Article:
Castillo-Rivero, L., McCann, P. and Sijtsma, F.J. (2021) A multi-scale approach to rural depopulation in Mexico. Regional Science Policy & Practice, 13 (4). pp. 1328-1347. ISSN 1757-7802

https://doi.org/10.1111/rsp3.12381

Received: 11 June 2019 | Revised: 10 October 2020 | Accepted: 1 December 2020

DOI: 10.1111/rsp3.12381

ORIGINAL ARTICLE

A multi-scale approach to rural depopulation in Mexico

Liliana Castillo-Rivero[1] | Philip McCann[2] | Frans J. Sijtsma[1]

[1]Department of Economic Geography, Faculty of Spatial Sciences, University of Groningen, The Netherlands

[2]University of Sheffield Management School, UK

Correspondence
Liliana Castillo-Rivero, Department of Economic Geography, Faculty of Spatial Sciences, University of Groningen, Landleven 1, Groningen 9700 AB, The Netherlands.
Email: l.castillo.rivero@rug.nl

Abstract

This paper aims to sketch rural population decline in Mexico. A comprehensive multi-scale documentation of Mexico's urban and rural fabric and its depopulation dynamics is undertaken. This paper does not identify the causes and effects of rural depopulation, but aims to detect its geographical presence in a manner which other approaches are unable to do. The granularity of rural depopulation is identified as manifested at four different scales: national, state, municipal, and local village scale. We use census data for the period 2000–2010. We relate rural depopulation to spatio-geographical features found in the literature; the relationship of depopulating territories with urban ones and the altitude range in which they are located. We find that proximity to and remoteness from urban areas as well as that of altitude do not follow the typical patterns often observed elsewhere. Unlike that shown in other countries, in Mexico, rural depopulation is manifested mostly in lower-lying areas and despite the fact that most of the country is at altitude. Rural depopulation and disappearance occur mainly in the areas of plains below 1,000 metres above sea level, regardless of the population density of the territories where they were located. Also, our multi-scaling approach has allowed us to identify not just at what scale the phenomenon of rural depopulation is observed, but also, to identify the areas in which the phenomenon is manifested

regionally or locally. As we see, much of the phenomenon is concentrated in different areas to what national narratives suggest.

KEYWORDS
altitude, Mexico, multi-scale, urban system, rural depopulation

JEL CLASSIFICATION
J11; R10; Q56

1 | INTRODUCTION

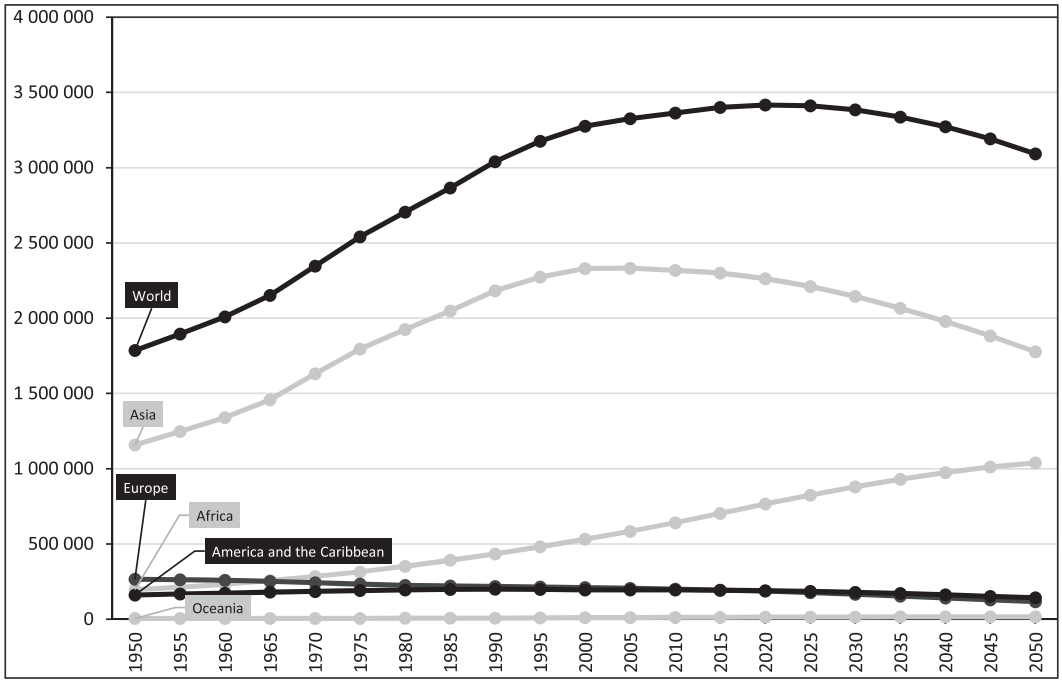
Depopulation is defined as "a demographic and territorial phenomenon consisting of a decrease in the number of inhabitants in a territory or nucleus relative to a previous period. The fall in absolute terms of the number of inhabitants can result from a negative natural growth (when deaths exceed births), negative net migration (emigration exceeds immigration) or both simultaneously" (Pinilla & Sáez, 2017, p. 2).

As of 2008 the majority of the world's population (50.6%) lived in cities, having increased from 30% in 1950, and this share is expected to increase to some 66% by 2050 (United Nations, 2018). These figures indicate the relative increase of urban population of the world with respect to total global population growth. If we focus just on the absolute growth, we also observe that the global urban population has increased from 751 million in 1950 to 4.196 billion in 2018 (United Nations, 2018). The worldwide population living in cities has increased both in relative and in absolute terms along with global population growth.

On the other hand, if we consider rural areas, we see that the global rural population has decreased in relative terms from 66.4% of the global population in 1960 to 44.7% in 2018. Nevertheless, in absolute terms, the rural population of the world has also increased from less than 2 billion in 1950 to 3.4 billion in 2018, although it is also projected to decline from just after 2020 onwards (United Nations, 2018). The worldwide population living in rural areas has increased in absolute terms but not in relative terms, while global population growth has continued.

That is that although the phenomenon of rural population is not existent worldwide, depopulation is now observable at smaller scales, going from regions of the world such as Asia, whose rural population began to decrease approximately since year 2000, Europe, which has done it so much earlier, or America and the Caribbean region, which has presented an absolute loss of its rural population since the mid-1990s (Figure 1). As the global rural population also begins to decline after 2020, this phenomenon will become even more pervasive across countries (Figure 2) and villages. The villages are the smallest geographic entity of the rurality, and many of them have entirely disappeared or they are in that process.

The literature examining rural depopulation considers it to be a complex and multifactor phenomenon, and the literature itself falls broadly into two broad strands, namely, the spatio-geographic and socio-demographic approaches. The first literature strand tends to emphasize more the geographic location and characteristics of depopulating territories as a key influence on population changes, including their remoteness from, or proximity to, urban territories, and also their physiographic and topographical features and the ecological and landscape changes involved in the process (Jacob et al., 2008; Liu, et al., 2010; MacDonald et al., 2000; Montserrat & Villar, 2008; Rizzo, 2016; Yonezawa & Aoyagi-Usuia, 2010). In contrast, the second strand of literature tends to emphasize the dynamics of population growth including issues such as mortality and fertility rates, household composition and formation processes, migration patterns, gender ratios, age and occupational structures, and other social, economic, and cultural features of the remaining populations (Anderlik & Cofer, 2014; Feldhoff, 2013; Noack & Bergmann, 2011; Stratta Fernández & de los Ríos Carmenado, 2010; Traphagan, 2008a, 2008b), as well as discussions of the



Source: Own elaboration based on United Nations (2018)

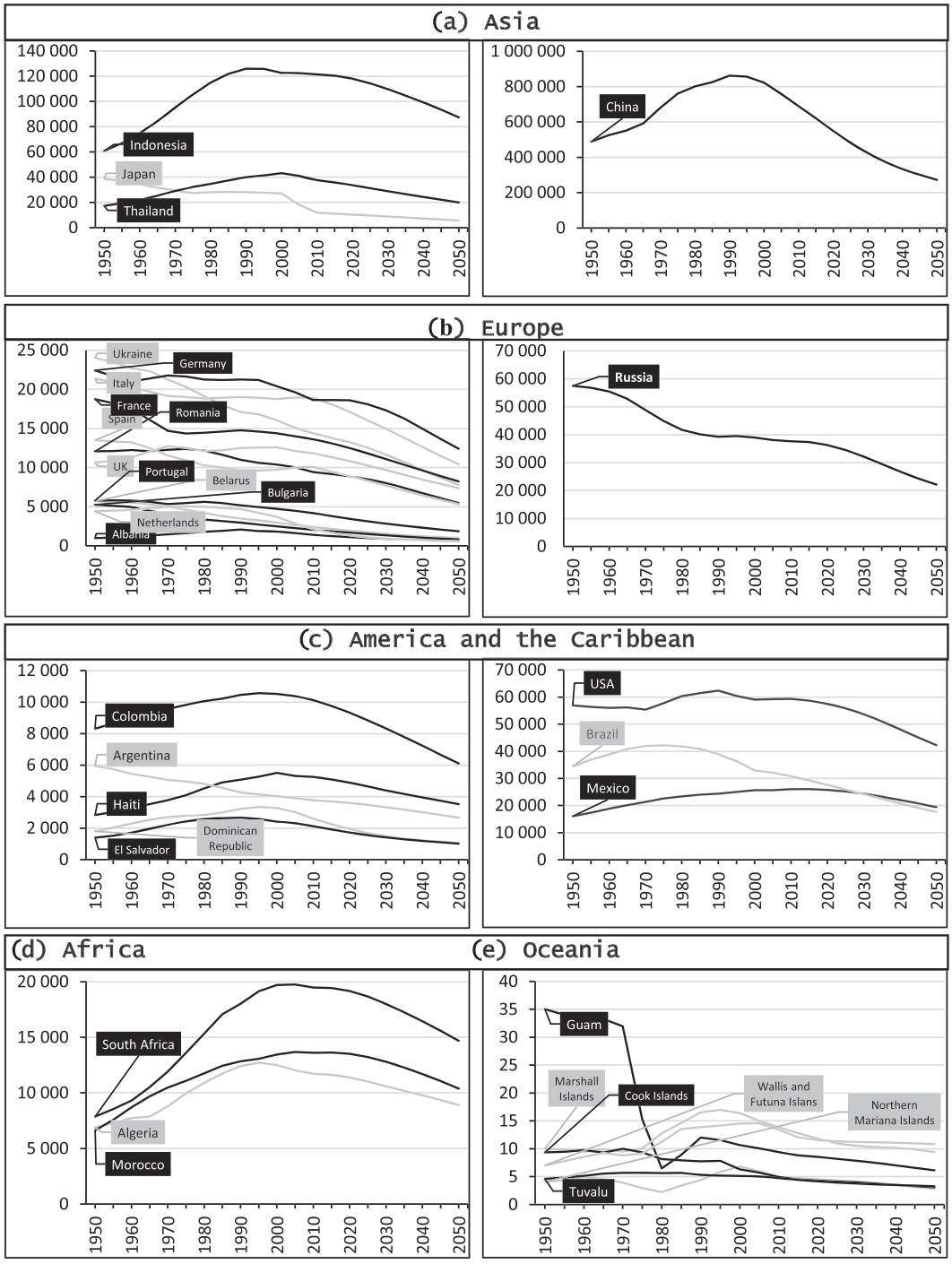
FIGURE 1 Rural population at mid-year, 1950–2050 (thousands)

institutional frames and public policies formulated for depopulating areas (Bielza de Ori, 2003; Cartwright, 2013; ESPON, 2017, 2018; Karcagi-Kováts & Katonáné-Kovács, 2012; López-Ruíz, 2005; Long et al., 2011; Pinilla & Sáez, 2017; Skryzhevska & Karácsonyi, 2012; Thompson, 2008).

