

Environmental Assessment of Brick Kilns in Chihuahua State, México, Using Digital Cartography

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1. Introduction

The world's population is concentrated in urban areas, which are characterized by being highly dynamic and complex. There are several enterprises responsible for high levels of pollution, one of them is the brick kiln. One standard traditional brick kiln may produce 86 kg of particulate matter on a 12 hours burn required to produce 10,000 bricks. There are many brick kilns of this size distributed around urban areas of the state of Chihuahua. These brick kilns represent an environmental problem due to their negative health effects if the amount of particulate matter is extrapolated to the total number of burns carried out. There is a need for a proper environmental management of natural resources and urban planning. This chapter presents two objectives using digital cartography as a tool and considering the complete and complex state of Chihuahua. One of the objectives of this study was to identify the location of the brick kiln in all the municipalities of the state and the other objective was to determine the best places, around the state of Chihuahua, to relocate the brick kiln industry in order to minimize environmental risk. Multicriteria Analysis (MCA) based on digital cartography and a Geographical Information System (GIS) were used. The factors selected for analysis included biophysical, social and economic aspects. In order to estimate the effects of brick kiln operation, a nine-level estimated risk scale was defined using hierarchical MCA and the modified Delphi technique. The weighted risk factors were mapped in the GIS using the Spatial Analysis® extension. Polygons showing the degree of population and ecosystem vulnerability were obtained by superposing the maps. Currently, 78.8 % of kilns are located in areas of medium to high vulnerability. Using the data obtained in this study, brick kilns in the state of Chihuahua can be relocated on the basis of reliable technical criteria. Risk maps are presented for those regions that contain brick kilns inside or close by the city.

2. Metropolis and pollution

From the perspective of landscape ecology, cities are mosaics of high heterogeneity due to the different materials, whether natural (rocks, soil, vegetation, water) or made by humans (concrete, asphalt, metal, plastic, glass), which are arranged according to a specific use: housing projects, transport system, commercial and recreational areas. Urban settlements

occupy a small fraction of the surface of the earth in terms of area, but rapid urbanization and industrialization are key factors that depend on social and economic development of regions as well as environmental changes (Ramadan et al., 2004). On the other hand, a high percentage of the world's population is concentrated in urban centers, which are characterized by being highly dynamic and complex. This may cause tension in the use and exploitation of natural resources, but also creates pressure on management systems and urban planning in the use of ground, transportation and environmental quality (Van der Sande et al., 2003).

Urban air pollution poses a major threat to human health and the environment in most countries of the world (De Vives, 2007). Rapid urbanization has resulted in increased air emissions due to transportation, energy production and industrial activity concentrated in densely populated areas. This topic is of increasing importance, since most of the world's population lives in urban centers and demands a healthier environment (Campos et al., 2008). Among urban air pollutants most common and important for their health risks are total suspended particulates, heavy metals, nitrogen oxides, carbon monoxide, sulfur dioxide, hydrocarbons and ozone. Ozone is produced by the reaction to the sun's light and nitrogen oxides and volatile organic compounds (Dalmasso et al., 1997). In humans the result of environmental degradation has been reflected by premature mortality due to exposure to pollutants and chronic effects, including reduction in fitness and permanent lung damage (Escobedo & Chacalo, 2008). Specifically, the World Health Organization (2002) considered air pollution as one of the most important global health priorities. It has been estimated that particulate pollution is responsible for 1.4% of all deaths worldwide (Cohen et al., 2003). Studies conducted in industrialized countries have shown that short-term changes in pollution levels are associated with changes in daily death rate. Damage was also expressed in economic terms as absenteeism, increased medical costs and, consequently, productivity losses (Escobedo & Chacalo, 2008). Although there are several enterprises responsible of high levels of pollutions, this chapter will focus on one of them: brick kilns.

3. The brick industry ... between right and wrong

Brick kiln are small businesses distributed along the poorest sides of the cities. Bricks are fabricated using clay, water, silt, and fuel. On one side these business provide food, education and housing to thousands of families. On the other side its operation generates pollutants to the environment. In México brick production, contrary to other Latin-American countries, still is a handmade craft activity, 90% of the producer does not have state of the art technology to fabricate the bricks. The different activities involved in the brick production include mixing, molding, drying, burning, and selling the final product as shown in Figure 1. Most of the work is hard and it is made under harsh conditions everywhere in México (González, 2008). Therefore, it is important to contribute with some ideas to improve the quality of life of the workers and the families that lives close by.

There is evidence that brick kilns emit a considerable amount of pollutants and they are included in national inventories (SEMARNAT, 2011). These pollutants are created due to the incomplete combustion process and the different types of fuel used in the kiln. The typical brick kiln is built open to the atmosphere; therefore consume large amounts of



Fig. 1. Brick fabrication process at Nuevo Casas Grandes, Chihuahua.

fuels. Fuel used varies according to what is available for brick makers and includes wood, recycled motor oil, coal, fuel oil, diesel, tires, trash and plastics among others. The inefficient combustion of these furnaces favors the emission of solid particles and greenhouse gases, among which are the oxides of nitrogen, sulfur, and carbon (Table 1). González et al. (1998), in Spain, reported the presence of fluoride, chlorine and bromine in addition to the mentioned emissions from the open brick kilns. And Bruce et al. (2007) reported the presence of carcinogenic polychlorinated organic compounds and heavy metals by burning some of the fuels mentioned above. Recent studies have revealed that a traditional oven emits about 863 pounds of pollutants for each production burns covering approximately 10,000 bricks (TCEQ, 2002). The problem is increased by the process. One clear example is the combustion of heavy metals. Heavy metals can remain in its original form during incineration or may react to form new compounds such as metal oxides, chlorides or fluorides (Brigden et al., 2000). It has been shown that in the incineration process mobility and bioavailability of toxic metals is greatly increased in comparison with the original waste (Brigden et al., 2000; Martirena & Martinicurena, 2001). The most common form of transport of the metals released in these and other processes is by air. The metals can thus travel thousands of miles to be deposited in the soil (Martirena & Martinicurena, 2001) affecting people's health.

Brick fabrication process	Activities that may generate pollutants	Pollutant
Clay extraction	Manual tools used for extraction	Suspended Particles
Mixing	Sieving and selection Mixing of clay, water and silt	Suspended Particles
Molding		None
Drying	Water vapor	None
Kiln fill in		None
Cooking	Fuel: wood and saw dust	Suspended Particles Nitrogen Dioxide Carbon Monoxide Volatile Organic Compounds Polychlorinated organic compounds
Classification	Discarding broken, un-cooked and deformed products	Solid waste
Transport	Discarding broken products	Solid waste

Table 1. Pollutants associated to the brick kiln industry.

