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Socioeconomic and environmental implications of hydraulic fracturing in Mexico

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Abstract:
Over the last years, hydraulic fracturing has been implemented in several countries. It is important to understand the consequences that soil and water modification has over the ecosystems and socioeconomic activity. Fracking in particular has proven to contribute to the increasing environmental and socioeconomic problems, which include climate change, losses in agricultural activity and even health risks. The number of boreholes in places like Mexico has increased, creating negative consequences for the environment and for the communities where these boreholes are located.

Keywords: fracking, water resources, soil, ecosystem degradation

1. Introduction

Currently, humanity faces the challenge of reverting the processes of natural resource degradation, lack of productivity in some economic sectors and international competition within primary and secondary markets. The difficulty to overcome these challenges increases as the impact of climate change becomes more evident worldwide. Even when the efforts at global level increase in order to combat these series of problems and carry out economic activity, by the means of a more rational use of resources, the main economic agents are still far from incorporating an environmentally sustainable consciousness to their practices. The main interest of many of these agents is economic growth and expansion, at the expense of a disproportionate use of natural resources and unfair practices within the socioeconomic and political contexts.

One portion of the world population comprehends that natural resources are part of the large ecosystems of which we are all connected to and we are part of. The increasing interest in the rational and sustainable use of resources, encourages the alternative practices that are more respectful of the environment and life within communities.

Within ecosystems, we consider three key components that enable life to flourish and socioeconomic activities to be carried out: soil, water and atmospheric conditions.

Soil structure plays an important role on the distribution and natural management of resources within an ecosystem. Texture and composition of soils determine how other resources like water and vegetation are distributed. Soil conditions are indispensable for human activity, as they are the maindrivers in self-organization of ecosystems and they shape the aboveground communities [1].

Soils provide a wide range of ecosystem services, such as biomass production, storing, filtering and transforming nutrients and water, and most important to serve as a regulator for climate and hydrology, among other important functions [2]. The characteristics of soils determine the type of socioeconomic activities that are more suitable and profitable according to each soil type. Blum [3] identifies six main social, economic and environmental soil functions. Understanding the interactions and competitions between these functions is of utmost importance for decision making and to propose and implement solutions to the problems that arise from soil uses. Among the main functions of soil are the ones destined to agricultural and forestry activities, industrial uses, physical infrastructure, as source of raw materials, physical human activities and ecological waste management.

Water resources contain elements that form naturally as a result of natural cycles and chemical processes that take place during these cycles. These resources nurture the soils, vegetation and animal life forms. The richness of vegetation and animal life forms that develop depend on the availability of water resources. Kreft and Jetz [4] demonstrated with the use of a combined multipredictor model that global species richness in plants is determined by several factors, of which the number of wet days and potential evapotranspiration are among the most significant ones. Zellweger et al. [5] not only found significant factors like site water balance, precipitation and topographic wetness but also soil Ph to be important factors in taxa richness in template forests.

Without elements like water availability and soil richness, imbalances can occur, leading to major environmental problems, that not only affect human activities and security for future generations, but Earth's ecosystems as a whole. Water managers face the fundamental decision on how to allocate water as a resource among human activities, without degrading it and exhausting it, disrupting the natural flow required to preserve ecosystems as a whole. The importance of biodiversity conservation and other environmental motivations for human well-being is emphasized in the definition of Environmental Flows developed in the Brisbane Declaration of 2007 [6].

Economic activity based on economic growth and expansion worldwide has proved to lead to a series of environmental problems that can have a long run impact for future generations. The use of chemicals and fuels based on oil and gas has a negative impact over the atmosphere, extensive areas of land and water resources. In vast amounts, as these resources are modified, the quality and quantity of their nutrients decline and the physical characteristics change in such a way that are less productive or no longer useful.

Hydraulic fracturing is currently becoming more widely used as a method to extract oil and natural gas from deeper layers of soil where these resources are trapped between the rocks. During such process, several forms of contamination occur, leading to risks such as degradation of soil and water resources, accumulation of toxic elements that create harmful effects on other forms of socioeconomic activity and ultimately health risks for human beings accentuation of climate change and imbalances in ecosystems. Additionally, a series of socioeconomic problems arise. Change in land use and degradation prevents owners, who lease to gas and oil corporations, to revert such processes for agricultural activity. Many of these impacts are becoming evident in several countries, including Mexico.

