



REVIEW ON THE POTENTIAL OF BASALT ROCK DUST FOR AGRICULTURAL SOIL MINERALIZATION AND ATMOSPHERIC CARBON SEQUESTRATION

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Abstract

The byproduct of volcanic eruption is basalt rock dust, and is of recent very popular for soil amendment because of its capacity to mineralize agricultural soil, improve crop productivity, and sequester atmospheric carbon IV oxide (CO₂). It is rich in minerals such as potassium, phosphorus, calcium, magnesium, and trace elements. It releases nutrients slowly and consistently to the soil, thereby resuscitating soil nutrient deficiency and enhancing the productivity of crops on the field. Beyond its support for improving crops' phenological developments and yield, it improves climate quality by forming stable bicarbonates in soil through reaction with atmospheric carbon IV oxide (CO₂), and transporting it to the ocean for permanent storage. According to previous research, the incorporation of basalt rock dust at the rate of 1, 4, 5, 25, and 50t/ha was reported to increase the supply of key minerals in the soil, improve soil pH, and reduce the availability of trace metals in the soil compared to the control. The yield of crops such as maize, sugarcane, rice, rape, bananas, and lupin was significantly improved as a result of the incorporation of basalt rock dust into the soil. Through the addition of basalt rock dust to soil, a 0.3t CO₂ t⁻¹ maximum atmospheric carbon capture potential was achieved. The use of basalt rock dust in agriculture is economical and climate friendly. This paper reviewed the potential of basalt rock dust as an alternative for addressing food security challenges, improving agricultural soil mineralization, and global climate.

Keywords: Anorthosite, Basalt, Carbon sequestration, Olivine.

Introduction

The properties of soil, such as reduced fertility and prolonged weathering rate, have exposed agricultural activities in tropical and subtropical regions to serious challenges (^aRodriquez *et al.*, 2021). The problems such as low level of organic matter, low nutrients, and acidity have exposed agricultural soils to degradation, thereby making them less productive (Castro *et al.*, 2015). The usual traditional farming systems, which involve activities such as the slash-and-burn approach and the excess use of inorganic fertilizers have increased the problems of soil nutrient dynamics, soil degradation,

and environmental pollution (Vanlauwe *et al.*, 2014). Recently, the increasing and major interest in sustainable practices in agriculture is improving soil fertility, crop productivity, and reduction of environmental impact. One of the sustainable practices that can be considered in agriculture is the use of alternative fertilizer sources for plant nutrient supply and for improved crop productivity (^bRodriguez *et al.*, 2022). The suggested climate-friendly and sustainable solutions for addressing the challenges facing agriculture are the use of organic and inorganic fertilizers (Ramos *et al.*, 2022).

The use of basalt rock dust was recommended as an alternative, sustainable and promising source of nutrients for plants; macro-minerals such as calcium, magnesium, and other trace elements are its constituents (Nunes *et al.*, 2014). The nutrients supplied by basalt rock dust last for a long period of time in soil and plants, and they are released consistently and slowly to meet crop needs (Conceicao *et al.*, 2022). According to (Augusto *et al.*, 2021), one of the promising alternative and sustainable practices for nutrient source for plants is the use of basalt rock dust, the dust was reported to contain essential macro-minerals such as trace elements, magnesium, and calcium (Nunes *et al.*, 2014). These minerals are released slowly and consistently to soil over time when basalt rock is ground into powder and added to soil, representing and making available a nutrient source that lasts for a long period of time for plants (Conceicao *et al.*, 2022). Over years, increased in soil water retention was also reported as a result of basalt addition to agricultural soils, and this supports crops' growth and productivity, most especially during drought. Positive results such as improved water absorption, robust root development, and availability of nutrients from the deepest soil layer were reported for areas where rock mill was applied (Ferreira *et al.*, 2023). Minerals such as iron (Fe) silicates of basic pH and magnesium (Mg) are abundant in basalt rock dust, and this makes it stand out among other silicate rocks for agricultural use. Other minerals such as micronutrients relevant for plant nutrition and macronutrients like calcium (Ca), potassium (K), and phosphorus (P) are abundant in basalt rock (Swoboda *et al.*, 2022).

