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Multidimensional Typology of Mexican Farmers in the Context of Climate Change

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Abstract: Mexico has a wide range of biophysical and socioeconomic conditions that result in farmers with highly diverse traits and activities in relation to their livelihoods. The aim of this research was to identify specific traits of Mexican farmers that would allow them to be classified through a multidimensional approach that includes the risk of production in the face of exposure and vulnerability to climate change. The method included three dimensions: producer sensitivity, production destination, and exposure to climate change. Principal component analysis combined with the Dalenius and Hodges optimal stratification technique was used to stratify the universe of agricultural producers. The results show that up to 227 groups of agricultural producers can be identified in Mexico, and it was possible to classify them into 19 types, ranging from agricultural producers at greatest risk due to the adverse effects of climate change to agricultural producers with fewer difficulties to produce in conditions of climate change. This proposed multidimensional typology of agricultural producers can become an essential input for designing, reorienting, or focusing public policies in the agricultural sector and moving towards fulfilling the commitments declared in the INDC-2030.

Keywords: agricultural systems; producer classification; producer sensitivity; producer stratification; producer typology; production environment

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1. Introduction

The challenge before the agricultural sector is to ensure that the world's population has sufficient food available on a permanent basis [1]. Farmers are very sensitive to changing climatic conditions, and they are under greater pressure to supply food [2]. The Intergovernmental Panel on Climate Change (IPCC) [3] reports that there has been a 1.1 °C increase in global average temperature [4,5]. In several countries, including Mexico, there is evidence of increased production and distribution costs [6], as well as losses in crops, agricultural products, or the quality thereof [7–10]. Climate change disproportionately increases the risk to agriculture activities, requiring farmers to take appropriate adaptive actions [3].

Some responses for coping with this challenge include achieving the goals set out in global (Sustainable Development Objectives), national (Intended Nationally Determined Contributions (INDCs)), and subnational (State Strategies on Climate Change) agendas. In the pursuit of reducing vulnerability caused by climate change [9,11], about 300 Mexican

municipalities have been classified as highly vulnerable areas [12], and Mexico has committed to reducing this condition in at least half of them [13]. In updating the INDCs, the adaptation component promotes resilient productive systems as well as food security [14]. Thus, the commitment demands detailed and precise approaches to achieve these goals by 2030.

A crucial link for creating accurate and target-group-oriented adaptation measures is understanding the structure of farmers and their land [15]. Every farm has particular climatic, biophysical, economic, and social characteristics. The construction of typologies allows for the identification of producers with common socioeconomic attributes, and is an efficient tool for realistically analyzing farmers' limitations and opportunities [16,17]. Differentiated solutions to cope with climate change and some socially problematic issues [18–24] can be designed. It thus becomes relevant to identify the different groups of producers that exist in a country or region to determine the heterogeneity of the agricltural systems and to develop better and more effective climate adaptation and mitigation outreach strategies.

Mexico is the world's seventh-largest agrifood exporter and is considered a country that is particularly vulnerable to climate change [25–27]. This fact is transcendent since 70% of the 5 million production units are family-run subsistence farms [28]. Over the last three decades, several studies have been conducted regarding the Mexican agricultural sector in which farmers have been characterized by several approaches: at the national level and based on maize yields [29], by the economic unit's income [30], by differentiating the agricultural specialization used [31], or by the area dedicated to basic activities [32]. Some socioeconomic characteristics and the management type of the production unit have been considered at the regional scale [33–35]. The results have made it possible to identify, at a large scale, the characteristics that differentiate small producers from medium-sized or large ones, based on sown area, their yields, or the production destination. However, the country's characteristics, such as the variety in production environments (climates, soils, plots) and sociocultural richness (traditions, indigenous groups), indicate the land's suitability and its limitations in producing yields and crops. If the degree of exposure and vulnerability to climate change is also included [36], it is thus necessary to know and characterize the agricultural producers in greater detail so that policies and efforts can be better directed in the country.

Hence, Mexico is considered among the ten highest-priority regions worldwide to promote adaptation to climate change [37]. Exposure to climate change relates to the climatic stress level of a unit of analysis due to climatic variations [38,39]; in Mexico, 72 municipalities are reported to have medium to very high exposure, and this number could slightly surpass 200 in the near future [36]. The country's agricultural activity, particularly rainfed farming, is exposed to climatic variations, which is an important reason for including this criterion in the producer classifications to address agricultural policies better. Estimating the capacity and potential of a system to face and adapt itself to climate change is a major challenge. It is especially true in the case of people whose livelihoods are highly dependent on natural resources or who live on marginalized lands, such as small agricultural producers [13,40]. To know in detail the traits defining agricultural producers in the country implies an approximation to determine the population subject to policy and assistance that contribute to the achievement of any government commitments.

Therefore, the aim of this study was to propose a classification of agricultural producers with a multidimensional approach that included the exposure and vulnerability to climate change in an empirical fashion. It will allow, in the future, to estimate the adaptive capacity of each group of producers and regions in the country to design support alternatives and prioritize public policies. The manuscript is presented as follows: first, the methodological process that was developed in three stages (conceptualization and rationale of the typology, source data and indicators, and statistical analysis) is described. Subsequently, the results obtained from the classification of producers based on the Dalenius and Hodges method are presented. Then, the most relevant findings are discussed, and, lastly, the conclusions are given.

2. Materials and Methods

2.1. Reference Framework and Classification Boundaries

A documentary review was carried out to determine the different types of producers and explore how they have been classified in Mexico. The first typology, CEPAL [29], was based on irrigated and rainfed maize yields by state, making them comparable based on the National Rainfed Equivalency (NRE). Soto Baquero [41] later classified households engaged in family farming (FF) into subsistence, transition, or consolidated groupings. SAGARPA & FAO [30] stratified producers using as the main criterion the income obtained by each rural economic unit (REU) from the sale of their agricultural products. The argument for using income is that it allows for the determination of the economic size of each unit based on its own performance. Yúnez Naude et al. [31] focused on FF by differentiating between specialized (SFF) and pluriactive (PFF) systems. Robles Berlanga [32] classified small and medium-sized producers based on the area dedicated to the primary production of agricultural and livestock products. Santos Chávez et al. [35], and Reyna-Ramírez et al. [34] classified some Mexican regions according to socioeconomic characteristics and management of the production unit. More recently, Coronado-Minjarez et al. [42] made a classification proposal considering the multidimensionality of agricultural producers in the Western Potosino High Plateau (Table 1).

