsinh (Precio de venta)			4.646***	(0.478)		arcsinh (Conteo organizaciones pertenecientes)		
arcsinh (Prop. tierra bosques)			-0.191	(0.389)		arcsinh (Superficie agrícola riego)		
arcsinh (Prop. tierra pastizales)			-0.405	(0.467)		arcsinh (Numero depreciado de tractores)		
arcsinh (Prop. tierra cultivos estacionales)			1.053**	(0.448)		arcsinh (Años promedio maquinaria)		
arcsinh (Prop. tierra sin uso agrario)			0.342**	(0.171)		arcsinh (Conteo de máquinas)		
arcsinh (Prop. tierra cultivos continuo)			0.0315	(0.418)		arcsinh (Capacidad de carga transporte)		
arcsinh (Tiempo min. localidad 100km)			0.0735	(0.201)		arcsinh (Suma anual de sueldos y jornales)		
arcsinh (Tiempo a aeropuertos)			-0.553**	(0.238)		arcsinh (Conteo trabajadores)		
arcsinh (Tiempo a puertos marítimos)			0.242	(0.187)		arcsinh (Conteo usos de estiércol)		
arcsinh (Tiempo a frontera)			-0.176	(0.195)		arcsinh (Conteo de IT)		
arcsinh (Req. riego medio)			-0.0348	(0.0428)		arcsinh (Edad del productor)		
arcsinh (Tierra apta agr. mecanizada continua)			0.0858	(0.0644)		arcsinh (Años de experiencia productor)		
arcsinh (Tierra apta agr. con tracción animal continua)			0.106**	(0.0492)		arcsinh (Promedio horas dedicadas)		
arcsinh (Tierra apta agr. manual continua)			-0.111*	(0.0671)		arcsinh (Dependientes econ. en la vivienda)		
arcsinh (Tierra no apta para agricultura)			0.116***	(0.0368)		arcsinh (Conteo de instalaciones)		
arcsinh (Tierra apta agr. manual estacional)			0.00972	(0.0455)		arcsinh (Conteo de instalaciones bovinas)		
arcsinh (Tierra apta agr. mecanizada estacional)			-0.613**	(0.303)		arcsinh (Gasto gub. no autorizado del 2015 )		
arcsinh (Tierra apta agr. tracción animal estacional)			0.197*	(0.107)		Cat. cambio de cultivo por prob. ambientales		
arcsinh (Prom. mensual precipitación 2000-2020)			-0.398	(0.504)		Cat. cambio de siembra por prob. ambientales		
arcsinh (Altitud)			0.0451	(0.0674)		Cat. ambos tipos de cambios		
arcsinh (Latitud)			0.115	(1.428)		Cat. desparasitación interna		
arcsinh (Longitud)			4.956	(4.799)		Cat. desparasitación externa		
<i>Random error v</i>						Cat. ambos tipos de desparasitación		
arcsinh (Num. terrenos o parcelas)			-0.102	(0.0634)		Cat. pastoreo con pasto incluido		
arcsinh (Superficie total)			0.0737	(0.0690)		Cat. pastoreo con pasto inducido		
arcsinh (Existencia total de reses)			0.303***	(0.114)		Cat. pastoreo con ambos		
arcsinh (Desv. est. mensual de precipitación 2000-2020)			-1.296	(0.957)		Cat. pastoreo con ambos		
Observaciones			2,520			Cat. uso de hormonas		
						Cat. transferencia de embriones		
Source: Ortega-Díaz, Molina, Flores Guzman (2023) using ENA2019.						Cat. dos tratamientos		
						Cat. todos los tratamientos		
						Cat. asistencia técnica para producción		

## Price coefficient of bovine cattle

Cattle	cluster ent					cluster mun		
	Before interviews					After Interviews		
	F1	F2	F3	F4	F5	F6	F7	F8
ihs_P_bovino_imp	1.452***	1.616**	1.420***	1.639***	1.615***	1.591***	1.352***	1.416***
	Variables in Tables 6 and 7					Additional Variables		
						Corruption	Corruption	Corruption
	Irrigation need	Irrigation	Irrigation					
	Land tipology	land	land					
		Problems	Problems (count)					
			Support programs					



Opinion of different type of experts and actors to investigate factors that encourage production and others that hinder it and that are not reflected in national surveys.

## Price coefficient of milk

Milk	cluster mun							
	Before Interviews		After Interviews					
	F1-Sale	F1-Sale & Auto-consumption	F2-Sale	F2-Sale & Auto-consumption	F3-Sale & Auto-consumption	F4-Sale		
ihs_P_n_imp	4.140***	3.181***	4.187***	2.820***	4.701***	2.731***	4.646***	
	Variables adicionales							
	Variables; Table 6 to 7		Corruption		Corruption		Corruption	
			Need for Irrigation		Need for Irrigation		Irrigation	
			Land Tipology		Land Tipology		Land Tipology	
					Problems		Problems (count)	
							Support programs	



These factors were considered to improve the estimation of the production frontier, and to be able to deliver more precise public policy recommendations.