The fertility of agricultural soils are improved by basalt rock addition by correcting soil pH and enabling necessary nutrient release. Reliable results for a minimum period of five years are provided by basalt addition to soil without the need for applying it at each planting season (Guelvi-Silva *et al.*, 2014). Precise amounts of nutrients needed by plants are provided as a result of basalt rock addition without contaminating the soil, even when it is applied in excess (Burbano *et al.*, 2022). It assists in reducing the adoption and dependence on inorganic fertilizers for improved crop productivity, this describes one of its best attributes as an alternative fertilizer. Economically, basalt saves nothing less than 50% production cost on the farm. Series of positive effects were reported as a result of basalt addition to agricultural soils, these includes potential use as fertilizer and reduction in farm expenses (Swoboda *et al.*, 2012). The relevance of this study is establish the relevance of basalt rock dust as a natural fertilizer for improving the production of crops and

to improve climate quality through the process of atmospheric carbon sequestration.

Review of Basalt Rock Dust on Agricultural Soil Mineralization

The mineralization of agricultural soils has been one of the potential benefits pointed out from the use of basalt rock dust. Rocks normally contain essential nutrients needed by plants to grow well while the quantities and availability of their mineral composition vary. In agronomic studies, the potential of rocks as an alternative source of plant nutrient supply was investigated (Augusto *et al.*, 2021). The diversity of these rocks such as sedimentary, metamorphic, and igneous rocks vary for possible use in agriculture. These rocks consist reasonable amount of essential plant nutrients such as phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg). The availability of its nutrients in soil for plants are promoted through dissolution when applied to agricultural soils (Augusto *et al.*, 2021). According to (Silva *et al.*, 2012), the use of basalt rock dust has reliably enhanced the fertility and chemical properties of different agricultural soils (Silva *et al.*, 2012).

The different particle sizes and application rates (0, 1, 5, 25, 50 t/ha) of basalt rock dust were used successfully for the amendment of seven highly weathered tropical soils in Australia (Gillman *et al.*, 2002). Significantly, the cation exchange capacity (CEC) was improved and the level of soil acidity was reduced compared to the control plot (no treatment). Also, minerals such as sodium (Na), potassium (K), magnesium (mg), and calcium (Ca) were improved. Only a proportion of the amount applied to soil are constituted by exchangeable cations from basalt addition, underscoring the potential of basalt in retaining cations as reserve for a prolonged soil enrichment. Although, in specific amounts, crops like rice and sugarcane require silicon (Si) for enhanced growth, the mineral is not really considered important but can be derived from basalt addition. For the highly weathered seven tropical soils considered, the concentration of silicon in the soil samples increased considerably due to the addition of crushed basalt.

Some soil properties, their response, and interactions with basalt rock dust addition are under-explored, this calls for their adequate review for validation. Micronutrients such as copper (Cu), manganese (Mn), boron (B), zinc (Zn) and macronutrients such as magnesium (Mg), calcium (Ca), potassium (K), and phosphorus (P) which are needed by crops, are released by basalt rock dust because of their potential in cellular structures, protein structures, chemical signaling, and enzyme co-factors (Kabata-Pendias and Szteke, 2015).

Table 1: Review of different soils mineralized with incorporation of basalt rock dust

S/N	Rock Type	Soil	Application Amount (t/ha)	Duration (Months)	Trial Type	Results
1.	Basalt/GML/Organic fertilizer	Soil mineralization	Basalt dust (4t/ha) / GML dust(4t/ha) / Organic Fertilizer (0.25t/ha)	4	Pot	<i>Increase in supply of soil Ca, Mg, K, and P compare to others and control. It improves soil pH and decrease Al.</i>
2.	Basalt dust	Soil Mineralization And acidity reduction	0, 1, 5, 25, and 50	3	Pot and Field	<i>Basalt dust reduces soil pH without lime, and restore soil nutrients</i>
3.	Basalt dust	Soil acidity reduction	5, 10, 20, 40, 80	24	Pot and Field	<i>Improvement in soil pH and cation exchange capacity (CEC).</i>
4.	Basalt+Dolerite, Gneiss+K-sp	Acidic Australian Soil	-	12	Pot	<i>Increased soil mineral contents</i>

(Swoboda *et al.*, 2022)**Table 2:** The table showing basalt rock dust effects on the yield of different crops

