



## Evaluation of Some Soil Properties in the East Isfahan Region Affecting Soil Wind Erodibility

Hamidreza Karimzadeh<sup>1</sup>, Mahdi Adelnasab<sup>1\*</sup>

<sup>1</sup>Department of Natural Resources Engineering, Isfahan University of Technology, Isfahan, Iran.

\*Corresponding Author

E-mail: [m.adelnasab@na.iut.ac.ir](mailto:m.adelnasab@na.iut.ac.ir)

### ABSTRACT

Wind is recognized as a major contributing factor to soil erosion in arid and semi-arid regions. In these environments, sparse vegetation and fragile soils make the land highly susceptible to wind-driven erosion. Wind can easily transport loose soil particles, intensifying erosion processes. The presence of a gravel layer on the surface of bare, unvegetated soils can significantly influence the severity of wind erosion. This study aimed to investigate certain soil characteristics in the eastern region of Isfahan that affect soil susceptibility to wind erosion. To achieve this, nine different geomorphological surfaces were selected: young alluvial fan, relatively mature alluvial fan, mature alluvial fan, gypsum mine, piedmont plain, sand and gravel mine, agricultural land, playa, and alluvial plain. From each surface, three soil samples were collected from the top 0–7 centimeters. The experiments were designed as a factorial trial within a completely randomized design, incorporating three factors: soil treatment, wind speed, and the presence of gravel. The physicochemical properties of the soil samples were analyzed. Results indicated that the mature alluvial fan had the highest gravel content (75%), while the playa had the lowest (3%). These findings underscore the critical role of gravel cover in mitigating wind erosion intensity.

**Keywords:** Surface gravel, Wind erosion, Vegetation cover, Physicochemical soil properties.

### Introduction

Wind is a significant contributor to soil erosion in arid and semi-arid regions. In these areas, the scarcity of vegetation cover allows wind to easily mobilize and transport loose soil particles, leading to wind erosion. In Iran, soil degradation is estimated to exceed 4.5 billion tons annually, resulting in further vegetation loss and a range of associated environmental issues. Globally, desert lands cover approximately 1,978 million hectares, of which around 34 million hectares are located in Iran. Effective control of wind erosion requires a thorough understanding of the factors that influence it. Therefore, studying the mechanisms by which wind detaches and transports soil particles, the erosive force of wind, and the erodibility of different soil types is essential for developing effective erosion control strategies (Refahi, 2004).

Wind erosion is an undeniable phenomenon that poses a serious threat to soil—one of the most vital and foundational resources for sustaining agricultural productivity. Wind plays a key role in the detachment, transport, and deposition of fine soil particles. Remarkably, this form of erosion is not limited to Earth; it has also been observed on other planets (Fryrear *et al.*, 1999). From a process-oriented perspective, wind erosion occurs when environmental conditions favor the detachment and movement of soil particles (Refahi, 2004).

Wind erosion is widely regarded as one of the most significant land degradation processes, particularly in semi-arid regions and agricultural areas around the world (Buschiazzo *et al.*, 2007). This phenomenon carries substantial economic and social repercussions, contributing to recurrent droughts. It strips away the most fertile layer of soil, weakens plant resilience, diminishes crop yield and quality, facilitates the spread of diseases, reduces visibility, contaminates the air, and poses serious risks to human and animal health (Armbrust, 1987). In Iran, approximately two-thirds of the land lies within arid and semi-arid zones, with nearly 45 million hectares classified as desert areas

(Karimi Nazar *et al.*, 2009). Effective wind erosion control requires a detailed understanding of the processes through which wind detaches and transports soil and sediments, the erosive power of wind, and the erodibility of soils (Refahi, 2004).

In addition to its other impacts, wind erosion is characterized by significant spatial and temporal variability, as well as fluctuations in soil surface levels (López Sánchez, 1998). Since the direction of wind-driven particle transport plays a key role in the erosion process (Visser *et al.*, 2004), accurately understanding wind erosion dynamics is essential for developing and evaluating effective control strategies (López Sánchez, 1998). Measuring the factors that influence wind erosion under natural field conditions is often challenging and constrained. Therefore, wind tunnels are commonly used as a practical tool for simulating and quantifying wind erosion (Fryrear *et al.*, 1999). In this study, a wind tunnel will be employed in the East Isfahan region, as it allows for reliable estimation of soil displacement at various wind speeds (Kohake *et al.*, 2010). While wind tunnels offer a controlled environment for experimentation, their limited size and short testing durations can make it difficult to extrapolate the results to real-world conditions (López Sánchez, 1998).

