Effect of air pollution from quarry activities on agriculture and plant biodiversity in South-Eastern Nigeria

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Abstract

There are several quarry activities spread across Southeastern Nigeria contributing 8.7% GDP annually to the economy. However, these industries are usually associated with air pollution. To assess the impact of quarry dust on plant biodiversity, $PM_{2.5}$, PM_{10} and some meteorological parameters were measured using Aeroqual 500 series as well as taking a social survey. High amount of particulate matters that exceeded the international standard were recorded at the four chosen quarry locations in Ebonyi State. The correlation coefficient between the particulate matters with the meteorological parameters of the locations all show a strong relationship with temperature recording a stronger value of 0.981. Similarly, the coefficient of determination 0.962 shows that temperature has the highest meteorological percentage variation on $PM_{2.5}$ and PM_{10}. Furthermore, a notable negative impact of quarrying on plant biodiversity, habitat destruction and plant survival are also revealed based on respondents' results where wide range of local plants were affected with vegetables been the most with respondent of 30%. From the obtained results, it is highly recommended that there should be an establishment of dust control mechanism- by developing green belt around the quarrying using pollutant-tolerant trees in order to restrict spreading of dust and regulating the industry as a self-regulatory mechanism.

1. Introduction

Quarry is the exploitation of various lithologic materials given by nature to mankind. It is a place from which dimension stones, rocks, construction aggregates, riprap, sand, gravel or slate have been excavated from the ground (Ukpong, 2012: Nartey et al 2012). The quest for harnessing the litho materials that abound in our environment will continue to increase due to the need for urbanization, road and rail construction, airport and beautification of infrastructural facilities around us. Quarrying as we know is a good source of income and revenue for both the government and individuals. There are several quarries spread across the southern part of Nigeria with a total annual yield of 1,954,263.83 tons of granite dust and 1,604,822.71 granite aggregates. The quarry and mining industry in Nigeria contributed 8.7% of Gross Domestic Product (GDP) with a sum of N5.37 Trillion in 2021 according to National Bureau of Statistics (NBS,2022).

Unfortunately, these quarry industries cause significant impact on the surrounding environment. In fact, the extraction process normally depends on heavy machines and explosive, where both processes are associated with air pollution, water pollution, soil pollution, noise pollution, damages to biodiversity and habitat destruction (Lameed and Ayodele,2010: Ogbonaya and Phi-Eze, 2020).

Owing to the fact that man's quest for development is at times wayward, there are little or no consideration to the negative impacts of these activities to both plant and animals alike. Quarrying activities have adversely altered preexisting ecosystem hence, occur change in hydrogeological and hydrological regimes. This in turn induces damages to properties, depletion of underground water, loss of soil fertility, forest degradation, destruction of aquatic biodiversity and public health challenges (Akanwa et al 2016a; Aloh *et al*, 2017).

From the agricultural point of view, quarry activities released dust not only settled on land, plants and tress but also on surface water and thus causing various negative impacts on the ecosystem as a whole (Nyapala and kamwele 2015). Dust can also have physical effect on the surrounding plants, such as blocking, damaging their internal structure, abrasion of leaves and cuticle, as well as chemical effect which may affect long time survival (Guach,2001).

Furthermore, fertile soil is dislocated and interrupted after excavation, pits are left unfilled or abandoned and may lead to gully erosion. This is not only unsightly but poses danger to livestock, wildlife and people as well (Mbuyi, 2017).

One of the biggest negative effects of quarry on the environment is biodiversity (Anand, 2006). Biodiversity simply refers to the range of living species such as birds, fish, plants, fungi, reptiles, microorganism etc. Conservation of biodiversity is important as all species are interlinked and human survival depends on the equilibrium that exist within nature. An altering of plant biodiversity through the effect of quarry on the environment has a resultant effect on component of the ecosystem, as plants (vegetation cover) play a major role by maintaining the balance in volume of oxygen and carbon dioxide through photosynthesis activities (Osha 2006). Generally, air pollution especially dust from quarry site are known to be responsible for vegetation injury and crop yield lost. Thus, becomes a threat to the survival of plants in that environs (Igbal and shefig, 2001).