However, in the particular case of Mexico, there are very few studies about rural depopulation (Bocco Verdinelli & Segundo Métay, 2012; Canales, 2009; García-Barrios et al., 2009; Mojarro & Benítez, 2010; Segundo Métay, et al., 2012;). Although there is much research on migration, there is relatively very little coherent or a comprehensive research on the remaining rural populations or the characteristics and transformation of the emptying territories, left behind by the out-migrants. While, it is very possible the emergence of literature during the next years when the phenomenon will be at national level (Figure 2), this work coincides with the idea that an approach of any population shrinkage should be done from a multi-scale perspective, even if it is manifested only in one part of a territory, acknowledging that its implications could vary between cities, suburbs, rural villages, or even neighbourhoods (Bontje, 2018; Hollander, 2018).

In this work, we approach the phenomenon in a descriptive and explorative manner from a spatio-geographic view. Our thinking regarding this approach is that in topics which have not been explored enough, the descriptive approaches are not just necessary but fundamental in order to think of an agenda for its deeper investigation. As we will demonstrate, because aggregate populations in both Mexican urban and rural areas have increased, as they have across the globe, identifying the spatio-geographical dimensions of Mexican rural depopulation is therefore only possible at smaller spatial scales. Indeed, as we will show in this paper, the extent to which these phenomena can be observed depends crucially on the spatial scales of analysis, and the chosen scale of analysis heavily influences both the observation and the interpretation of the phenomenon.

What our multi-scale analysis demonstrates is that although the Mexican population is growing, rural population decline is a phenomenon taking place across the whole country. However, purely national level analyses hide this



Source: Own construction based on United Nation (2018)

FIGURE 2 Rural depopulation, outstanding cases by region (thousands)

fact. One level lower, at the state-level, rural depopulation appears to be a regional phenomenon in the north and in the west; whereas, in the centre and south-southeast it is clearly a more local phenomenon. Thus, a multi-scale perspective demonstrates that the phenomenon is widespread in all parts of the country as the scale of

observation gets smaller. As for the local scale analysis, we will, also, observe some spatio-geographic features of the depopulating territories identified through this work, such as their relationship with urban territories, which implies a look into different population densities, and the altitude in which they are located. The time period under study is 2000–2010.

In order to do this, data from different national data-sources have been merged, coded and categorized using geographical information systems (GIS) techniques. This has been done in order to document and locate every single village in Mexico according to its population, and whether it has depopulated, survived or disappeared during the decade 2000–2010. Each of the nested hierarchical administrative units are also documented, along with all of the urban centres, conurbations and metropolitan zones. This construction provides the requisite multi-level framework for us to uncover the patterns of rural depopulation.

The rest of the paper is divided into four sections. Section 2 presents a brief review of the literature concerning rural depopulation and Section 3 outlines the data and methods used in this research. Section 4 reports the results of our analysis in the form of maps, tables and charts, and Section 5 offers some concluding comments.

2 | RURAL DEPOPULATION

Depopulation territories may exhibit different geographical characteristics. These characteristics can be very complex and often they may be difficult or even impossible to generalize. In such situations, a multi-scale approach which exploits different hierarchical and geographical scales of observation can be a way of making progress in better understanding its key features and ongoing spatial transformations.

Rural depopulation has been studied at different levels in some of the European Union member states (Aldrey-Vázquez, 2009; Barrachina, 2007; Bielza de Ori, 2003; Cartwright, 2013; ESPON, 2017 & 2018; Karcagi-Kováts & Katonáné-Kovács, 2012; López-i-Gelats, 2013; López-Ruíz, 2005; MacDonald et al., 2000; Mann, 2005; Montserrat & Villar, 2008; Noack & Bergmann, 2011; Pinilla & Sáez, 2017; Pires de Almeida, 2017; Poinsot, 2007; Rizzo, 2016; Skryzhevska & Karácsonyi, 2012; Viñas, 2019; Westhoek et al., 2006); in Japan (Feldhoff, 2013; Nakagawa & Izuta, 2017; Perez-Barbosa & Zhang, 2017; Thompson, 2003, 2008; Traphagan, 2008a, 2008b; Yonezawa & Aoyagi-Usuia, 2010; Yoshida, 1999); in China (Li, 2015; Liu et al., 2010; Long et al., 2011; Wang et al., 2019), and in some Latin American countries such as Argentina (Lausirica & Sardi, 2008; Steimbreger & Kreiter, 2008; Stratta Fernández & de los Ríos Carmenado, 2010), or Mexico (Bocco Verdinelli & Segundo Métay, 2012; Canales, 2009; García-Barrios et al., 2009; Mojarro & Benítez, 2010).

Although an explicit multi-scale approach is absent in these studies, from an overview of these various pieces of research it is possible to identify some key country-related themes in demographic analysis. It is apparent from the literature that countries such as Japan and some European countries, such as Spain, Italy, Greece, Switzerland, France, Baltic countries, and some European Eastern countries, experience rural depopulation primarily in mountainous areas and those which are remote from urban areas. By contrast, China experiences what is called "rural hollowing" manifested as rural depopulation mostly at the core of rural villages located at the urban fringes and in the plains agricultural areas adjacent to cities whose radius is gradually expanded towards surrounding urban centres. The case of the United States is also documented in the Great Plains area (Anderlik & Cofer, 2014; Johnson & Litcher, 2019).

In the case of Mexico, however, there is as yet no clear knowledge regarding specific locations and geographic features of the rural depopulating territories. Given that the Mexican population as a whole is still growing, the structural and spatial characteristics of Mexican rural population decline are currently not very evident. Given that the country is predominantly mountainous and experiencing rapid urbanization processes, we would expect that Mexico might share some similarities with other mountainous country cases, and with some other countries experiencing similar rhythms and patterns of urbanization processes. However, our intention here is to demonstrate that the picture on the ground is in reality far more complex and nuanced than either simple country-based comparisons

suggest, or simple urban versus rural narratives imply. Rural depopulation in Mexico is taking place in different ways all over the country and a multi-scale approach helps to uncover these various nuances.

3 | THE DATA SOURCES AND URBAN ENTITIES

Our understanding of the diversity, specificity and granularity of rural depopulation is limited by our ability to disaggregate national trends to regional and local trends. Such possibilities are greater in advanced economies with rich, detailed and continually updated datasets, but in many countries such data are not available. In the particular case of Mexico, there are detailed population data which are contained within different national datasets, but in order to understand the Mexican relationships between local, regional and national rural depopulation, and the relationship with the urban territories, in this work it was necessary to build an integrated dataset by combining these different data sources and then disaggregate them at the different spatial scales.

The different scales under observation which we employ are the Mexican political-administrative unities (national, state, municipal, and local-village), ordered under a nested hierarchy. As of 2010, there were 196,351 rural villages, contained within 2,456 municipalities, which are grouped together into 32 Mexican states. For each of these spatial-administrative scales we are able to observe changes in population 2000–2010, and we employed GIS techniques to map these changes. The spatial (vector) data for the polygons for states, municipalities, urban territories, and dots for villages, were obtained from the National Geostatistical Framework of the National Institute of Statistics and Geography (INEGI, 2010a). The data sources used at different spatial scales are the National Census for years 2000 and 2010 (INEGI, 2000a, 2010b), the System of Territorial Integration (ITER) for both years from the National Institute of Statistics and Geography (INEGI, 2000b, 2010c), and the National Commission for the Knowledge and Use of the Biodiversity (CONABIO, 2000, 2010).

In terms of definitions and categories, if we take the very smallest spatial and administrative unit, according to the last Mexican Census 2010, a *village* is defined as every place which is occupied by at least one house, even if it is not inhabited. A village is recognized by a name given legally or by tradition of its inhabitants, and a village can be *rural* or *urban*. A *rural village* is a village with less than 2,500 inhabitants (INEGI, 2010d).[1] In this work we follow the definition of *rural depopulation* as the absolute loss of population in this kind of villages grouped by the different scales, and this allows us to identify the depopulating and disappearing rural villages during the decade 2000–2010. A *rural depopulating village* is one with a negative absolute change in its population during that decade, while a *rural disappeared village* is identified as that one with zero inhabitants in 2010 or the villages that does not appear registered anymore in the database of 2010 neither as a rural nor as an urban settlement.[2]

3.1 | Urban entities

The national urban system of Mexico (SUN), is comprised by 384 urban entities, and they are divided by different categories, defined as metropolitan zones, conurbations and urban centres, respectively, in descending order of size (CONAPO, SEDESOL, 2012), (Figure 3).

[1]The definition of what is rural is an important discussion placed in the social scientific table. As this study is devoted to sketch the rural depopulation phenomenon in Mexico, we have taken the official definition of what is rural within this country. We understand that there may be limitations with this approach, given the complexity involved in this concept, which being defined just by population inhabitants and not by density or other factors such as facilities provided, etc., is a very constrained definition. However, for our data purposes this is the most workable definition.

[2]A village could have been registered as a *rural village* in 2000, but it does not appear as a *rural village* in 2010. There are two possibilities: (i) The village is not registered as a *rural village* anymore because it has become an *urban village*; or (ii) The village has disappeared. In the first case, the code of the village still appears in the database for 2010, but not as a *rural village*. In the second case, the village is not registered in the database for 2010 anymore. In this study, the rural disappeared villages are the latter cases and those ones which are accounted with zero inhabitants in 2010.

