Emissions Inventory from Forest Wildfires and Agricultural Activities in Northeastern Mexico during Spring and Summer of 2000

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INTRODUCTION

Northeastern Mexico is a region that is characterized by having more than 70% of its wildfires during the months of April and May. During the spring, this region is very dry; between the months of January and April Nuevo Leon and Coahuila receive less than 180 mm of rain, and Tamaulipas receives even less. April is a key month. After 5 months of drought, temperature increases dramatically. This sudden change in temperature makes the land suitable for fire ignition and spreading. Although July is on average the hottest month, it is not a dry month. Nuevo Leon and Coahuila receive more than 100 mm during this time. Thus, fires do not spread as much during this month.

The main objective of the study was to create an inventory of air pollutant emissions from forest, grasslands, rangelands and agricultural fires for the period of January 1 to August 31, 2000. Emissions were estimated for three Northeastern Mexican States: Coahuila, Nuevo Leon and Tamaulipas. The inventory was constructed with the most important compounds released to the atmosphere during an outdoor fire: carbon monoxide (CO), methane (CH_4), non-methane hydrocarbons (NMHC), ammonia (NH_3), nitrogen oxides (NOx) and particulate matter (PM). Particulate matter was categorized into PM_{10} and $PM_{2.5}$. Almost all outdoor fires registered for the period of interest were wildfires.

DEVELOPMENT OF THE INVENTORY

Data Gathering Procedures

Procedures employed were based, in part, on previous work conducted to derive a similar emissions inventory, but for the State of Texas.[1-3] Information related to wildfires, including their location, duration and acreage (area) burned was obtained from CONAFOR (Mexican Forestry Agency) and *Proteccion Civil* (Mexican Emergency Service) for the months of April to September, 2000. The database was complemented with fires identified using satellite images obtained from CONABIO (National Commission for the Understanding and Use of Biodiversity). The images covered the period from January 1 to August 31, 2000. A hierarchical procedure was used to analyze the Advance Very High Resolution Radiometer (AVHRR) data sets that were obtained from CONABIO through its Heatpoints (Fires) Monitoring Program. Satellite images were processed, and spatial coordinates for each pixel catalogued as “fire” were assigned. Finally, all pixels of interest were classified using a GIS system. Figure 1 is a summary of all fires identified using this procedure.

Information provided by the Ministry of the Environment and Natural Resources (SEMARNAT) and the Ministry of Agriculture, Rural Development, Fisheries and Food (SAGARPA) indicated no important contribution of prescribed agricultural burning to the total emissions. The official information was validated using other sources. Based on this, the inventory presented here does not take into account emissions from prescribed agricultural burning, except for sugar cane.