Table 1. Typology proposals for Mexican farmers and their main characteristics.

Author	Classification Scale	Central Criterion	Number of Defined Types	Main Variables Used
CEPAL, 1981 [29]	National	Maize yield and National Rainfed Equivalency	11	Social reproduction. Number of contracted workdays. National rainfed equivalent. Agricultural income. Value of livestock capital.
Soto Baquero et al, 2007 [41]	National	Family farming	3	Household income from agricultural and non-agricultural activities. Plot size.
FAO and SAGARPA, 2012 [30]	National	Income from the sale of agricultural and livestock products	6	Socioeconomic characteristics. Income. Production technology. Productive assets.
Yúnez Naude et al., 2013 [31]	National	Family farming	2	Family labor/workforce.
Robles Berlanga, 2013 [32]	National	Dedicated area	3	Land size. Head of livestock.
Santos Chávez et al., 2014 [35]	Local (Texcoco, Mexico)	Decision-sensitive features in terms of public policy	4	Agricultural and non-agricultural income structure. Family workforce.
Coronado-Minjarez et al., 2019 [42]	Regional (Potosino High Plateau)	Multidimensionality of farmers	5	Economic, productive, technological, social, non-agricultural, and market-related variables.
Reyna-Ramírez et al., 2020 [34]	Regional (Mixteca and Guatemalan highlands)	Family income Family work	5	Investment capacity, remittances, type of work (outside and inside the production unit) and livestock activity.
This study	National	Producer sensitivity Destination ofproduction Production risk due to climate	19	Land tenure; Irrigation infrastructure; Number of activities carried out in the production units; Income from the sale of agricultural products; Current and future exposure to climate change.

The above classifications mainly use socioeconomic, area, or yield criteria. Land suitability and its current and future production capacity have been omitted. Cultural and cultural production aspects and worldviews have also been excluded. Including prospective criteria is a challenge since they are part of the characteristics that producers must integrate into agricultural production, as well as policies should integrate them into their programs (subsidies) to make sure they do not fail [43]. This proposal explores a producer typology to identify common characteristics and similar challenges of facing climate change. In particular, it seeks a typology oriented to boosting adaptive capacity to climate change. Studies on climate, its variability, and climate change answer questions

such as: what should producers adapt to? Studies similar this one answer questions such as: what are the characteristics of producers that must be addressed to promote adaptation?

The country comprises 32 states, which in turn are divided into 2469 municipalities and 189,000 localities (a 'locality' is considered to be any place occupied with one or more dwellings, and they may be or may not be inhabited; according to their characteristics, and for statistical purposes, localities are classified as urban and rural [44]). Thus, the selected scale of analysis was the 'locality' (village) since it allows a better dimensioning of what happens within the municipalities. Mexico has an area of 198 million hectares [28], of which 133.62 million hectares are used for primary activities such as agriculture, livestock farming, forestry and gathering, aquaculture, and fishing [45]. For this research, all of them are considered as part of the agricultural sector.

A key criterion in the composition of the producer typology was that the information to be used should be from national, official, and open access sources. Multidimensionality refers to (1) the production environment that defines the producer's sensitivity, (2) characteristics and attributes of the Rural Economic Units (REUs, referred to as production units subsequently), as well as the destination of their production, and (3) production risk due to climate exposure, understanding risk as "the nature and degree to which a system is exposed to significant climate variations" according to the IPCC [25] (Figure 1).

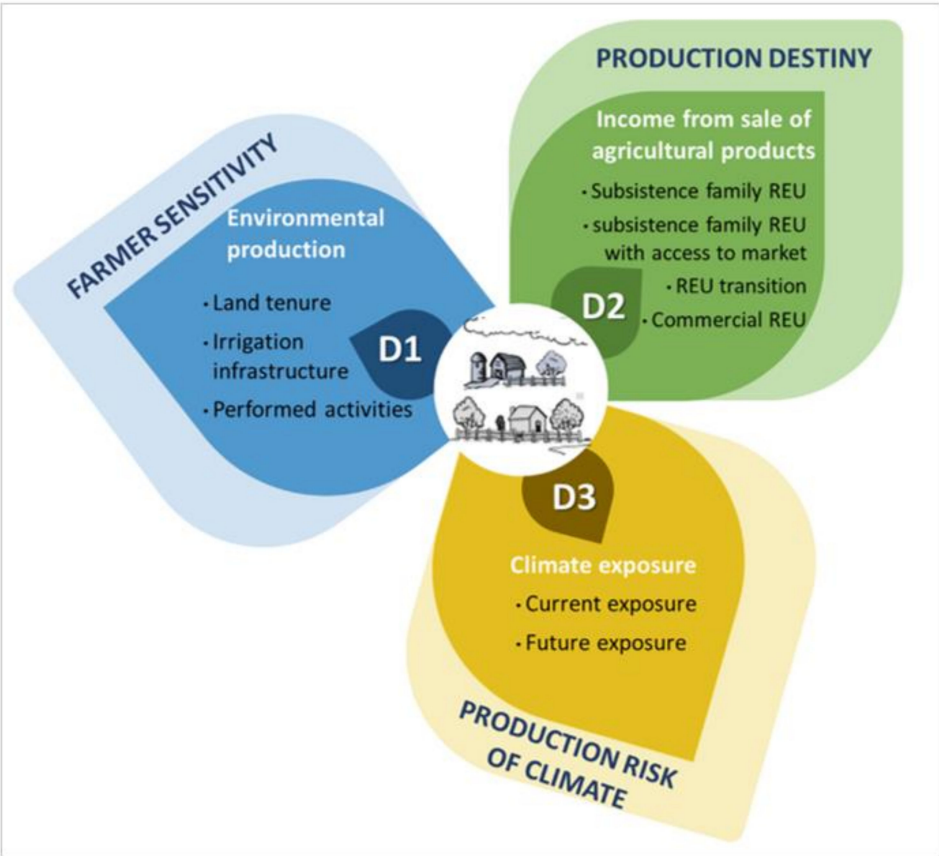

Figure 1. Dimensions included in the Multidimensional typology of Mexican farmers.