The main objective of this research is to access the effect of quarrying activities in the South-Eastern Part of Nigeria ecosystem in general and plants biodiversity in particular.

2. Materials And Methods

2.1 The Study Areas

The four quarry locations chosen for the study are Umuoghara Quarry Clusters at Lat.6.3058^{0}N and Long. 8.0135^{0}E in Ezza Local Government Area, Seaman Quarry Site at Lat. 6.4215^{0}N and Long. 7.8588^{0}E in Ishielu Local Government Area, Jinchiang Quarry Site at Lat. 6.4214^{0}N and Long. 7.7976^{0}E in Ishielu Local Government Area and Seaman Quarry Site at Lat. 6.4637^{0}N and Long. 7.7979^{0}E In Ohaukwu all in Ebonyi State (Fig. 1). These selected areas are one of the most famous quarry and stone cutting industries in Southeastern Nigeria with about 50 quarry industries scattered around. These quarry areas and others form part of the major lithologic formation in the Southern Benue Trough. It is prominent for the existence of pyroclastic rock materials which was deposited millions of years ago, forming a long stretch of ingenious materials- an uplift which is today referred to as Abakaliki anticlinorium in the present-day South-Eastern Nigeria (Aghamelu *et al*,2011; Akanwa et al 2016b).

2.2 Data collection

Particulate matters ($PM_{2.5}$ and PM_{10}), temperature, relative humidity and windspeed of the locations were all collected using Aeroqual 500 series device. The measurement was taken at each of the four (4) locations and one kilometre(1Km) away from the site for a period of 30 days. The 1km from the quarry location served as the base for the farmlands as there were several clusters of agricultural activities around these locations. Also, 400 questionnaires were specifically prepared as a social survey for the farmers residing around these locations.

2.3 Data analysis

Data analysis was done using SPSS version 25 for the correlation coefficient (r) and the coefficient of determination ($r^{2)}$. The graph and contour plotting were done using Python algorithm.

3. Results

The contour maps show the coordinates locations and slope where $PM_{2.5}$ and PM_{10} were more concentrated (Fig. 2 and Fig. 4). The daily average concentration of $PM_{2.5}$ at the four quarry locations namely; Umuoghara, Jinchiang, Seaman Ishielu and Seaman Ohaukwu, the 1km away from the quarry locations serving as farmland recorded values were 7889.5µg/m^3, 1831.8µg/m^3, 6608.31µg/m^3 and 6895µg/m^3 respectively (Fig. 3). Similarly, the PM_{10} 1km away from the active sites were 458.5µg/m^3, 229.3µg/m^3, 430.3µg/m^3 and 72015µg/m^3 respectively (Fig. 4). Using the WHO 2021 Air Quality Index of 15µg/m³ for $PM_{2.5}$ and 45µg/m³ for PM_{10} as the international standard (WHO AQI, 2021), it can be seen that the four quarry locations and its environs were heavily polluted with the particulate matters. This also affected the various farmlands around the quarry locations used by local farmers for crop cultivation. Thus, reaffirming (Saraya et al, 2016a, : Okafor, 2006) that huge amount of air pollution from quarry causes significant effect on plants biodiversity, habitat destruction and possibility of the heavy dust particles blocking and damaging the stomata such that photosynthesis and respiration are affected. The implication of these is that some of the plants may have retarded growth while others may be eliminated.