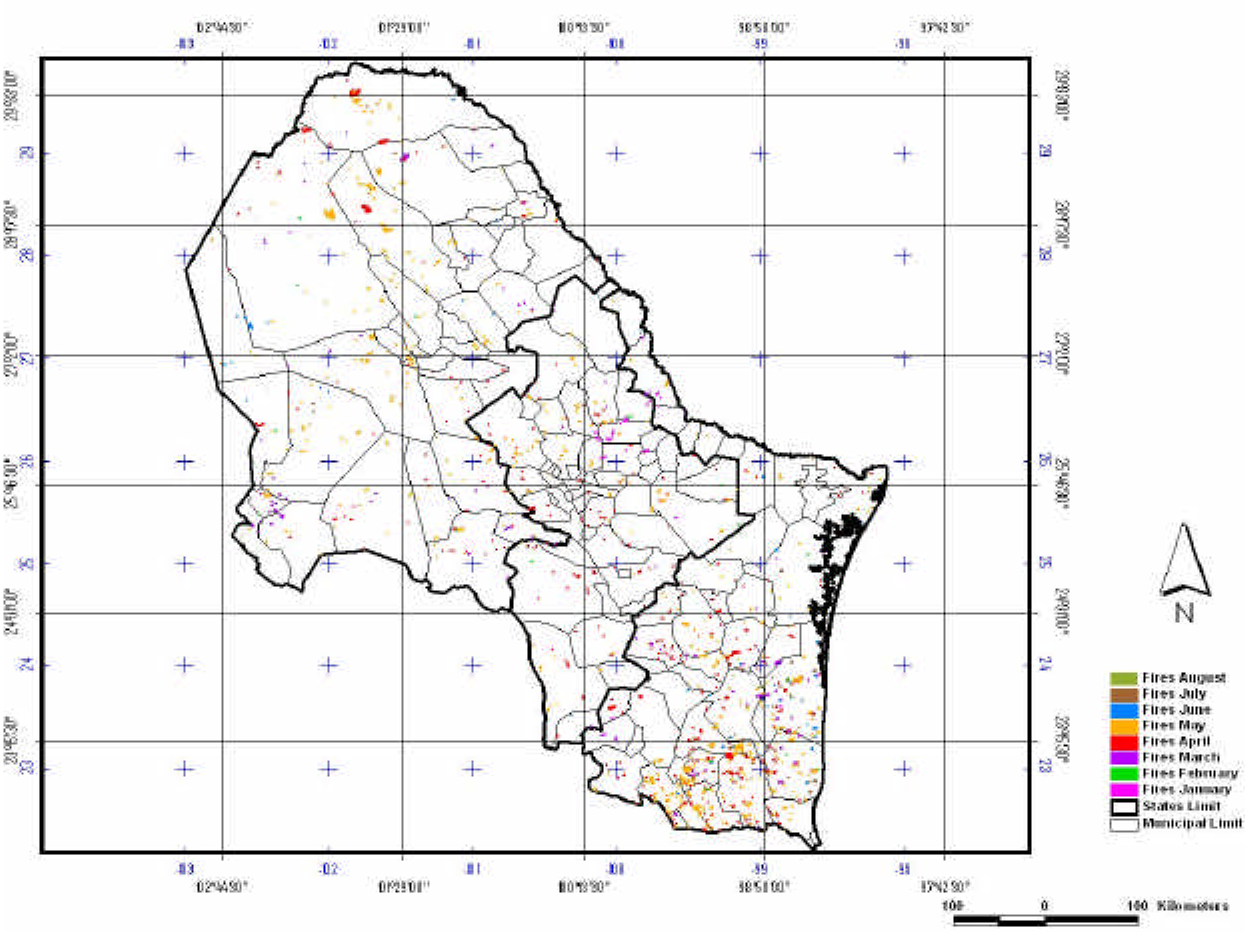

Figure 1. Classification of “fire” pixels by month in Northeast Mexico between January and August, 2000.

Emission Estimation Procedures

Emission factors for wildfires were estimated with the assistance of the First Order Fire Effects Model (FOFEM) v. 5.0.[4] FOFEM 5 computes emission factors for burned vegetation classes based on combustion efficiency algorithms and fuel components.

The emission estimation procedure was as follows. FOFEM provided the consumed load (ton of vegetation burned/acre) for each cover type burned. Then, emission factors (lb of pollutant emitted per ton of vegetation burned) for each cover type were estimated for each of the four seasons of the year using the proposed formulas by Ward *et al*.[5] For NOx and NH_3, the same criteria used by Allen, *et al*.[3] was used to estimate the emission factors for these pollutants. Finally, the consumed load was combined with the emission factors to get the final Composite Emission Factors (lb of pollutant/acre burned).

RESULTS

Table 1 lists a summary of the main results obtained in this study. They indicate that more than 50% of the fires occurred in the State of Tamaulipas, representing about the same percentage contribution in burned area. The State of Coahuila was affected by roughly 30% of the fires, leaving the State of Nuevo Leon with the lowest contribution in burned area.

Table 1. Summary of number of fires, total burned area, and air pollutant emissions estimated for Northeastern Mexico between January and August, 2000.

	State			Total
	Coahuila	Nuevo Leon	Tamaulipas	
Number of Fires	737	427	1,315	2,479
Total Burned Area (acres)	252,740.35	115,262.53	441,567.89	809,570.77
Total Emissions (short tons)				
CO	2.96E+05	5.49E+04	1.54E+05	5.06E+05
CH_4	1.40E+04	2.61E+03	7.35E+03	2.40E+04
NMHC	1.88E+04	3.51E+03	9.90E+03	3.22E+04
$PM_{2.5}$	2.44E+04	4.57E+03	1.29E+04	4.19E+04
PM_{10}	2.88E+04	5.39E+03	1.52E+04	4.94E+04
NOx	2.44E+03	4.80E+02	1.37E+03	4.29E+03
NH_3	3.08E+03	5.68E+02	1.60E+03	5.24E+03

Figure 2 illustrates the frequency of different vegetation types involved in the fires analyzed from January 1 to August 31, 2000. Results indicate that in Coahuila, most of the fires involved mixed desert scrub, desert scrub, Chaparral and mosaic cropland. Nuevo Leon was preferably affected in lands covered by Tamaulipan thornscrub, mosaic cropland, shrub steppe and cultivated grasslands. Finally, in Tamaulipas most of the burned areas were covered by mosaic cropland, deciduous seasonal forest, cultivated grassland, Tamaulipan thornscrub and shrub steppe.