According to the Swiss Soil Conservation Research Institute, soil erosion rates below 2 to 4 tons per hectare per year are considered acceptable thresholds (Prasuhin, 2012). Analyzing the spatial distribution of soil erosion is crucial for identifying the sources of erodible materials and implementing effective protection and control measures (Yong *et al.*, 2008). These spatial patterns reveal a strong correlation between erosion intensity and soil morphology (Chandler *et al.*, 2002). Globally, water erosion affects approximately 1,094 million hectares of land, with 751 million hectares classified as severely degraded. Wind erosion impacts an estimated 549 million hectares, of which 296 million hectares are severely affected (Lal, 2003).

Mashkooch *et al.* (2005) developed a map highlighting vegetation degradation, wind erosion, and saline land distribution across a portion of the Ardakan Plain in Yazd. Their findings indicated that vegetation cover had degraded from severe to very severe levels, salinity had expanded moderately to severely, and wind erosion ranged from mild to moderate. However, the natural tendency for these processes in the region is classified as very severe for vegetation degradation, severe for salinity expansion, and moderate for wind erosion. In another study, Ahmadi *et al.* (2004) assessed wind erosion in desert habitats of Khorasan (specifically the Sarakhs region), concluding that erosion-enhancing factors negatively impact the habitat quality of local fauna, reducing the ecological value of habitats in proportion to their area. Majdi *et al.* (2006) investigated the effectiveness of different clay mulches in controlling wind erosion and found that although clay mulches provide initial resistance, they degrade when subjected to wind-driven particle impact. Similarly, Ahmadi and Ekhtesasi (2000) evaluated the use of sandy mulch for mitigating wind erosion in non-recoverable saline clay soils. Their results showed no statistically significant reduction in wind erosion at the 1% level across the studied areas.

The intensity of wind erosion is influenced by both the erosive force of the wind and the erodibility of the soil (Skidmore, 1974; Gomez *et al.*, 2003; Mahmoudabadi *et al.*, 2011). Soil erodibility is primarily determined by its physical and chemical characteristics (Azimzadeh *et al.*, 2001) and serves as a key indicator of a soil's vulnerability to erosion (Yang *et al.*, 2005). In contrast, the actual occurrence of erosion is governed by atmospheric dynamics, particularly wind speed (Azimzadeh *et al.*, 2001). Most factors contributing to wind erosion vary over time and across different locations (Zhao, 2010; Pei). Among these, wind direction and speed are especially critical, as they directly affect the rate of soil particle detachment and transport (Nordstrom, 2004; Hotta). These wind-related variables are highly dynamic, often changing rapidly with both time and geography (Zhao, 2010). However, soil properties such as mineral composition and original particle size tend to remain stable over long periods (Zhao, 2010). Research indicates that soils differ in their sensitivity to wind erosion due to inherent physical properties (Liu *et al.*, 2007), with soil particle stability and size being among the most influential factors affecting erodibility and susceptibility to erosion (Colazo, 2007; Buschiazzo).


One of the key motivations for conducting this research is the need to assess and monitor wind erosion in regions such as East Isfahan, which serves as a major source of fine dust transported to large urban centers like Isfahan. Mitigating wind erosion in these areas can play a crucial role in preserving natural ecosystems for future generations. Furthermore, given the diverse landforms across Iran—each with distinct surface characteristics—and particularly in East Isfahan, which is recognized as a highly sensitive zone for wind erosion, this study represents a novel effort to



identify erosion-prone surfaces and to help prioritize vulnerable areas for future research and conservation efforts. Accordingly, the primary objective of this study is to investigate selected soil properties in the East Isfahan region that influence susceptibility to wind erosion.

