

Economic and Social Impacts of the Mining of Rare Earth Resources: Taking the United States as an Example

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Abstract. Rare earth elements are very important and can be widely used in the manufacture of various components. China is currently in a monopoly position and has a tendency to reduce exports. The situation of the global rare earth market is becoming more and more serious. The United States restarted rare earth mining. However, rare earth mining and extraction are highly contaminative and have caused environmental disruption, diseases, and poverty in Native American (NA) reservations. By using life cycle assessment, spatial analysis, and social class theorem, this paper draws the conclusion that poverty, high prevalence rates, and low education level are positively correlated with the environmental damage caused by rare earth mining. At the same time, environmental inequity informs and is informed by the social class stratification and solidification in U.S. society. The conclusion reveals that people should pay attention to the impact of environmental inequity on economic inequity and social class mobility. It may also give policymakers some inspiration when establishing policies against ethnic minorities and the underclass.

1 Introduction

Rare earth elements (REEs) are critical raw materials that have strategic significance to almost all countries. The present-use fields include the military, metallurgical industry, and even agriculture. They're also indispensable in producing high-technology equipment and other modern electronics like cell phones, computers, automobiles, and airplanes.

Before the 1980s, the United States ranked first in the world's rare earth output, accounting for one-third of the world's total amounts. However, after the 1990s, the United States stopped mining rare earth due to environmental concerns. Meanwhile, China's low price of rare earth and advanced smelting technologies have attracted the United States, Japan, and Europe to import rare earth from China and even move companies to China. By 2000, China accounted for an estimated 90 percent of the global output.

Before 2010, China's rare earth industry lacked regulations and overall planning. The malignant competition among companies caused the export prices of rare earth to plummet continuously and therefore a large number of rare earth resources outflowed. To solve these problems, the Chinese government established the export policy- "export quota+tariff", which triggered the United States to take action to avoid depending fully on China for the supply of rare earth.

Now that the United States is in urgent need of rare earth metals, the US government took measures to restart mining. In 2017, President Donald Trump issued Executive Order 13817, a federal strategy to state the importance of restructuring the United States' rare earth

industrial chain. In February 2020, Trump used The Defense Production Act (DPA) of 1950 to instruct the expansion of rare earth mining. In August 2021, President Joe Biden passed the "Rare Earth Magnet Manufacturing Production Tax Credit Act" (the "Rare Earth Magnet Act"). It stated that the U.S. government would provide 20 USD for one kilogram of rare earth metals produced. Plus, if all its components are manufactured in the U.S., they would offer 30 USD. However, in most cases, these mines distribute in undeveloped places in Western America, where Native Americans live (early Indian Reservations). Native Americans there have been suffering from unemployment, high rates of crimes and juvenile delinquency, violence, sexual assaults, and so on.

This paper aims to investigate the environmental impact of rare earth mining on these places and how it affects the American social structure, featuring low-ranked Native Americans, with environmental economics and sociology theories.

2 Literature review

2.1 The US rare earth market

Huang et al. review and compare the development of rare earth environmental regulations in China, the United States, and Australia in four aspects: management of radioactive pollutants, land reclamation of mining areas, air pollution emission management, and environmental tax. The study finds that the United States has strict environmental regulations, forcing rare

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earth companies and related downstream industries to carry out international transfers to avoid the high costs. The United States has established international trade channels on a global scale to transfer pollution and preserve the US's rare earth resources [1]. Lee and Dacass use supply and demand models and welfare analysis to evaluate the effects of the US government's proposed strategies to reduce supply risks caused by potential export restrictions from China. The results show that finding substitutes for rare earth metals to cut down its demand provides the biggest welfare gains. The next optimal solution is to increase the supply of rare earth metals in the U.S., followed by seeking other stable foreign supply sources. The research models the rare earth market and may quantify the effects of different strategies to make comparisons [2]. To sum up, the United States is highly dependent on rare earth imports, and the best way to get out of this restriction is to restart mining while facing the challenge of environmental disruption caused by rare earth mining.