The pollution generated by the brick industry is a recurring problem worldwide. However, this micro-industry provides income to thousands of families and cannot be removed easily. Each country, city or town must look for better alternatives to address this problem. Corral Avitia et al., 2009 reported the environmental impact of brick industry from the construction site to the abandonment. The results showed that a clean technology should be adapted to minimize the critic effect of air pollution. However, prior to the use of clean technologies; studies must be performed to determine, geographically, the best sites for the relocation or

construction of the kilns. However, there are different factors that must be addressed in each region. First of all, the location of the total number and type of brick kilns should be documented. The best places for relocation should be known to determine if the kilns require to be relocated. Also, techniques that will improve the brickmakers quality of life (appropriate technology) must be located and implemented. And finally, environmental policy strategies to change attitudes and activities with the support of various economic, social and governance entities must be designed.

4. Risk mapping and multi-criteria analysis

In recent decades, the mapping of risk has gained importance as an evaluation tool to natural or technological disasters. Therefore, research has focused on studying physical factors that influence the onset of disasters and on identifying temporal recurrence, in order to define the potentially affected area and assess possible damage. In the case of technological risks, studies have focused mainly on territorial vulnerability and spatial distribution of potentially hazardous facilities or activities (Bosque Sendra et al., 2004). Cartographic expression is a useful tool in assessing and managing risks. It establishes the zoning from the combination of levels of risk mapping, vulnerability and exposure. The execution risk mapping land proposed to avoid damage to vulnerable communities. The risk map is a resultant guidance tool for land use planning (Aguirre-Murua, 2005, Bosque-Sendra et al., 2005). From the theoretical-scientific, environmental maps are invaluable in projecting the field of practical applications for solving problems which commonly involve the interaction of different variables. The multicriteria analysis (MCA) enables the integration and interrelationships search for making good decisions (García-Abad, 2002).

During the last decade has increased the use of geomatics, which integrates geographic information systems (GIS), remote sensing and geo-positioning systems (GPS) in order to perform land management. Besides, incorporating MCA has proven to be efficient in certain geographical areas and it is ideal to respond to environmental impact studies and risk assessment for industry and agricultural activities (Ciminari et al., 2003; Diaz-Muñoz & Diaz-Castillo, 2002; Frau Mena et al., 2006; Malczewsky, 1999). It is also useful to relocate undesirable facilities with two objectives: to avoid negative impacts and to protect the industries operational costs. For the first objective, it is required to build the industry as far as possible of urban areas to avoid negative impacts over the population's health. But the second requires that the facilities are located as close as possible to their suppliers to achieve operational efficiencies (Medina & Cerda, 2008). Therefore, the results must present alternative solutions to the multiple actors involved in decision-making (Ciminari et al., 2003; Diaz-Muñoz & Diaz-Castillo, 2002; Malczewsky, 1999). However, it is difficult to determine optimal sites for industrial development, because it involves a complex array of critical factors in several disciplines such as economic, technical, social and environmental (Jun, 2000).

There are some research published in scientific literature addressing the application of information technology techniques, multi-objective and MCA to relocate industries, landfills, power plants and solid waste disposals. Lowry et al., (1995) developed a GIS mapping analysis to estimate the degree of potential risk associated with an industrial area between México and the U.S. border. He used vulnerable areas and exposure zones to create

a risk scenario assessing the most sensitive areas in the event of an accident. Tudela-Serrano et al. (2000) conducted a search for suitable areas for building thematic developments by local analysis tools, reclassification and overlaying maps, based on physical and economic criteria. Vatalls and Manoliadis (2002) and Frau Mena et al. (2006), reported the best area to build a landfill using environmental factors, socioeconomic and technical-operational areas. Zambon et al. (2005) applied the technique of MCA associated with a GIS to assess the territory for the purpose of locating power plants by reducing the environmental impact to a minimum. Using the same technology tools, Gallardo et al. (2005) and Silva et al. (2006) described a methodology to determine the most appropriate location of sites for solid waste disposal. Corral Avitia et al. in 2010, published the first study using these integrated techniques to find the best places to relocate the brick industry in Ciudad Juárez. This study was used for the State and Municipal Government on 2010 to manage the purchase of land for the relocation of brick kilns. The relocation of the owners of the kilns is still in process due to the actual unsafe conditions of the city.

Based on all the antecedents, the contribution of the authors pretends to be useful for government and brickmakers. This chapter presents two objectives considering the complete and complex state of Chihuahua. The first objective of this study was to identify the location of the brick kiln in all the municipalities of the state and it is presented in section 5. The second objective, presented on section 6, was to determine the best places in the state of Chihuahua to relocate the brick kiln industry in order to minimize environmental risk.

5. Brick kilns in Chihuahua State

Research indicates that the brick industry is distributed in several countries but there is a lack of real information. México has a total of 32 states, however there is only a few of them who have reported inventories of kilns that are normally operating (SEMARNAT, 2011). These small businesses are hardly registered on economical census. One clear example is Chihuahua state, there are 277 brick kilns registered in the 2009 Economic Census of the National Institute of Statistics and Geography (INEGI, 2009) but in Juárez alone there are 312 Brick kilns (Corral Avitia, 2005). Therefore, there is a need to know the real problem. During 2010 and 2011 a census was carried out in all the municipalities in the state of Chihuahua in order to determine the total number of kilns, brick-burning capacity, type of furnace, fuel used and exact geographical location (González et al., 2011).

Chihuahua is the largest state located at 31° 54' - 25° 29' N latitude and longitude of 103° 16' - 109° 17' O North México. It has a total population of 3,406,465 inhabitants. Its total extension is 247,460 km². It is divided on 64 municipalities being the most populated in decreasing order Juárez, Chihuahua, Cuauhtémoc, Delicias, Hidalgo del Parral, Nuevo Casas Grandes, Camargo, Jiménez, Guerrero and Saucillo with population higher than 30,000 inhabitants. The municipalities of the state in which the brick industry has developed in an intensive manner are presented in Table 2.