Table 1 shows the correlation coefficient (r)and coefficient of determination (r^2) between the particulate matters with the meteorological parameters (temperature, relative humidity and windspeed) of the locations. It can be seen that there is a strong correlation between $PM_{2.5}$ and the meteorological parameters with temperature having the strongest relationship of 0.981. Similarly, PM_{10} also recorded a positive relationship with the meteorological parameters with temperature recording the highest value of 0.961. The coefficient of determination (r^2) is a statistical measurement which determine the proportion of variance in the dependent variable that can be explained by the independent variable and it is measured in percentage. Through r^2, the variation of particulate matters as caused by meteorological parameters were known. From the result, the r^2 between $PM_{2.5}$ with temperature, relative humidity and windspeed were 0.962, 0.388 and 0.682 respectively. This simple means that 96.2% increase in $PM_{2.5}$ was caused by the variation in temperature of these quarry locations. Similarly, the highest r^2 with PM_{10} was temperature with 92.5%. Hence, an increase in temperature directly leads to an increase in $PM_{2.5}$ and

PM_{10}. In other words, daily rise or fall in temperature has a resultant effect in the amount of particulate matters produced in these quarry locations and its environs.

Table 1
Correlation coefficient (r) and Coefficient of determination (r^2) between the particulate matters with the meteorological parameters of the locations

Pollutant with met.	r	r^2
$PM_{2.5}$with Temp.	0.981	0.962
$PM_{2.5}$with Rh	0.623	0.388
$PM_{2.5}$ with Wspeed	0.682	0.465
PM_{10} with Temp	0.961	0.923
PM_{10} with Rh	0.721	0.520
PM_{10} with Wspeed	0.590	0.349

4. Discussion

To access the effect of quarry dust on agriculture and plant biodiversity, 400 structured questionnaires were distributed to local farmers. The result obtained revealed different ranges of affected local farm crops due to quarry activities and the respondents show 26% for Yam, 15% for Cassava, 30 for Vegetables, 7% for Plantain and 27% for other crops. The result shows that vegetable was the most affected crop with 30% (Fig. 6).

Concerning the effect on crop yield, majority of the respondents (93%) stated that crop yield decreases to about 30% annually (Fig. 7). Physiological mechanism behind these could be attributed to one or combination of the following factors; that dust might cover the leaves with white layer resulting to decrease in chlorophyll cells exposed to light thus, reducing the total photosynthesis activities (Missanjo et al 2014: Raina et al, 2008); dust also reduces plant growth (number of leaves, leaves surface and size) therefore affecting photosynthesis, respiration and transpiration, (Prajapati and Tripathi 2008); Some release toxic compounds(fluoride, magnesium, zinc, lead, copper, sulphuric acid and hydrochloride acid)

that are damaging to vegetation (Iqbal and Shafig 2001b). Leaf trichomes (hair) are affected by dust thereby decreasing the natural defense mechanism against pest and diseases (Missanjo et al 2014b).

In addition to the earlier mentioned effect, 80% and 70% respondents stated that effect of quarry activities had led to soil erosion and water contamination respectively with both contributing to decrease in crop yield (Fig. 7). The accumulation of these activities over the years might have resulted to change in soil properties such that soil in and around the quarry areas (0- 1km) may be found to be more of alkaline. Attributing it to the high concentration of hydroxyl, carbonate and bicarbonate present in mined materials as confirmed by Haritash et al 2007.

5. Conclusion

Quarry activities at the four locations produced high amount of $PM_{2.5}$ and PM_{10}, far more than the recommended WHO Air Quality Index standard. The high amount of this dust resulted to decrease in local crop production such as vegetable, yam and cassava. Many plant species that are present in the locations are climax type, meaning a slight change in their environmental need due to quarry activity might result to complete loss or retardation of the plant. This is because such climax species are more specialize in their environmental needs and less adaptable. Correlation coefficient between the particulate matters and meteorological parameters shows a strong relationship with temperature recording the strongest value. Similarly, the coefficient of determination shows that temperature has strongest meteorological percentage influence on $PM_{2.5}$ and PM_{10}. The quarry activities also affected water and soil texture of the locations which are vital ingredient for agriculture thereby, aggregating the problems. However, further studies are needed to investigate the effect of quarry activities on the physiological mechanism of the plants and the physiochemical properties of soil and water. From the results obtained, the following are some of the recommendations that are feasible for quarry activities which are necessary for regular assessment of environmental impact that can mitigate the effect of the problems

1. To develop a green belt surrounding the quarry using pollutant- tolerant trees; especially with broad leaves in order to restrict spreading of the quarry dust through intercepting, filtering and absorbing pollutants.
2. Formation of a code of conduct for the industry as a self-regulatory mechanism
3. Specialize training for owners of the quarries, crop farmers and community chiefs living in the affected areas on mitigations to these dust problems.