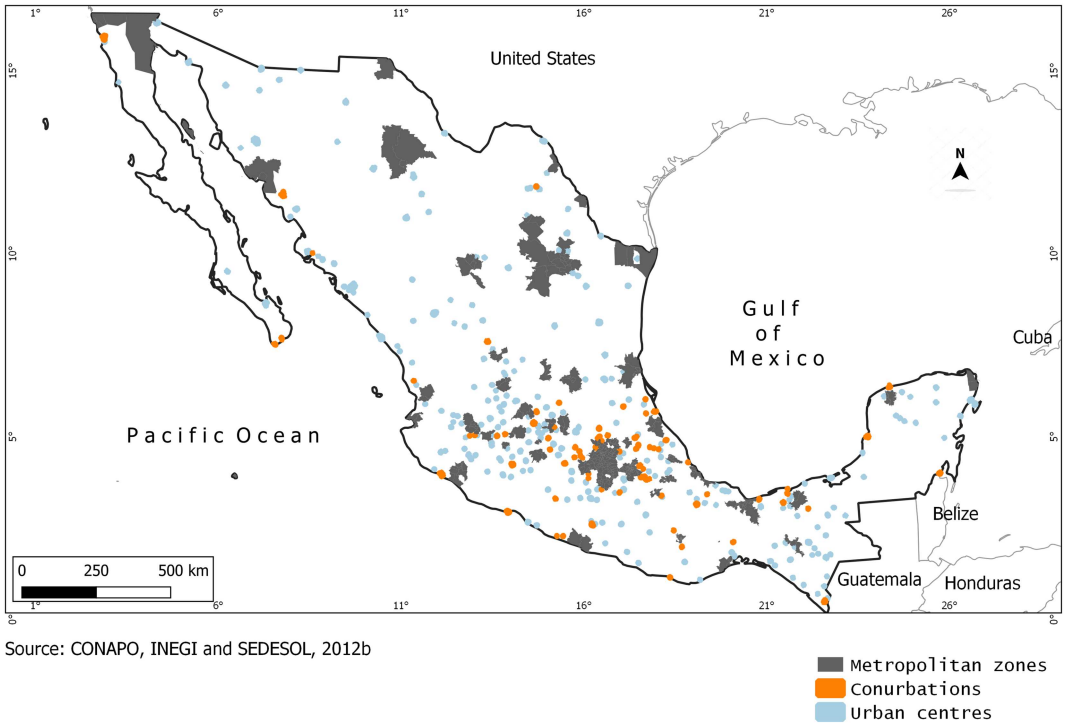


FIGURE 3 Mexico. National Urban System (SUN)

In the SUN, the urban entities are hierarchized in terms of the stage of urban development from lowest to highest as follows:

- *Urban centres* are urban territories in the first stage of formation. They are comprised by all the urban territories with 15,000 or more inhabitants, and do not exhibit the characteristics of a conurbation or a metropolitan zone. During the period 2005–2010 there emerged 26 completely new urban centres; two conurbations were reclassified as urban centres, 14 old urban centres were reclassified as conurbations, and five were reclassified as metropolitan zones. The net balance was the increase of nine urban centres in the SUN.
- *Conurbations* are the second category of the urban territories. A conurbation is an urban area resulting from the physical continuity between two or more *urban centres*, forming one urban unity within a range of population between 15,000 and 49,999. The conurbations can be inter-municipal or inter-states. During the period 2005–2010, there emerged 20 new conurbations (14 urban centres that were reclassified as conurbations, plus 6 completely new conurbations). On the other hand, two old conurbations were reclassified as urban centres, one was eliminated from the list due to lost population, and another three old conurbations were reclassified as metropolitan zones. The net balance was the increase of 14 conurbations in the SUN.
- *Metropolitan zones* are the highest category range of the urban entities. They are comprised of a group of complete municipalities that share a central city with officially 50,000 inhabitants or more (but in practice 100,000 or more), and are highly functionally interrelated. In addition, the concept of a metropolitan zone comprises all urban territories with more than 1 million inhabitants even if they do not overpass municipalities' boundaries.

There are three types of municipalities within a metropolitan zone: *Central municipalities* where the central city, which gives origin to the metropolitan zone, is located; *Exterior municipalities defined by statistical and geographical criteria* which are contiguous to the central municipalities; and the *Exterior municipalities defined by planning and urban*

policies which are recognized as metropolitan municipalities by the federal and local governments. According to the last delimitation of metropolitan zones in 2010, in México there were 59 metropolitan zones, comprised by 367 municipalities, 263 of them were central municipalities. Between 2005 and 2010 there were 3 new metropolitan zones (CONAPO, INEGI and SEDESOL, 2012).

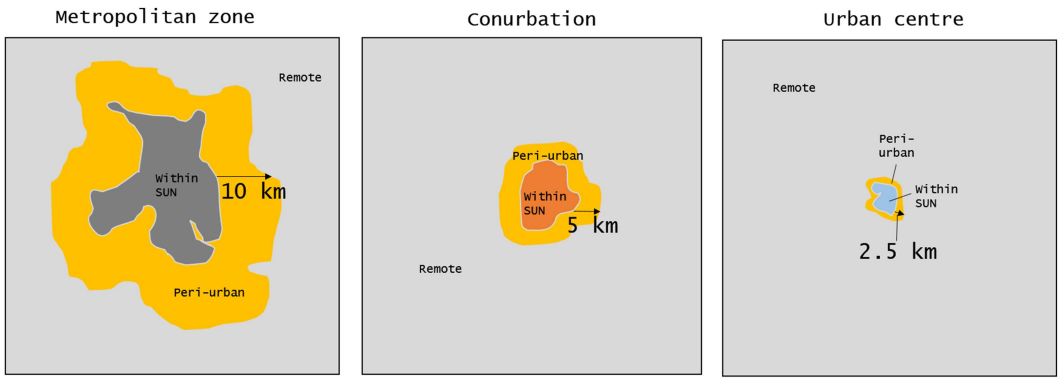
In order to classify the villages and their relationship with the SUN, we have constructed areas around the outside of metropolitan zones, conurbations, and urban centres. These areas are concentric rings of a distance of 10 km, 5 km, and 2.5 km, respectively beyond the edge of the continuously built-up urban boundary (Figure 4). Outside of the metropolitan zone we construct a ring of 10 km, outside the conurbations we construct a ring of 5 km, and outside of urban centres we construct a ring of 2.5 km. Outside of the SUN but within these respective surrounding rings are the areas that we designate as being peri-urban. Even within the SUN there are sometimes standalone/rural villages, because not all city developments are entirely contiguous. Cities have very differentiated and diffuse spatial structures which are often characterized by sprawl, ribbon developments, and fragmented morphologies, and this allows for the presence of standalone/rural villages to exist even within the SUN.

4 | RESULTS

In the following subsections we report the findings from our multi-scale GIS-facilitated analysis of the features and nuances of Mexican rural depopulation patterns by breaking the analysis into three elements, namely: a multi-scale analysis, an analysis of the role of proximity versus remoteness, and finally an analysis of the role of altitude.

4.1 | A multi-scale perspective on rural depopulation

When observing rural depopulation at the national level there is no real evidence of it. This is because the total Mexican rural population has increased from 24,128,494 in 2000 to 24,550,862 in 2010, even though its share of the total population has fallen from 25% to 22%. Yet, changes in the spatial distribution of the rural population have not been homogeneous, and therefore the phenomenon of rural depopulation starts to become visible at smaller spatial scales. As we see in Figure 5, at the level of the 32 states, between 2000 and 2010 rural depopulation appears to be primarily contained within most of the Northern states of the country.



- Villages within all kind of urban entity (grey for metropolitan zones, orange for conurbations, and blue for urban centres), are classified as villages *within SUN.*
- Villages within the areas constructed around entities (yellow areas: 10 km around metropolitan zones, 5 km around conurbations, 2.5 Km around small urban centres), are classified as *peri-urban.*
- Villages which are beyond all of these areas throughout the national territory (white areas) are classified as *remote.*