2.2 The environmental impacts of rare earth mining

Chen et al. carry out water quality evaluation by sampling the surface water from the upper, middle, and lower courses of Ganjiang, using the modified Nemerow index method to determine the metal concentration. It also tries to determine the consequent health risks by comparing metal concentration with their carcinogenicity and other health-damaging indicators. The research clearly shows the pollution caused by rare earth mining is considerable and may pose huge threats to human health [3].

Guo et al. analyzed ecological environmental contaminations caused by rare earth mining and the related measures for controlling these pollutions. The study comprehensively reviewed pollution in soil, waters, atmosphere, natural landscape, animal and plant health, and human health. It also compared the advantages and disadvantages of three rare earth-contaminated soil restoration methods: the physical, chemical, and biological methods. At the same time, it emphatically analyzed the effects and mechanisms of the arbuscular mycorrhizal fungi method and predicted its future prospect [4].

2.3 Current situation of native Americans

Liu discusses the attempts made by the US government to assimilate Indians and Indians' social changes: including poverty, non-participation in politics, undereducation, and the disappearance of tribal organizations and culture. It begs a question of what principles should people abide by when they're implementing policies against ethnic minorities, which may inspire research on rare earth mining's impacts on Native American society [5]. Zhao reviewed the mainstream opinion that racial attribute plays a decisive role in the distribution of environmental rights and burdens, and environmental discrimination forms a part

of racial discrimination in the United States. The study pointed out that their non-participation in politics and low social and financial status put them at a disadvantage to fight for environmental equity through casual correlation analysis [6].

In terms of the US rare earth market, most studies examine how rare earth mining inform the global trade, supply, and demand between countries. This paper would analyze how environmental impacts inform and be informed by economics. At the same time, the past studies on the contaminations caused by rare earth mining are comprehensive but lack organization. This paper will use life cycle environmental assessment to examine all the pollution rare earth would generate in mining, extraction, and roasting phases. Regarding the Native American issue, this paper will use spatial analysis to test the correlation between pollution levels and Native Americans' living conditions and will analyze the social stratification in the U.S. showed in the rare earth mining setting about environmental equity, environmental racism, and environmental justice.

3 Theoretical analysis and discussion

3.1 Life cycle environmental assessment of rare earth mining

Life cycle assessment is a method for quantifying the potential environmental impacts produced by the whole phase of a product from input to output.

Figure 1 below shows the stages that are considered in the life cycle of rare earth resources. On the left side, raw rare earth materials and energy are consumed as input for rare earth mining, beneficiation, and extraction. On the right side, emissions to air and water are produced as output in these stages [7].

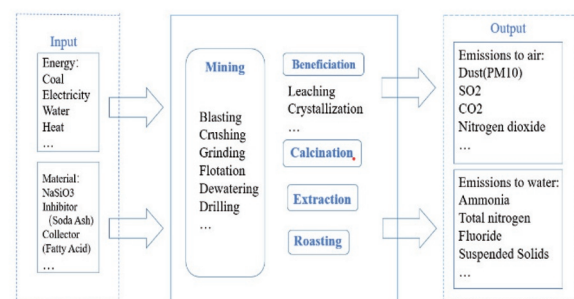


Fig. 1. System boundary of this study (Photo credit: Original).

As shown in the figure, besides nitrogen—the normal element in the atmosphere, the outputs also include poisonous gases and solids. Specifically, dust is almost the cause of most respiratory diseases and tuberculosis. Sulphur dioxide forms acid rain, causing soil acidification, plant death, and building facades to peel off. Toxic halogen elements such as fluoride affect all beings.

These emissions to air and water enter human bodies through food chains. Since human bodies don't need

rare earth elements, they can't be converted, absorbed, or utilized. Consuming food with high rare earth element concentrations may pose potential but long-lasting threats to people's health. Research shows that people who live near rare earth mines have a much higher concentration of rare earth elements in their hair. The intelligence quotient of children who live in rare earth-polluted areas is significantly lower than the control group [8, 9]. What's more, long-term intake of rare earth in low doses can still lead to a variety of lesions in the brain, liver, bone, and immune system [10].

