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A Review

Wind Erosion - Causes and Effects

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Abstract

Wind erosion is the detachment, movement and abrasion of soil by wind. It begins when the pressure of the wind against the surface soil grains overcomes the force of gravity on the grains. Wind moves soil grains along the surface of the ground in a series of jumps known as saltation. Wind erosion occurs in many arid, semiarid and agriculturally used areas around the world, and is influenced by geological and climatic factors, as well as human activities. Researchers pointed out that annual average soil losses up to 40 t ha^{-1} are possible without any visible sign of erosion. Erosion and deposition processes both take place on large areas and are therefore difficult to identify. In contrast to water erosion, where the eroded material follows determined paths, wind-eroded material is widely dispersed over the landscape. Furthermore, the direction of transport is subject to changes and in some cases completely the opposite, and so are the areas of erosion and deposition.

Keywords: *wind erosion, processes, factors, vegetation.*

1. Introduction

Wind erosion occurs in many arid, semiarid and agriculturally used areas around the world, and is influenced by geological and climatic factors, as well as human activities [12, 1].

Wind erosion is the detachment, movement, and abrasion of soil by wind (Figure 1). It begins when the pressure of the wind against the surface soil grains overcomes the force of gravity on the grains. Wind moves soil grains along the surface of the ground in a series of jumps known as saltation [9].

Wind carries more fine sediment than any other geological agent.

It has been estimated that windblown dust from soil erosion contributes about 500 x 10^6 t of particulates to the atmosphere each year [8].

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In view of this fact, it can be concluded that dust is an active factor in the climate system.

Model calculations indicate that about 50% (± 20%) of the total atmospheric dust originates from disturbed soils, i.e. soils affected by cultivation, deforestation or erosion [19].

This is mainly attributed to the removal of fine particles and organic material, which are the most fertile parts of the soil carrying the nutrients and other agents such as pesticides or herbicides.

In addition to creeping degradation, single wind erosion events may result in soil losses of more than 100 t/ha^{-1} and cause considerable on- and off-site damages [6, 7].

Vegetation reduces wind erosion by reducing the forces that the wind applies to the soil surface (reduced erosivity) and by increasing the resistance of the soil to erosion (reduced erodibility). Standing vegetation, including live growing vegetation and standing stubble from harvested crops, has a major effect on reducing wind erosion [3, 14].

Figure 1. Wind erosion [21]

2. Causes of wind erosion

Wind erosion is a serious problem in the word where vegetation is sparse, rainfall is low, and temperature is high.

Potential evaporation is higher than precipitation for most of the year, which causes depletion of soil moisture, organic matter and structure. Storms are regular events there, and in dry warm season, strong winds uplift small soil particles and carry them to distance places. Ecosystems in arid and semiarid regions are fragile by natural and are sensitive to human disturbances.

Under population pressure and socio-economic backwardness, human actions cause stresses on all natural resources. Land mismanagement, overgrazing, overcutting for fuel wood and deforestation, and misuse of water resources have been responsible for the loss of natural vegetative cover and hence accelerated wind erosion [13].

The spatial extent of wind erosion has increased in recent decades, mainly caused by changes in agricultural practices. The first reason is the spectrum of growing crops, which has changed to greater proportions of arable land crops. Other factors include disturbances of the soil surface by ploughing and a multitude of tillage operations. The time of highest mechanical stress by tillage operations coincides with the time of highest climatic erosivity in spring. Some more factors influencing wind erosion have been identified:

• The higher level of mechanization has led to larger fields and in consequence to the removal of hedges and other landscape structures.

• Drainage of arable land has caused faster drying of the soil surface, resulting in decomposition of organic matter and decreasing soil aggregate stability.

• Overgrazing is a significant causative factor in the semi-arid and arid regions, where no other type of land use is possible [5, 20, 16].

3. Processes of wind erosion

There are three typical processes of soil particle movement during wind erosion. These are saltation, suspension and surface creep (Fig. 2). These three processes of wind erosion occur simultaneously. Saltation causes other particles to move in suspension and surface creep. Neither creep nor suspension can occur without saltation.

In saltation, fine soil particles (0.1-0.5 mm in diameter) are rolled over the soil surface by direct wind pressure to some distance and then abruptly jump up vertically to a height of 20-30 cm. Lifted particles gain in velocity and then descend in an almost straight line at an angle 5-12° from the horizontal. The horizontal distance traveled by a particle is four to five times the height of its jump. On striking the surface, the particles may rebound into the air or knock other particles into the air before coming to rest. Thus, saltation is a progression of particles of successive jumps.