### Materials and Methods

In this study, nine locations within the East Isfahan region were selected for sampling. The study area is located on the central Iranian plateau within the Zayandeh Rud River basin, less than 20 kilometers from the city center of Isfahan. This region is characterized by a dry climate with high temperatures. The area, covering 328,542 hectares, lies between the longitudes of 52°30'00"E to 51°40'00"E and latitudes of 32°07'00"N to 33°00'00"N. The study boundaries include Shahid Babaei Airport, Nuclear Energy Mountain, Zayandeh Rud River, the villages of Qahi and Harand, the foothills, the Karkas mountain range, alluvial deposits, Kamshchek Industrial Town road, agricultural lands, and Arghavanieh highway. One study boundary is the Kamshchek Road – Nuclear Energy Mountain, another is the Zayandeh Rud River, and the third boundary is the area between the villages of Qahi and Harand extending to the Karkas mountain range. The average annual rainfall is about 50 millimeters in lowland areas and approximately 250 millimeters in the northern highland areas of the region



For soil sampling, a geomorphological map of the region was first developed, and based on the identified operational units, nine distinct areas were selected as sampling sites. From these sites, nine soil samples were collected, each with three replicates and varying particle size distributions, reflecting the importance of wind erosion in the East Isfahan region. Sampling locations were chosen to ensure a wide range of particle size distributions, resulting in a total of 27 distinctly different soil samples. After air-drying, the samples were sieved through a 2-millimeter mesh for subsequent physical and chemical analyses. The prepared soil samples were then transported to a field laboratory for testing using a wind tunnel apparatus designed to determine the threshold wind velocity for each sample. The wind tunnel comprises two main components: (1) a wind generator capable of producing various wind speeds at a controlled height, and (2) a test surface—a tray measuring approximately 30 by 30 centimeters—where soil samples are placed. The wind passes through a cross-sectional area of similar dimensions (30 × 30 cm). In total, 273 test measurements were conducted in the laboratory based on these soil samples

#### *Determination of the Physical and Chemical Properties of Soils*

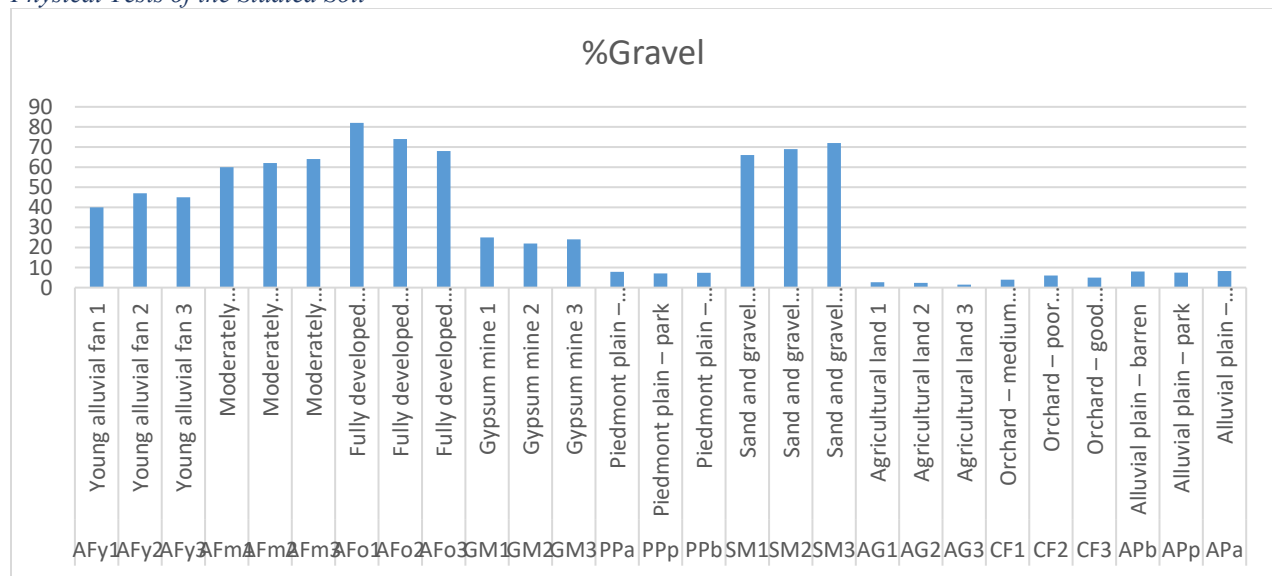
After transferring the soil samples to the Soil Science Laboratory of the Faculty of Natural Resources at Isfahan University of Technology, some of their physical and chemical properties were determined according to standard methods. The physical properties included: gravel percentage measured by crushing the soil and passing it through a 10-millimeter sieve (Bottomley, 2014); texture determined by the hydrometer method (Bottomley, 2014; Bauder, 1986); bulk density measured by clod method; and saturated moisture percentage determined using an oven (Bottomley, 2014).