2. Impact of soil and water modification on ecosystems and socioeconomic activity

Important changes in natural soil conditions and the quality and quantity of water resources can contribute to accentuate global climate change. In turn, climate change contributes to accentuate the already persisting environmental problems, creating vicious cycles (Figure 1).

Changes in soil functions and uses are not only derived by socioeconomic activities but also by environmental conditions. The direct effects of climate change include the effects of temperature changes over soil organic matter decomposition and indirect effects cause changes in soil moisture [7].

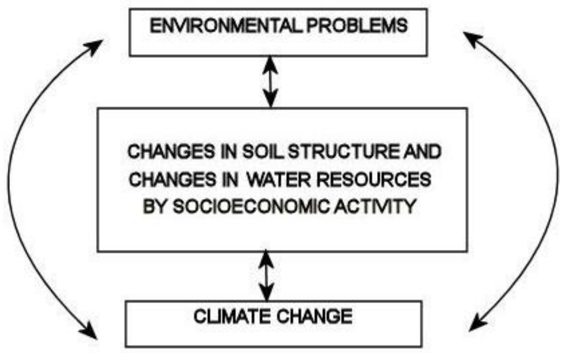

Figure 1. Changes in soil structure and changes in water resources as a result of socioeconomic activity can lead to environmental problems that accelerate climate change, which in turns create more environmental problems. Source: self-elaborated.

In order for agricultural activity to sustain communities and nations as a whole, soil must be fertile and free of hazardous substances, such as toxic chemicals and heavy metals. The consequences of the presence of heavy metals in agricultural soils are functional disorders in soil, retarded plant growth health problems in humans and increase in their concentration as they pass from organism to organism [8]. Soil degradation is one of the biggest environmental challenges to ecosystems and economic activity. It compromises the current global food supply and the capacity of land to provide food and water for future generations. In severe cases of degradation, techniques used to restore soil productivity might no longer be effective [2].

Water degradation and contamination not only affects the health of humans and the inability to use this valuable resource in the future, but also the natural cycles of water flows, soils, and all life forms. In one way or another, human activities contaminate the waters, but wastes from industries, especially manufacturing and power generating industries pollute the water resources more than any other industrial activity [9]. Urbanization and the activities derived from it, has led to the contamination of water found in superficial sources and has also generated a negative impact in groundwater. One of the adverse effects of this problem is the increasing costs of water treatment within hundreds of millions of urbanities [10].

3. Soil and water modification caused by hydraulic fracturing

Several countries have diversified their energetic matrix in order to replace the dependency of fuel sources like carbon and oil, to natural gas and some renewable energetic sources. China has made the transition from the extensive extraction of carbon, being one of the largest producers of carbon dioxide emissions to the atmosphere, to fracking since 2007. However, most of the gas is extracted from the province of Zichuan, which is mostly composed of dryland, generating pressure over the water resources found within the basins [11]. In Latin American countries like Mexico, Argentina, Brazil, Uruguay, Colombia, Bolivia and Chile, efforts have been made to forbid and halt fracking activities based on the precautionary principle, preservation of superficial and groundwaters, and the health and life of people. Additional efforts include to educate the people of these countries about the impact of such activities and the promotion of civilian dialogues [12].

The method of extraction of shale gas involves several steps. De la Vega and Ramírez [13] describe such process in summary. The first step involves a compilation of data about the resources and exploration process within an area. If the initial perforation for research purposes shows viable results, then the next steps will be taken. The second step involves the vertical perforation of layers of soil to reach the shale layer where gas is trapped, and from there, either more vertical perforation is done, or horizontally. Once the well has been isolated in order to prevent leakages, the stimulation process of hydraulic fracturing begins. A mixture of water, sand and chemicals is injected at high pressure to generate the fracturing of the lutites, thus liberating the gas contained within the rocks.