Declarations

Authors contributions

Imoh Ekpa conceived and design this project; Imoh Ekpa, David Laniyan and Cletus Agbor carried out the field work; Ubong Ben analyzed the data; Imoh Ekpa and Joseph Okon wrote the paper. All authors contributed critically to the drafts and gave final approval for publication.

Conflict of interest

The authors declared that no conflict of interest exist.

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Figures

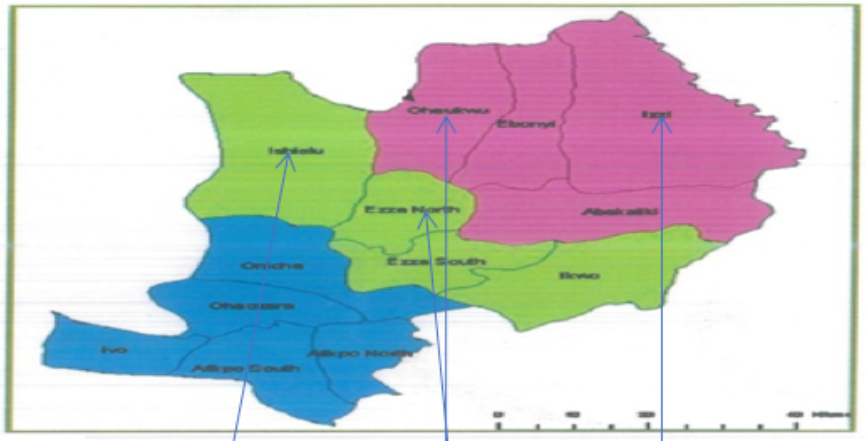
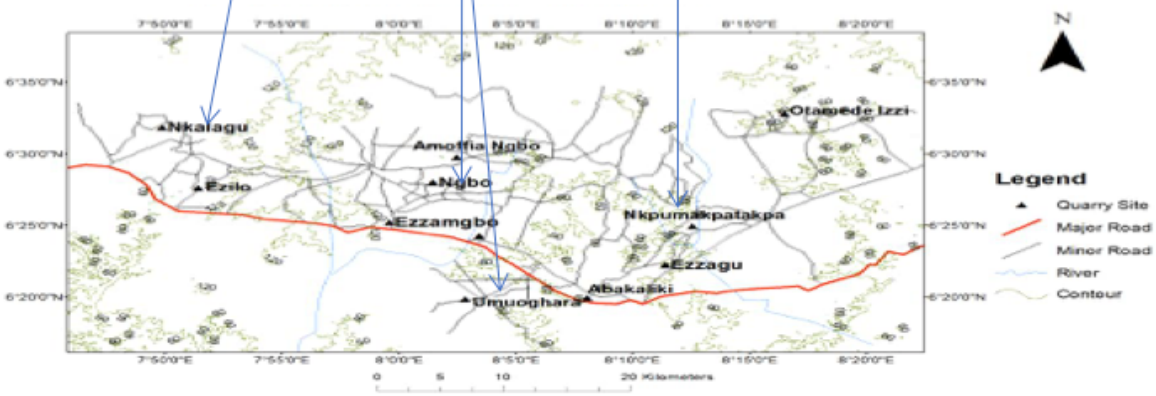


Fig. 1.1: Map of Ebonyi State showing the study area



A B C

Figure 1

Study sites (A) In the mist of quarry dust at one of locations (B) Crushing stage where large dust is been released (C) With Aeroqual 500 series device.