## Price coefficient for sugarcane

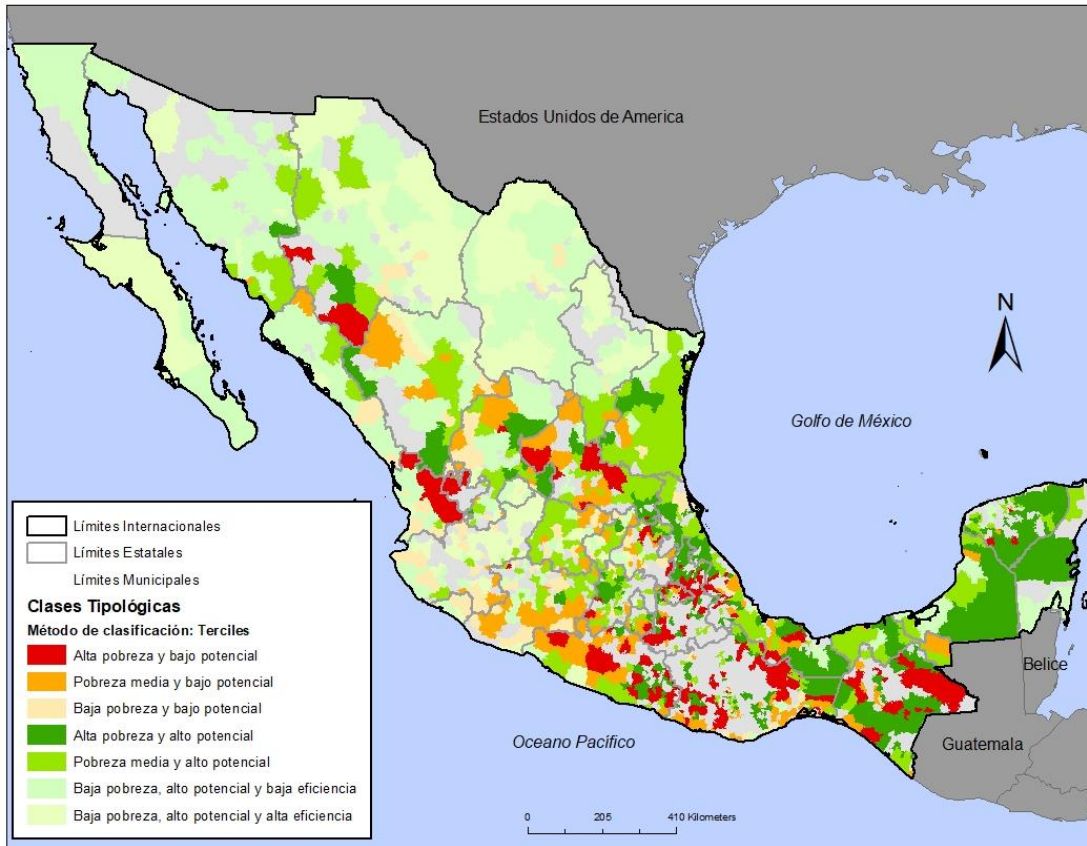
Sugar Cane	cluster mun					cluster mun			
	Before Interview					After interviews			
	f1	f2	f3	f4	f5	f6	f7	f8	f9
ih_s_P_imp	1.792***	1.770***	1.760	1.816***	1.816***	1.784***	1.806***	1.838***	1.824***
Variables in Tables 6 and 7						Adition Variables			
						Corruption fertilizers	Corruption fertilizers	Corruption fertilizers	Corruption fertilizers
						need for irrigation	need for irrigation	need for irrigation	need for irrigation
						Land tipology	Land tipology	Land tipology	Land tipology
								Type of problems	Count problems
									Support programs