2.2. Data and Indicators

The "producer sensitivity" dimension is determined by the production environment; it refers to the fragility of farmers when carrying out their activities due to the conditions available in their production unit (this concept does not refer to sensitivity as a component of vulnerability to climate change). The variables used were: (1) land tenure, (2) irrigation infrastructure, and (3) the number of primary activities. Land tenure considers whether the farmer owns or rents land. Irrigation infrastructure refers to the availability (or not) of irrigation technology in the production unit. Furthermore, primary activities refer to the

number of activities that farmers stated they carry out in the production unit. This dimension is relevant considering the great heterogeneity of the biophysical and socioeconomic conditions in the country, which makes it possible to discern that the contexts in which producers carry out their activities are very different. The data analyzed for these three variables were extracted from the Secretariat of Agriculture, Livestock, Rural Development, Fisheries and Food (SAGARPA) programs' 2008 baseline [46], a representative sample of the production units of the Mexican Agricultural and Fishing Sector. This baseline represented the universe of 5,424,430 production units (according to the expansion factor used) [30]; however, for this study, 4,875,514 production units were classified since only those units dedicated to primary activity were considered. This baseline also contains relevant socioeconomic information that was used to describe each group (age, schooling, and geographic location).

The dimension "production destination" describes the production units based on the income obtained by producers from the sale (or not) of products from primary activities. The information source was the stratification of rural economic units defined by SAGARPA-FAO [30]. It considers six groups, including two of subsistence family farming, one of transition agriculture, and three of entrepreneurial agriculture.

The dimension of "production risk due to climatic and climate change exposure" considers the presence of people and primary activities that are or could be negatively affected by climate change [47]. Exposure to climatic phenomena was taken from [48], who considered the existence of the following: extreme events (presence of floods, frost and hail, total heavy rains, total landslides or droughts, from 2005 to 2015), environmental problems (illegal logging, wildfires, pests, biodiversity loss, and water pollution, etc.), and future climate. This dimension explores the main threats that risk agricultural producers' livelihoods.

2.3. Statistical Analysis

The statistical integration occurred in two stages: first, within each dimension, and then integrating the three dimensions to obtain a single producer typology.

Sensitivity, Destination and Risk Dimensions. The three variables regarding land tenure, irrigation infrastructure, and total activities carried out were combined in the producer sensitivity dimension using a qualitative–quantitative analysis, aided by a triple-input table (Table 2). This process involved identifying the producer's sensitivity level to carrying out a primary activity based on the three variables. Values were assigned to each variable. The highest value (5) was for the condition that makes the producer the most susceptible, and the lowest value (1) was for when it makes the producer the least susceptible; afterwards, the algebraic sum of the values was calculated to obtain a final grade. The range of colors, from red to green tones, shows the different producer sensitivity classes: from the highest (S1) to the lowest (S11).

The six categories defined by SAGARPA-FAO [30] were used for the production destination dimension: family subsistence, family subsistence with market sales, transition, entrepreneurial, thriving entrepreneurial, and dynamic entrepreneurial. For the production risk dimension, as determined by climatic and climate change exposure, the five classes in [36] were also taken: very high, high, medium, low, and very low exposure. It should be noted that exposure is a function of the frequency of extreme events experienced, the environmental problems observed, and the future behavior of two climate variables, temperature and precipitation.

Producer typology. The variables in farmers' typology included: (1) the production environment that defines the producer's sensitivity, (2) characteristics and attributes of the Rural Economic Units, as well as the destination of their production, and (3) production risk due to climate exposure previously defined (Figure 1). Values were assigned to the variables to categorize them; the highest value (5) is for producers having the least favored condition for carrying out primary activities and the lowest value (1), on the other hand, reflects the most favorable conditions (Table 3, value column). Finally, an algebraic sum of the values was performed to obtain a final grade, and the values were standardized.

Table 2. Classification of eleven producer sensitivity levels.

Land Tenure	Type of Production	Total Activities Carried Out				
		Only One Primary Activity	Agriculture and Another Primary Activity	Two Primary Activities	Three Primary Activities	More than Three Primary Activities
With no land of their own	Neither rainfed nor irrigated	S1	S2	S3	S4	S5
Rented land	Neither rainfed nor irrigated	S2	S3	S4	S5	S6
	Rainfed	S3	S4	S5	S6	S7
	Irrigated	S4	S5	S6	S7	S8
	Rainfed and irrigated	S5	S6	S7	S8	S9
Own land	Neither rainfed nor irrigated	S3	S4	S5	S6	S7
	Rainfed	S4	S5	S6	S7	S8
	Irrigated	S5	S6	S7	S8	S9
	Rainfed and irrigated	S6	S7	S8	S9	S10
Own land and rented	Neither rainfed nor irrigated	S4	S5	S6	S7	S8
	Rainfed	S5	S6	S7	S8	S9
	Irrigated	S6	S7	S8	S9	S10
	Rainfed and irrigated	S7	S8	S9	S10	S11

The range of colors, from red to green tones, shows the different producer sensitivity classes: from the highest (S1) to the lowest (S11).

Table 3. Dimensions and variables included in the producer typology.