Results were further analyzed by State and by month. Figures 3 and 4 present the number of fires and total area burned for each month in the period of interest, respectively. Most fires are reported between April and May, with a very drastic reduction in fires during the rain season (summer). Thus, most of the emissions were generated during this period, as seen in Figure 5. Emissions for each pollutant by month follow a very similar pattern as the one shown in Figure 5, with small differences from one State to another.

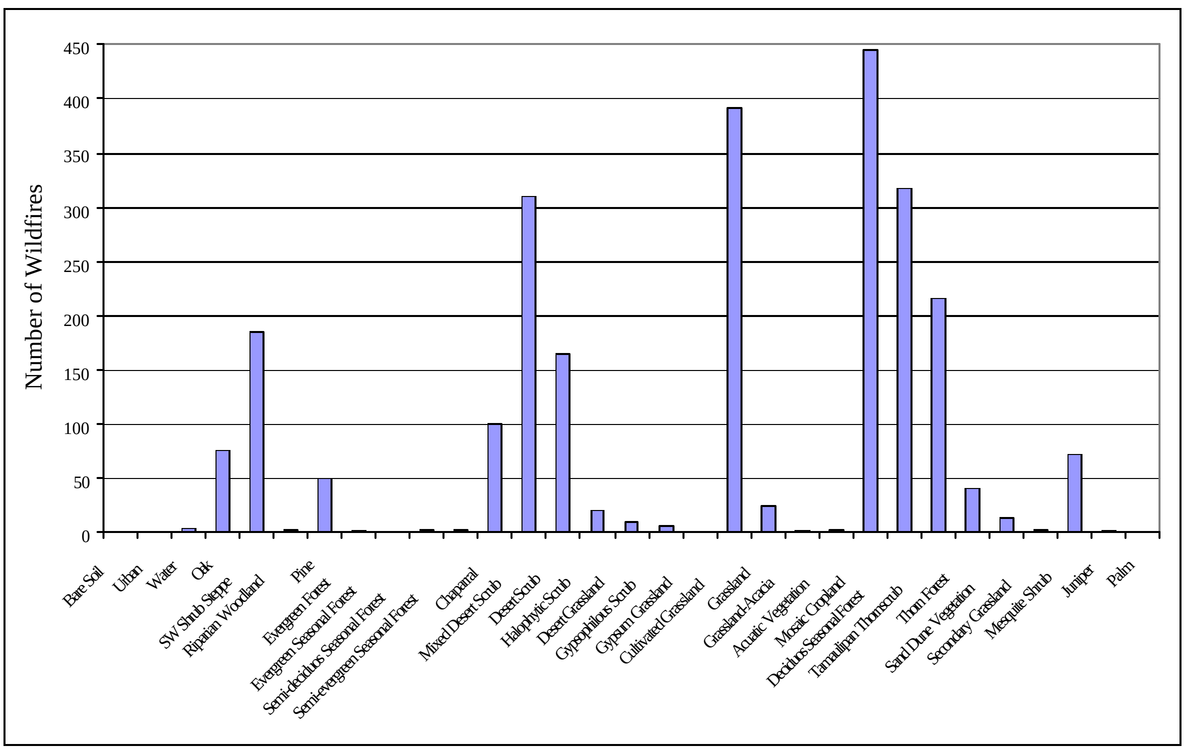

Figure 2. Number of wildfires for each vegetation class considered in the study for the period of January-August 2000.