The chemical properties included: sodium and potassium cations measured using a saturated paste extract and flame photometer (Page *et al.*, 1992; Bottomley, 2014); calcium and magnesium measured by versin titration method (Page *et al.*, 1992; Bottomley, 2014); soil acidity (pH) measured using a 1:5 extract and glass electrode (Thomas, 1996; Bottomley, 2014); electrical conductivity (EC) of 1:5 extract measured using an electrical conductivity meter (Bottomley, 2014; Rhoades, 1996); organic carbon measured by the Walkley-Black method (1934); lime measured by acid-base titration (Bottomley, 2014); and gypsum measured by the acetone method (Bottomley, 2014).

The tests were conducted in a completely randomized three-factor design. In this study, 27 soil samples were subjected to threshold wind speeds as well as two and four times above the threshold speed at a height of 30 centimeters for a duration of 5 minutes, under the effect of gravel treatment. The treatments used in the experiments included one type of gravel with a diameter of 1.5 centimeters applied at three coverage levels: control (no gravel treatment), 15%, and 30% gravel cover.

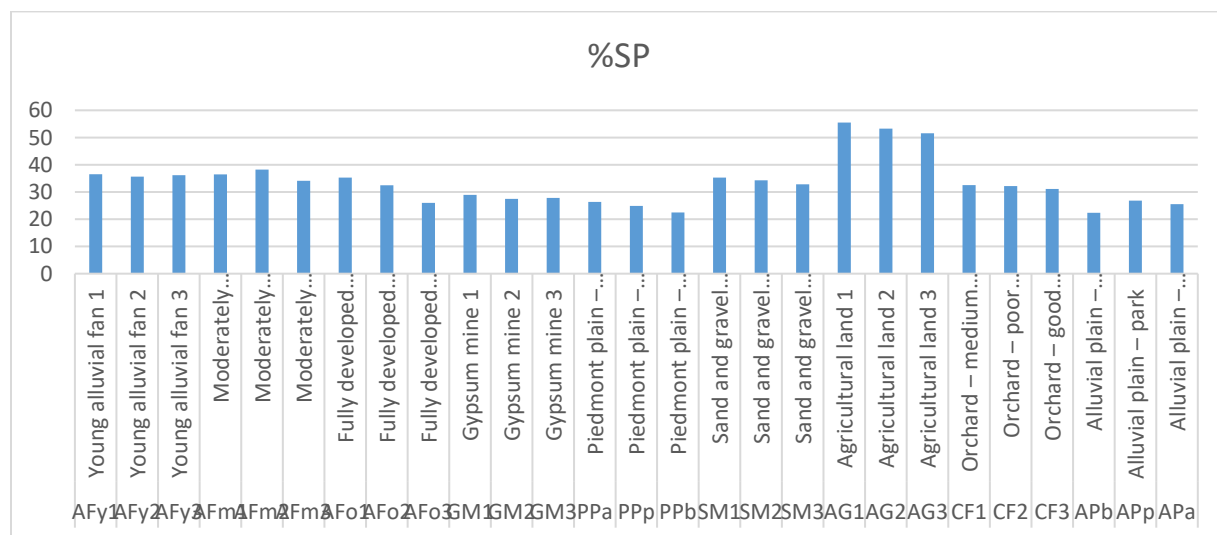
**Results and Discussion**

*Physical Tests of the Studied Soil*



**Figure 1.** Gravel percentage in various soil samples.

To determine the gravel percentage, a 10-millimeter sieve was used. One kilogram of soil was crushed and then sieved to separate the gravel particles (Bottomley, 2014). The gravel percentage for the mature alluvial fan and sand and gravel mine samples was higher compared to other samples, while the lowest gravel content belonged to the agricultural land and playa samples.