DIMENSION Variable	Code	Value	Production Units Surveyed *	Production Units in the Country **
(A) PRODUCER SENSITIVITY DIMENSION				
Primary activities				
Only one primary activity	AP1	5	14,897	2,910,089
Agriculture and another primary activity	AP2	4	6715	1,373,649
Two primary activities	AP3	3	663	109,045
Three primary activities	AP4	2	1481	411,532
More than three primary activities	AP5	1	162	71,199
Land tenure				
Have no land of their own	T1	4	387	72,112
Rent land	T2	3	1249	266,154
Own land	T3	2	20,633	4,249,864
Own land and rent additional land	T4	1	1649	287,383
Type of production				
Neither rainfed nor irrigated	TP1	4	802	151,764
Only rainfed	TP2	3	17,321	3,802,828
Only irrigated	TP3	2	4055	596,084
Rainfed and irrigated	TP4	1	1740	324,838
B) PRODUCTION DESTINATION DIMENSION				
Family subsistence	E1	4	3635	919,408
Family subsistence with market sales	E2	3	11,904	2,602,916
Transition	E3	2	2416	415,371
Entrepreneurial	E4	1	2945	498,661
Thriving entrepreneurial	E5	1	2881	423,421
Dynamic entrepreneurial	E6	1	137	15,736
C) PRODUCTION RISK DIMENSION (Exposure to climate change)				
Very high exposure	CC1	5	179	67,519
High exposure	CC2	4	730	176,126
Medium exposure	CC3	3	6882	1,587,013

Table 3. *Cont.*

DIMENSION Variable	Code	Value	Production Units Surveyed *	Production Units in the Country **
Low exposure	CC4	2	12,240	2,246,371
Very low exposure	CC5	1	3887	798,486

Production units are the land(s), machinery, equipment, and other assets farmers use to carry out their agricultural activities. * It refers to the number of production units interviewed in the SAGARPA 2008 baseline. The study is based on 23,918 interviews with production units throughout the country. ** The estimated number of production units for each condition in the country. Source: Prepared by the authors. Source: Prepared with data from SAGARPA programs' 2008 baseline [46].

A principal component analysis (PCA) was combined with the Dalenius and Hodges optimal stratification technique [49] to classify the types of producers. See Supplementary Material File S1 for a short description of PCA. The Dalenius and Hodges optimal stratification model was applied to the data obtained for the first principal component (PC1) [50,51]. It is a statistical technique of high discriminatory quality in constructing an indicator, and various national and international institutions use it for the stratification of indices such as the Human Development Index (UNDP) or the Marginalization Index (CONEVAL). There is evidence that it is an efficient method for agricultural producer stratification since it minimizes variance among producer groups [52]. The data from PC1 were sorted ascendingly; the observations were clustered into J classes, where $J = min(L * 10, n)$, and the number of adequate intervals and the limit for each class were calculated according to Equations (1) and (2):

$$\lim \inf C_{(k)} = \min\left\{x_{(i)}\right\} + (k-1) * \frac{\max\left\{x_{(i)}\right\} - \min\left\{x_{(i)}\right\}}{J} \tag{1}$$

$$\lim \sup C_{(k)} = \min\left\{x_{(i)}\right\} + (k) * \frac{\max\left\{x_{(i)}\right\} - \min\left\{x_{(i)}\right\}}{J} \tag{2}$$

Once the limits were determined, the frequency of cases within each class $f_i(\mathrm{i} = 1, \ldots, J)$ was obtained and the square root of the frequency of each class was calculated (Equation (3)). Then the sum of the square root of the frequencies was accumulated.

$$C_i = \sum_{h=1}^{i} \sqrt{f_n}(\mathrm{i} = 1, \ldots, J) \tag{3}$$

Finally, the last accumulated value was divided by the number of strata [53]

$$Q = \frac{1}{L} C_J \tag{4}$$

3. Results

3.1. Producer Sensitivity

Eleven sensitivity classes of agricultural producers in Mexico were identified. The main characteristics found for the sensitivity classes are presented in Table 4. These were obtained from the combination of the three variables: land tenure, irrigation infrastructure, and total activities carried out in the production unit (Table 2). The highest sensitivity class (S1) is comprised of those producers with no land of their own who stated that they have only one primary activity and no infrastructure for irrigated or rainfed farming. On the contrary, the least sensitive producers (class 11) are those who stated that they have more than three primary activities, produce under irrigated and rainfed conditions, and own land and rent other plots. The producers have different social, economic, and environmental conditions to undertake their primary activities, and the dimension can identify them.

Table 4. Main characteristics of the eleven types of producer sensitivity identified in this study.

Class	Description	Main Characteristics
S1	Very limited conditions and very high sensitivity	Environment in which the producer has no land of his/her own, relies on a family workforce and works in a primary rainfed activity on rented land or in a backyard.
S2	Limited conditions and very high sensitivity	Environment in which the producer does not own land and carries out predominantly rainfed agriculture and sometimes another rainfed primary activity (in parallel or combined).
S3	Limited and highly sensitive conditions	Environment in which the farmer does not own land and carries out one to two primary rainfed activities in a rented area or in his/her backyard.
S4	Minimal conditions for diversification and highly sensitive	Environment in which it is possible for the farmer to diversify his/her activities into up to three primary activities, mostly rainfed ones. Some farmers have their own land, but most have to rent.
S5	Minimal conditions for diversification with medium sensitivity	Environment where the farmer owns land or has the possibility of renting a space to carry out from one to more than three activities, mostly rainfed ones.
S6	Favorable conditions and medium sensitivity	Medium sensitivity environment: conditions are more favorable than in the previous classes. There are some farmers who do not own land but have the resources to rent a plot and can carry out two or three primary activities. There are other producers who own land and can carry out from one to three primary activities on the same plot. Some others, the minority, own a plot and have the possibility of renting an extra plot to carry out one or two primary activities (irrigation and rainfed).
S7	Favorable conditions and low sensitivity	Low sensitivity environment, considering that in this category, the farmer owns land or has the possibility of renting a plot to carry out one to three or more primary activities, which can be rainfed or irrigated.
S8	Very favorable conditions and low sensitivity	Low sensitivity environment, where farmers own or rent land, or both; they carry out two to more than three primary activities, and most of them have irrigation technology.
S9	Very favorable conditions and very low sensitivity	Very low sensitivity environment. In this category are producers with their own land, even with the possibility of renting an extra plot to carry out two or more primary activities; their production does not strictly depend on rainfed agriculture since they have irrigation technology, but they can use both farming systems.
S10	Very favorable conditions and minimum sensitivity	Minimal sensitivity environment, since in this category are producers with very favorable conditions: they own and rent land and have irrigation technology, but some of them can produce rainfed or irrigated crops. They regularly carry out more than three primary activities.
S11	Extremely favorable conditions	Environment with the best conditions. In this category, farmers have sufficient resources to rent extra land or produce more than three primary activities on their plot with irrigation technology, or if they prefer, they can produce in rainfed conditions, but they are not subject to rainfed conditions.