## White corn price coefficient

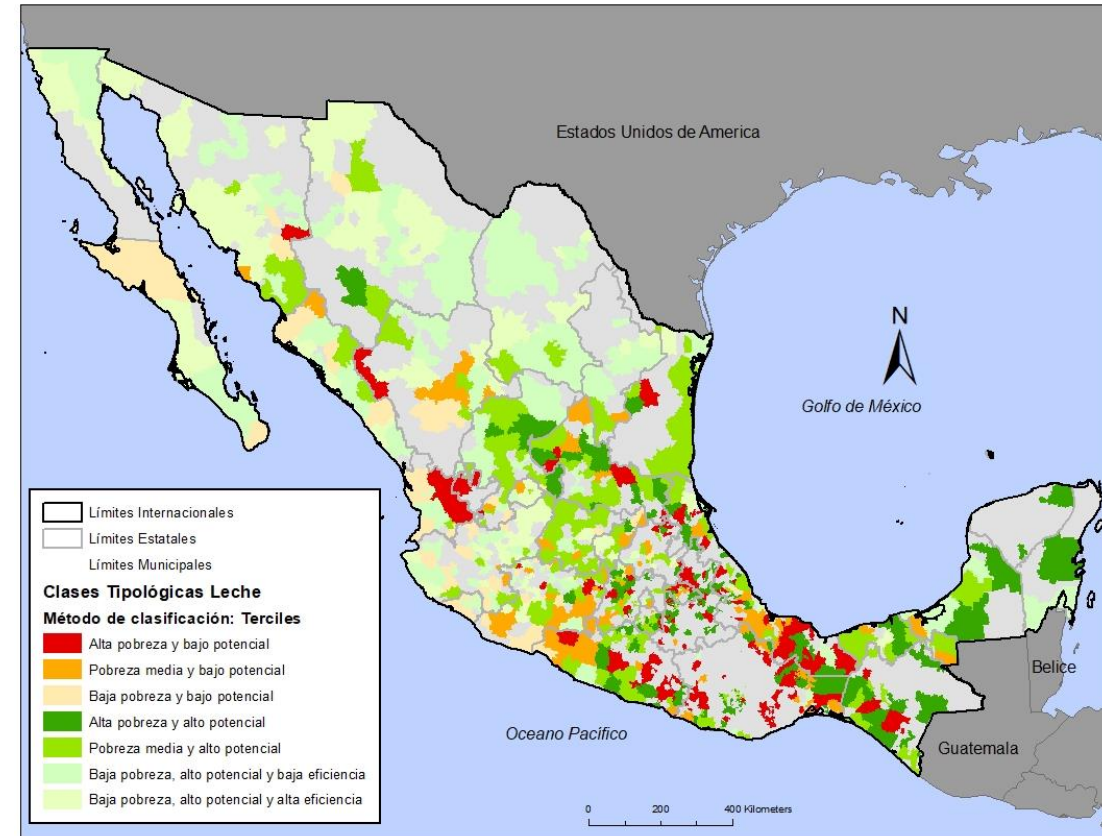
White corn	cluster entidad					cluster municipio				
	Before Interview					After Interview				
	f1	f2	f3	f4	f5	f6	f7	f8	f9	f10
ih_s_P_imp	1.448***	1.451***	1.433***	1.422***	1.422***	1.324	1.302	1.315	1.308***	1.308***
Variables in Tables 6 and 7						Adicional Variables				
						Corruption Prices	Corruption Prices	Corruption Prices	Corruption Prices (imp.)	Corruption Prices (imp.)
						Irrigation need	Irrigation land	Irrigation land	Irrigation land	Irrigation land
						Land tipology			Problems	Problems (count)
										Problems (count)
										Support programs