**Figure 2.** Variation in SP Percentage for Each Sample.

First, a saturated paste was prepared, and after 24 hours, a small sample of the paste was taken with a spatula and placed into a pre-weighed Petri dish. The dish was then oven-dried at 110°C for 24 hours. Using the relevant formula, the saturated moisture content (SP) was calculated (Bottomley, 2014):

$$SP = \frac{(\text{Wet paste weight} - \text{Oven-dried paste weight})}{(\text{Oven-dried paste weight})}$$

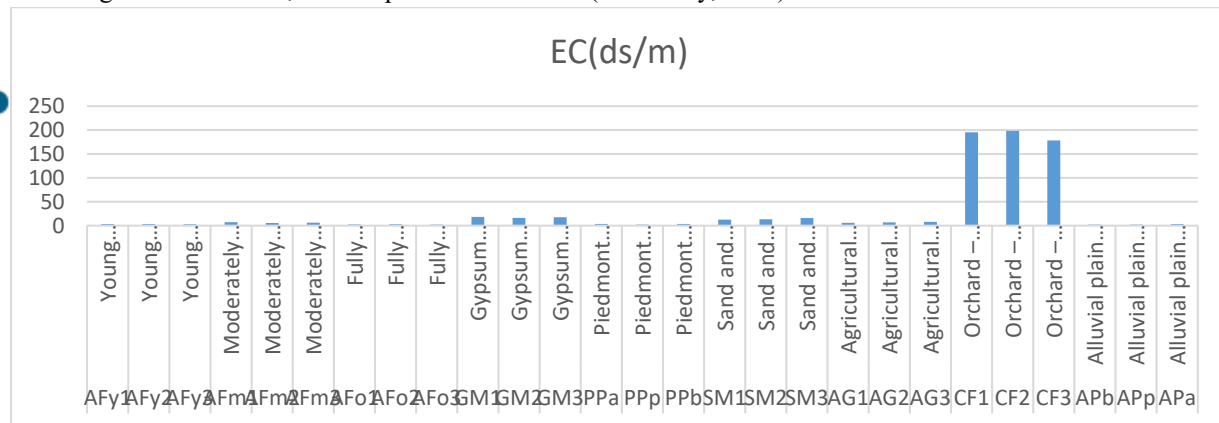
Based on the obtained data, grouping was performed according to the saturated moisture content of each sample

Where clods were present, the clod method was used for measurement. Two clods about the size of walnuts with the least angles were selected. One of them was tied with sewing thread to make a loop at the top, then hung from the bottom part of the scale. Next, it was coated with paraffin and weighed again in air below the scale. Then, a container of water was placed underneath, and the weight in water was measured according to Archimedes' method (Bottomley, 2014).

### *Chemical Tests of the Studied Soil*

#### *pH: Soil Acidity*

Soil acidity was measured in the saturated paste by inserting a pH meter electrode into the saturated paste. After removing the surface film, the soil pH value was read (Bottomley, 2014).



**Figure 3.** Variation of EC for Each Sample (dS/m).

#### *EC: Soil Salinity*

The saturated paste extract was obtained using a vacuum pump, and salinity was measured with an EC meter (Bottomley, 2014).

#### *Calcium and Magnesium*

- Calcium and magnesium were measured using the saturated paste method and by titration with Baur's method. First, the total calcium and magnesium content was determined, then calcium was measured separately, and magnesium was calculated by subtracting calcium from the total (Bottomley 2014).
- Since the variations of calcium and magnesium followed a similar trend across samples, they were categorized into 4 separate groups:
  - **Group 1:** Young Alluvial Fan 1, 2, 3; Relatively Mature Alluvial Fan 1, 2, 3; Gypsum Mine 1, 2, 3; Agricultural Piedmont Plain; Park Piedmont Plain; Barren Piedmont Plain
  - **Group 2:** Mature Alluvial Fan 1, 2, 3

- **Group 3:** Sand Mine 1, 2, 3; Barren Alluvial Plain; Park Alluvial Plain; Agricultural Alluvial Plain
- **Group 4:** Agricultural Land 1, 2, 3; Playa with Medium Tamarisk Cover; Playa with Poor Tamarisk Cover; Playa with Good Tamarisk Cover

#### Sodium and Potassium

- Sodium and potassium were measured in the saturated paste extract using a flame photometer (Bttomley 2014). Since their variations followed similar trends, the samples were grouped separately for sodium and potassium as follows:

#### Sodium Groups

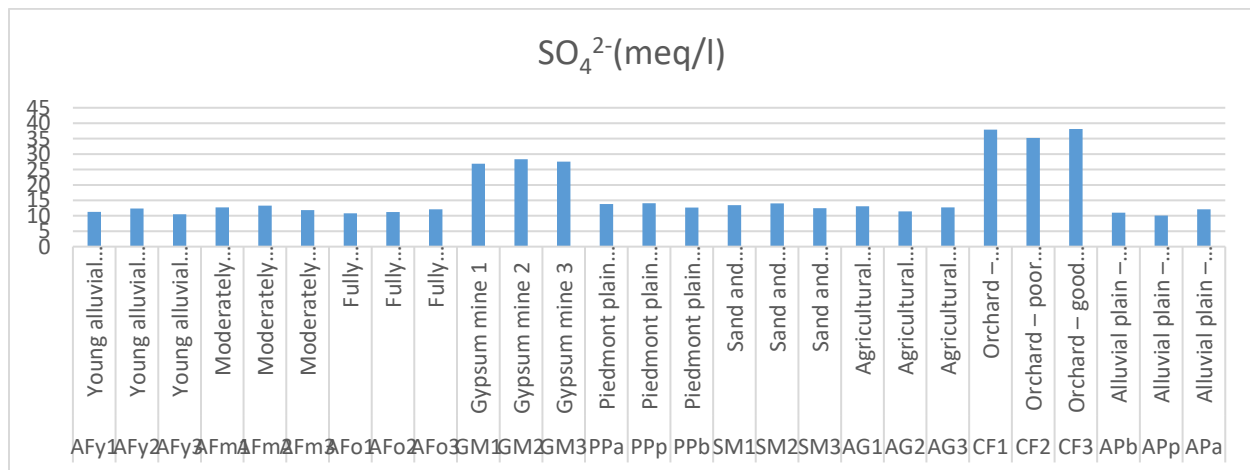
- **Group 1:** Young Alluvial Fan 1, 2, 3; Relatively Mature Alluvial Fan 1, 2, 3; Mature Alluvial Fan 1, 2, 3; Agricultural Piedmont Plain; Park Piedmont Plain; Barren Piedmont Plain; Barren Alluvial Plain; Park Alluvial Plain; Agricultural Alluvial Plain
- **Group 2:** Gypsum Mine 1, 2, 3; Sand Mine 1, 2, 3; Agricultural Land 1, 2, 3
- **Group 3:** Playa with Medium Tamarisk Cover; Playa with Poor Tamarisk Cover; Playa with Good Tamarisk Cover

#### Potassium Groups

- **Group 1:** Young Alluvial Fan 1, 2, 3; Relatively Mature Alluvial Fan 1, 2, 3; Mature Alluvial Fan 1, 2, 3; Gypsum Mine 1, 2, 3; Agricultural Piedmont Plain; Park Piedmont Plain; Barren Piedmont Plain; Sand Mine 1, 2, 3
- **Group 2:** Agricultural Land 1, 2, 3; Barren Alluvial Plain; Park Alluvial Plain; Agricultural Alluvial Plain
- **Group 3:** Playa with Medium Tamarisk Cover; Playa with Poor Tamarisk Cover; Playa with Good Tamarisk Cover

#### Carbonate and Bicarbonate

- Carbonate and bicarbonate were measured by titration in 2 ml of saturated paste extract. Bicarbonate was titrated using methyl orange indicator, and carbonate was titrated with phenolphthalein indicator and sulfuric acid (Bttomley 2014).