S/N	Rock Type	Crop	Soil	Application Rate (t ha ⁻¹)	Period (Months)	Type of Trial	Results
1.	Basalt rock	Sugarcane, Manioc, Maize, Rice.	Sandy clay	2 – 3	6	Field	<i>Improved yield and stronger water retainability.</i>
2.	Basalt	Lupin, Rape, Banana, Maize	Nutrient solution	40	36	Field	<i>Increased in weathering rates compared to control</i>
3.	Basalt	Cocoa	Oxisol Ultisol	5,10,20,40,80	24	Pot and Field	<i>Increased in cocoa growth. Best results at 10t/ha.</i>
4.	Basalt+Dolerite, Gneiss+K-sp	Grass	Acidic Australian Soil	Bs+Dlt:416; Gn:25100, K-sp: 5-20	12	Pot	<i>Increased plant yield and mineral contents</i>

Augite, anorthosite, diopside, olivine, and apatite are minerals that can be derived from basalt rock dust, the dissolution of these minerals in soil leads to the availability of micro- and inorganic macronutrients in the soil (Vienne *et al.*, 2022). The minerals are isomorphically substituted at trace concentrations within the minerals and contain crucial micronutrients and inorganic macronutrients. Also, as a trace mineral, boron (B) may be present (Richardson, 2024). Table 1 reveals the potential effects of basalt rock dust for the mineralization of different agricultural soils.

Review of Basalt Rock Dust Potential on Crop Yield

The micronutrients (B, Cl, Cu, Fe, Mn, Mo, Ni, and Zn) and macronutrients (C, H, O, N, K, Ca, Mg, P, and S) are the essential elements needed by plants to grow well. At various concentrations, these minerals can be found in rock except for nitrogen, and it is a major source of nutrients required by plants (Seidel *et al.*, 2021). In Malaysia, the agronomic parameters and yield of cocoa planted insitu are improved significantly by basalt addition. Significantly, the toxicity of manganese (Mn) and aluminum (Al) concentrations reduced to a safe level while the concentrations of minerals like sodium (Na), silicon (Si), calcium (Ca), and magnesium (Mg) increased. The increasing application rate of basalt also improved the cation exchange capacity (CEC) and pH of the soil. The single combination of rice husk and basalt at the rate of 5 t ha⁻¹ each was reported to give the best agronomic values (Barak and Chen, 1983). The deficiency in the concentration of iron (Fe) for peanuts grown on a calcareous soil was improved, the result is the same as with the efficiency of the usual organic chelate FeEDDHA *Eifelgold* when applied. Another rock powder was mixed with cattle manure and basalt rock dust, this reduced the rate of emission of ammonia (NH₃) from the manure after field application. A significant increase in the growth of maize and grass was recorded (Sha *et al.*, 2018).

In the absence and presence of crop plants like lupin, banana, maize, and oil seed rape, a laboratory study was carried out for 36 days while comparing the minerals released as a result of basalt addition leached in a dilute salt solution. The release of elements like silicon (Si), sodium (Na), magnesium (Mg), and calcium (Ca) was recorded in the presence of plants by a factor of 1 to 5, though sodium (Na) and calcium (Ca) concentrations were more than others, suggesting the rapid dissolution of plagioclase compared to other minerals. In the presence of plants, the concentration of iron (Fe) released was 100 to 500 fold larger compare to the treatments without plants. The highest elemental uptake for magnesium (Mg) and silicon (Si) was

recorded for banana while the highest elemental uptake for fluorine (F) and sodium (Na) was recorded for maize (Hinsinger *et al.*, 2001). An application rate of 150 – 1600 t ha⁻¹ was reported in a trial experiment with the combination of greywacke, porphyry, and basalt with improved field capacity and yield of oat, barley, clove and rape grown in sandy soil. At highest application rate of greywacke and porphyry in a clay soil, a reduced yield without significant improvement in soil properties was recorded. The potential effects of basalt rock dust on different crops' yield is shown Table 2.