# Results

## Typology of Cattle



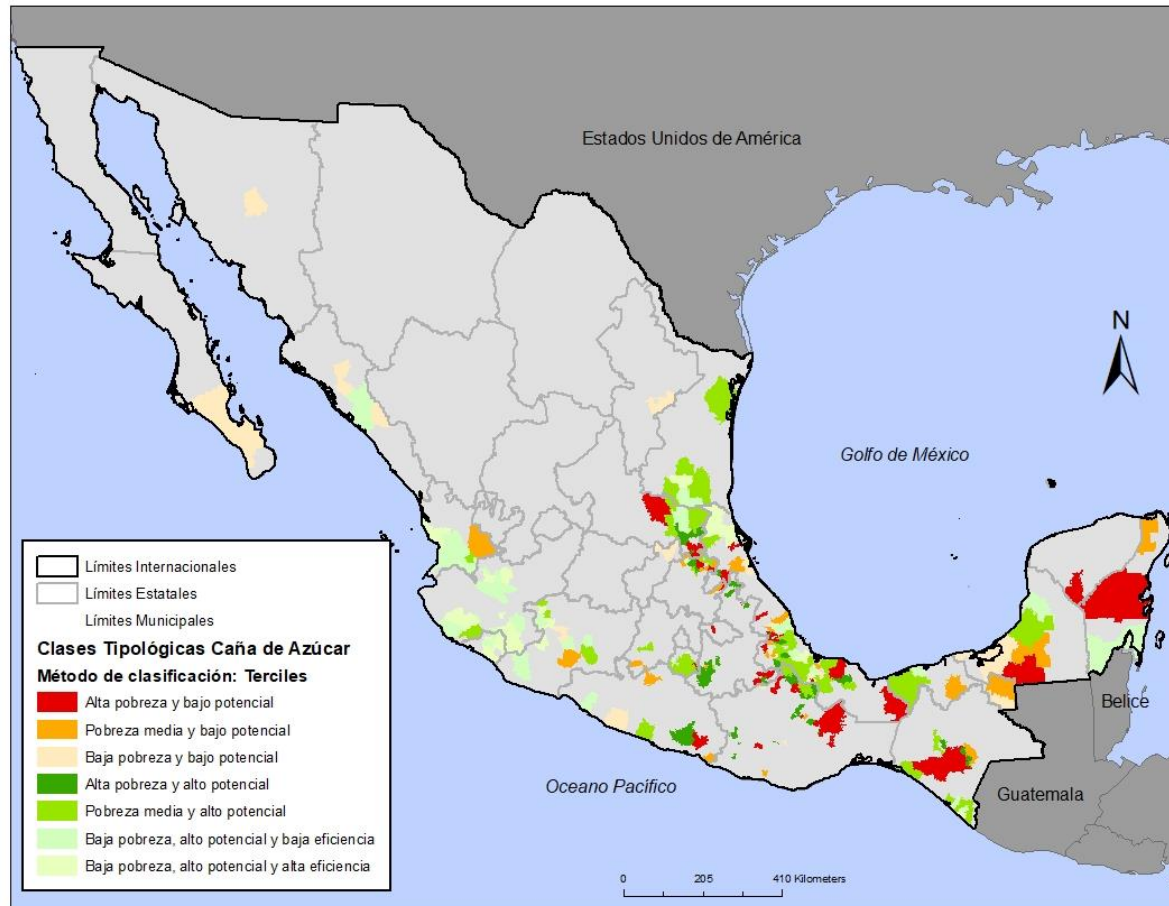
## Milk Typology



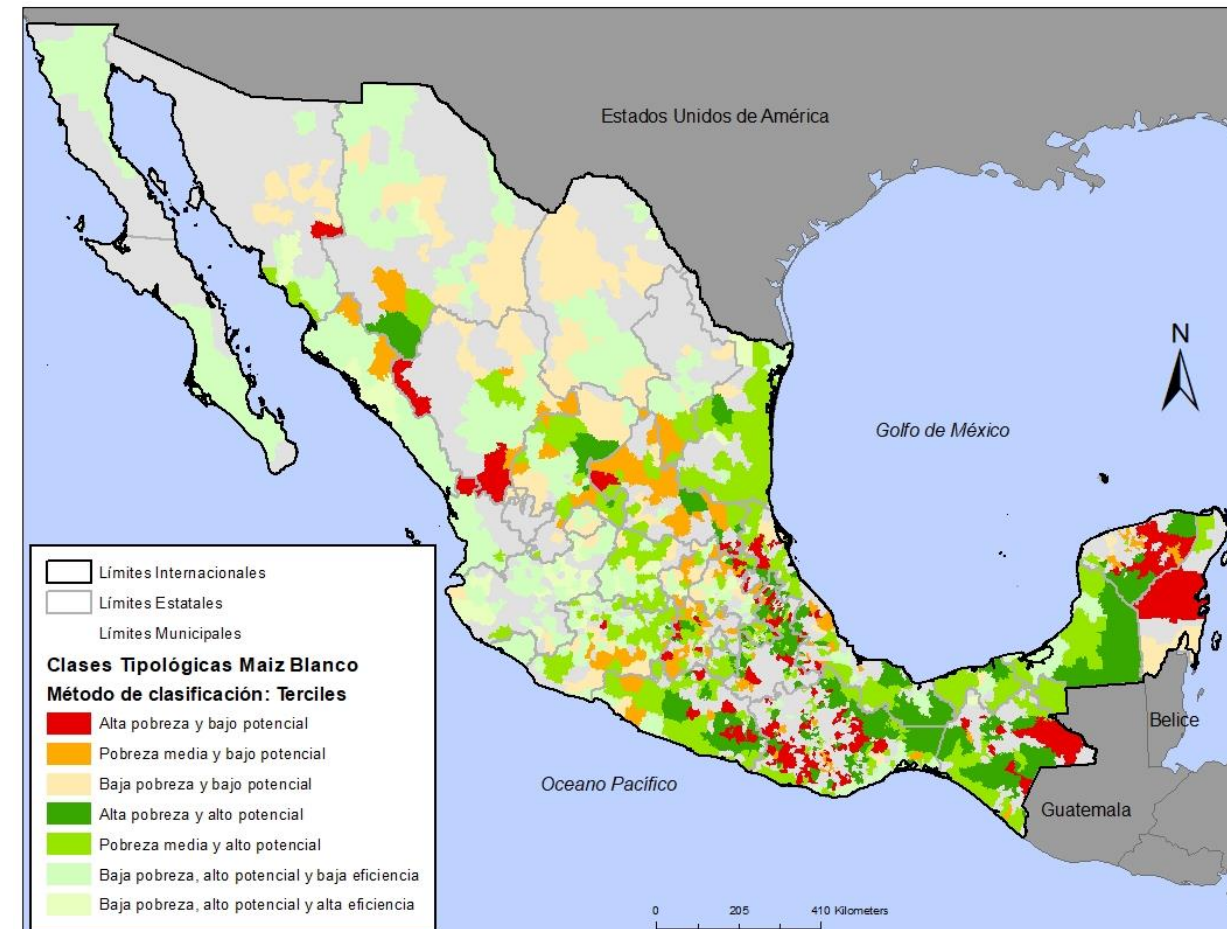
Source: Ortega, Molina, Flores, Guzmán (2023) using ENA-2019

# Map Annex

## Typology of Sugarcane



## Typology of White Corn



Source: Ortega, Molina, Flores, Guzmán (2023) using ENA-2019

# States with Municipalities in High Priority Typology

These states contain high-priority municipalities (high potential and high poverty), and those highlighted in pink are the ones with the highest production at the national level according to ENA-2019.