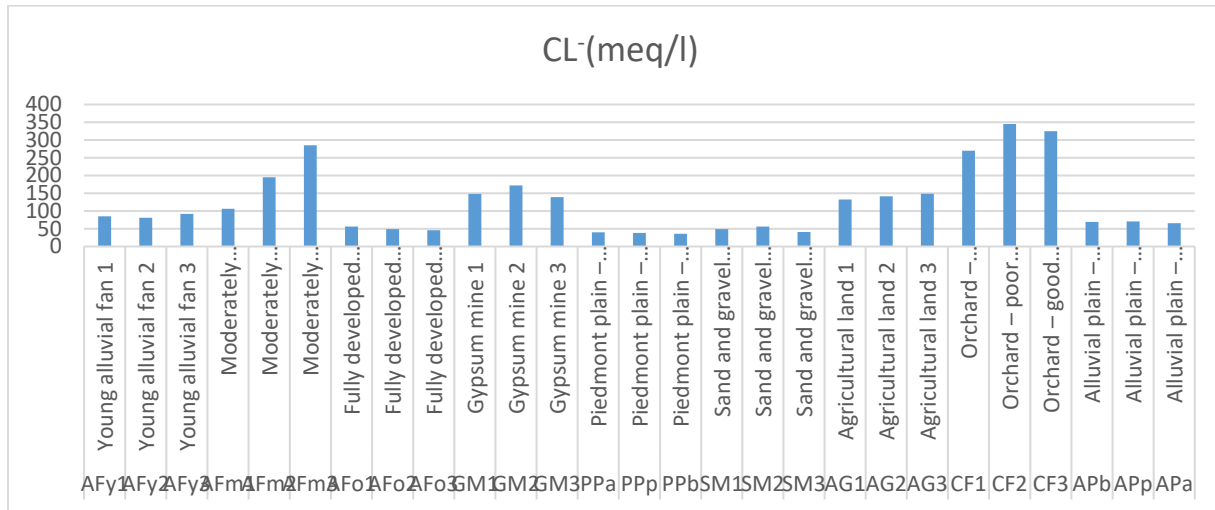


**Figure 4.** Variations in sulfate levels for each sample (meq/l).

#### Sulfate:

Sulfate was measured using the furnace method with ashless filter paper (Bttomley 2014).

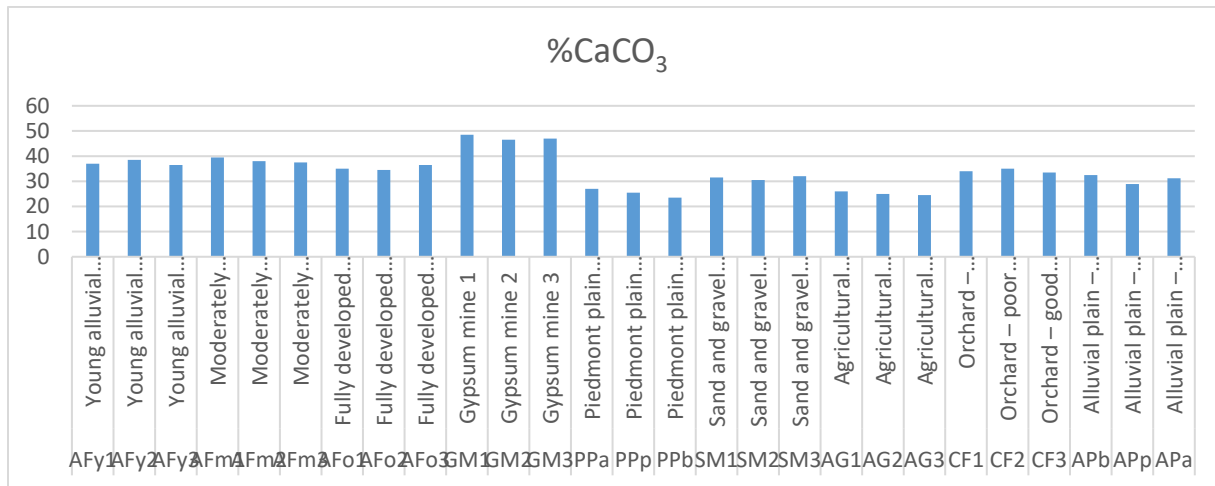




**Figure 5.** Variations in chloride levels for each sample (meq/l).

*Chloride*

Chloride was measured by titration with silver nitrate in the presence of potassium chromate indicator (Bttomley 2014).



**Figure 6.** Variations in calcium carbonate for each sample.

*Lime (Calcium Carbonate)*

Lime was measured using acid-base titration. One gram of soil was placed in a 250 ml Erlenmeyer flask, then 20 ml of 1N hydrochloric acid was added and heated on a hot plate. After drying, 100 ml of distilled water and a few drops of phenolphthalein indicator were added. The solution was then titrated with 1N sodium hydroxide until a purple color appeared (Bttomley 2014).

Phenolphthalein is colorless in acidic environments and turns purple in neutral and alkaline environments.