3.2. Production Destination

The six strata shown in Table 5 were considered. This stratification conducted using FAO-SAGARPA [30] was based on the grouping of farmers according to production destination, where the main variable used was the income obtained by the REUs from the sale of their agricultural or fishery products. We use this source of information as a basis since the data were obtained from a direct survey of agricultural producers and is a representative sample of the production units in Mexico.

Table 5. Stratification of the Rural Economic Units (REUs) used in this study.

Stratum	Main Characteristics
I. Family subsistence REU without market sales	The target of their production is not the market; they use all of their production to cover the family's food needs, and, occasionally, it is not enough. The members of this stratum do not consider agricultural activities relevant to their income generation. They complement their income through diversification of activities outside the REU. Work is mainly performed by the family.
II. Family subsistence REU with market sales	This is the predominant stratum in Mexican agriculture, and it is characterized by low income. They send small surpluses of agricultural production to the market, sell their labor outside the REU and engage in non-agricultural activities such as working in small stores and tortilla factories, among others. Like the REU in Stratum E1, they are impoverished, which impedes them from engaging in activities that generate sufficient income for the family's development. Work is mainly performed by the family.
III. REU in transition	These REUs earn income from the sale of their agricultural products, which is sufficient to cover the family's basic needs; however, farmers in this group market their products individually, technological and development capacity levels are low, and the main problem they face is the insufficient profitability of their small business.
IV. Entrepreneurial REU with fragile profitability	Unlike the previous three, these REUs have an entrepreneurial character, but their profitability is fragile. These REUs are the main suppliers of regional markets. The main problem they face is fragile profitability since although half of the REUs in this stratum have a benefit–cost ratio greater than 1, 61.1% of the REUs in this stratum do not exceed the ratio necessary to cover the opportunity cost of capital. The REUs have low entrepreneurial management capacity.
V. Thriving entrepreneurial REU	These are large companies engaged in the agricultural and livestock sector. They are concentrated in the domestic market, where profit margins have been affected by the adverse macroeconomic environment. Their main problem is fragile competitiveness.
VI. Dynamic entrepreneurial REU	They are REUs of considerable scale that could be compared to industrial companies. They obtain 100% of their income from primary activities, mainly agriculture and livestock farming. They are located in areas of low marginalization; they can trade in national and international markets.

Source: Based on the Diagnostic of the Mexican rural and fishery sector [30].

3.3. Production Risk Due to Exposure to Climate Change

Table 6 shows the degrees of exposure to climate change in Mexico, adapted from Monterroso and Conde's results [36]. The classification considered the occurrence of extreme events, environmental problems, and climate change projections in terms of temperature and precipitation.

Table 6. Degrees of exposure to climate change in Mexican municipalities.

Exposure	Description
Very high exposure	In the 1980–2000 period, these municipalities had more than 10 floods, more than seven frosts or hailstorms, more than two heavy rains, and more than three landslide events. They currently have 18% or more of their territory without any type of vegetation, more than 67% of their production units have reported losses due to climatic issues, and more than 30% report losses due to soil fertility deficiencies. The municipal area dedicated to the primary sector is greater than 70%. Future climate change scenarios indicate a temperature increase of more than 2 °C in the studied period and a reduction in precipitation of over 50 mm.
High exposure	In the 1980–2000 period, more than six floods, more than two frosts or hailstorms, more than two heavy rains, and more than one landslide event were observed in these municipalities. These have 15% or more of their territory without any type of vegetation, more than 56% of their production units have reported losses due to climatic issues, and more than 25% report losses due to soil fertility deficiencies. The municipal area dedicated to the primary sector is greater than 65%. Future climate change scenarios indicate a 1.5 to 2 °C temperature increase in the studied period and a 20 to 50 mm reduction in precipitation.

Table 6. *Cont.*

Exposure	Description
Medium exposure	In the 1980–2000 period, more than two floods, more than one frost or hailstorm, more than one heavy rain, and one landslide event were observed in these municipalities. They also have 10% or more of their area without some type of vegetation, more than 45% of their production units have reported losses due to climatic issues, and more than 14% report losses due to soil fertility deficiencies. The municipal area dedicated to the primary sector is 50%. Future climate change scenarios indicate a 1.3 to 1.5 °C temperature increase in the studied period and a 15 to 20 mm reduction in precipitation.
Low exposure	In the 1980–2000 period, one flood, one frost or hailstorm, one heavy rain, and one or less than one landslide event were observed in these municipalities. They have less than 10% of their territory without some type of vegetation, 35% of their production units have reported losses due to climatic issues, and more than 8% reported losses due to soil fertility problems. The municipal area dedicated to the primary sector is 40%. Future climate change scenarios indicate a 1.3 to 1.5 °C temperature increase in the studied period and a 15 to 20 mm reduction in precipitation.
Very low exposure	In the 1980–2000 period, one flood, one frost or hailstorm, one heavy rain, and one or no landslide events were observed in these municipalities. They have less than 5% of their territory without any type of vegetation, less than 30% of their production units have reported losses due to climatic issues, and less than 8% report losses due to soil fertility problems. The municipal area dedicated to primary production is less than 40%. Future climate change scenarios indicate a temperature increase equal to or less than 1.3 °C in the studied period and a reduction in precipitation of less than 15 mm.