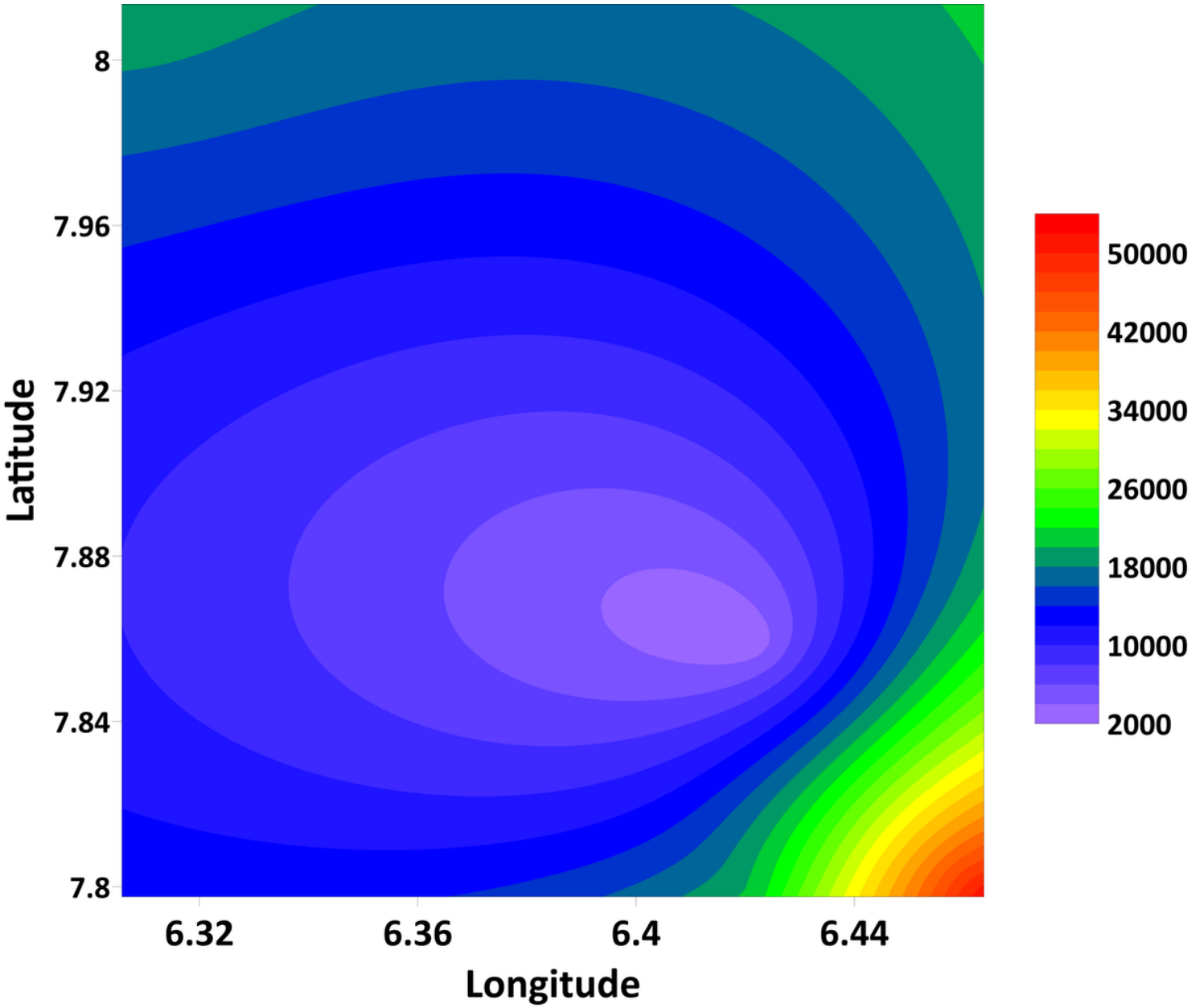


Figure 2

contour map for $PM_{2.5}$ in μg/m³

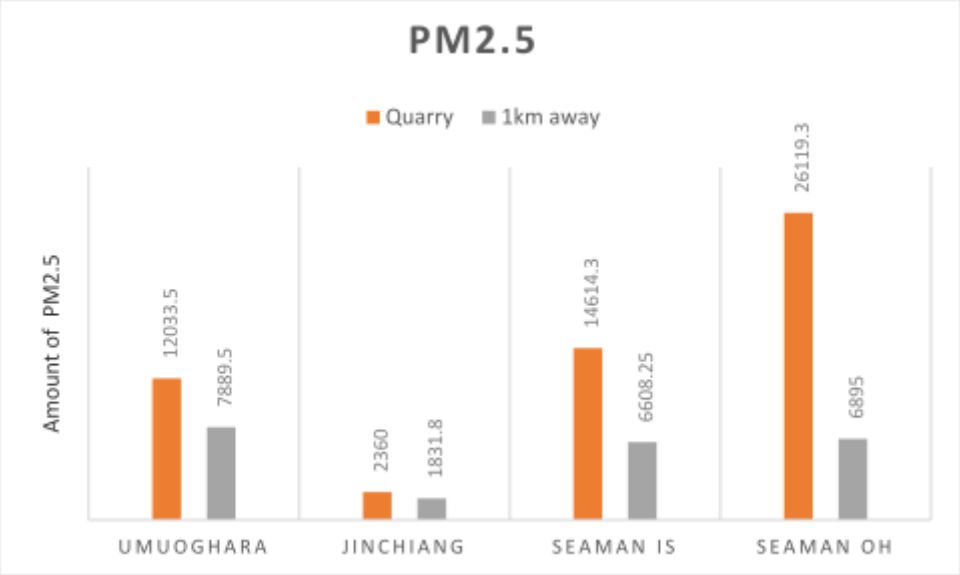


Figure 3

Daily average of $PM_{2.5}$ in µg/m³ at the four-quarry site and lkm away from the quarry source