FIGURE 4 Construction of areas around urban entities

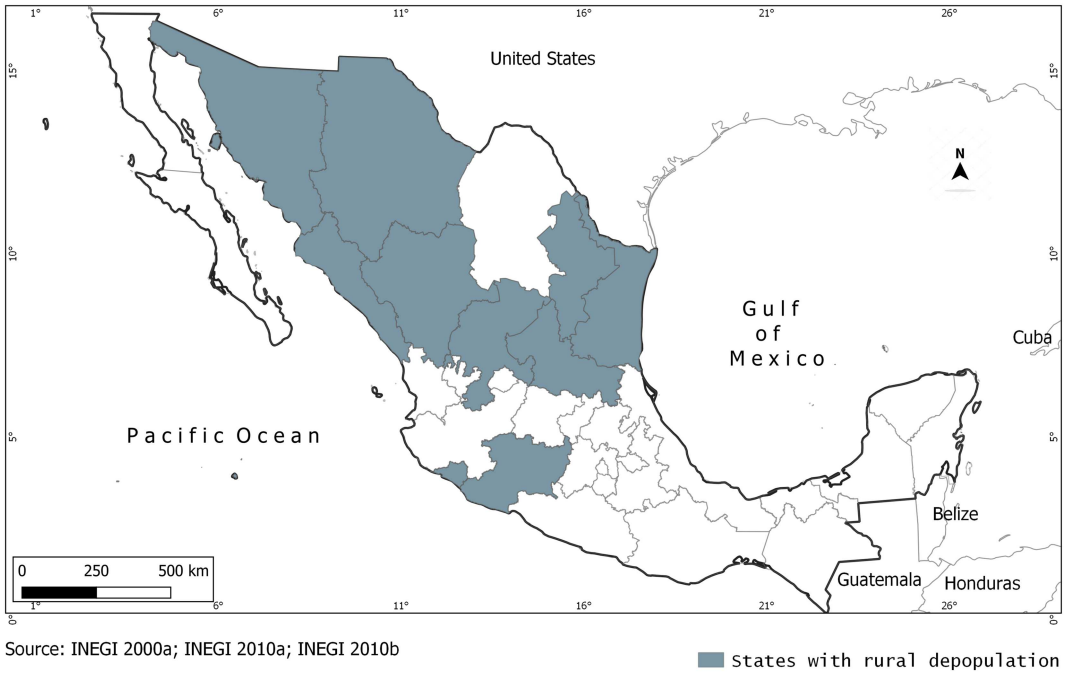


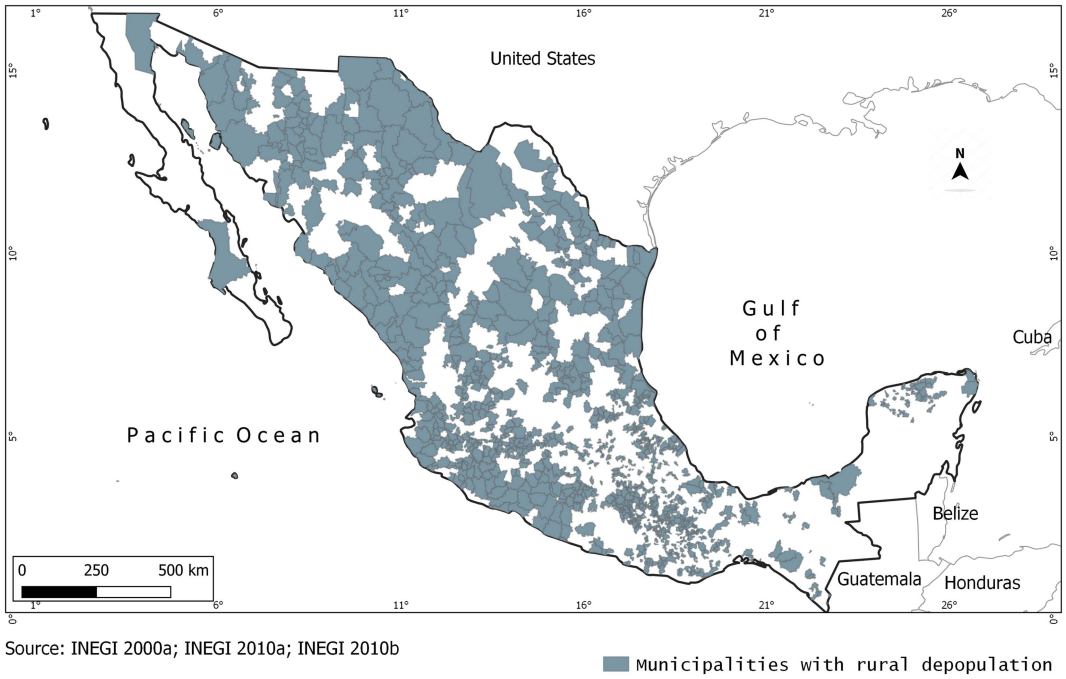
FIGURE 5 Mexico. Rural depopulation at state scale, 2000–2010

These states are generally of low rural population density and in terms of area they are the biggest states of the country, summing all together, an area of 952,541.80 Km^2, which represents almost half of the total national area (1,960,670.2 Km^2) (INEGI, 2015). The only parts of the north not facing population decline were the states in the Baja California pensinsula, and the state Coahuila, both some of the least densely populated states in the country.

If we adjust our observations to a smaller spatial scale, namely the municipal scale, we observe that 43% of all the municipalities of the country showed rural depopulation processes during the decade under study (1,049 out of 2,456 municipalities), as shown in Figure 6. As we also see in Figure 7, in terms of 2010 population densities, 49% of these rural depopulating municipalities lie in the lowest third of municipalities, defined according to population density, with less than 27 inhabitants per Km^2. The middle third of municipalities, defined according to their densities, account for 31% of depopulating municipalities, while the top third most densely populated municipalities account for 20% of depopulating municipalities. In other words, as we see in Figure 7b, 51% of depopulating municipalities are actually in the middle and most densely populated areas, most of which, are very small municipalities and lie in the centre or the south of the country. The contrary case, namely that of municipalities without rural depopulation, shows very similar figures but the other way around, from the centre and south to the north of the country. As such, at a municipal scale, rural depopulation is a phenonemon which is equally shared between low density areas and medium or high density areas. This cannot be understood by simply observing national or state-level data.

Our understanding and interpretation of the phenomenon of Mexican rural depopulation changes considerably again when we observe it at the very local scale, namely the rural village, where the rural village is the smallest administrative and geographical entity of observation. Around 61% of all rural villages of the country were undergoing a depopulation process during the decade 2000–2010, with 38% of these actually disappearing during this period (Figure 8).

The rural villages are the majority type of settlements in Mexico, and they are characterizied by being very dispersed throughout the national territory. Figure 9 shows that rural growing villages are distributed quite evenly throughout the least, middle and most densely populated areas of the country (33%, 35%, and 32%, respectively).



Source: INEGI 2000a; INEGI 2010a; INEGI 2010b

FIGURE 6 Mexico. Rural depopulation at municipal scale, 2000–2010

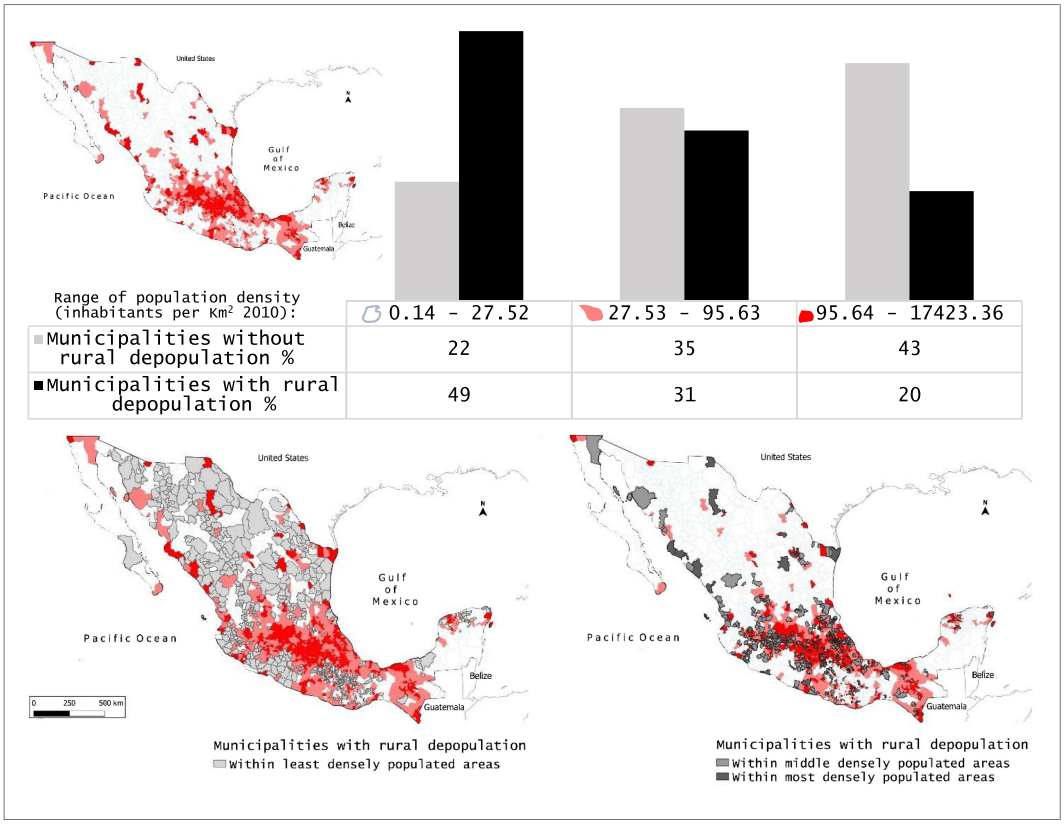
Meanwhile, the depopulating and disappeared ones are mainly concentrated at the least densely populated areas (42% and 48% respectively), a situation which is very similar to the municipalities observation. Importantly for our purposes, almost the half of depopulating and disappeared villages are located at the the middle and most densely populated centre and south of the country (Figure 9 and Figure 8). These observations sketch out how, when interpreted as the regional scale, rural depopulation is a phenomenon understood as being mainly present in the least densely populated areas, mostly in the North. However, when interpreted at the smaller municipality and village scales, rural depopulation becomes increasingly understood as being evenly shared by the middle and most densely populated areas of the centre and south of the country.

4.2 | Local rural depopulation and urban entities

We take a look into the patterns of rural depopulating territories and their spatial relationships with the national urban system (SUN).

The location of rural villages with respect to the SUN are shown in Figure 10. What we see is that the patterns of growing, versus declining, versus disappearing villages, are different between villages located within the SUN, versus those located in peri-urban areas, versus those which are remotely located. Figure 10 shows that out of all rural villages located within SUN and peri-urban areas, the majority are growing villages (41%, and 44% respectively), whereas rural villages located at the remote areas are mainly depopulating villages. Regarding disappeared villages they contribute mainly for those rural villages located within SUN.

We can also consider how these patterns of village population growth, decline, and disappearance are related to the population density of the surroundings areas. In Figure 11, we can appreciate the great importance of depopulation processes on rural villages located mostly at middle densely populated zones, overall for the remote areas (42% of all remote rural villages in the middle densely populated areas were depopulating), but also within SUN (37% of all rural villages located within SUN in the middle densely populated areas were in a depopulation process). Also, in



Source: Own elaboration based on INEGI 2000a; INEGI 2010a; INEGI 2010b

FIGURE 7 Mexico. Population decline (2000–2010), and density in municipalities (2010)

comparison only with disappeared villages, we can see the important presence of rural depopulating villages at peri-urban zones in general (least, middle and most densely populated areas). In the same line, we can see the great importance of rural disappearing manifestation at the least densely populated areas, but within the SUN. For growing villages, they outstand naturally in the most densely populated areas for all categories.

There are three general themes which emerge from Figure 11. First, reading across each group of villages, we see that most disappearance occurred in the least densely populated areas, but within the SUN. Second, rural depopulation is manifested importantly in the least densely populated areas, but mainly away from the SUN, that is in the peri-urban and principally in remote areas. In other words, most demographic declining changes ocurred in low density areas, but depopulation and disappearance relate differently with urban entities. And third, rural depopulation processes expand importantly towards the middle densely populated zones. Figure 12 synthesises schematically our observations to help us to visualize the distributions. Each dot represents each percentage point observed in Figure 11.

4.3 | Rural depopulation and altitude

One other possible issue which might heavily shape the geographical features of Mexican rural depopulation patterns is the question of topography. Just around a third part of the country is flat, and more than the half of the national territory is 1,000 metres above sea level (García-Martínez, 2008). As such, many parts of Mexico are very mountainous and it may be the case, as it is in many other countries that altitude is a key feature of population decline.