The census (González et al., 2011) indicates that there are 959 brick kilns distributed in 16 municipalities and these can be observed in Figure 2. Most of these are located within these municipalities: Juárez (312), Chihuahua (296), Cuauhtémoc (88) and Hidalgo del Parral (85).

Figure 3 presents the location of the brick kilns with respect to the urban area on these four municipalities. Figure 4 presents the urban areas of Delicias, Camargo, and Nuevo Casas Grandes, with 49, 48 and 33 brick kilns, respectively. On a recent effort, the Secretary of Urban Development and Ecology successfully relocate the brick kilns in Cuauhtémoc and Camargo as can be observed on Figure 3c and 4a, respectively. However, there are still municipalities that have most of the kilns inside the cities; such as Juárez, Chihuahua and Nuevo Casas Grandes. On the other hand, two others, Delicias and Hidalgo del Parral, are under the risk to be reached by the urban area. Therefore, the risk cartography will be presented for those five municipalities in the next section.

Municipality	Total population	Brick kilns
Ascensión	23,975	2
Buenaventura	22,378	10
Camargo	48,748	48
Casas Grandes	10,587	11
Cuauhtémoc	154,639	88
Chihuahua	819,543	296
Delicias	137,935	49
Galeana*	5,892	6
Guerrero	39,626	2
Hidalgo del Parral	107,061	85
Janos	10,953	1
Jiménez	41,265	9
Juárez	1,332,131	312
Nuevo Casas Grandes	59,337	33
Rosales	16,785	3
Saucillo	32,325	4

*State Housing Program. The brick kilns were built to provide the bricks required for the program. They were temporary.

Table 2. Chihuahua's municipalities with brick industry. Relation between population and number of kilns.

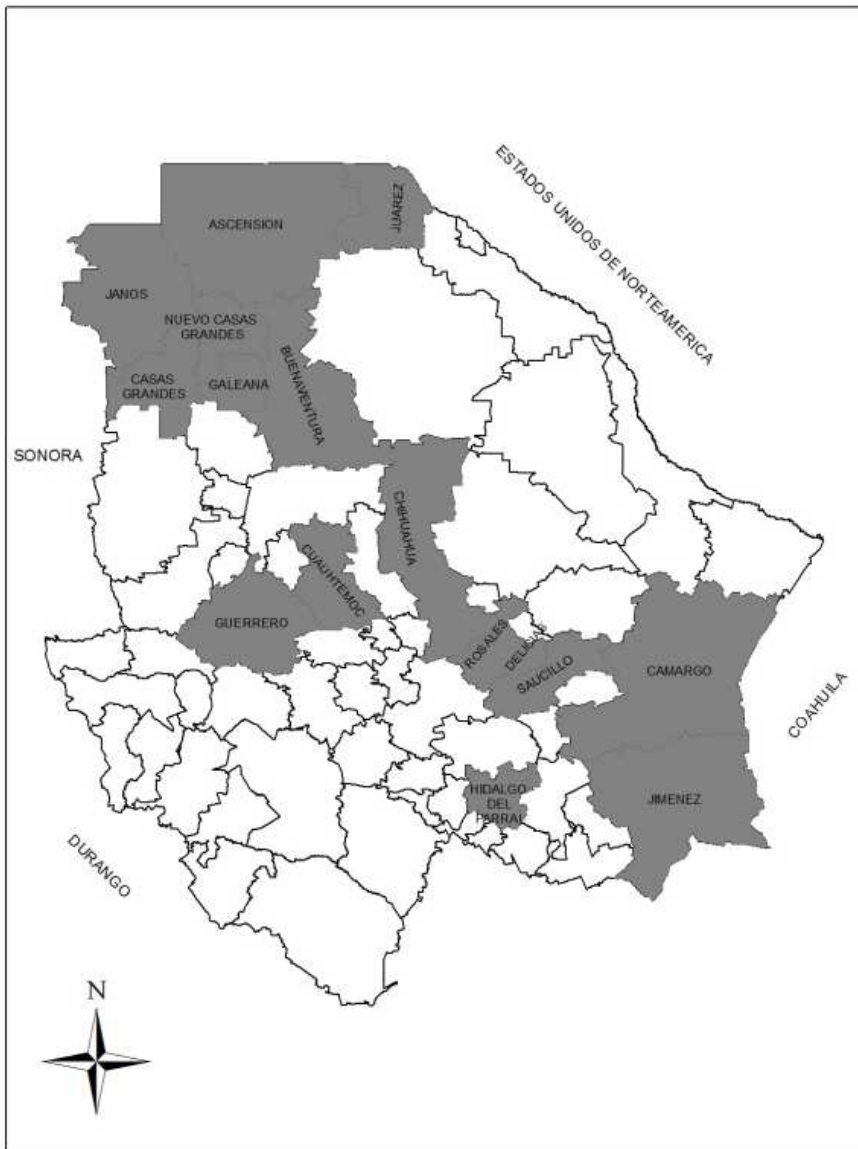


Fig. 2. State of Chihuahua’s municipalities with brick industry.