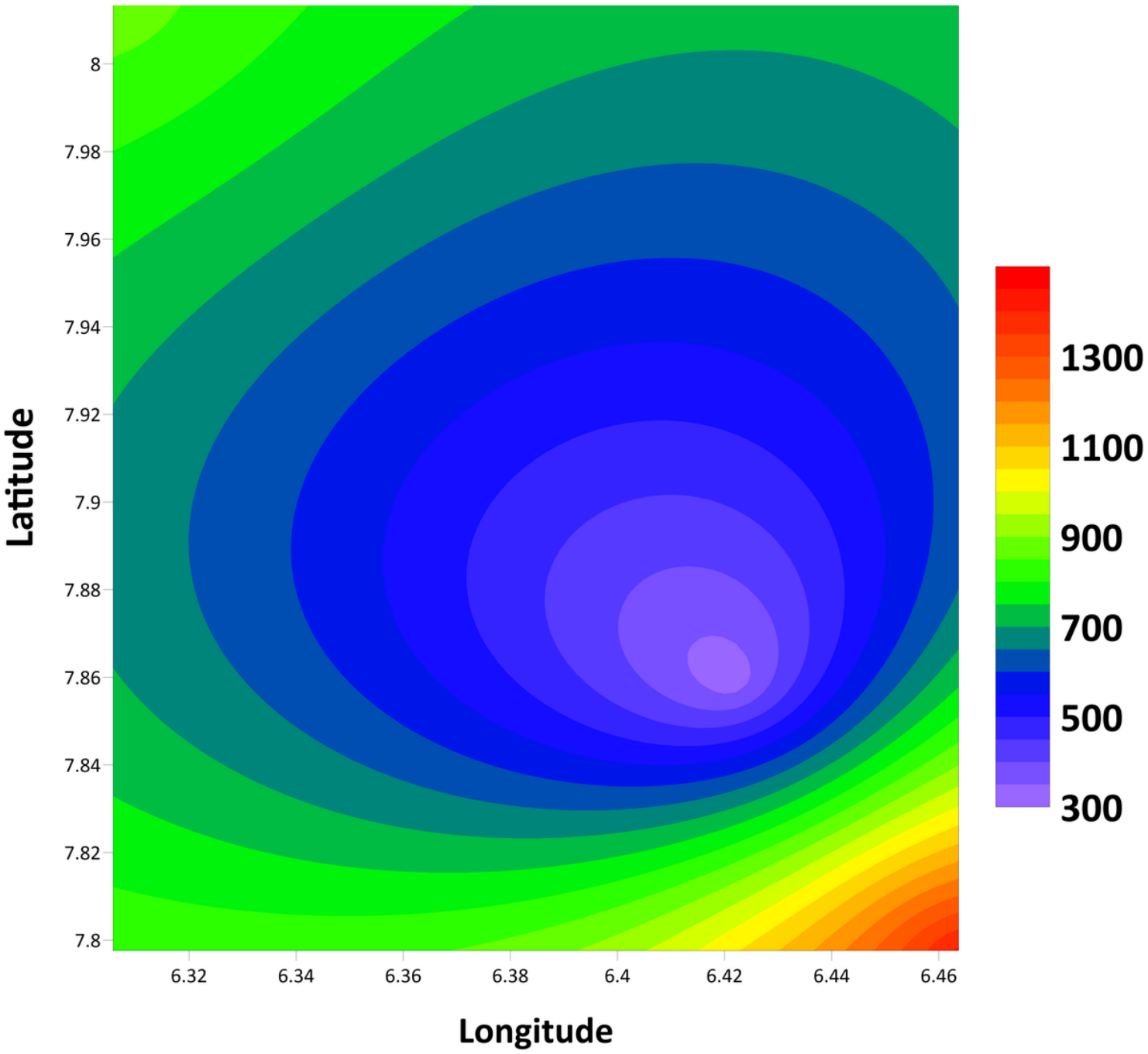


Figure 4

Contour map for PM_{10} in µg/m³

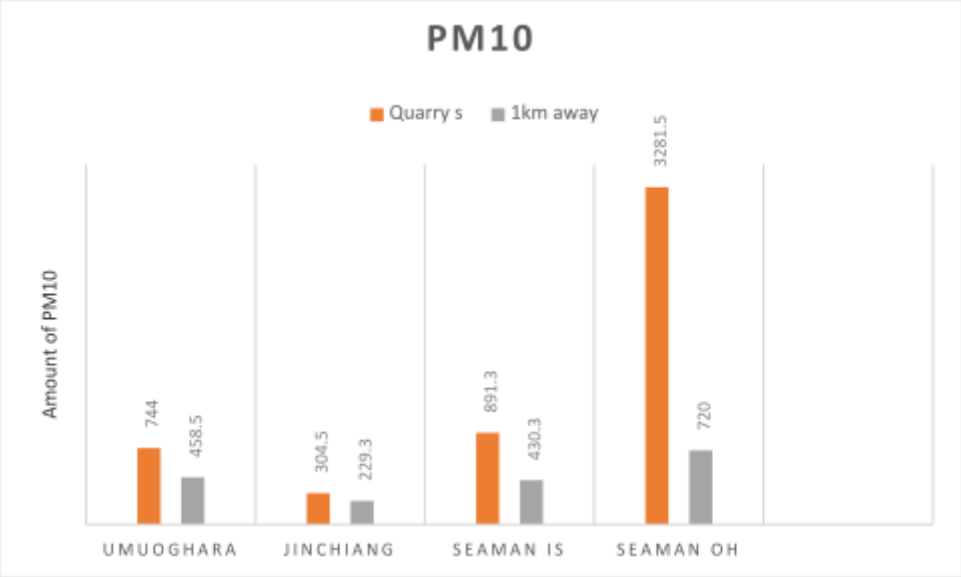


Figure 5

Daily average of PM_{10} in µg/m³ at the four-quarry site and lkm away from the quarry source