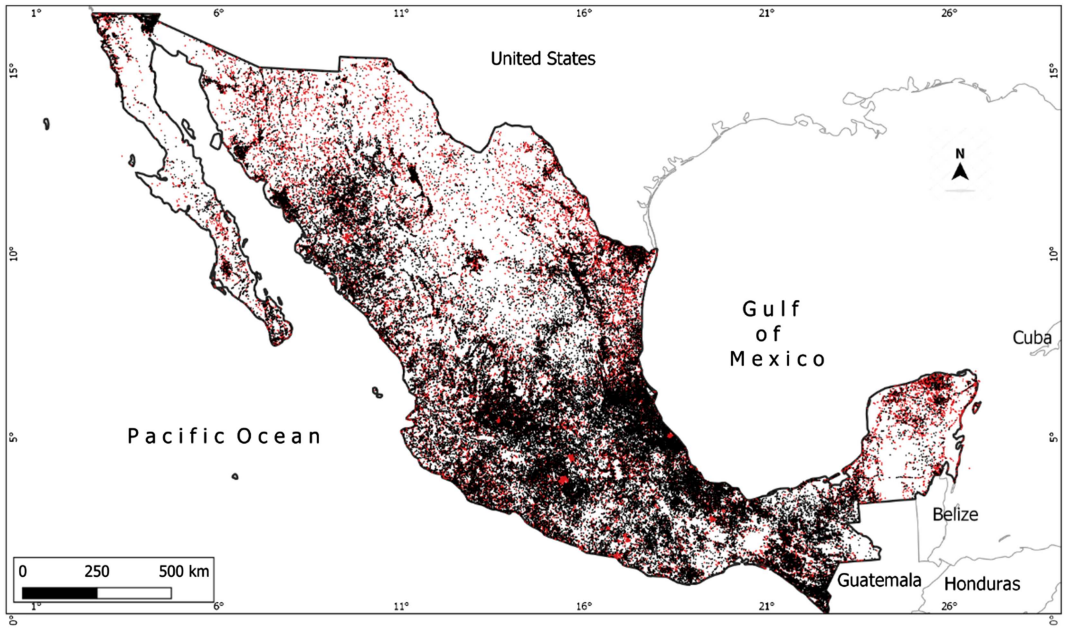
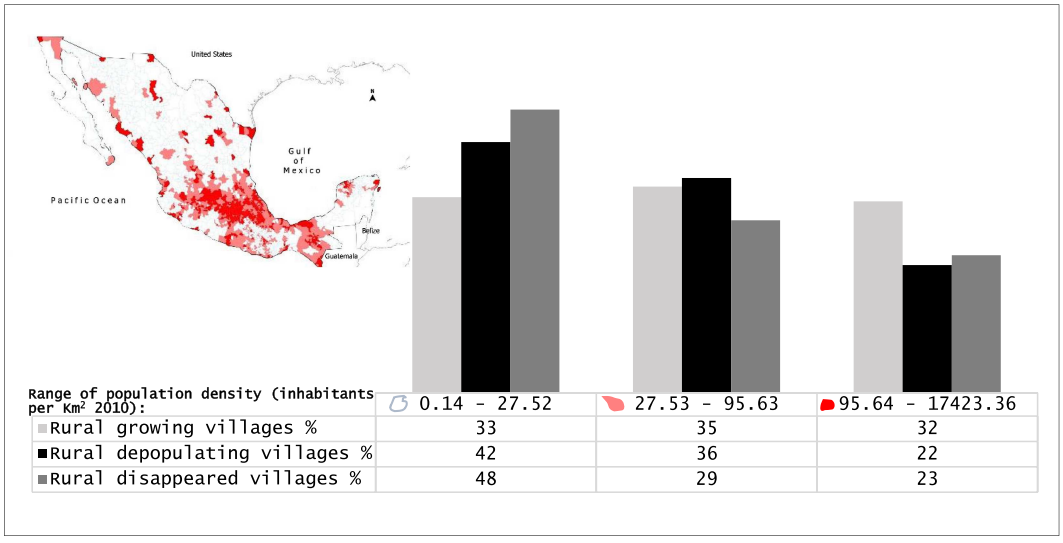


FIGURE 8 Mexico. Rural depopulation at village scale, 2000–2010

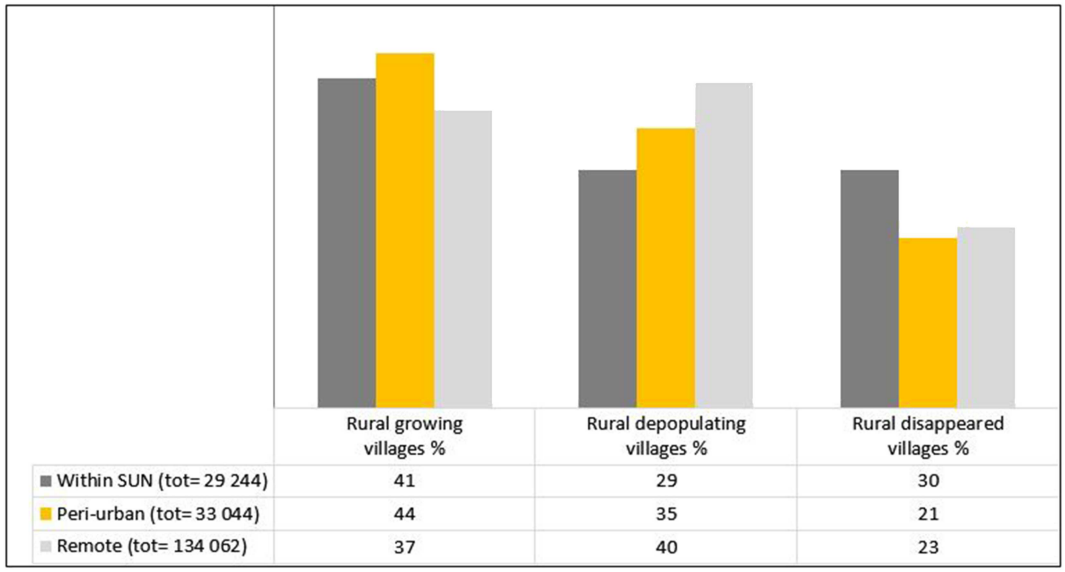


Range of population density (inhabitants per Km² 2010):	0.14 - 27.52	27.53 - 95.63	95.64 - 17423.36
Rural growing villages %	33	35	32
Rural depopulating villages %	42	36	22
Rural disappeared villages %	48	29	23

Source: Own elaboration based on INEGI 2000a; INEGI 2010a; INEGI 2010b

FIGURE 9 Mexico. Rural depopulation by population density areas at local/village scale (2000–2010)

In this subsection, we categorize the elevation levels of Mexico, and observe seven categories of altitude. We start with the figure that a third of Mexican territory is under 1,000 metres above sea level (masl), which comprises our first category. Given that the capital of the country, Mexico City, is located at 2,240 masl, and most of the SUN



	Rural growing villages %	Rural depopulating villages %	Rural disappeared villages %
Within SUN (tot= 29 244)	41	29	30
Peri-urban (tot= 33 044)	44	35	21
Remote (tot= 134 062)	37	40	23

FIGURE 10 Mexico. Rural depopulation and SUN, local scale (2000–2010)

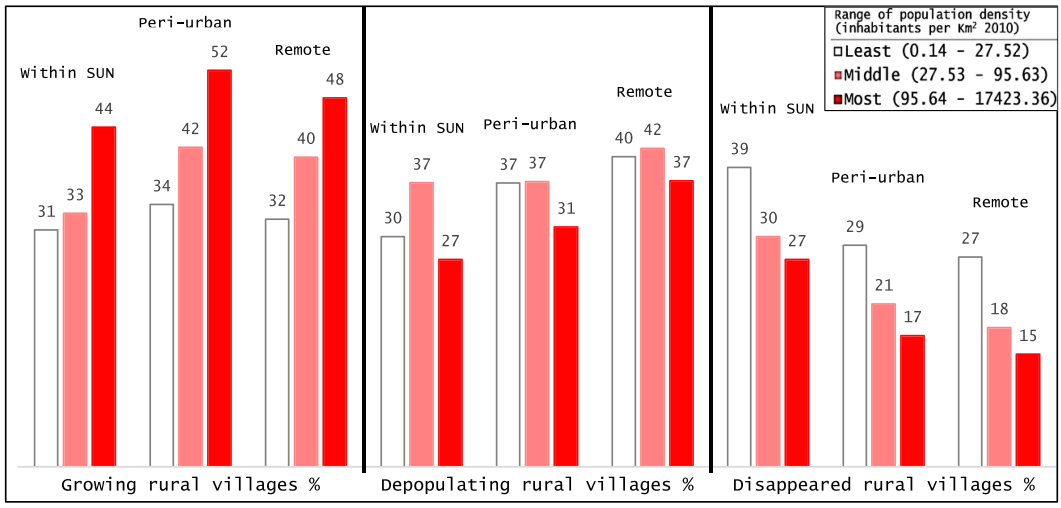


FIGURE 11 Mexico. Rural depopulation and SUN. distribution throughout density areas (2000–2010)

is located at the central fringe of the country with the highest altitudes of the country, we have divided the altitude levels above 2,500 masl into shorter interval categories. These altitude intervals are 1,000–1,500 masl, 1,500–2000 masl, 2000–2,500 masl, 2,500–2,800 masl, 2,800–3,000 masl, and above 3,000 masl. These altitude interval categories are used to depict the geography of high altitude rural village depopulation (Figure 13a), disappearance (Figure 13b) and growth (Figure 13c).