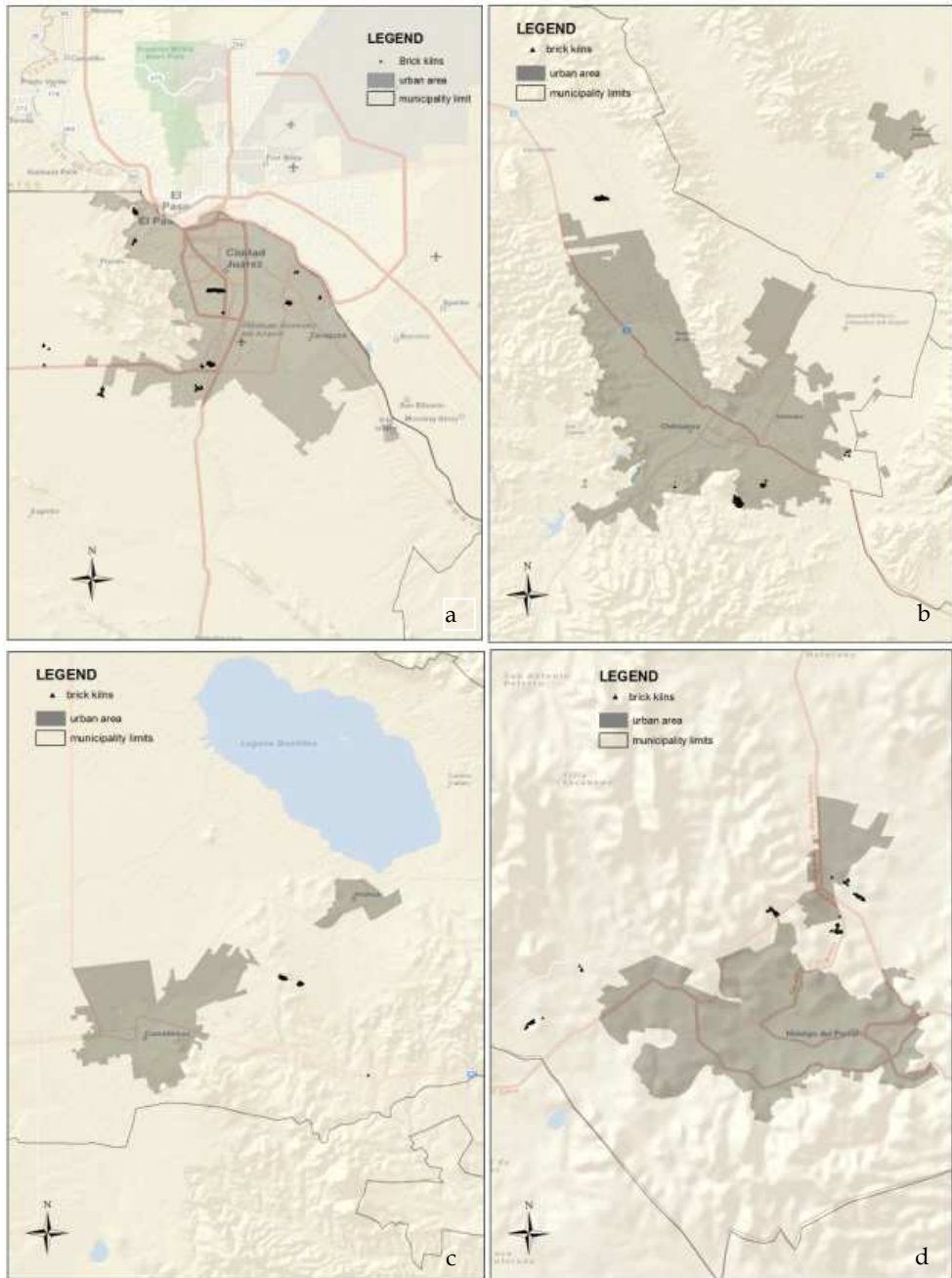


Fig. 3. Municipalities with more than 80 kilns. a) Juárez, b) Chihuahua, c) Cuauhtémoc and d) Hidalgo del Parral.

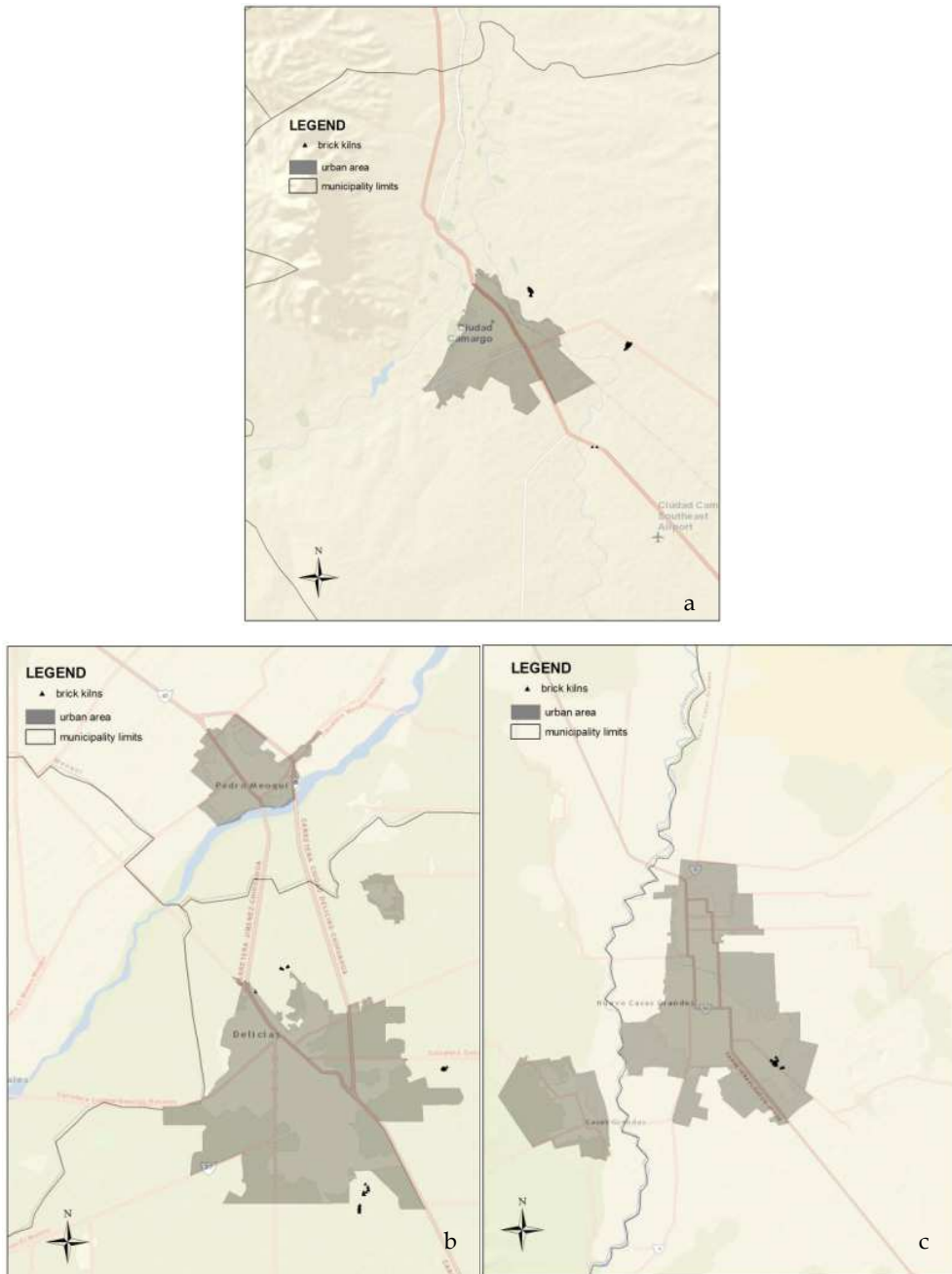


Fig. 4. Municipalities with more than 30 kilns. a) Camargo, b) Delicias and c) Nuevo Casas Grandes.