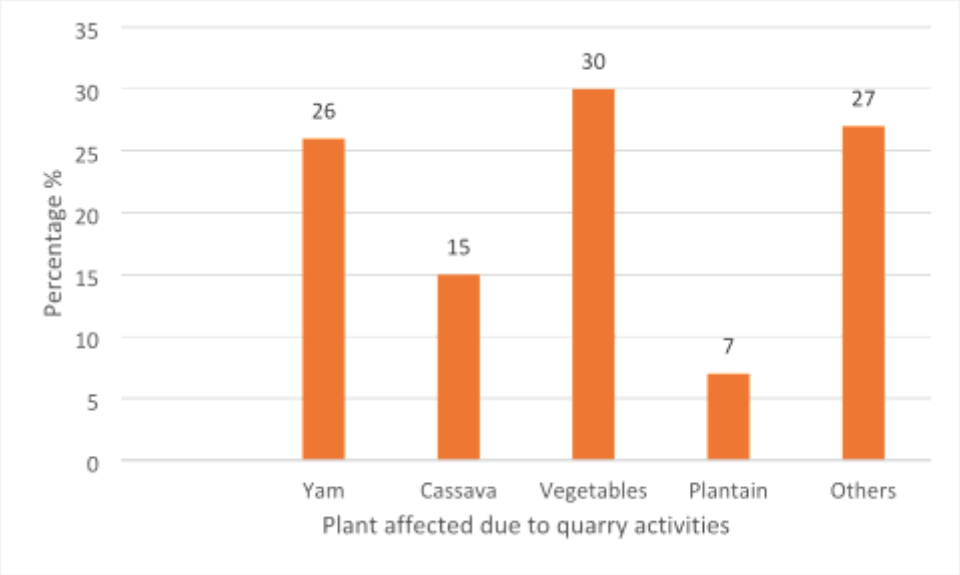


Figure 6

Percentage of crops been affected by the quarry activities.

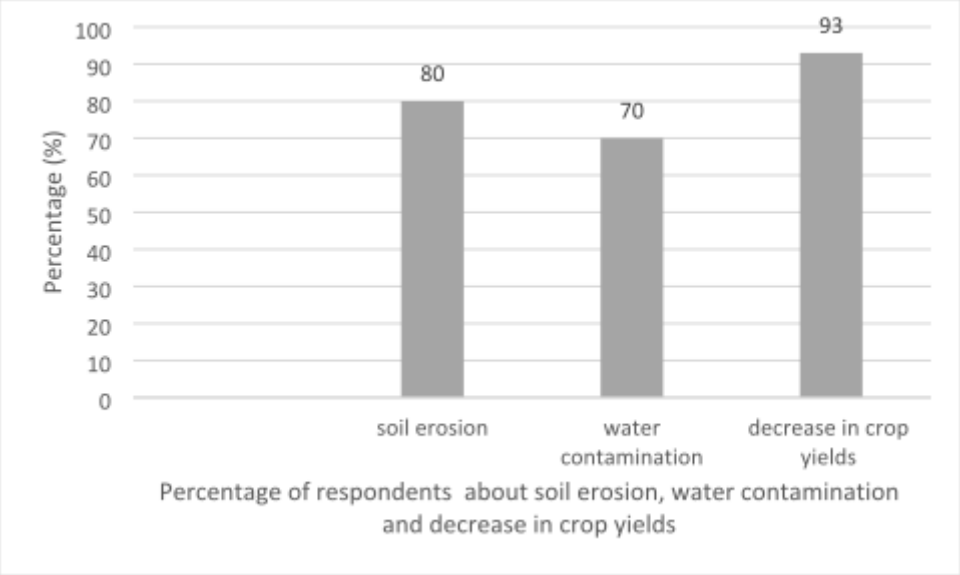


Figure 7

Percentage of respondents about soil erosion, water contamination and decreases in crop yield.