Figure 13 shows that 50% of the villages that are not facing either depopulation of disappearance are located below 1,000 masl, 12.0% are located between an altitude of 1,000 masl and 1,500 masl, and 19.3% are located between 1,500 masl and 2,000 masl. Figure 13 also shows us that 53.9% of depopulating rural villages are below an altitude of 1,000 masl, 12.4% are located between an altitude of 1,000 masl and 1,500 masl, and 18.1% are located

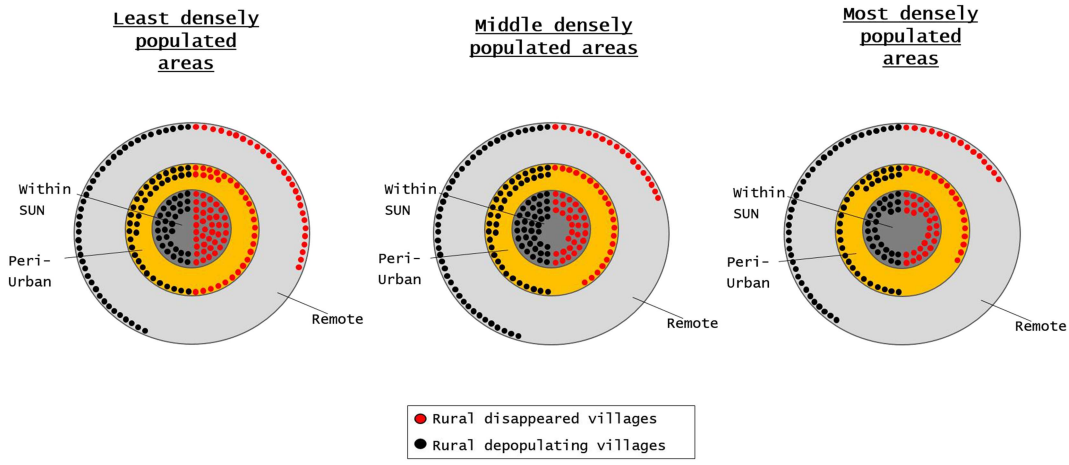


FIGURE 12 A synthesis. Diagram of rural depopulation and SUN at the local scale

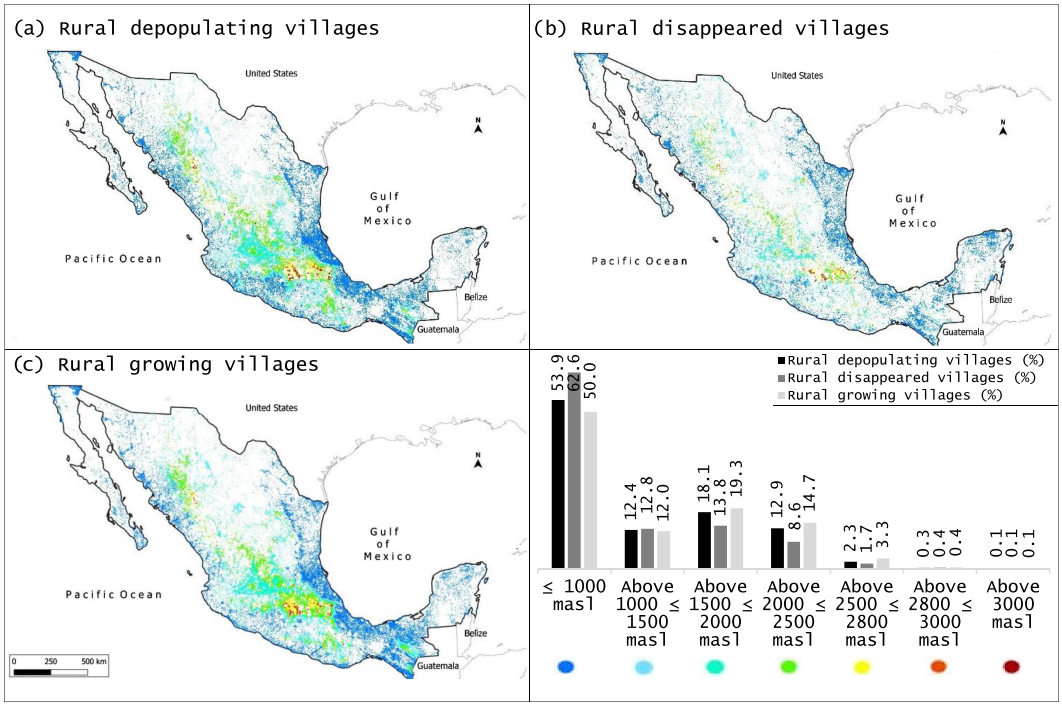


FIGURE 13 Mexico. Altitude of rural villages (2000–2010)

between 1,550 and 2,000 masl. Meanwhile, 62.6% of disappearing rural villages are below an altitude of 1,000 masl, 12.8% are located between an altitude of 1,000 masl and 1,500 masl, and 13.8% are located between 1,550 and 2,000 masl.

That is, that the spatial distribution of all rural villages of different categories is similar throughout the whole altitudinal spectrum; but it is clear that rural village population decline is more present on the low lying and plain areas below 1,500 masl, categories in which they overcome the growing rural villages. This characteristic is much more

evident for the disappeared villages. That is, that rural village population decline or rural village disappearance in Mexico tends to be relatively more prevalent in lower-lying and flat areas than in mountainous and high altitude areas. This is the opposite of countries such as Japan, and some European members.

The last statement can be complemented and ratified by observing the relationship between the (negative) growth rate of rural depopulating villages and altitude (Figure 14). The villages showing figures of population loss roughly between 0% and 40% are mainly concentrated below 200 masl, and also within the range of approximately 1,500 masl <=2,500 masl. Meanwhile, when the figures of population loss are larger than 40%, the phenomenon of depopulation tends to manifest itself mainly at low altitudes, below 200 masl. In other words, much of the most severe depopulation occurs in lower-lying areas.

In Figure 15 we repeat the same exercise as in Figure 14 but this time the scatterplot relates to population decline to local population density. What we observe is that much of the population decline is in areas with less than 1,000 inhabitants per square km.

For ease of exposition, in Table 1 we synthesize the observations of the spatial relationship between rural depopulation, the SUN and the observations regarding the altitude range in which villages are located. Table 1 is constructed with the information of Figure 10 and Figure 11. The first column states the most relevant information regarding rural depopulating and disappeared villages we found, and their relationship with the SUN. The second column, states the type of density area in which the observations of the first column took place. The third column confirms the altitudinal ranges in which the set of villages referred to in the second column are distributed. For instance, the statement in the first column (a) rural depopulation is an important phenomenon in remote areas (from Figure 10), is broken down in the second column to show that some 40% were located in the least densely populated areas, and 42% were located in middle densely populated areas. The third column of Table 1 shows the altitudinal spectrum in which these (40% and 42%) sets of depopulating villages are distributed.

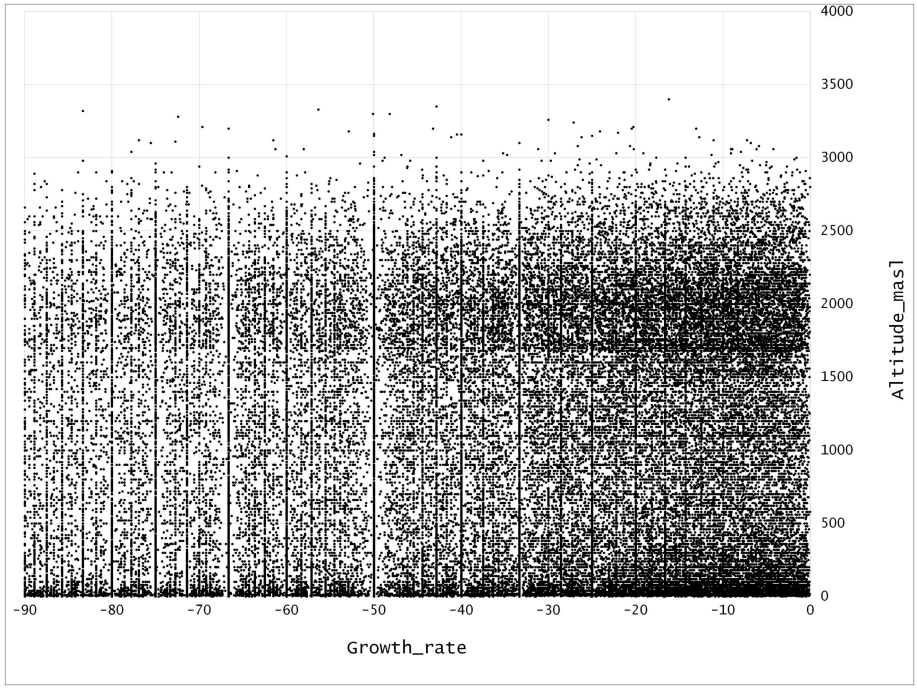


FIGURE 14 Mexico. Growth rate of population of depopulating villages and altitude

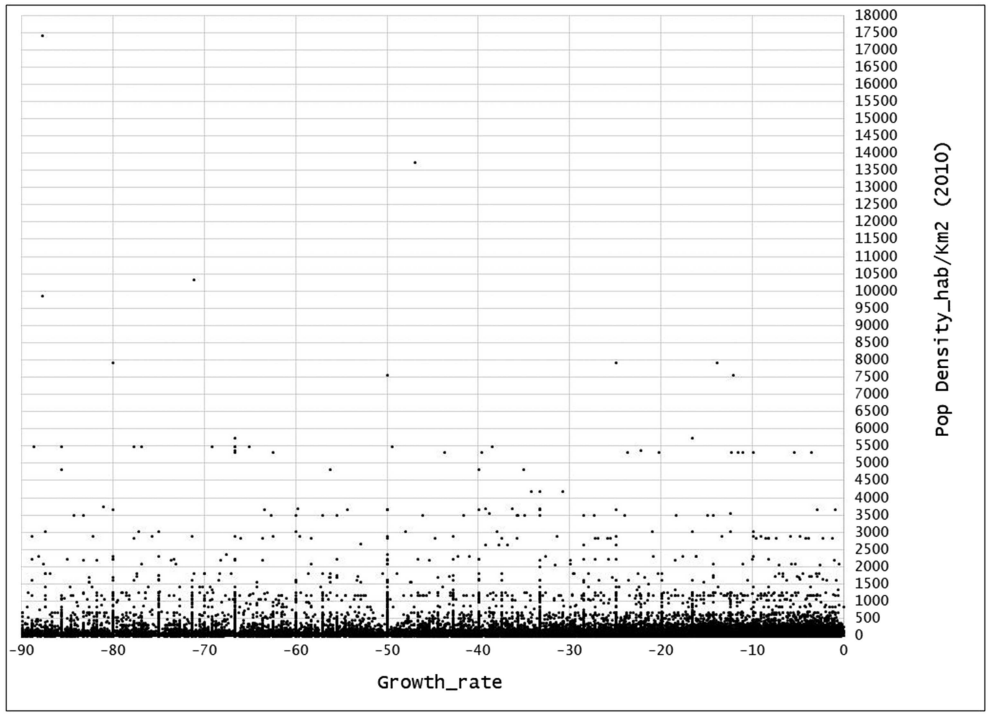


FIGURE 15 Mexico. Growth rate of population of depopulating villages and population density