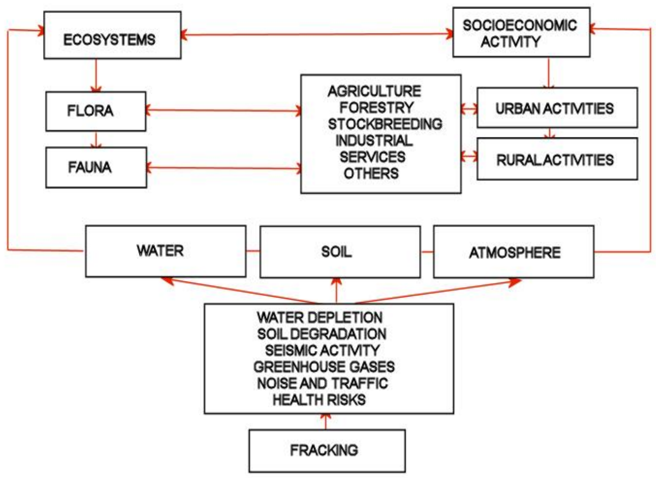

Figure 2. Ecosystems and socioeconomic activity are mutually interconnected by a series of factors. Three main elements (water, soil and air) are key components in the relationship between ecosystems and human activities. Fracking causes a series of environmental problems that impact water, soil and atmosphere, which in turn affect ecosystemic balance and socioeconomic activities as a whole. Source: Self-elaborated.

One of the major implications of the method of extraction of natural gas by hydraulic fracturing is the requirements of large amounts of water used to pump the gas to the surface. The overall process generates important changes in the form of physical modification of several layers of soil, including erosion, and masses of water. Additionally, a combination of chemicals, are used during the process of extraction, which are known to be highly toxic. For every perforation, around 4000 tons of chemicals are used, which not only contaminate the soil and water resources, but also pose a risk when these chemicals are transported to the place where the boreholes are perforated [14]. Natural water resources in the form of aquifers are polluted, as these chemicals reach these water masses and the land. Atmospheric contamination happens as vapors are released from residual waters within deposits. Acoustic contamination and even the risk of generating seismic activity in nearby zones can be present [15]. Using a sample set of 109 fracking examples, Wilson et al. [16] found that injection volume and rate showed statistically significant relationships to the furthest detected microseismic activity. Also, the authors remark that the extent of fracture propagation and stress changes is likely the result of operational parameters, borehole orientation, local geographical factors and regional stress state. Therefore, extractive activity represents a greater risk if these geological conditions are not carefully analyzed and considered, especially if a reasonable distance between geological faults and boreholes has not been properly established. Even the use of technological means required to extract natural gas represent a source of contamination in the form of traffic and emanation of toxic gases, such as the Heavy-Duty Vehicles associated with the use and disposal of water and chemicals [17].

Non-conventional gas is mostly composed of methane, which is a gas that causes greenhouse effect on the atmosphere when released. If during the process of perforation, fracturing or production of gas leaks occur, the effects of such leaks are more damaging than the gases emanated during combustion [14].

In a study conducted by McBroom et al. [18] stormwater concentrations and sediment losses, nutrients and minerals were quantified in a natural well site in Cherokee County, Texas. Within the two natural gas locations the results of the study show that it is evident that storm runoffs happen where the soil has been left bare and compacted. Sediment losses were also evident in these areas unlike the quality of soil in undisturbed forestlands.

4. Environmental and socioeconomic implications in Mexico

Since the year 2003, fracking has been implemented in Mexico by PEMEX (Petróleos Mexicanos) through concessions in which foreign companies participate. The states where the largest number of boreholes have been perforated are Coahuila, Nuevo León, Puebla, Tabasco, Tamaulipas and Veracruz [19]. By 2017, almost 4000 boreholes had been perforated already [20]. The basins where shale gas is extracted are found within these states as displayed in the following map:

Figure 3. The area highlighted in green color shows the areas of extraction of shale gas within the highlighted Mexican states [21].

In the following graph, the proportion of shale gas at basin formation levels is shown:

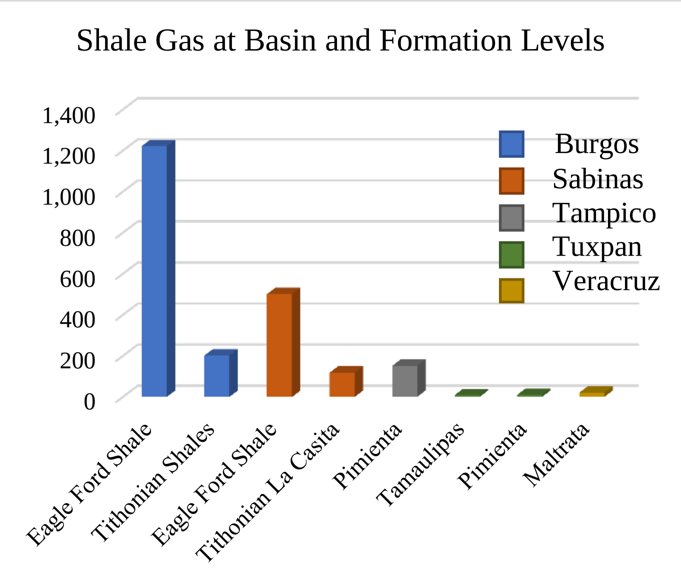

Figure 4. Elaborated using data obtained from the U.S. Energy Information Administration [22].

The larger accumulations of shale gas within the Mexican regions are found in the Burgos and Sabinas basins (Figure 4).

In her study on energetic and environmental policies in Mexico, Gutierrez [23] states that, in terms of sustainability, Mexico has an ambiguous and declarative policy while the energetic reform of 2014 welcomes the private sector both nationally and internationally. As end result, the economy becomes "fossilized" in order to achieve economic growth without distinction among conventional and non-conventional resources, intensifying the exploitation of gas and oil, in spite of the high social, environmental, technological and economic costs. In some instances, the magnitude of negative consequences of the use of aquifers is yet to be known. Hatch [24] states that, in the case of the aquifer Edwards-Trinity-El Burro, there is a lack of studies that can allow for necessary measures to be taken in order to prevent the irrational use of water that might lead to pollution and excessive use during the process of shale gas extraction. In this particular instance, aspects of the aquifer that are shared both by Mexican and US territories have not been carefully defined and evaluated.

Where there is a lack of regulation and delimitation of natural resources negative environmental consequences cannot be mitigated. Such deficiencies prevent the indiscriminate use of these resources, even if concerns are exposed. As a consequence of the excessive use of water during the extraction of gas, communities and the population in general is at risk of facing water scarcity for daily consumption and for agricultural purposes [15]. An example of water scarcity caused by fracking has been observed in Agua Fría and Francisco Zeta Mena, in the state of Puebla, and Papantla in Veracruz. Water is extracted from rivers through the use of pipes, leaving the inhabitants of nearby communities without enough of the vital resource for their daily activities [20].

Not only is the environment affected, where resources like soil and water are concerned, but also the owners of the lands exploited are harmed in several ways. Nuñez et al. [15] point that lands are provisionally occupied by companies, as long as these are productive. Once these lands have been exhausted and become unproductive, then the companies migrate to other lands rich in deposits in order to exploit them. Previously, these lands served for agricultural purposes that provided the owners within communities sustenance, which is then replaced with a temporary income in the form of leasing. However, this income does not compensate for the damage caused to the lands in the form of pollution, erosion and the inability to be used for agriculture.

In addition, another relevant aspect is the prevalence of water scarcity within the northern Mexican states, where hydraulic fracturing takes place. Among the most vulnerable areas prone to recurrent drought are the northern municipalities in Coahuila and Tamaulipas [25]. Shale gas is extracted within these areas with water scarcity.

5. Conclusion

All elements of nature are important for ecosystem balance. Among the most important ones are soil and water resources, as humanity is dependent on them to carry out the necessary socioeconomic activities for sustenance. Unfortunately, the balance is easily lost when socioeconomic activity is no longer sustainable and as consequence resources are degraded, polluted and exhausted. One such example is hydraulic fracturing, which has proven to manifest a series of lasting negative consequences for the environment and for human health and other socioeconomic activities. In Mexico, not only are the physical resources at risk of being extensively polluted and exhausted, as is the case of the acquifers, but also landowners are negatively affected. When their lands are contaminated, and they are deprived of the use of water resources, life in communities is affected and they cannot continue earning income from agricultural activities. Hydraulic fracturing is justified by governments seeking to diversify their energy matrix, but this type of energy exploitation causes environmental damage that can be irreversible, mainly in terms of aquifer pollution and in long term for the soil contamination. It is recommended that the energy matrix be diversified with renewable energy, optimizing the use of natural resources in the northern and central areas of Mexico.

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