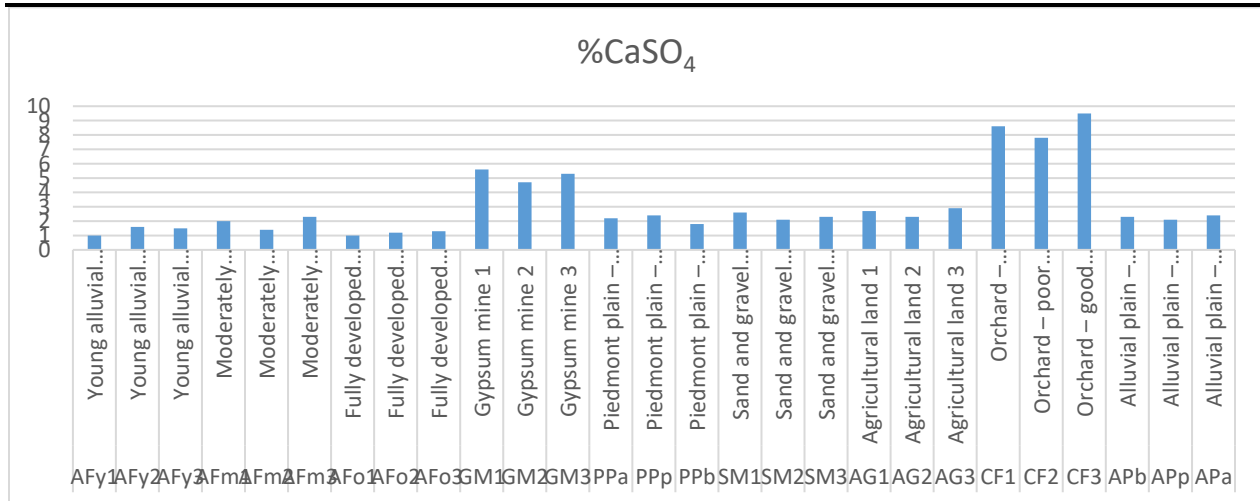


Figure 7. Variations in calcium sulfate for each sample.

### Gypsum

It was measured using the acetone method. One gram of sieved soil was thoroughly ground in a ceramic mortar, weighed, and placed into an 80 ml polyethylene bottle. Then, 50 ml of distilled water was added, and the mixture was shaken on a shaker for 30 minutes. After filtering the soil-water mixture with filter paper, 20 ml of the obtained extract was poured into an 80 ml polyethylene container, and 20 ml of acetone was added. The sample was then placed in a centrifuge and spun at 2000 rpm for 5 minutes. Afterwards, it was left for 10 minutes beside a sink. After settling, the white floating layer was discarded into the wastewater drain. The tubes were then placed in an oven to completely evaporate the acetone. Finally, 50 ml of distilled water was added, the container was shaken well, and its electrical conductivity (EC) was measured using an EC meter (Bttomley 2014).



### Conclusion

Based on the statistical analyses obtained from software using multiple regression for threshold wind velocity, the soil properties most effective on soil loss are calcium, magnesium, potassium, and calcium carbonate. Calcium and magnesium have the greatest impact, and since these two cations are key agents in the flocculation (binding) of soil particles, their presence reduces soil erodibility. On the other hand, as the percentage of gravel decreases, soil protection diminishes, and the threshold erosion velocity also decreases, resulting in increased soil erodibility. Additionally, calcium carbonate was identified as an effective property influencing soil loss. It was found that in the East Isfahan region, the amount of calcium carbonate plays a significant role in wind erosion, such that higher lime content increases soil aggregate stability and decreases soil loss. Furthermore, it was shown that increasing the surface coverage of gravel reduces wind erosion, while increasing wind speed leads to greater wind erosion.

Results indicate that the highest gravel percentage (75%) belongs to the mature alluvial cone, and the lowest (3%) belongs to the playa. These findings highlight the importance of considering gravel cover in controlling the intensity of wind erosion. Given the sensitivity of soils and the wind-prone nature of the region, it is recommended that land surfaces remain covered throughout the year and be exposed to direct erosive winds for the shortest possible time. Responsible executive organizations such as the Governor's Office, Agricultural Jihad, Natural Resources, and Regional Water Authority should refrain from issuing exploitation permits that lead to the destruction of natural soil surface covers, such as gravel cover in alluvial cones and plains.

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**Ethics Statement:** None

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