6. Risk mapping for brick kilns in Chihuahua State

This session provides the methodology to determine the best places in the state of Chihuahua to relocate the brick kiln industry. Being the ultimate objective to minimize environmental risk for the population living close to this micro-industry. The mapping was developed for five municipalities Juárez, Chihuahua, Hidalgo del Parral, Delicias and Nuevo Casas Grandes.

Since none of the five municipalities had legislation on the installation and operation of brick kilns, the factors considered in environmental impact analysis were determined by literature review and consultation with specialists in the environmental area. It was used as a reference the Ecological Law of the State of Guanajuato in the technical standard and factors proposed by NTE-IEG-001/98. The working group members are specialists in various environmental areas such as biota, water, soil, air and energy. The selection of a risk factor was based on the fact of being able to be represented spatially, so the databases used were those of the National Institute of Statistics and Geography as is the National Census of Population and Housing 2005, Digital Cartography Unit of the Biology Program at the Biomedical Science Institute of the Autonomous University of Juárez City and the National Biodiversity Commission. Maps used were soil science, geology, hydrology, vegetation and other landscape units (scale 1:250,000). The risk factors considered to evaluate each municipality are described next.

- a. Vulnerable species. The mappings used were those corridors and polygons with the presence of species with ecological or economic interest.
- b. Ecological zones. The information used was about natural and protected areas, such as national parks, biosphere reserves and buffer zones of flora and fauna, considered as priority areas for conservation.
- c. Groundwater hydrology. It was considered the average of the mirror as groundwater wells in the state. It was assumed that shallow groundwater levels are more vulnerable to contamination than deeper.
- d. Surface hydrology. Buffer zones were established. Special care was placed on surface water flows to ensure a minimal impact on hand contamination and to prevent the destruction of the kilns for potential flooding.
- e. Urban areas. Urban areas are considered as exclusion areas for the brick industry; but should be considered on a relative proximity to allow the movement of employees into the workplace as well as its proximity to points of sale.
- f. Elevation. The minimum and maximum desirable elevation was established in relation to the relative height above sea level for the installation of the brick industry. This was performed independently for each municipality.
- g. Pedology. Soil, structure and type, are important factors that allow an efficient construction and a long-term performance of the kilns. Besides it provides resistance to infiltration of contaminants.
- h. Pending. The slope of the land has a strong influence on the selection of sites for construction of kilns. It helps to reduce costs associated with it and avoid losses by landslides or mudslides.
- i. Geology. Gives stability to the kilns and prevents pollutants infiltration.
- j. Roads. The proximity to roads reduces the costs associated with freight transportation as well as raw material to finished product.

- k. Land use. Some municipalities have land use plans that consider defined areas for the implementation of dangerous or hazardous industry. Therefore, they must be taken into account as a priority for the development of the brick industry.
- l. Archaeological areas. Archaeological areas with buffer areas were considered exclusion areas for the final maps.
- m. Raw materials depots. The proximity to the banks of material decrease production costs of the brick, however the environmental impact caused by removing the soil must also be considered.
- n. Airport. In those municipalities that have an airport, the polygon area was considered for exclusion.
- o. International and municipal limits. To avoid conflicts between countries or municipal authorities it was decided to respect the boundary edges using buffer zones.
- p. Transmission lines. For safety reasons, the construction of brick kilns is prohibited in areas where transmission lines, gas, pipelines or aqueducts are present.

Multi hierarchical criteria (Malczewsky, 1999) and a modified Delphi technique (ESRI, 1991) were applied in order to establish the importance criteria and weighting of the analysis. The risk factors (a to p) cited above were classified within the corresponding category and subcategories as shown on Table 3. The participation or not of the risk factors was depended on the municipality natural and anthropogenic characteristics. Once weighted (W_c y W_f), digital map were generated with the extension Spatial Analysis (ArcGIS 9.3®) with normalized weighted data (N) according to risk factors. Using algebra and overlap maps, the polygons with different degrees of vulnerability were presented on each map. This allows to have a better view about the zones were the brick industry can be relocated without harming the environment and the brickmakers budgets.

CATEGORY	W_c	SUBCATEGORY	FACTOR	W_f	N
Environmental	Wcenv	Biological	B1	WfB1	WcenvWfB1
			B2	WfB2	WcenvWfB2
			Bn	WfBn	WcenvWfBn
		Physical	Ph1	WfPh1	WcenvWfPh1
			Ph2	WfPh2	WcenvWfPh2
			Phn	WfPhn	WcenvWfPhn
Economical	Wceco	Construction	C1	WfC1	WcecoWfC1
			C2	WfC2	WcecoWfC2
			Cn	WfCn	WcecoWfCn
		Access	A1	WfA1	WcecoWfA1
			A2	WfA2	WcecoWfA2
			An	WfAn	WcecoWfAn
Social	Wcsoc	Population	P1	WfP1	WcsocWfP1
			P2	WfP2	WcsocWfP2
			Pn	WfPn	WcsocWfPn
		Sensitive features	SF1	WfSF1	WcsocWfSF1
			SF2	WfSF2	WcsocWfSF2
			SFn	WfSFn	WcsocWfSFn

Table 3. Evaluation matrix by weight values by category (W_c) and factor (W_f) and the resulting normalized value (N) according to experts consulted. Factors vary depending on each municipality conditions.

6.1 Juárez

Juárez has 312 brick kilns distributed in 13 different sectors all around the city (Corral Avitia, 2005; Romo et al., 2004) For the municipality of Juárez shown in Figure 4, it was concluded that 90.3% of kilns are located in areas of medium to high vulnerability (Corral Avitia et al., 2010). The state acquired a land on 2010 for the relocation of brick kilns based on this map, but the project still in process and the relocation has not been achieved to this date.