As the saltating particles crash into the surface, they splash up more particles that also bounce across the surface. This bombardment of the surface causes an avalanching effect that spreads out in a fan shape, with more and more soil particles being mobilized downwind. Between 50 and 75% of the soil is carried by saltation [13].

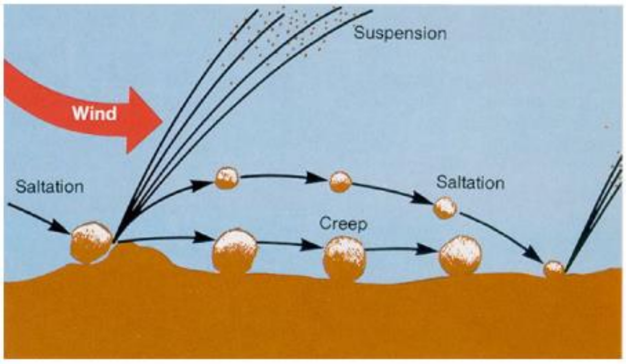

Figure 2. Wind erosion processes [22]

Suspension refers to the vertical uplift and horizontal transport of very small soil particles that are generally removed from the local source area. Suspended particles may end up on some meters or hundreds of kilometers downwind.

They can range in size from about 2 to 100 µm, with mass median diameter of about 50 µm in an eroding field. However, in long-distance transport, particles < 20 µm in diameter predominate because the larger particles have significant sedimentation velocities [2]. Some suspension-size particles are present in the soil, but most are created by abrasive breakdown during erosion.

Because organic matter and some plants are usually associated with the finer soil fractions, suspension sample are enriched in such constituents compared with the bulk soil source [11]. In the Great Plains, found that the average dust storm lasted 6.6 h and estimated the median dust concentration to be 4.83 mg m^{-3}. Suspension movements are easily noticed as dust storms (Fig. 3). Soil particles or aggregates of 500-1000 μm diameter are too large to be lifted up in normal erosive winds.

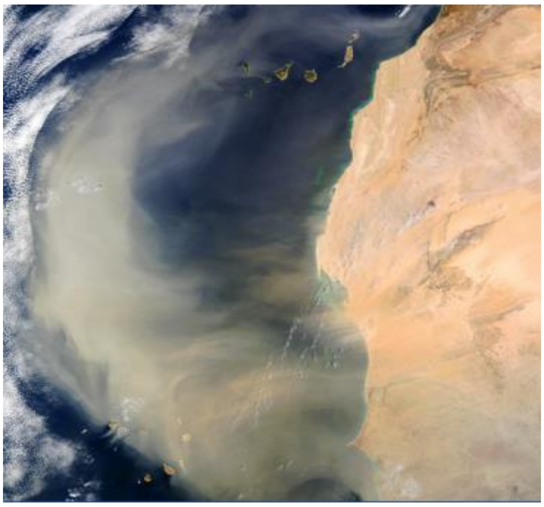

Figure 3. Satellite image of dust storm over the Africa [23]

They are pushed, rolled and driven by the impacts of spinning particles in saltation. In high winds, the whole surface appears to be creeping slowly found out that the threshold velocities of soil particles depend on the average diameter of soil aggregates instead of the grain size of single particles. After conducting experiments in a wind tunnel, [13, 4] discovered that the relationship for wind erodibility of aeolian sand as a function of its grain size follows a discontinuous function, with 0.09 mm sand being the most susuceptible to wind erosion.

The erodibility of aeolian sand can be divided into 3 categories: difficult to erode at > 0.7 and < 0.05 mm, moderately erodible at 0.7- 0.4 mm and 0.075 - 0.05 mm, and most erodible at 0.4 -0.075 mm.

With similar grain size, a mixture of size is more susceptible to wind erosion that is a uniformly sized material [15].

Figure 4. Factors influencing wind erosion

4. Factors influencing wind erosion

Wind is moving air and is caused by pressure differences in the atmosphere, which in turn result from temperature differences at the Earth's surface. Wind consists of a steady mean part and a superimposed turbulent part. The transport of moisture, heat, momentum and pollutants in the atmospheric boundary layer is dominated in the horizontal direction by the mean wind and in the vertical direction by turbulence.