Región W	Bovinos	Leche	Cazúcar	Maíz
W2	Campeche	Campeche		Campeche
W1	Chiapas	Chiapas	Chiapas	Chiapas
W6	Chihuahua	Chihuahua		Chihuahua
W4	Durango			
W1	Guerrero	Guerrero	Guerrero	Guerrero
W2	Hidalgo	Hidalgo	Hidalgo	Hidalgo
W3	Michoacán de Ocampo	Michoacán de Ocampo		Michoacán de Ocampo
W4	Morelos	Morelos	Morelos	Morelos
W6	México	México		México
W4		Nayarit		
W1	Oaxaca	Oaxaca	Oaxaca	Oaxaca
W2	Puebla	Puebla	Puebla	Puebla
W4	Querétaro	Querétaro		
W5	Quintana Roo	Quintana Roo		
W2	San Luis Potosí	San Luis Potosí	San Luis Potosí	San Luis Potosí
W6	Sonora			
W2	Tabasco	Tabasco		Tabasco
W6	Tamaulipas	Tamaulipas		Tamaulipas
W4	Tlaxcala	Tlaxcala		Tlaxcala
W2	Veracruz de Ignacio de la Llave	Veracruz de Ignacio de la Llave	Veracruz de Ignacio de la Llave	Veracruz de Ignacio de la Llave
W4	Yucatán	Yucatán		Yucatán
W3	Zacatecas	Zacatecas		Zacatecas

The Ws represent INEGI wellness zones.

The 6 suggested states are:

Chiapas  
 Durango  
 Michoacan  
 San Luis Potosi  
 Veracruz

And as a state of contrast: highly producer:  
 6. Jalisco

Las Ws: son regiones de México según mapas de bienestar del INEGI.

Typology	Examples of interventions according to interviews and SWOT
<b>High poverty and low potential</b>	<p><b>Aid package:</b> Increase in short, medium and long-term investments in agriculture, such as the financing of R+D activities to generate technological changes and important investments in infrastructure.</p> <p><b>Training:</b> Urgent short-term targeted assistance programs, such as conditional cash transfers that incentivize investments in human capital.</p> <p><b>Land tenure:</b> Land titles that allow investment and guarantees or guarantees, especially for peasants and ranchers.</p>
<b>High poverty, high potential and low efficiency</b>	<p><b>Costs:</b> Reducing market access costs by improving roads, lighting, transport and safety.</p> <p><b>Prices:</b> Price information system for inputs such as pesticides, herbicides, vaccines, deworming and cattle technologies.</p>
<b>Medium poverty, high potential and low efficiency</b>	<p><b>Credit:</b> Inclusive and unbureaucratic financial instruments to enable investments in production, credits for working capital and insurance to mitigate the risk of crop failure due to climate change.</p>
<b>Low poverty, high potential and low efficiency</b>	<p><b>Organization:</b> Strengthening of horizontal and vertical integration institutions that provide market power to small producers and guarantee their social security and the sale of their products at competitive prices.</p> <p><b>Technification:</b> Investments in medium and small-scale productive infrastructure, such as irrigation projects and land management projects.</p> <p><b>Training:</b> Knowledge of the agricultural business to prevent new generations from leaving the field.</p>
<b>Low poverty, high potential and high efficiency</b>	<p><b>Exports:</b> Orientation to export markets, laws that guarantee competitive prices and diversification of the range of products (e.g. bioethanol).</p> <p><b>Certification</b> and organic production to obtain higher income from agricultural production.</p> <p><b>Financial inclusion</b> to enable higher returns on savings on earnings, facilitate access to credit to purchase additional land, and expand agricultural and non-agricultural businesses.</p> <p><b>Innovative markets</b> that are not only based on supply centers, but that bring the gourmet experience closer to buyers of high-potential agricultural products.</p>

Source Ortega, Molina, Flores, Guzmán (2023) based on Maruyama *et al.* , 2018, and in expert interviews

# Conclusions: findings

- We find five **priority states**: Chiapas, Durango, Michoacán, San Luis Potosí and Veracruz.
  - **Interviews** conducted with experts in the four subsectors analyzed —sugar cane, white corn, cattle and milk— and in food of the vulnerable population validated the results obtained and provided additional variables that should be considered: corruption, insecurity, support programs, prices of inputs, access to credit and training, among others.
  - Reestimating the boundaries with the inclusion of these new variables led to similar findings.
  - The typology of microregions of Mexico identified for the four subsectors analyzed allows actors in the agricultural sector to design public investment plans with the greatest possible socioeconomic impact.
1. Regions where public investment is a priority have been identified. They include areas of **low potential and high poverty**. These require a source of long-term investment in infrastructure, training and social programmes, as an aid package.
  2. Regions that are not a priority, but have **high potential and medium levels of poverty**. They need to be exposed to international markets for their competitiveness and they also need financial investment and innovation in the



# Conclusions: Priority areas

- **Priority areas** require short-, medium- and long-term investments to help producers with programs at different stages of need:
- R&D + commercialization of technologies that help improve irrigation;
- Roads that allow producers to communicate with markets directly and avoid the need to use intermediaries;
- Improving the pricing system to make it more transparent and timely.
- In addition, it is necessary to train the new generations who are leaving the countryside,
- Expand land tenure for men and women,
- Strengthen the organization of farmers – dispersed and without bargaining power to ask for credit, loans or fair prices – invest for the benefit of producers,
- Urgently establish a competitive and innovative rural development bank



Investigación con Impacto Social

# Thank you

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Center for Development with Equity (EQUIDE- Universidad Iberoamericana)

Production chains of white corn, sugar cane, cattle and milk.