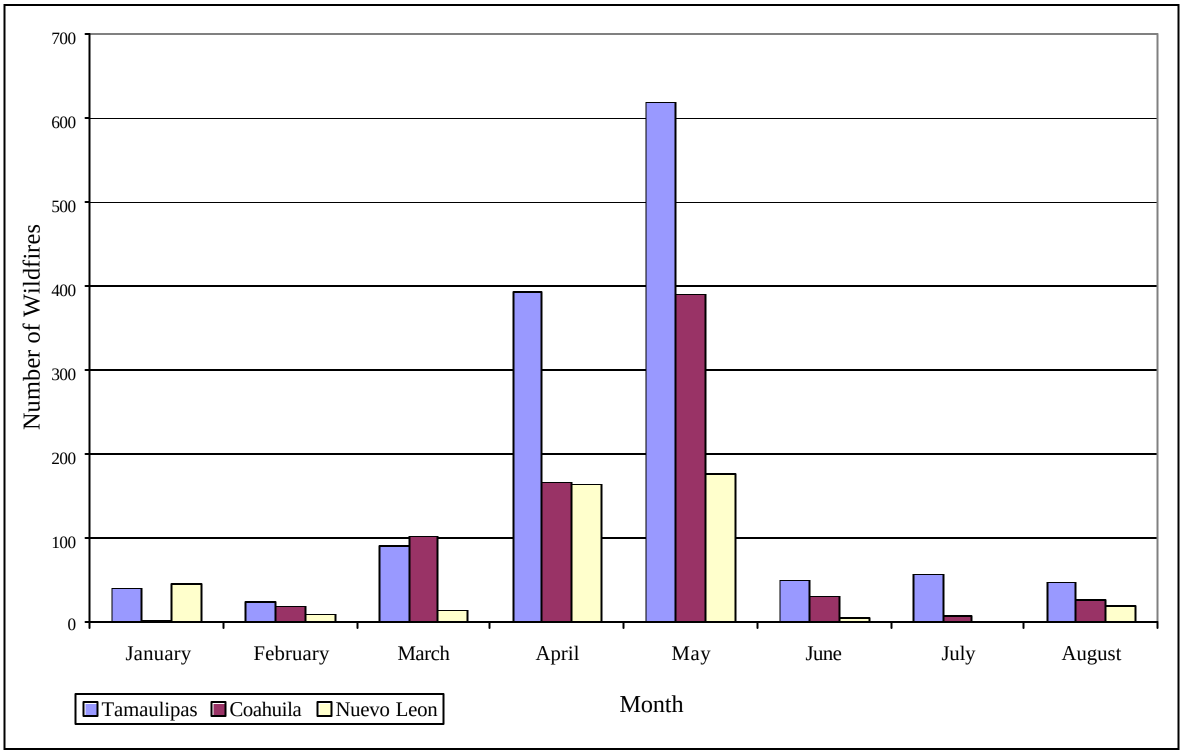

Figure 3. Number of wildfires per month by State.