Source: Adapted from Monterroso, A. & Conde, C. [36].

3.4. Producer Typology

Based on the combination of the three dimensions (producer sensitivity, production destination, and production risk due to exposure to climate change), it was found that there are up to 227 specific groups of producers in Mexico; however, because it is not practical to work with a typology with so many groups, the Dalenius optimal stratification technique was used; managing to classify the universe of specific groups into 19 types of agricultural producers (Table 7 and Supplementary Material Table S1).

Table 7. Nomenclature of each producer type obtained with the Dalenius & Hodges method.

TYPE	NOMENCLATURE
T1	Family subsistence producer with very high sensitivity and medium level of exposure to climate change
T2	Family subsistence producer with very high sensitivity and low level of exposure to climate change
T3	Family subsistence producer with very high sensitivity and very low level of exposure to climate change
T4	Family subsistence producer with high sensitivity and low-to-medium level of exposure to climate change
T5	Family subsistence producer with minimal conditions for diversification, high sensitivity, and very low-medium level of exposure to climate change
T6	Family subsistence producer with minimal conditions for diversification, medium-high sensitivity, and very low-low level of exposure to climate change
T7	Family producer with agricultural income, medium-high sensitivity, and very low-medium level of exposure to climate change
T8	Family producer with agricultural income, medium sensitivity, and very low-medium level of exposure to climate change
T9	Family producer with agricultural income, low-medium sensitivity, and very low-medium level of exposure to climate change
T10	Producer in transition with medium-high sensitivity, and low-medium level of exposure to climate change
T11	Producer in transition with low-medium sensitivity. and low-medium level of exposure to climate change
T12	Entrepreneurial producer with low profitability, low-medium sensitivity, and low-medium level of exposure to climate change

Table 7. *Cont.*

TYPE	NOMENCLATURE
T13	Entrepreneurial producer with low-medium sensitivity and low-medium level of exposure to climate change
T14	Entrepreneurial producer with low sensitivity and very low-medium level of exposure to climate change
T15	Entrepreneurial producer with very low-low sensitivity and very low-medium level of exposure to climate change
T16	Entrepreneurial producer with minimal-low sensitivity and very low-low level of exposure to climate change
T17	Entrepreneurial producer with very low sensitivity and low level of exposure to climate change
T18	Entrepreneurial producer with minimal sensitivity and very low-low level of exposure to climate change
T19	Entrepreneurial producer with minimal sensitivity and low-medium level of exposure to climate change

Type T1 is the most fragile group regarding climate change conditions and risk, whereas group T19 has the best conditions for carrying out primary activities. Groups T5, T7, and T8 predominate since they account for more than 2.4 million producers (Figure 2).

Most producers are involved in agriculture, producing between 1 and 5 agricultural species, except groups T1 and T2, which mainly produce backyard livestock and engage in gathering activities or fishing. At least 30% of the producers in groups T3–T19 produce one to three animal species, and 19% of producers in groups T5–T19 grow between one and three perennial species (Supplementary Material Table S2).

The geographic distribution of the different producer groups in each state is diverse; 13 and 18 types were identified. The Guerrero, Michoacán, and San Luis Potosí states have the most remarkable diversity (18 types), with T7, T8, T10, and T11 predominating, while the Campeche, Durango, Tabasco, and Baja California states have the least diversity in types (13 different types, predominantly T5, T6, T7, and T8; and T10 and T11 in the case of Baja California) (Figure 3). The most representative types in the country are T5–T8 and T10–T11, T12 and T13 for the Sonora and Sinaloa states, and T14 for Nuevo León state. In the states with the greatest number of production units (Oaxaca, Chiapas, Guerrero, and Veracruz), types T5–T8 predominate (Supplementary Material Figure S1).

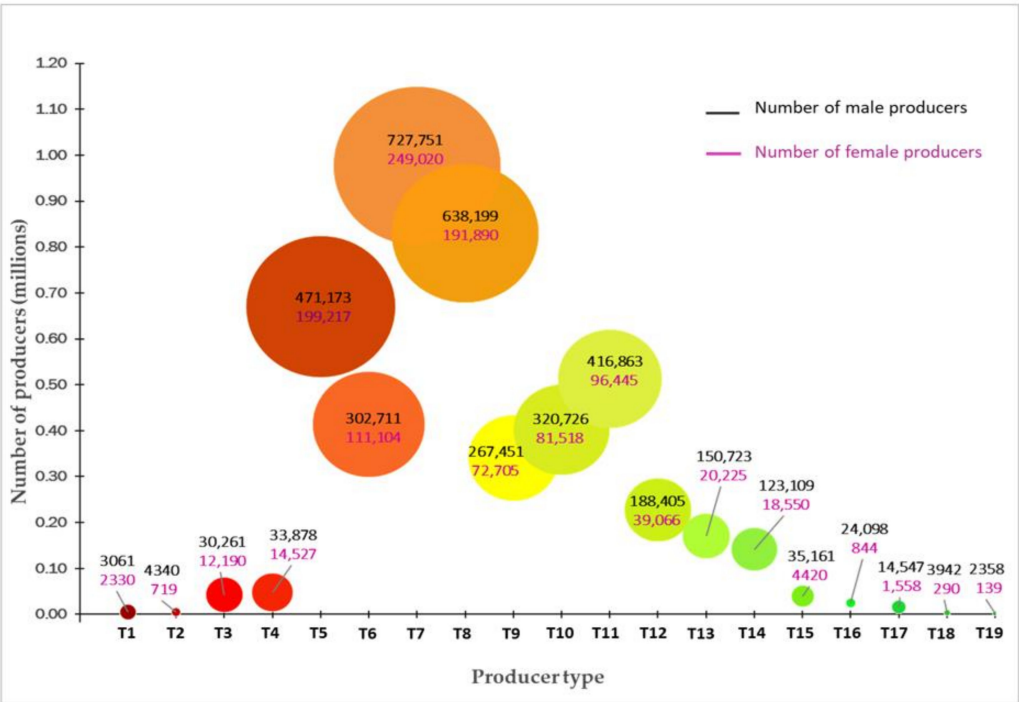

Figure 2. Producer types (T) and total producers in each group.