Project leader: [Dra. Araceli Ortega Díaz](#) (EQUIDE)

Typology maps: Dr. Miguel Flores Segovia(UDEM)

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David Guzmán(UANL)

FAO-Italy Counterpart

Leader: Dr. Cristian Morales Opazo (FAO)

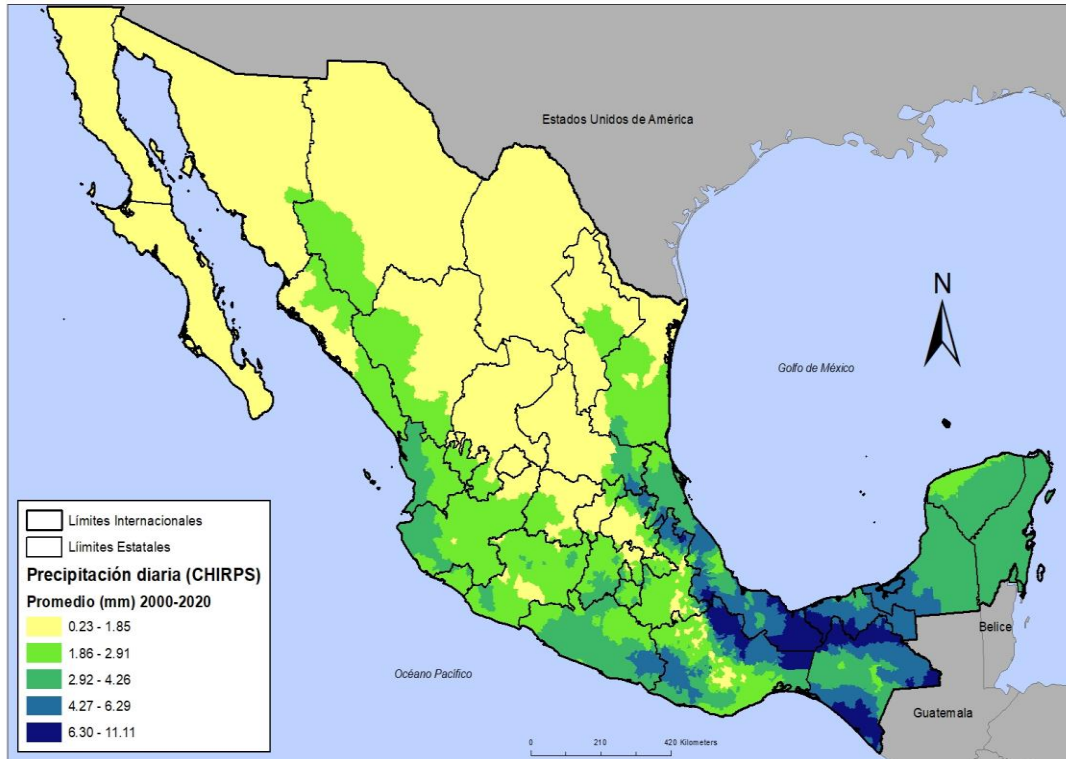
Economist: Ana Díaz González(FAO)

# Some references in this ppt

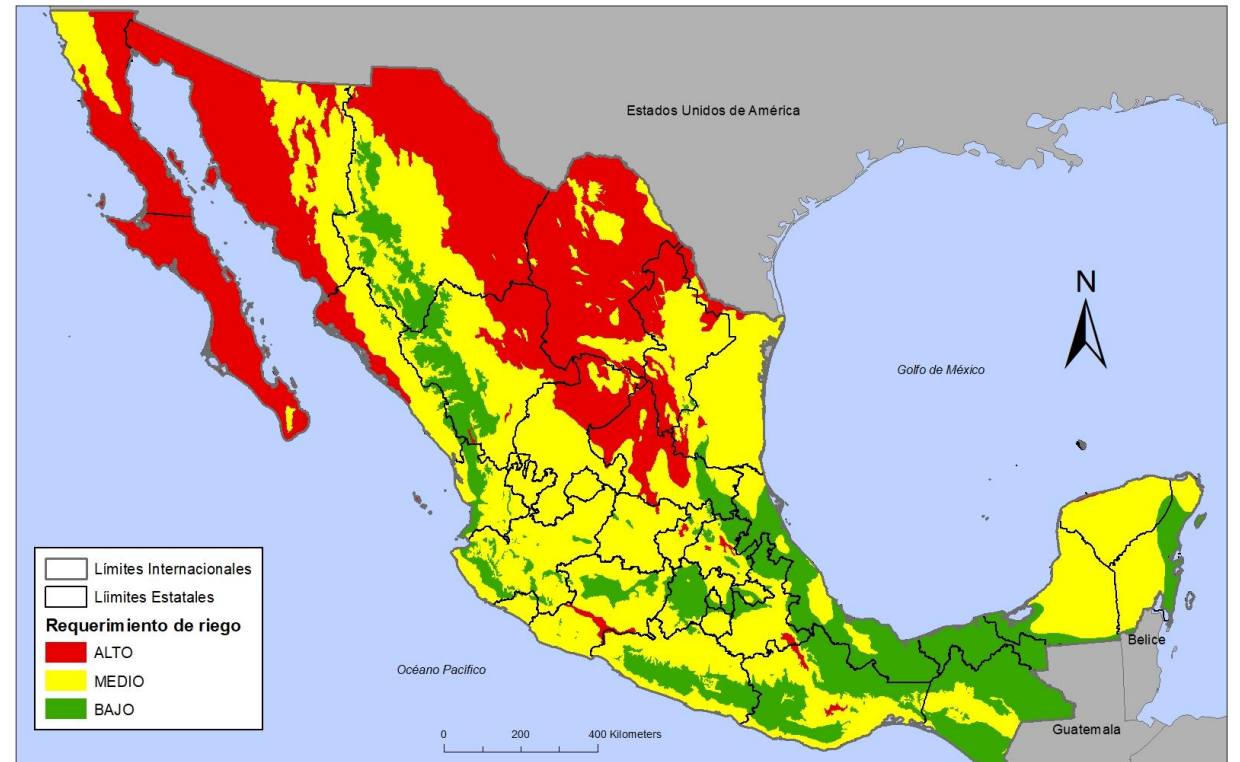
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# Annex. Geographic variables