TABLE 1 Key messages. Rural depopulation, SUN, and altitude, 2000–2010

Key message number	Key aspects of rural depopulation		
	Relationship with SUN	Distribution throughout density areas	Altitude ranges
1	Rural depopulation is an important phenomenon in remote areas.	Mainly, in the least and middle densely populated areas (40% and 42% respectively).	The majority of those located in the least densely populated areas were at low altitudes (<= 1,000 masl, the 52.6%). The majority of those located in the middle densely populated areas were at low altitudes (<= 1,000 masl, the 57.7%)
2	Rural depopulation is an important phenomenon taking place in peri-urban areas.	Mainly in the least densely populated areas (37%).	Mainly at low altitudes (<= 1,000 masl, the 60.7%)
3	Rural depopulation is an important phenomenon within the SUN.	Mainly in the middle densely populated areas (37%).	Mainly at low altitudes (<= 1,000 masl, the 83.8%)
4	Rural disappearance is an important phenomenon taking place within the SUN	Mainly in the least densely populated areas (39%).	Mainly at low altitudes (<= 1,000 masl, the 67.3%)

5 | CONCLUSIONS

The results reported in this paper are the outcome of the most comprehensive spatial data construction effort yet undertaken regarding the geography of rural depopulation in Mexico. By integrating data from diverse sources and at different spatial scales within a GIS framework we are for the first time able to identify the granularity of rural depopulation proceses at different spatial scales across Mexico. The data construction allows us to observe rural depopulation processes from four scales, namely the national, state, municipal and local village scales. Our multi-scaling approach has allowed us to identify not just at what scale the phenomenon of rural depopulation is observed, but also, to identify the areas in which the phenomenon is manifested regionally or locally. Taking into account just the multi-scaling approach, our research has uncovered two new key observations.

First, the observed patterns, and therefore also our understanding of Mexican rural depopulation, are heavily influenced by the choice of the spatial scale we adopt. From a multi-scaling view, rural depopulation is not observed at the national Mexican scale, whereas at the state scale, rural depopulation appears to be primarily a regional phenomenon of the northern and western states. In particular, at the state level rural depopulation appears to be dominated by the least densely populated states, all of which are located in the north of the country. Yet, when we move down through the municipal scale and the local village scales, rural depopulation emerges as a major phenomenon in many parts of the country, including in both the densely populated central and southern parts of the country, the areas which are more rapidly urbanizing.

In terms of the specific features of the depopulating territories, namely, their relationship with urban entities and also the altitude in which they are located, our research has uncovered new key observations. In particular, major demographic declining changes in rural villages tended to be observed in the extreme scenarios, namely in conditions of desolate areas of low population density but within the national urban system for the extreme condition of depopulation which the disappearance of villages, or also in the proximity to urban areas for the case of depopulating villages not yet disappeared. It is a much more mixed picture than the literature suggests when points out the low density and remote areas as the areas in which depopulation in prone to occur. Moreover, rural depopulation and disappearance takes place primarily in the plains areas below 1,000 masl. This observation is fundamentally different to the experience of many other countries. There is no systematic altitude aspect of Mexican village decline, and indeed, if anything, the evidence points to the contrary.

The results from our multi-scale and multi-altitude analysis can help us reconsider our interpretation of the phenomenon of rural depopulation, along with the effective public policies it may require. Differently from other countries, in Mexico there is currently a vacuum of policy measures oriented explicitly to rural population decline. This work detects the geographical presence of the phenomenon, but not the causes and effects of it, so additional research is therefore needed to be able to diagnose the phenomenon as a negative or positive one at the different scales. These kinds of studies could be really important for advising on public policy-design. The geographical detection of these different patterns undertaken here allows us to begin to identify the target areas in order to study more deeply the spatial impacts and the sectors of population involved.

ORCID

Liliana Castillo-Rivero https://orcid.org/0000-0001-9531-8799

REFERENCES

Anderlik, J. M., & Cofer, R. D. Jr. (2014). Long-term trends in rural depopulation and their implications for community banks. *FDIC Quarterly*, *8*(2), 44–59.

Barrachina, M. (2007). The effects of land use change on landscape: The case of VallFosca (Catalan Pyrenees). In Proceedings of man in the landscape across frontiers. IGU-LUCC Central Europe conference (pp. 20–32).

Bielza de Ori, V. (2003). Problemas socioeconómicos y territoriales de la despoblación y principios de intervención de las políticas públicas. In S. Escolanos & J. De la Riva (Eds.), *Despoblación y ordenación del territorio. Institución Fernando El Católico* (pp. 15–26). Zaragoza: Colección Actas Geografía.

Bocco Verdinelli, G., & Segundo Métay, I. G (2012). Usando datos censales desde un enfoque geográfico. El Caso del despoblamiento de pequeñas localidades rurales en México (2000-2010). Realidad, Datos y Espacio. *Revista Internacional de Estadística Y Geografía*, *3*(3), 114–131.

Bontje, M. (2018). Book review of Hollander, J. (2018) a research agenda for shrinking cities. *Regional Science Policy & Practice*, *10*, 406–408.

Canales, I. A. (2009. In Despoblamiento, pobreza y remesas: Impactos sociales y demográficos de la migración internacional. (Ed.), *Foro Nacional Las Políticas de Población en México. Debates Y Propuestas Para el Programa Nacional de Población 2008–2012* (pp. 33–41). Mexico: National Council of Population, CONAPO.

Cartwright, A. (2013). Knowing when it is time to go: Managing rural decline in central and Eastern Europe. *Pannon Management Review*, *2*(1), 33–48.

CONABIO. (2000) Localidades de la República Mexicana 2000. Catálogo de metadatos geográficos. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CIONABIO is the National Commission for Knowledge and Biodiversity Use), Government of Mexico. http://www.conabio.gob.mx/informacion/metadata/gis/loc2000gw.xml?_xsl=/db/metadata/xsl/fgdc_html.xsl&_indent=no

CONAPO, INEGI, SEDESOL. (2012) Delimitación de las Zonas Metropolitanas de México, 2010. Government of Mexico

CONAPO, SEDESOL. (2012) Catálogo. Sistema Urbano Nacional 2012, Sun. Government of Mexico

ESPON. (2017) Shrinking rural regions in Europe. Towards smart and innovative approaches to regional development challenges in depopulating rural regions, Policy Brief, 1–14, European Union, Luxemburg

ESPON. (2018) Fighting rural depopulation in Southern Europe. Transnational Observation, 1–10, European Union, Luxemburg

Feldhoff, T. (2013). Shrinking communities in Japan: Community ownership of assets as a development potential for rural Japan? *Urban Design International*, *18*(1), 99–109. https://doi.org/10.1057/udi.2012.26

García-Barrios, L., Galván-Miyoshi, Y. M., Valdivieso-Pérez, I. A., Masera, O. R., Bocco, G., & Vandermeer, J. (2009). Neotropical forest conservation, agricultural intensification, and rural out-migration: The Mexican experience. *Bioscience*, *59*(10), 863–873. https://doi.org/10.1525/bio.2009.59.10.8

García-Martínez, B. (2008). Las regiones de México. *Breviario geográfico e histórico* El Colegio de México. Mexico City. https://doi.org/10.2307/j.ctvhn0d4x

Hollander, J. (2018). A research agenda for shrinking cities. Edward Elgar Publishing. Social and Political Science subject collection. https://doi.org/10.4337/9781785366338

INEGI. (2000a). *Censo de Población y Vivienda*. Instituto Nacional de Estadística y Geografía, Goverment of Mexico. https://www.inegi.org.mx/programas/ccpv/2000/

INEGI. (2000b). Principales resultados (ITER) del Censo de Población y Vivienda. Estados Unidos Mexicanos, Instituto Nacional de Estadística y Geografía, Government of Mexico. Available at https://www.inegi.org.mx/programas/ccpv/2000/default.html?init=2

INEGI. (2010a) Marco Geoestadístico Nacional. Instituto Nacional de Estadística y Geografía, Government of Mexico. Available at https://www.inegi.org.mx/app/biblioteca/ficha.html?upc=702825292812

INEGI. (2010b) Censo de Población y Vivienda. Instituto Nacional de Estadística y Geografía, Government of Mexico. Available at https://www.inegi.org.mx/programas/ccpv/2010/

INEGI. (2010c) Principales Resultados (ITER) del Censo de Población y Vivienda. Estados Unidos Mexicanos, Instituto Nacional de Estadística y Geografía, Government of Mexico. Available at https://www.inegi.org.mx/programas/ccpv/2010/#Microdatos

INEGI. (2010d) Glosario del Censo de Población y Vivienda. Instituto Nacional de Estadística y Geografía, Government of Mexico. Available at https://www.inegi.org.mx/app/glosario/default.html?p=cpv2010

INEGI. (2015) Encuesta Intercensal 2015. Panorama sociodemográfico de México 2015. Instituto Nacional de Estadística y Geografía, Government of Mexico. ISBN 978–607–739–718–2. Available at http://internet.contenidos.inegi.org.mx/contenidos/productos//prod_serv/contenidos/espanol/bvinegi/productos/nueva_estruc/inter_censal/panorama/702825082246.pdf

Jacob, A. L., Vaccaro, I., Sengupta, R., Hartter, J., & Chapman, C. A. (2008). Integrating landscapes that have experienced rural depopulation and ecological homogenization into tropical conservation planning. *Tropical Conservation Science*, *1*(4), 307–320. https://doi.org/10.1177/194008290800100402

Johnson K, & Litcher D (2019) Rural depopulation in a rapidly urbanizing America. Research Publications in Portal of University of New Hampshire, Carsey School of Public Policy. Available at https://carsey.unh.edu/publication/rural-depopulation

Karcagi-Kováts, A., & Katonáné-Kovács, J. (2012). Factors of population decline in rural areas and answers given in EU member states' strategies. *Studies in Agricultural Economics*, *114*, 49–56. https://doi.org/10.7896/j.1105

Lausirica, C. L., & Sardi, M. G. (2008). Despoblamiento rural en el Espacio Agropecuario de Mercado, 1991-2001. *Huellas*, *12*, 74–89.

Li, X. (2015). Rural depopulation in China: A comparative perspective. *International and Multidisciplinary Journal of Social Sciences*, *4*(1), 149–174. https://doi.org/10.17583/rimcis.2015.1503

Liu, Y., Liu, Y., Chen, Y., & Long, H. (2010). The process and driving forces of rural hollowing in China under rapid urbanization. *Journal of Geographical Sciences*, *6*(20), 876–888.