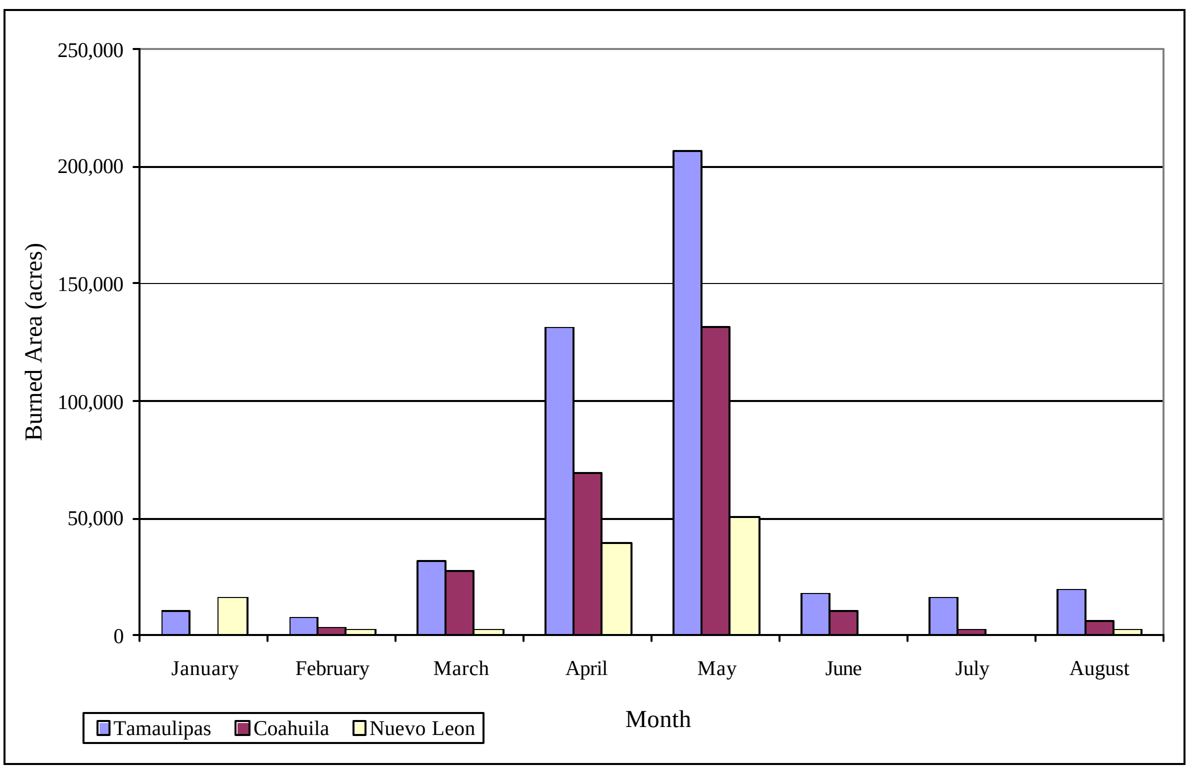

Figure 4. Total burned area per month by State.

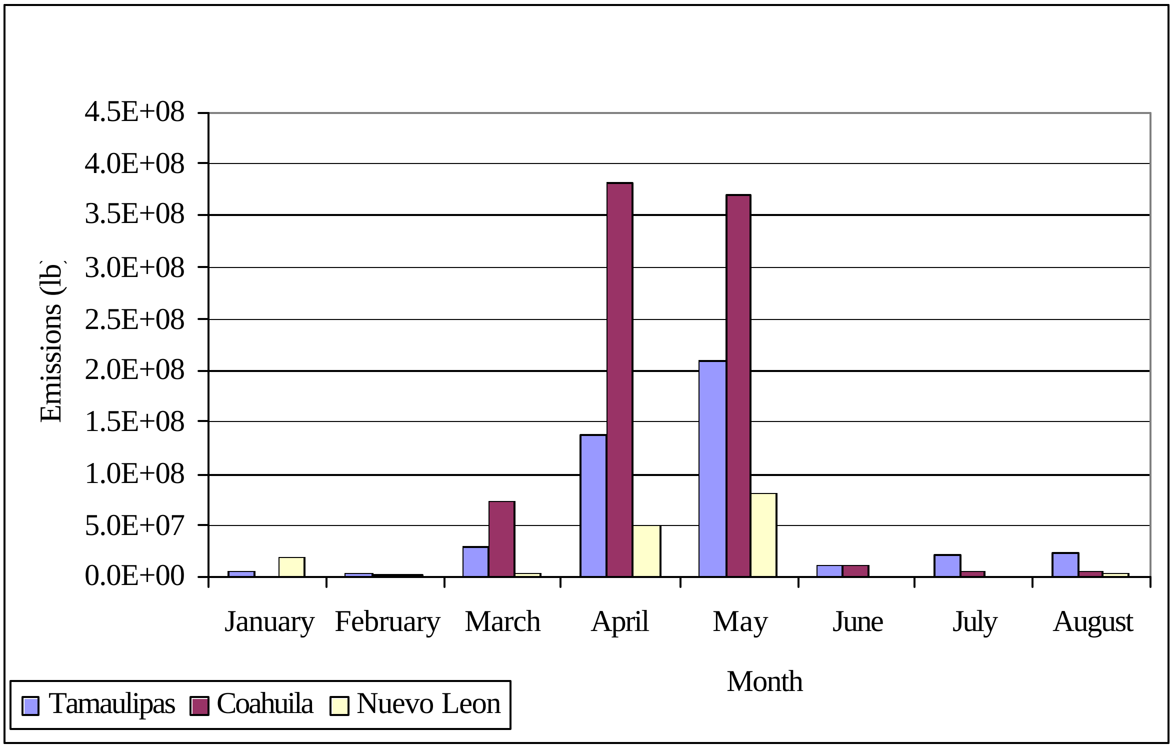

Figure 5. Total emissions per month by State.