Moreover, some rare earth mining has long adopted the "open-pit mining, pool leaching beneficiation" method due to their unique mode of existence. Taking Ganzhou, China, as an example. According to the Ganzhou City government's rare earth governance documents, the rare earth mining there has triggered landslide and debris flow, which has caused 37,000 mu of soil to erode, and more than 4,000 mu of farmland to be flooded. More than 30 villages and more than 50,000 villagers were directly harmed.

3.2 Spatial analysis

3.2.1 Data selection

To test the hypothesis that the pollution caused by rare earth mining happens mainly in regions where ethnic minorities (NA) live and can significantly lead to high prevalence rates, and poverty, the following data are collected (as shown in Table 1).

Table 1. Data for spatial analysis in this research.

Year	Data	Data source
2016	Historic Native American Territories in California	ArcGIS Hub
2018	California cities	ArcGIS Hub
2019	California deep landslide susceptibility and landslide inventory	ArcGIS Hub
2001-2021	California gross domestic product by County	California reaproject

3.2.2 Distribution of environmental burdens and NA distribution

The largest mine in the U.S.—Mountain Pass is located in east-western California. This paper takes California as an example and examines the correlation between deep landslide susceptibility and the percentage of Native Americans in each county by spatial analysis in the maps below.

Calculated by the California Geological Survey, the first map shows areas that are susceptible to deep-seated

landslides based on the location of past landslides, the location and relative strength of rock units, and the steepness of the slope (see Figure 2). The darker the red shadows are, the more susceptible the land is to landslides. Basically, the most susceptible areas are faults on the west coast. Mountainous regions in the eastern California, including Mount Pass, the richest mine in the United States for rare earth minerals, are also highly prone to deep landslides. Based on the map in Figure 3, which draws a picture of the distribution of Native American populations in the United States, and Figure 2, polluted waste and environmental damages (deep landslides) are disproportionately located in Native American communities.



Fig. 2. California deep landslide Susceptibility. Source: California Deep Landslide Susceptibility and Landslide Inventory. <https://www.arcgis.com/index.html>

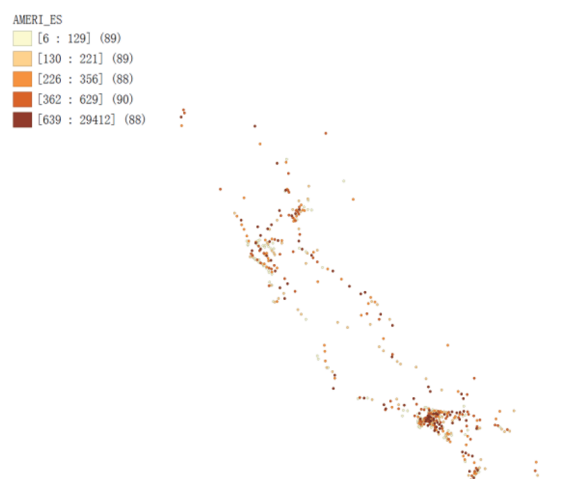


Fig. 3. Native American population distribution in 2018 (Photo credit: Original).

3.2.3 Economic Impacts

(i) Current situation of major rare earth companies—MP materials. On Friday, February 25, U.S. rare earth miner

MP Materials (MP. US) announced its fourth quarter and full year 2021 financial report. MP Materials' revenue in the fourth quarter was 99.109 million US dollars with a year-on-year increase of 135%; its net profit was 48.989 million US dollars with a year-on-year increase of 103%. MP Materials' real price of rare earth oxides (REO) in the fourth quarter was \$10,101 per metric ton, increased by 48% year-over-year; Production costs per metric ton were \$1,525, decreased by 4% year-over-year. REO sales were 9,674 metric tons, which decreased by 6% year-on-year. MP Materials' full-year revenue was \$332 million, increased by 147% year-over-year; MP Materials' full-year REO production was 42,413 metric tons, which increased by 10% year-on-year; Real prices were \$7,745 per metric ton, which increased by 134% year-on-year. As the U.S. restarted mining, the sales and profitability of the major rare earth company is going up.