Carbon Sequestration Potential of Basalt Bock Dust

Sometimes, farmers apply lime and granular fertilizers on their farms; basalt is suggested and recommended as an alternative. Basalt is abundant in magnesium, calcium, and it is weatherable for the removal and reduction of atmospheric carbon (IV) oxide. Globally, about 12 million km² are covered by forage, arable, fruits, and fiber (Monfreda *et al.*, 2008) and extra available degraded land of about 1-10 × 10⁸ ha can also be revived by basalt addition. The terrestrial surface of about 11% is used for the production of crops; this will provide a great opportunity for the removal of atmospheric CO₂ through carbon sequestration within a decade or two. In the latter half of the twenty first century, the immediate deployment of techniques for atmospheric CO₂ removal is crucial for eliminating the emission of carbon to avoid extreme heat condition and accumulation of atmospheric CO₂ which might trigger economic and adverse ecological consequences (Field and Mach, 2017). The assessment on the sequestration of atmospheric CO₂ can be carried out in areas where agricultural practices is intense and availability of basalt rock is abundant. The availability of other materials like machinery for rock crushing, means of transportation to the site, and rock spreaders should be considered like in UK or North America (Kantola *et al.*, 2017).

The removal of atmospheric CO₂ on a large scale can be achieved significantly through the deployment of ground basalt. A value of 0.3t CO₂ t⁻¹ was reported to be the carbon capture potential of basalt rock dust, provided the basalt rock dust was well crushed and milled for effective dissolution (Renforth, 2012). Factors such as biological activity, climate, and mineralogy contents of the rock determine the actual particle size of basalt after crushing and milling, the initial particle size of 10 – 30 µm diameter was estimated for this in previous calculations, but further investigation and validation about this are required. In the corn belt of North

America, it was reported that a 10 to 50 t ha⁻¹ yr⁻¹ application rate of basalt on 70 × 106 ha land planted with corn/soy could sequester 0.2111 PgCO₂. In the long-run, this value is like 13% of the emission from agriculture (Kantola *et al.*, 2017). There is uncertainty in the theoretical estimate for the rate of sequestration and atmospheric CO₂ capture involving silicate rock powder and global cropland.

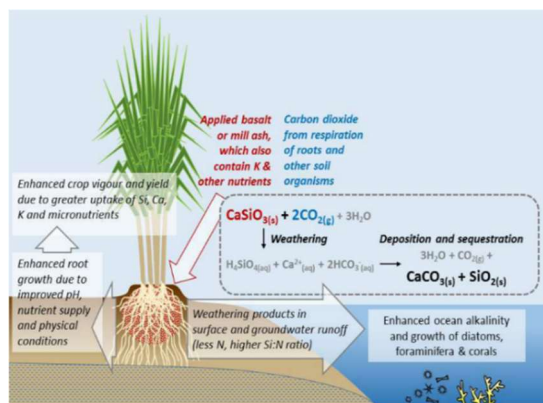


Figure 1: The potential of basalt rock dusts for improving agricultural soil mineralization, global food security, and climate change (Beerling *et al.*, 2018)

Conclusion

The utilization of basalt rock dust at increasing application rate provide a realistic and fast intervention for global carbon cycle dynamics, it improves soil health and crop productivity. On the other hand, unanswered social and technical questions attributed to its usage need to be addressed, this can be achieved through thorough testing in the domain where carbon cycle strategies can be established. Also, the full potential of basalt rock dust for the sequestration of atmospheric CO₂, the ethics attributed to its usage, its techno- and socio-economic benefits is underexplored.

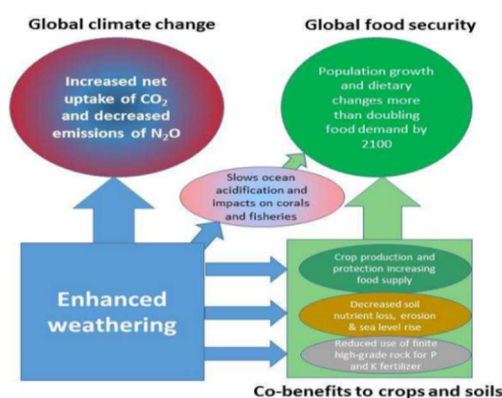
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The treatment of soil with basalt will amend two-thirds of the soil (9 × 108 ha) meant for cropping at a 10-30 t ha⁻¹ yr⁻¹ application rate and will sequester 0.5 - 4 PgCO₂ yr⁻¹ by 2100 depending on soil, crop, and climate (Beerling *et al.*, 2016). The agricultural and climate benefit of basalt rock dust is shown in Fig 1.



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