WIND TRAJECTORIES ANALYSIS

We further investigated into the possible impact of transboundary transport between Mexico and the United Sates of the emissions estimated. Generally speaking, prevailing wind patterns are east-west. Wind back- and forward-trajectories simulations were done for the transport analysis. The Hybrid-Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model[6] was used for this purpose.

The largest wildfire reported took place in May, in Tamaulipas, with an estimated total burned area of 5,144 acres. The vegetation involved was mainly Mosaic Cropland. Figure 6 depicts the trajectories computed by HYSPLIT. Trajectories for other large wildfires occurring in April and May in the three States showed similar behavior: surface winds coming from the Gulf, and upper winds traveling north.

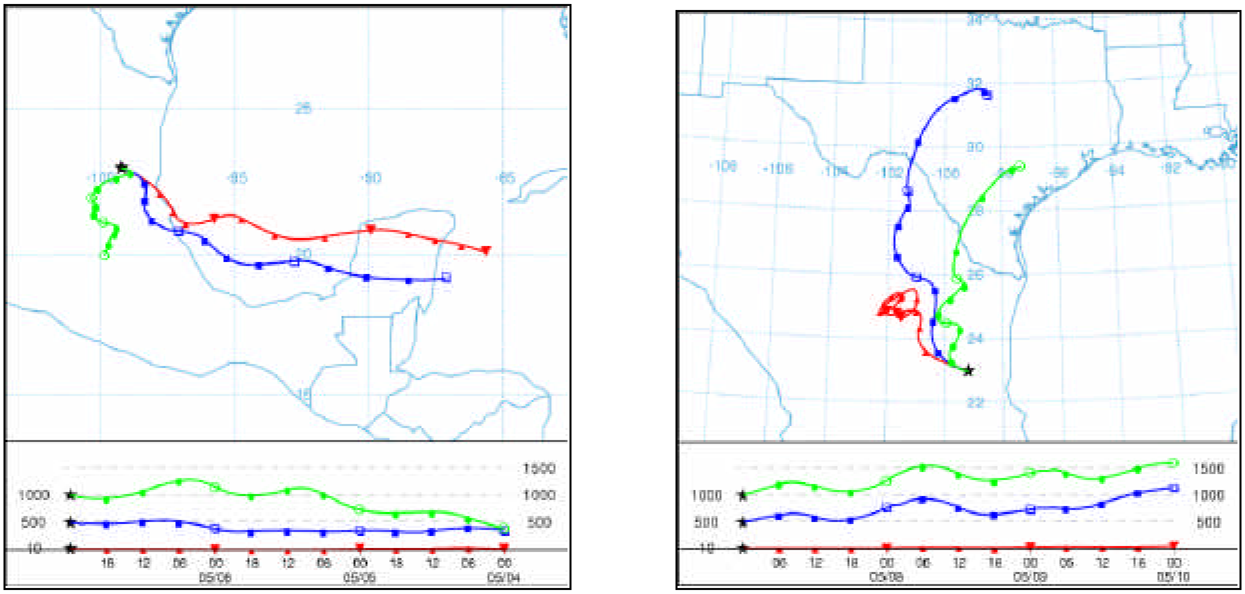

Figure 6. Back- (left pane) and forward- (right panel) trajectories for a wildfire occurring May 7, 2000.

CONCLUSIONS

Emissions from wildfires and prescribed agricultural burning can have an important contribution in the degradation of air quality. A first step to obtain the contribution and impacts of such events is to generate an emissions inventory from that source. Here an inventory of air pollutants emitted from wildfires in Northeastern Mexico between January and August of 2000 was created. Surveys conducted indicated that prescribed agricultural burning is not an important contributor to the total emissions. Only sugar cane prescribed burns were considered. A total of 2,479 wildfires were identified in the domain for the period of interest, which represented roughly 810,000 acres burned and 621,130 short tons emitted (81% being CO). The main source of this information came from satellite imagery. Almost 50% of the fires occurred in the State of Tamaulipas, and most of the burned areas were covered by mosaic cropland, deciduous seasonal forest, cultivated grassland, Tamaulipan thornscrub and shrub steppe. With respect to the temporal distribution, April and May were the months were more fires occurred. Preliminary analysis of wind forward-trajectories of air masses passing through the areas burned indicate possible transboundary transport of the emissions from Mexico to the United States during the occurrence of major wildfires identified.

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