Rain Map



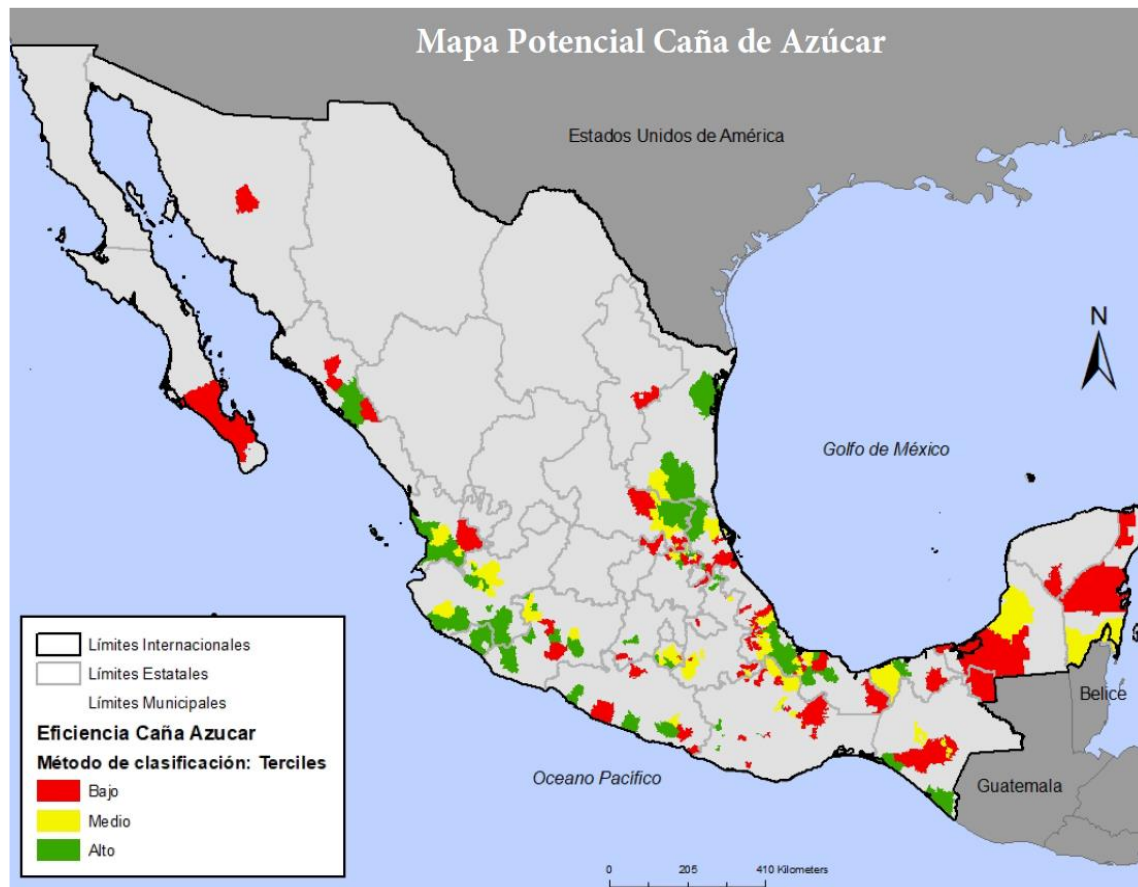
Irrigation Need Map



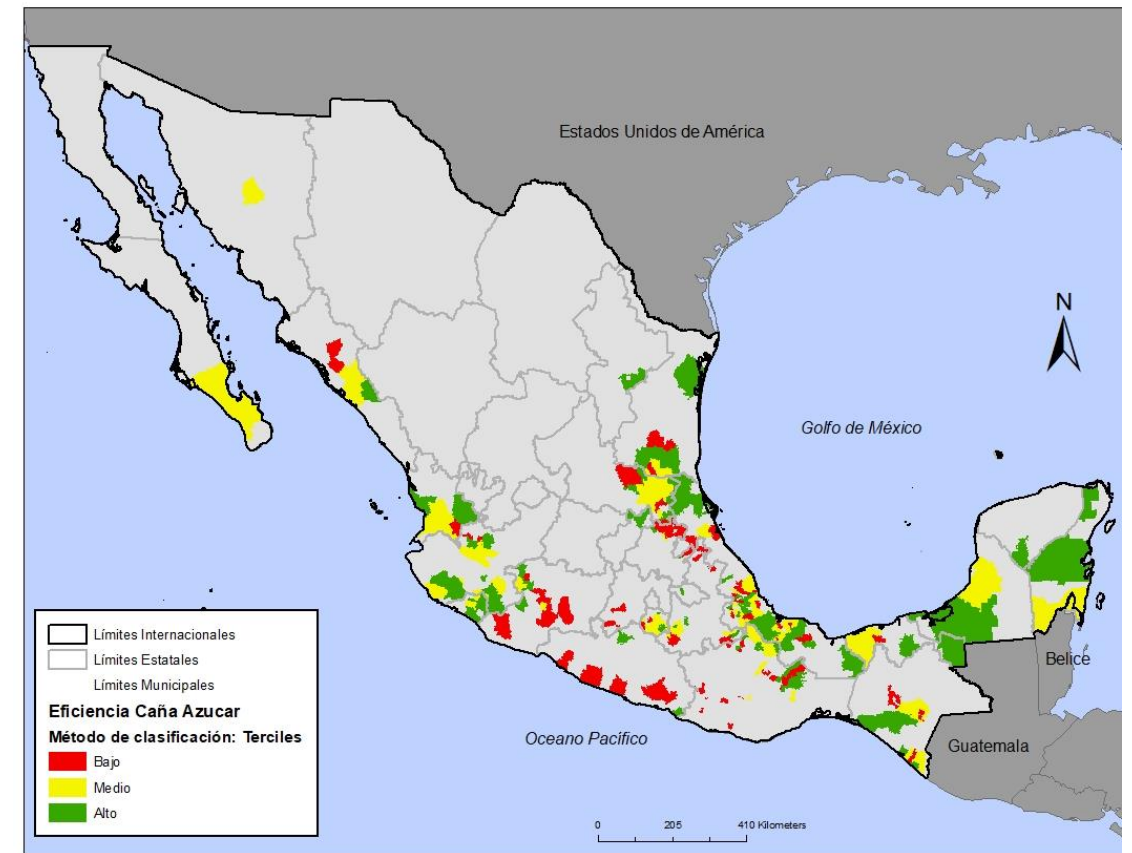
Own elaboration with satellite data 2021

# Map Annex

## Sugarcane Potential



## Sugarcane efficiency



Own elaboration estimating the typologies with data from the ENA-2019

# Sources of inefficiency: Main problems faced by agricultural producers

Problem and trend	Percentage of producers reporting the problem			
	ENA 2012	ENA 2014	ENA 2017	ENA 2019
High costs of inputs and services ↓	81,4	83,4	75,7	73,8
Loss of crop or animals due to climatic causes ↑ ↓	74	78,2	74,7	ND
Loss of crop or animals due to biological causes	ND	ND	44,2	ND
Lack of training and technical assistance ↓	51,9	45,5	33,1	30,8
Marketing difficulties due to low prices ↓ ↑	ND	37,2	31,7	33,1
Loss of soil fertility ↓	48,6	39,4	28,4	27,9
Difficulties selling to another country	ND	ND	28,2	ND
Export difficulties due to strict technical and phytosanitary requirements ↑	ND	ND	9,2	10,4
Insufficient infrastructure for production ↓	45	34,9	24	20,8
Difficulties in marketing due to the existence of intermediaries ↑ ↓	26,5	37,2	22,8	24,3
Difficulties in transport and storage ↓	ND	25,7	19,7	12,2
Elderly or sick producer ↓ ↑	23,3	24,6	18,9	19,5
Insecurity ↓ ↑	ND	25,3	17	19,6
Difficulties in exporting at higher prices in the local market ↑	ND	ND	9,6	12,6
Lack of information on product prices ↓ ↑	ND	21,9	9,5	10,9

Source: Ortega, Molina, Flores, Guzmán (2023) using ENAs.

# Reasons why sugarcane and white corn producers did not plant their crops, excluding fallow

Cause	Percentage
Drought	26,0%
Another cause	25,9%
Lack of money	20,9%
Absence of support	9,4%
Water access problems	4,7%
Not profitable	3,7%
There was no one to carry out the planting.	2,8%
They were not interested in planting the crop	2,5%
Soils that are not very fertile	2,1%
Waterlogging or excess moisture	1,2%
Invaded surface	0,4%
Delinquency	0,3%
	100,0%

Solvable problems that can Increase efficiency.

Source: Ortega, Molina, Flores, Guzmán (2023) using ENA-2019