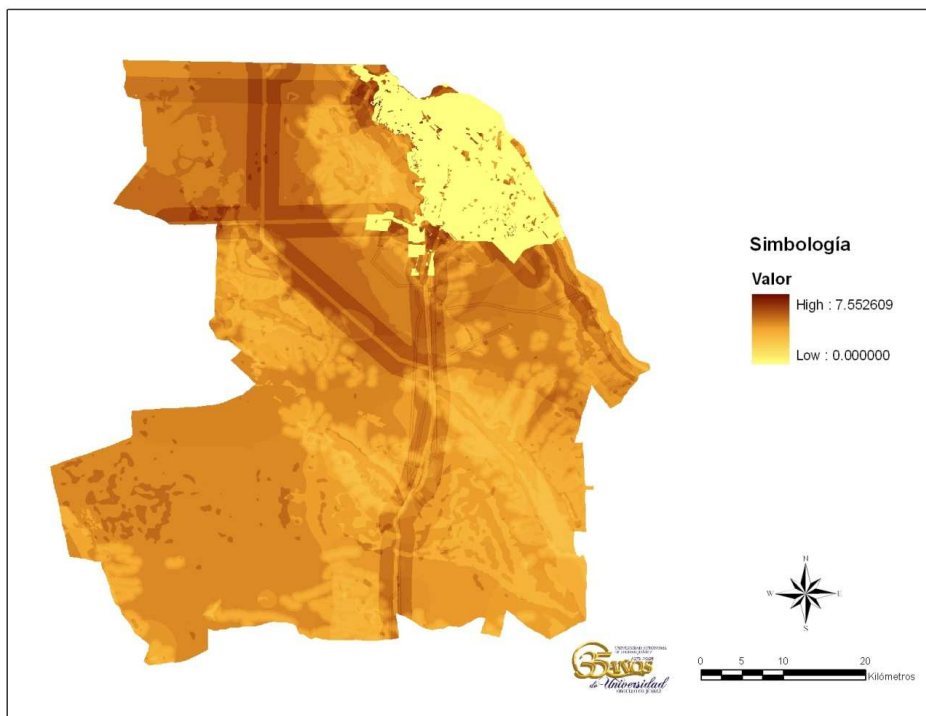


Fig. 5. Suitability map for the establishment of the brick industry in Ciudad Juárez, Chihuahua, México.

Most of the kilns in Juárez are built in the traditional way. However, there are 24 MK kilns in three of the sectors built by El Paso Electric on 2003 (TCEQ, 2002). These MK kiln have a dome that minimizes 80% of the emissions to the atmosphere. The burns are made more efficiently, because it keeps the heat inside minimizing the amount of fuel required and allowing 100% of finished product. Although these kilns offer economic and environmental advantages, the brickmakers are resistant to build more because they are waiting for the relocation.

6.2 Chihuahua

Chihuahua has 296 brick kiln distributed in five sectors. These kilns are called “camperos” because they are built with the bricks that are going to be fired. This kind of kilns represents a problem for an inventory because they may be or not in the site from one day to the other. They burn saw dust and wood in most of the cases. Relocation of kilns was made on the 90’s but the urban growth is reaching them again as can be seeing on Figure 3b. There are more kilns on the Southwest side of the city close to the hills. The kilns in this area have a capacity of 20 to 30,000 bricks per kiln. This can also be translated as higher pollution levels due to the amount of fuel required to obtain that amount of product. The resulting risk map on Figure 6 can be used if a new relocation wants to be made. The best polygons are towards the Northeast side.

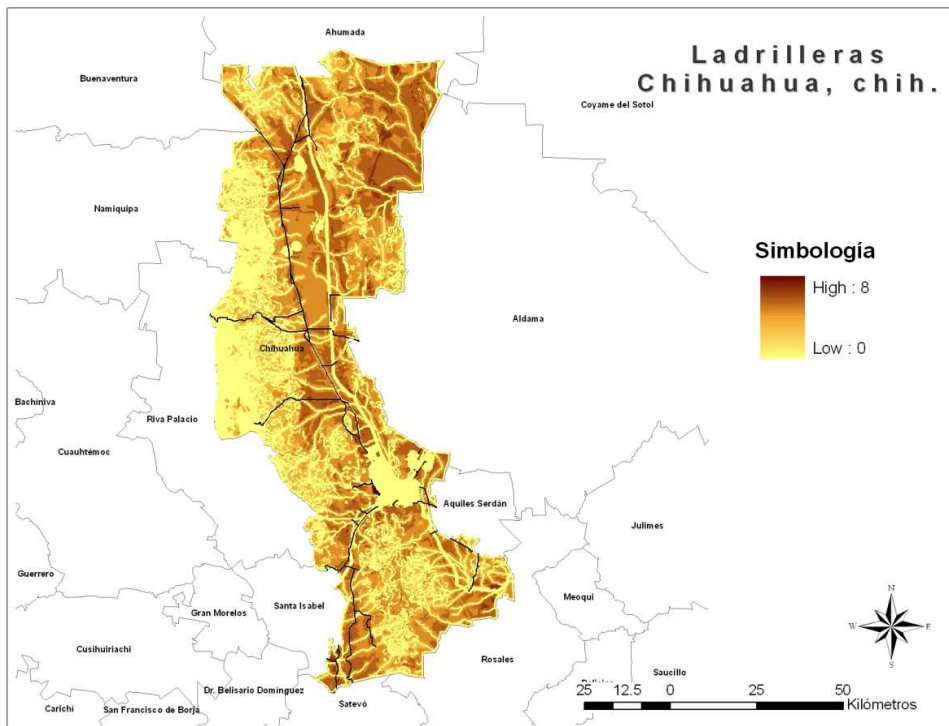


Fig. 6. Suitability map for the establishment of the brick industry in Chihuahua, Chihuahua, México.

6.3 Nuevo Casas Grandes

In Nuevo Casas Grandes, brick industry consists of several individual producers engaged in the manufacture and sale of bricks of different sizes with the objective of providing the capital city and conurbation areas. Currently, there are 33 producers operating for the last 25 years individually. All brick kilns are immersed in the urban area which is a health problem for the inhabitants of the area. As shown in the suitability map in Figure 7 the best areas would be located north and east of the municipality. This map was presented to the municipal authorities who are interested in the community health. They propose to donate some land for the relocation of brick kilns. The proposed site is marked (black square) in the map with a medium high category suitable for this use.