Mean wind is responsible for rapid horizontal transport and can exceed velocities of 100 km/h^{-1}. Turbulence is generated by frictional drag on the air moving over rough surfaces. It results in an irregular swirling motion with turbulent eddies moving up and down. Owing to the increase in wind velocity with height, the net effect of the turbulent motion is always a downward flux of momentum and an upward flux of constituents. Thus, detached soil particles are passed to higher layers of the atmosphere. The magnitude of the vertical wind is about one tenth of the horizontal velocity [18].

Wind is the driving force of wind erosion if it exceeds a given threshold wind or friction velocity. The latter is better suited to express the momentum flux that the wind exerts on the soil surface and is influenced by the wind and also by surface roughness.

The other climatic factors influencing wind erosion are temperature, humidity, radiation, precipitation and evaporation (Figure 4). They cause temporal changes of the actual erodibility by affecting the soil water balance. In general, wet surfaces are stable enough to resist the wind forces, but for the initiation of wind erosion a very thin dry surface layer is sufficient. The water content of this layer is mainly dependent on climatic factors because the evaporation exceeds the hydraulic conductivity of sandy soils to a significant extent. An estimation of the surface water content can be derived by the comparison of the water content of the top layer (< 5 mm) and the evaporation [17].

4.1. Vegetation

Vegetative cover reduces the wind velocity at the soil surface and also generally decreases the soil erodibility. The relationship between vegetation coverage and wind erosion rate is an exponential function, with the increase of vegetation coverage the wind erosion rate decreases exponentially. The measurements of threshold velocity and wind erosion in wind tunnel tests under various vegetation conditions showed that the threshold velocity increases with vegetation coverage, and that wind erosion rate decreases sharply as vegetation coverage increases. Quantitative relationship between the crop residues and wind erosion were reported early by [3]. Several latter workers observed that crop residues and stubbles effectively reduce wind erosion. Amounts of wheat straw needed to protect most erodible dune sand and less erodible soils against strong winds were established [13].

5. Effects of Wind Erosion

The effects of wind erosion are soil deterioration, crop damage and pollution of adjacent areas (Figure 5). Soil deterioration includes the loss of fine material and organic matter, the degradation of soil structure and the loss or redistribution of fertilizers and herbicides [12]. Not only it affects agricultural lands but also quality of forest, pasture, and rangelands. Cropland soils are, however, more susceptible to erosion because these soils are often left bare or with little residue cover between the cropping seasons [10, 14].

Even during the growing season, row crops are susceptible to soil erosion. The primary on-site effects or erosion is the reduction of topsoil thickness, which results in the soil structural degradation, soil compaction, nutrient depletion, loss of soil organic matter, poor seedling emergence, and reduced crop yields.

Removal of the nutrient-rich topsoil reduces soil fertility and decreases crop yield. Soil erosion reduces of functional capacity of soil to produce crops, filter pollutants, and store C and nutrients. One may argue that, according to the low of conservation of matter, soil losses by erosion in one place are compensated by the gains at another place.

The off-site wind erosion preferentially removes the soil layers where most agricultural chemicals (e.g. nutrients, pesticides) are concentrated. Thus, off-site transport of sediment and chemicals causes pollution, sedimentation, and silting of water resources [10].

Figure 5. Wind erosion effects [24]

Sediment transported off-site alters the landscape characteristics, reduces wildlife habitat and causes economic loss. Erosion also decreases livestock production through reduction in animal weight and forage production, damages water reservoirs and protective shelterbelts and increases tree mortality.

Accumulation of eroded materials in alluvial plains causes flooding of downstream croplands and water reservoirs. Soil erosion also contributes to the projected global climate change.

Large amounts of C are rapidly oxidized during erosion, exacerbating the release of CO_2 and CH_4 to the atmosphere [10].

Wind erosion causes dust pollution, which alters the atmospheric radiation, reduces visibility and causes traffic accidents.

Dust particles penetrate into buildings, houses, gardens, and water reservoirs and deposit in fields, rivers, lakes, and wells, causing pollution and increasing maintenance costs.

Dust storms transport fine inorganic and organic materials, which are distributed across the wind path.

Most of the suspended particles are transported off-site and are deposited hundreds or even thousands of kilometers far from the source [10].

6. Conclusion

Wind erosion is one of the basic geological processes that shape and mold the landscape. Deep deposits of rich loess soil are evidence that wind erosion and deposition have played role in modifying the earth's surface. These loess soils are vital agricultural regions in modern agriculture.

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