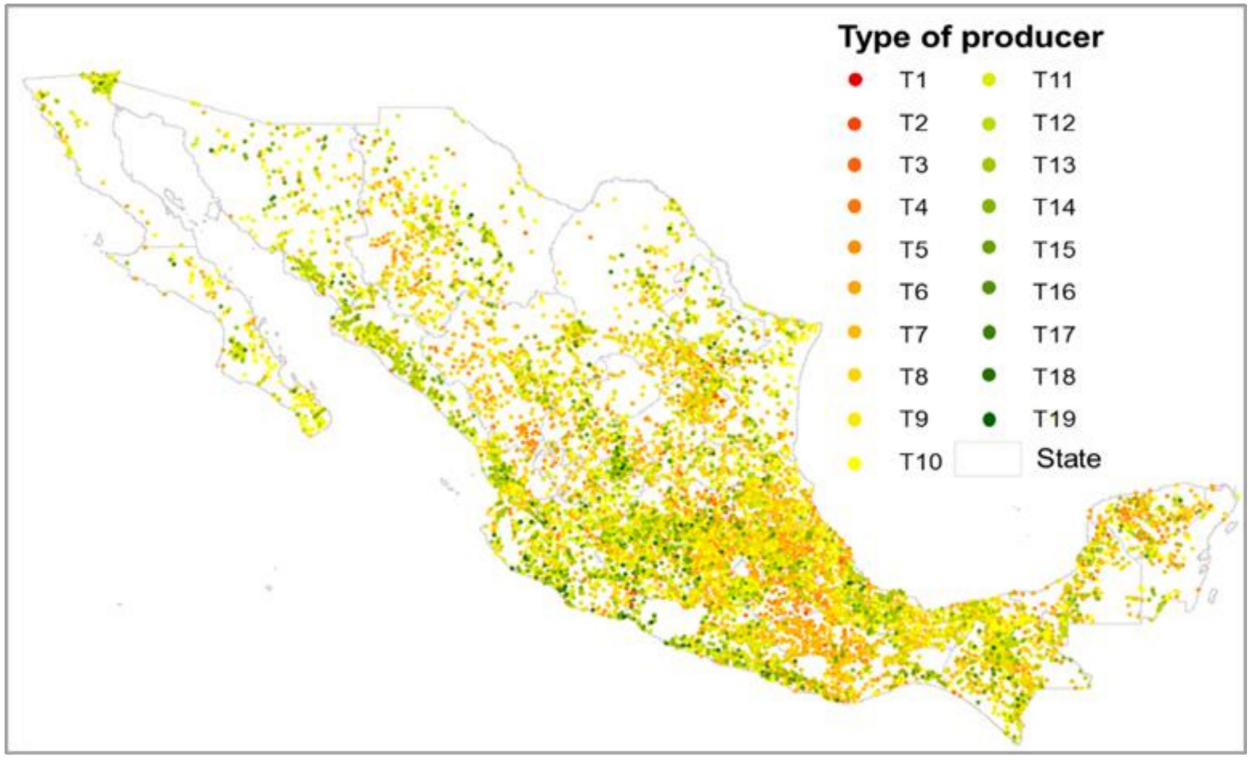

Figure 3. Geographic distribution of the main producer types (T1-T19).

In terms of schooling, it was found that most producers in groups T3 to T15 have some elementary education. In contrast, in groups T16 to T19, it was observed that at least a quarter of them have a high school education or even a bachelor's degree. Groups T1 and T2 are made up of producers without any formal education (Supplementary Material Figure S1).

4. Discussion

4.1. Conditions Determining the Sensitivity Level of Mexican Agricultural Producers

The sensitivity level is determined by a combination of three factors: land tenure, irrigation infrastructure, and the diversification of productive activities. As climatic conditions change, producers must adapt their production methods according to their possibilities; under these changing circumstances, the production environment can make a difference.

Land tenure plays a significant role in the development of producers. It allows them to design and plan long-term decisions on production unit management. It also guarantees their investment and provides them with the security to implement technological innovations in the production unit. All of this strengthens production conditions, affects product quality, and contributes to producer improvement of their adaptive capacity. Insecure land tenure is a crucial constraint on the ability to adapt to new conditions [54].

In Mexico, most producers have land to produce (87%). However, there is a considerable difference in the type of property: on the one hand, small producers mostly have ejido plots or communal land [55,56], which makes them more sensitive; while entrepreneurial producers have mainly private land, they also have the possibility of increasing the production area by renting extra land (6%), which makes them less sensitive. The remaining 7% of producers do not have their own land, so they have to rent a space to carry out their productive activities.

In the face of the impacts of climate change, producers with private land tenure can take adaptation actions quickly and individually, whereas producers with ejido plots cannot always act individually; for major actions, they depend on social synergies at the ejido or community level. This situation implies, among other things, that policies focused on

the agricultural sector component involving producers using ejido land should have a territorial approach [57,58].

The second condition is irrigation infrastructure. According to the results of this research, at least 78% of the producers carry out primary rainfed activities (approximately 3.82 million); in contrast, 12% (596 thousand producers) have irrigation systems, of which 305 thousand correspond to entrepreneurial and low sensitivity producer groups, and 10% have the necessary conditions to develop rainfed and irrigated activities in their production units.

This condition, combined with their land tenure, allows producers to be much less fragile than those who do not have secure land tenure or depend on rainfed land to produce. It should be noted that land area is another factor that can influence the development of one more primary activity within a production unit [55].