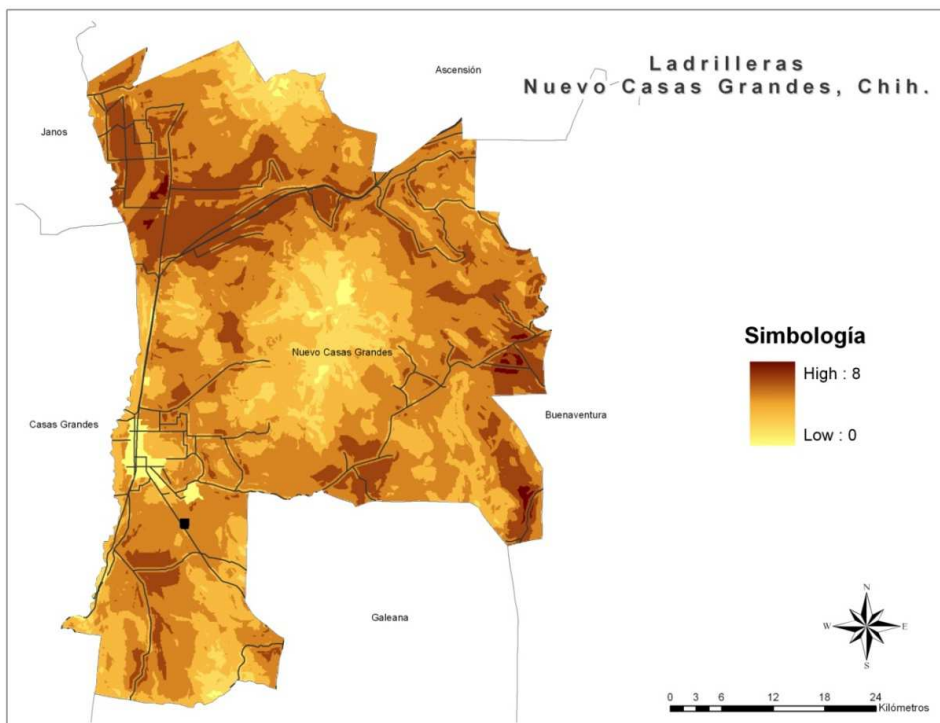


Fig. 7. Suitability map for the establishment of the brick industry in Nuevo Casas Grandes, Chihuahua, México.

6.4 Hidalgo del Parral

There are 85 kilns distributed in 7 sectors at Hidalgo del Parral, but only two of them are far from the urban area. The other 5 sectors are close and soon will be reached by human developments. Therefore, the map can be useful to make the correct decision on where they can be relocated.

The kilns are static and the production is adequate to use the MK kiln. The brickmakers have the advantage of selling the product to people from communities that are close to Hidalgo del Parral. That justifies the lack of brick kilns in its vicinity.

6.5 Delicias

Delicias has 49 brick kilns in 5 different sectors. The kilns in this areas are static, they may be counted for the inventory and signs will be left they move to different places. Most of the kilns were located close to streams of water that are used to irrigate the crop fields. They are located outside the urban area but they may be reached if urban development is not controlled. This map may be used to orientate the location of the kilns in the future.

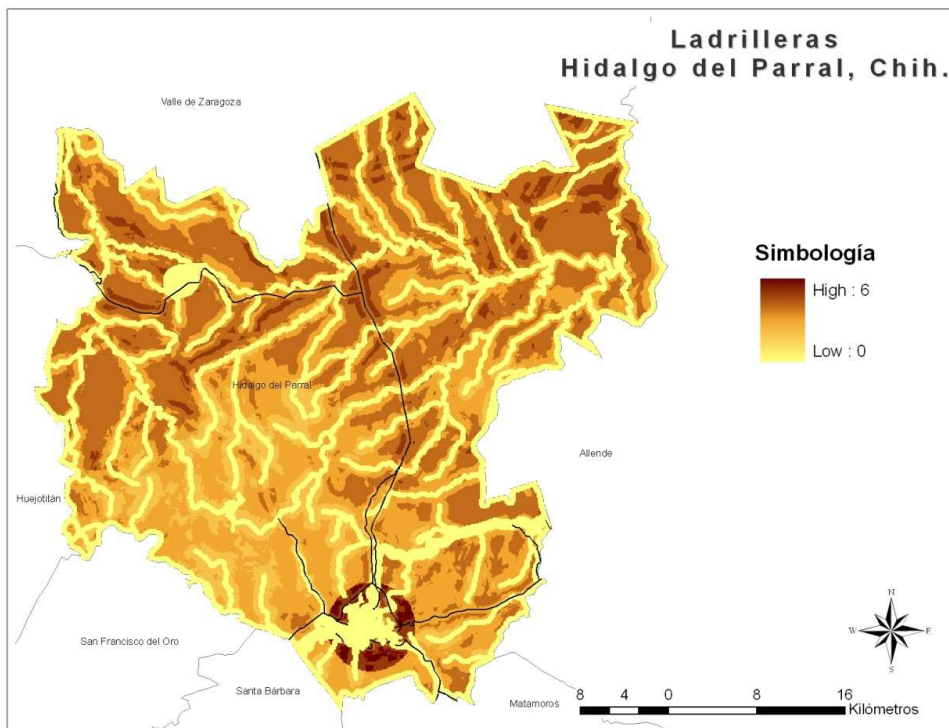


Fig. 8. Suitability map for the establishment of the brick industry in Hidalgo del Parral, Chihuahua, México.