(ii) GDP in NA communities. According to the real gross domestic product by county in California, counties with huge Native American populations like Imperial County, Kings County, San Benito County, and Humboldt County all got GDPs less than 1,000,000 dollars in 2021. Also, income is closely related to environmental pollution, and the classical environmental Kuznets curve hypothesis states that per capita income has an inverted U-shaped relationship with environmental pollution. At the micro level of Native American residents, the higher their wage is, the more likely people will be environmentally conscious while the environmental burden is holding down their wages.

(iii) Economic Analysis. The reason why pollution is unevenly distributed in Native American communities isn't only owed to racism and their lack of political rights. There may be some economic reasons. The cost of polluting poor and underdeveloped areas is relatively low, and the marginal cost of pollution regulation may outweigh the benefits [11]. This default in decision-making has promoted pollution emissions.

3.2.4 Social impacts

The status and role of tribes in the implementation of federal environmental protection programs are often wrongly excluded from federal environmental legislation and government decisions. This "non-Indian" environmental regulatory system has not only caused the uneven distribution of environmental burden and resource degradation but has also caused harm to the health of Native Americans, and inflicted mental and psychological trauma on them by preventing the exercise of their collective power.

Oglala Lakota County, contained entirely within the boundaries of the Pine Ridge Reservation, has the lowest per capita income 8,768 USD and the median household income is 26,721 USD while the United States average is 53,482 USD. With a labor force of 29,539 in the tribe, just 3,131 were employed, which means an unemployment rate of over 90 percent.

Based on data from the Oglala Sioux Tribe, there're pressing health concerns in the Indian Reservation: (i) Tuberculosis: 800 percent higher than the nation, which can be the result of serious air pollution. (ii) Infant mortality: 300 percent higher than the nation.

Almost 85 percent of the Indian populations abuse alcohol, and 25 percent of the infants are born with fetal alcohol syndrome because of this. People living in Indian Reservations also lack schooling: Only 28.7% of the native population on Pine Ridge Reservation have attained a high school diploma.

3.3 Analysis of social structure in the U.S.

Through this issue and the analysis above, it can be found a trend of class solidification in the U.S. society. According to the latest data of the Gini coefficient and the household income quintile provided by U.S. Census Bureau in 2017, the gap between the rich and the poor in U.S. society is widening [12]. Environmental inequity, the interregional injustice of public services distribution, as the outcome of social stratification, has aggravated class solidification, which forms a vicious cycle. In many aspects of U.S. society, not just in environmental equity, the free market capitalism and economic system tend to emphasize efficiency over equity, which has caused social class conflicts and solidification.

4 Conclusion

Though rare earth mining plays a critical role in the United States' economy and industry, it also has come with many complications. Serious environmental damage like landslides, floods, and debris flow. Pollution posed threats to the area's biodiversity and human health. As these mines are mostly located in underdeveloped areas or Indian reservations, the diseases, poverty, lack of education and social rights Native Americans are now suffering are positively correlated with environmental damage. This paper tests the hypothesis and examines the intrinsic nature of ethnic inequality and social class stratification in the U.S. mainly by spatial analysis and social class theorem. The environmental equity problem lacked legal documents. It may be time for the U.S. government to devise better rules for promoting ethnic environmental equity and justice.

Future policy recommendations can be put forward. First, pay attention to the sustainable development between the environment and the society (the society here refers particularly to groups like the poor, females, and ethnic minorities) by adopting the idea of fairness and equity, rather than merely efficiency. Second, since mainstream society has controlled where environmental laws and policies will go and they sometimes exclude underdeveloped communities, which are exactly those in danger of environmental damage, the residents are in great need of Environmental Poverty Alleviation Law to help them react promptly.

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