The third condition in the production environment is the diversification of primary activities. In recent decades, the low productivity of crops and the low prices of agricultural products, especially for small producers, have forced them to diversify their primary activities and, as a result, they have become multifunctional as a resilience mechanism [42,59]; moreover, they have even had to venture into other waged activities to supplement household income [60].

In the face of a socially and environmentally changing environment, diversification of activities is a smart way to take advantage of the soil resource and improve producers' adaptive capacity. The diversification of activities offers producers more risk management strategies and options to adapt to the effects of climate change [1].

4.2. Agricultural Producers and the Context of Climate Change

In the last 50 years, the average temperature in Mexico has increased by almost 1 °C, which coincides with the global average increase [9,40]. In the country, some municipalities located in the intertropical zone are more vulnerable to climate change [61], and coupled with poverty conditions, their production conditions are limited. This is the case for producers located in the south-southeast of the country, the most fragile ones, as they depend on rainfall and essential crops that will potentially be affected (maize, beans, potatoes, or rice) [62].

Entrepreneurial producers usually produce in large areas and have irrigation systems. They represent no more than 10% of all producers and are located mainly in the north and northwest of the country [63]. They are exposed to increasingly intense and prolonged droughts that impact the development of crops, both rainfed and irrigated [26,27,64]; however, their socioeconomic conditions allow them to react more efficiently and adapt to climate changes.

4.3. Challenges Facing Mexican Agricultural Producers

Factors related to the production unit affecting producers' sensitivity in the context of climate change were mentioned above. However, other factors may have an impact on increased sensitivity, such as the aging of producers and low educational levels.

It was found that the average age of agricultural producers in Mexico is 55; these data coincide with those reported in the National Agricultural Survey [28], where more than 44% of the country's producers are aged 40 to 60 years. The schooling level of most of the country's producers is low, mainly in the south-southeast of the country. A low schooling level influences the sector's low productivity, and in the context of increased vulnerability to climate change, it can become a barrier to the adaptation of producers to climate change [65–68] and achieving food security [69]. According to other studies, the older population with a low educational level will have greater difficulties developing innovations or changes in their form of production to adapt to climate change [55].

4.4. Limitations of the Agricultural Sector Policy

Mexico's public spending in the agricultural sector has been high within the framework of the sectoral GDP; however, it does not reflect growth in rural areas, nor has it decreased poverty or inequality [70]. The sector's public policies have operated under an assistance character [71]. Some recurrent failures of the sector's policies are: resources are distributed by demand or even to meet political commitments, without considering national priorities [72], and without encouraging competitiveness in the agricultural development of the neediest producers.

The Commercialization and *Alianza para el Campo* (Alliance for Agriculture) Programs were oriented to large or entrepreneurial producers, and most of the beneficiaries were from Mexico's northern states [73]. The Financing Fund for the Agricultural Sector has been highly regressive; it is focused on providing support only to the country's large producers.

The direct field support program (PROCAMPO) was created to compensate for the unfavorable effects of the North American Free Trade Agreement (NAFTA); however, some analysis and evaluation studies have concluded that its objectives have not been met since the distribution of its resources has predominantly favored larger-scale producers and even those with irrigation technology (Mexico's northern states: Sinaloa, Tamaulipas, Sonora, Jalisco, and Chihuahua) [32,74,75], and although one of its objectives is to encourage productive conversion, it has not been satisfactorily fulfilled [76].

The "production for welfare" program is currently operating to serve small and medium-sized producers; however, farmers regard it as a form of income assistance and not as support aimed at increasing productivity [77]. An area that has been signaled out for improvement is that the distribution of resources from this program is based on the area or the number of head of cattle of the production unit; it continues to be a demand-based support program, and beneficiaries must be included in the welfare census.

The implementation of public policies should incorporate a prioritization strategy based on a multidimensional analysis of production units and not on a single relevant characteristic, such as the production unit's area or the producer's income. A common failing is that public policymakers assume that there is relative homogeneity among Mexico's rural producers, whereas the reality is that conditions are heterogeneous [78]. This study identified 227 groups by the affinity of conditions. However, because it is not practical to prioritize actions with so many groups, they were classified into 19 types, proposing a more specific and multidimensional way to give prioritized attention to the country's producers.

The typology of farmers allows for the evaluation of agricultural management indicators at the production unit level and the design of differentiated agricultural policies [20]. The multidimensional approach used in this study can be replicated to analyze the heterogeneity of agricultural producers in any region or country; however, data availability is the key to achieving this; in our case, having had data and statistics that described the socioeconomic characteristics, conditions of the production environment and exposure to climate change, in a representative sample for the country, was an advantage. Nevertheless, the limits of the classification are directly influenced by the variables used in the study.

5. Conclusions

This study analyzed three current determining dimensions for the classification of producers: producer sensitivity, production destination, and production risk due to climate change. It identifies which producer types face the most significant difficulties in producing today. The results can serve as a basis for the design of future differentiated policies for the agricultural sector; it can even be an input to reorient the operation of subsidy programs for the countryside, considering focused attention on the types of producers with the greatest risk due to climate change, aligned with the efficient use of public resources in transit.

It is recommended to estimate the adaptive capacity of each group of agricultural producers classified in this study in order to identify where institutional efforts should be directed to improve their adaptive capacity and thus contribute to reducing the vulnerability of those communities with the highest risk in the face of climate change and thereby move

towards compliance with the Intended Nationally Determined Contributions (INDC-2030) and the objectives of sustainable development.

Federal institutions should consider updating data at the production unit level since the last agricultural census was conducted in 2007, and the baseline study of the agricultural sector herein used was obtained in 2008. An update would allow a more realistic typology of producers considering current national problems (climate change and the effects of the COVID-19 pandemic in the countryside).

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/agriculture12081079/s1, File S1. Principal Component Analysis (PCA); Table S1. Example of locality by each producer type; Table S2. Characteristics of producer types according to the Dalenius & Hodges method; Figure S1. Distribution by state of the identified producer types according to the Dalenius & Hodges method.

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