Long, H., Li, Y., Liu, Y., Woods, M., & Zou, J. (2011). Accelerated restructuring in rural China fueled by 'increasing vs. decreasing balance' land-use policy for dealing with hollowed villages. *Land Use Policy*, *29*(1), 3–12.

López-i-Gelats, F. (2013). Is mountain farming no longer viable? In S. Mann (Ed.), *The future of mountain agriculture* (pp. 89–104). Berlin: Springer Geography. https://doi.org/10.1007/978-3-642-33584-6_7

López-Ruíz. (2005) La despoblación de la montaña palentina. Recomendaciones para la intervención. *Centre for Studies on Depopulation and Development of Rural Areas (CEDDAR)*, Inform 9, 2,005–2,003

MacDonald, D., Crabtree, J. R., Wiesinger, G., Dax, T., Stamou, N., Fleury, P., … Gibon, A. (2000). Agricultural abandonment in mountain areas of Europe: Environmental consequences and policy response. *Journal of Environmental Management*, *59*(1), 47–69. https://doi.org/10.1006/jema.1999.0335

Mann, S. (2005). The Depopulation of Rural Areas and the Farming System. *Research in Agricultural & Applied Economics. European Association of Agricultural Economists (EAAE)*. https://doi.org/10.22004/ag.econ.24415

Métay Segundo, I. G, Bocco Verdinelli, G, & Urquijo Torres, P. S (2012). Capítulo 5. Despoblamiento rural y geografía ambiental. Consideraciones desde lo local. *Corografía y escala local*, Enfoques desde la geografía cultural (pp. 83–96). Morelia: Universidad Nacional Autónoma de México. Centro de Investigaciones en Geografía Ambiental.

Mojarro O, Benítez G (2010) El despoblamiento de los municipios rurales de México, 2000–2005. La situación demográfica de México 2010. CONAPO, Government of Mexico, Mexico City

Montserrat, P., & Villar, L. (2008). Consecuencias ecológicas del abandono de tierras y de la despoblación rural. *Forest Systems*, *8*(3), 135–141.

Nakagawa, M., & Izuta, G. (2017). An investigation of the depopulation in northeastern rural regions of Japan based on the conjoint analysis modeling approach. *Asian Journal of Humanities and Social Studies*, *5*(2), 2321–2799.

Noack, E. M., & Bergmann, H. (2011). Elderly People's perspective on rural medical care: A case study from northern Germany. *Hrvatski Geografski Glasnik*, *73*(1), 149–163. https://doi.org/10.21861/HGG.2011.73.01.10

Perez-Barbosa, D., & Zhang, J. (2017). Future migration intention of young Japanese in the context of rural depopulation. *Journal of the Eastern Asia Society for Transportation Studies*, *12*, 1076–1095.

Pinilla V, & Sáez LA (2017) Rural depopulation in Spain: genesis of a problem and innovative policies. Informes Centre for Studies on Depopulation and Development of Rural Areas, *2*, 23.

Pires de Almeida, M. A. (2017). Territorial inequalities: Depopulation and local development policies in the Portuguese rural world. *Ager, Revista de Estudios Sobre Despoblación Y Desarrollo Rural*, *22*, 61–87.

Poinsot, Y. (2007). Sobre algunos efectos del despoblamiento agrícola. *Ería*, *72*, 23–34.

Rizzo, A. (2016). Declining, transition and slow rural territories in southern Italy characterizing the intra-rural divides. *European Planning Studies*, *24*(2), 231–253. https://doi.org/10.1080/09654313.2015.1079588

Skryzhevska, Y., & Karácsonyi, D. (2012). Rural population in Ukraine: Assessing reality, looking for revitalization. *Hungarian Geographical Bulletin*, *61*(1), 49–78.

Steimbreger, N., & Kreiter, A. (2008). La paradoja de los pueblos rurales de la Línea Sur rionegrina: Entre la desaparición y el crecimiento. *Huellas*, *14*, 31–52.

Stratta Fernández, R., & de los Ríos Carmenado, I. (2010). Transformaciones agrícolas y despoblamiento en las comunidades rurales de la Región Pampeana Argentina. *Estudios Geográficos*, *71*(268), 235–265. https://doi.org/10.3989/estgeogr.0504

Thompson, C. S. (2003). Depopulation in Rural Japan: "Population politics" in Tôwa-chô. In J. Knigh & J. W. Traphagan (Eds.), *Demographic change and the family in Japan's aging society* (pp. 89–106). Albany, NY: State University of New York.

Thompson, C. S. (2008). Chapter Nineteen. Population decline, municipal amalgamation, and the politics of folk performance preservation in Northeast Japan. In F. Coulmas, H. Conrad, A. Schad-Seifert, & G. Vogt (Eds.), *A demographic challenge. A handbook about Japan* (pp. 361–386). Leiden: BRILL. ISBN 9047428110, 9789047428114.

Traphagan, J. W. (2008a). In Ancestors, burial rites, and rural depopulation in Japan. In F. Coulmas H. Conrad A. Schad-Seifert & G. Vogt (Eds.), *The demographic challenge. A handbook about Japan* (pp. 387–396). Leiden: BRILL. ISBN: 9789047428114.

Traphagan, J. W. (2008b). Population aging and Japan's declining rural cities. In P. Oswalt & F. Türetken (Eds.), *Shrinking cities: Complete works 3 Japan,13:17*. Berlín: Kulturstiftung des Bundes.

United Nations. (2018) World urbanization prospects 2014 revision. Methodology United Nations, Department of Economic and Social Affairs. Population Division, New York, 2015. Available at https://population.un.org/wup/DataQuery/

Vázquez, J. A. A (2009). Implicaciones socioterritoriales de la despoblación en la montaña astur-galaico-leonesa. *Despoblación, envejecimiento y territorio: un análisis sobre la población española* (pp. 547–566). Spain: Servicio de Publicaciones.

Viñas, C. D. (2019). Depopulation processes in European rural areas: A case study of Cantabria (Spain). *European Countryside*, *11*(3), 341–369. https://doi.org/10.2478/euco-2019-0021

Wang, C., Wang, Y., Gao, B., Weng, Z., & Tian, Y. (2019). Manifestations and patterns of village abandonment in mountains of China from a dynamic perspective. *GeoJournal*, 1–16. https://doi.org/10.1007/s10708-019-10062-w

Westhoek, H. J., Van den Berg, M., & Bakkes, J. A. (2006). Scenario development to explore the future of Europes's rural areas. *Agriculture, Ecosystems and Environment*, *114*(1), 7–20. https://doi.org/10.1016/j.agee.2005.11.005

Yonezawa, K., & Aoyagi-Usuia, M. (2010). Scenario analysis of generational change of farmland managers for a depopulated rural community in Japanese less favored areas. *Asian Rural Sociology Association (ARSA) Interntional Conference*, *4*, 389–400.

Yoshida, T. (1999). An attempt of finding way to deal with and recover declining primary industry with depopulation making use of traditional cultural heritages, in case of the small mountain village Nakajou-mura, Naganoken. *Studies in Humanities: Human Science*, *33*, 107–126.

How to cite this article: Castillo-Rivero L, McCann P, Sijtsma FJ. A multi-scale approach to rural depopulation in Mexico. *Reg Sci Policy Pract*. 2021;13:1328–1347. https://doi.org/10.1111/rsp3.12381

DOI: 10.1111/rsp3.12381

Resumen. El objetivo de este artículo es esbozar el declive de la población rural en México. En él se realizó una exhaustiva documentación de escala múltiple del tejido urbano y rural de México y de su dinámica de despoblación. El artículo no identifica las causas y los efectos de la despoblación rural, sino que intenta detectar su presencia geográfica de una manera que otros enfoques no pueden hacer. Se identificó la granularidad de la despoblación rural, que se manifiesta en cuatro escalas diferentes: nacional, estatal, de municipalidad y por pueblo. Se utilizaron los datos del censo para el período 2000-2010. Se relacionó la despoblación rural con las características espacio-geográficas encontradas en la literatura, a saber, la relación entre los territorios en proceso de despoblación y los urbanos, y el rango de altitud en el que se encuentran. Se comprobó que la proximidad y la lejanía de las zonas urbanas, así como la altitud, no siguen las pautas típicas que suelen observarse en otros lugares. A diferencia de lo que ocurre en otros países, el despoblamiento rural en México se manifiesta sobre todo en las zonas bajas, a pesar de que la mayor parte del país se encuentra en zonas con una altitud elevada. El despoblamiento y la desaparición de las zonas rurales se producen principalmente en las planicies por debajo de los 1.000 metros sobre el nivel del mar, independientemente de la densidad de población de los territorios donde se encontraban. Asimismo, nuestro enfoque multiescalar nos ha permitido identificar no sólo a qué escala se observa el fenómeno de la despoblación rural, sino también identificar las zonas en las que el fenómeno se manifiesta a nivel regional o local. Como vemos, gran parte del fenómeno se concentra en áreas diferentes a lo que sugieren las narrativas nacionales.

抄録: 本稿では、メキシコの農村の人口減少を概観する。メキシコの都市と農村の構造とその過疎化のダイナミクスの多重スケールで包括的な検討を行った。ここでは農村の人口減少の原因と影響を特定するのではなく、他のアプローチでは不可能な方法で人口の減少を地理的に検出することを目的とする。農村の人口減少の粒度は、4つの異なるスケール、すなわち国、州、市町村、および地方村落の規模で特定する。2000~2010年の国勢調査のデータを用いて、農村の人口減少と文献に見られる空間的・地理的特徴、すなわち人口が減少している地域と都市の地域および人口減少地域の標高の範囲との関連性とを結びつける。都市への近接性や都市からの遠隔性は、標高の高い地域への近接性又は遠隔性と同様に、他の地域で観察される典型的なパターンではないことが分かる。他国の例と異なり、メキシコでは、国土の大部分が高地であるにもかかわらず、低地における人口減少が顕著である。農村の人口減少と消滅は、その農村がかつてあった地域の人口密度に関係なく、主に海抜1,000メートル以下の平原地域で起きている。また、今回用いた多重スケールアプローチは、農村における人口減少の現象がどの程度の規模で観察されるかを特定するだけでなく、現象が地域的又は局所的に発生する地域を特定することも可能であった。このように、人口減少の多くは、国家の言説（national narratives)による示唆とは異なる地域に集中している。