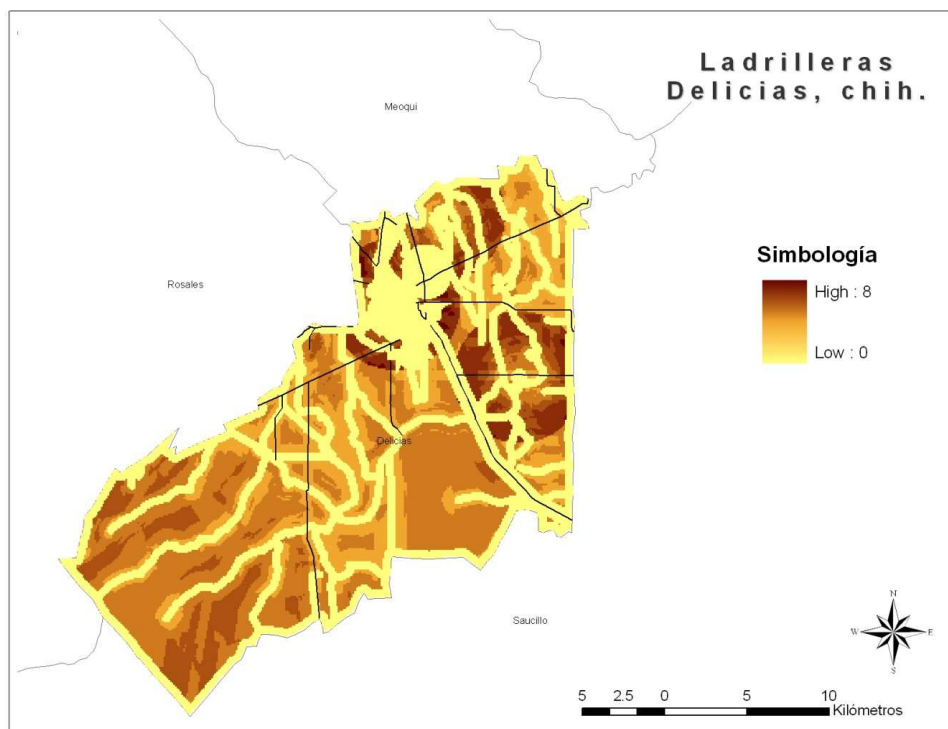


Fig. 9. Suitability map for the establishment of the brick industry in Delicias, Chihuahua, México.

7. Forecast in Chihuahua State

Finally Figure 10 shows the ability to forecast statewide. In this case, exclusion parameters were applied in municipalities with over 2,500 inhabitants, protected natural areas, and archaeological sites. The resolution of the resulting map of the general cartographic product is compromised due to the size of the state. The pixel size was too thick so it would be preferable to use the municipal level models instead. There is a natural correlation between the risk maps with that obtained after the census. Those zones where no kilns were found, correspond to excluded areas.

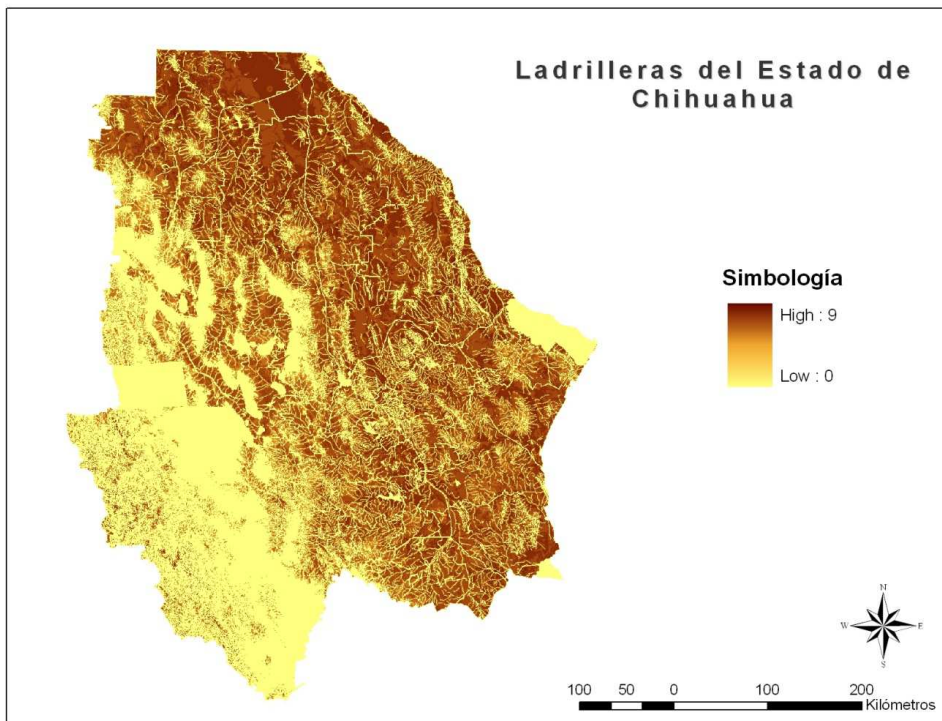


Fig. 10. Chihuahua State aptitude map.

8. Conclusion

The environment has been changing lately. Although, there are multiple factors, one of them is the anthropogenic activity performed recently. As the population grows, there is an increase on needs of housing. There are different kinds of materials used to construct houses; however bricks are traditional in most of the places and are always on demand. The problem is that some human needs, leads to air pollution being the case for brick production. However, the real dimension of the problem is still unknown. This chapter is an example of an initiative to know the root of the problem and to propose a solution. There were two objectives presented at the beginning of the chapter: to know the amount and location of the kilns in Chihuahua State and to elaborate risk maps for those sites with the highest amount of kilns. Both objectives were achieved. First, it was found that the number of kilns officially reported is far from reality. This difference leads to underestimate the problem of air pollution derived from this micro-industry. Second, environmental risk maps resulting from the combination of GIS and the AMC are valuable tools for solving the problem of the brick industry location. Their advantage lies in the exploration time savings through digital geographical reading of the variables included in the study to evaluate at one time the entire territory.

While this study presents a methodology with sound technical criteria for selecting areas of low vulnerability for the relocation of brick kilns, it is necessary to regulate the operation of this industry. The traditional type of kilns must be moved towards more efficient models as the one presented for Juárez (MK kilns), the type of fuel must be regulated, dates and hours of operation and maximum production allowed while it is established. All should be done by competent authority. Besides it is recommended to perform frequent inspection of the emission's monitoring and periodicity of medical checks of workers, among others, to achieve the overall goal, improve the quality of life of people involved in the process.

9. Acknowledgment

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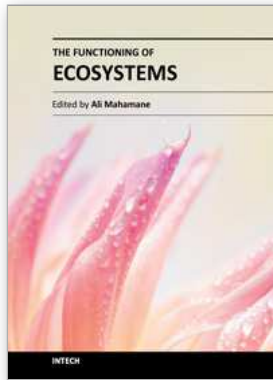
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The ecosystems present a great diversity worldwide and use various functionalities according to ecologic regions. In this new context of variability and climatic changes, these ecosystems undergo notable modifications amplified by domestic uses of which it was subjected to. Indeed the ecosystems render diverse services to humanity from their composition and structure but the tolerable levels are unknown. The preservation of these ecosystemic services needs a clear understanding of their complexity. The role of the research is not only to characterise the ecosystems but also to clearly define the tolerable usage levels. Their characterisation proves to be important not only for the local populations that use it but also for the conservation of biodiversity. Hence, the measurement, management and protection of ecosystems need innovative and diverse methods. For all these reasons, the aim of this book is to bring out a general view on the biogeochemical cycles, the ecological imprints, the mathematical models and theories applicable to many situations.

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