International Journal of Multidisciplinary Research and Development
Online ISSN: 2349-4182 Print ISSN: 2349-5979
www.allsubjectjournal.com
Volume 3; Issue 5; May 2016; Page No. 184-187

Erosion results in the degradation of a soil's productivity

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Abstract
Several erosion processes are known, the most important being erosion by owing water (water erosion), wind (`wind erosion') and soil translocation by tillage (`tillage erosion'). All three damage the soil resource but only the first two additionally cause severe environmental problems because translocate soil leaves the arable area and enters neighboring ecosystems. Although water and wind erosion are different processes, they are governed by similar principles as far as land use is concerned. Soil surfaces destabilized by tillage and covered with little living or dead biomass are susceptible to erosive forces exerted by air or water. Erosion results in the degradation of a soil's productivity in a number of ways: it reduces the efficiency of plant nutrient use, damages seedlings, decreases plants' rooting depth, reduces the soil's water-holding capacity, decreases its permeability, increases runoff, and reduces its infiltration rate.

Keywords: Erosion processes, Erosion Control, Sheet erosion, Gully erosion,

Introduction
Soil erosion
Soil erosion is caused by the erosive forces of wind or water. In this publication, we focus our attention on concepts surrounding water-induced soil erosion. This type of erosion threatens our ability as humans to sustain our global population with food and fiber, and is closely linked to economic vitality, environmental quality, and human health concerns. Roughly 75 billion tons of fertile topsoil is lost worldwide from agricultural systems every year. In the United States, we lose an estimated 6.9 billion tons of soil each year (Pimentel, 2000) [14]. Losses at this scale are not sustainable and result in our increasing dependence on costly inputs such as fertilizers and soil amendments that we use in an attempt to make up for the beneficial qualities that were present in the lost topsoil (Pimentel, 2000) [14]. This article is review and the aim is erosion results in the degradation of a soil's productivity.

Erosion processes
Several erosion processes are known, the most important being erosion by owing water (water erosion), wind (`wind erosion') and soil translocation by tillage (`tillage erosion'). All three damage the soil resource but only the first two additionally cause severe environmental problems because translocate soil leaves the arable area and enters neighboring ecosystems. Although water and wind erosion are different processes, they are governed by similar principles as far as land use is concerned. Soil surfaces destabilized by tillage and covered with little living or dead biomass are susceptible to erosive forces exerted by air or water. Wind erosion is mainly a problem of coastal landscapes or large plains, while water erosion is of significance more widely. Furthermore, the amount of soil lost by water erosion far exceeds the amount lost by wind erosion in most cases (Heimlich & Bills 1986). Hence, in the following analysis we will concentrate on water erosion, although to some extent our analysis may also hold true for wind erosion due to both processes having similar agricultural impact. Soil erosion is highly variable in time and space, which makes it difficult to base an assessment on short-term measurements only, for example over several years or on small plots. To overcome this problem many soil erosion models have been developed and are accepted tools for studying soil erosion (Nearing *et al*. 1990) [13]. The Universal Soil Loss Equation (Renard *et al*. 1994; Wischmeier & Smith 1978) [17, 23] is one of the oldest models, which is still frequently used. It has a large experimental background, has been adapted to many areas in the world and is still among the best tools for long-term assessment of soil erosion by water (Nearing 1998) [12]. The model has been extensively customized over 20 years using data of about 1000 rainfall simulations and 500 plot years under natural rain (summarized in Schwertmann *et al*. 1987).

Soil's productivity
Erosion results in the degradation of a soil's productivity in a number of ways: it reduces the efficiency of plant nutrient use, damages seedlings, decreases plants' rooting depth, reduces the soil's water-holding capacity, decreases its permeability, increases runoff, and reduces its infiltration rate. The loss of nutrients alone resulting from soil erosion has an estimated cost to the United States of up to $20 billion a year (Troeh, Hobbs, and Donahue, 1991) [22]. The sediment deposited by erosive water as it slows can bury seedlings and cause the formation of surface crusts that impede seedling emergence, which will decrease the year's crop yields. The combined effects of soil degradation and poor plant growth often result in even greater erosion later on. All of these effects occur at or near the erosion site. Off-site impacts relate to the transport of sediment, nutrients, and agricultural chemicals and can be even more costly than on-site impacts. Severe economic and environmental costs are associated with the removal of sediment deposits from roads and from lakes and other surface water bodies. In the United States, more than 60 percent of water-eroded soils (about 2.4 billion tons of soil a year) end up in watercourses (Pimentel, 2000) [14]. This leads to the

sedimentation of dams, disruption of aquatic ecosystems, and contamination of drinking water supplies.

Measurement of Surface Erosion

Erosion can be physically measured by erosion plots and erosion stakes or pins. Erosion plots are the most widely used method and consist of rectangular plots of specific size where the amount of eroded soil is collected down slope of the plot during and following natural or simulated rain events. The boundaries of the plots consist of walls of sheet metal, plastic, plywood, or concrete. A collection trough and container are installed on the downslope side to capture the runoff and sediment. The standard plot size is 6 feet by 72.6 feet (approximately 2 m by 22 m) that was used in the development of the Universal Soil Loss Equation (USLE). The USLE was developed by the United States Department of Agriculture, Agriculture Research Service in 1965 as a means to predict erosion over a broad set of surface conditions and climates (Brooks *et al*. 2013) [2]. For more detail on the USLE Equation, see Schoonover and Crim (2015, this issue), "An Introduction to Soil Concepts and the Role of Soils in Watershed Management." Erosion can also be measured from microplots 1 to 2 m2 in size, which are commonly used in research studies.

Types of soil erosion

In general, soil erosion is a three-step process. It begins with the detachment of soil particles, continues with the transport of those particles, and ends with the deposition of soil particles in a new location. Bare soils (soils that lack a cover of living or dead plant biomass) are highly susceptible to erosion, even on flat land. There are three main types of water- induced soil erosion: sheet, rill, and gully. The most common yet most overlooked form of soil loss is sheet erosion.

Sheet erosion

Sheet erosion is the uniform removal of a thin film of soil from the land surface without the development of any recognizable water channels (Figure 1). This type of erosion is barely perceptible, but the loss of a single millimeter of soil depth from an acre of land, which can be easily lost during a single irrigation or rain event, works out to a total loss of up to 6.1 tons of soil (Pimentel, 2000) [14]. Rill erosion is easier to recognize. It is the removal of soil through the cutting of multiple small water channels (Figure 1). Rills are small enough to be smoothed by normal tillage operations and will not form again in the same location. Together, sheet and rill erosion account for most soil erosion in agricultural land (Brady and Weil, 1999) [1].

Fig: Sheet erosion

Gully erosion

Gully erosion occurs in areas where water runoff is concentrated, and as a result cuts deep channels into the land surface. Gullies are incised channels that are larger than rills (Figure 2). You can remove small, ephemeral gullies by tilling, but they will form again in the same location on the landscape. Gullies actually represent less soil loss than sheet or rill erosion, but they pose added management concerns such as damage to machinery, barriers to livestock and equipment, and increased labor costs to repair eroded areas.

Fig: Gully erosion

Development and Transfer of Soil Conservation Technologies

Soil is a vital resource for crop production (Troeh *et al*., 1999) [21]. and so its productive capacity should be maintained through use of appropriate technologies. Through research several land management technologies have been developed to combat effects of land degradation. These technologies include: use of legumes in crop rotation, mulching, terracing, biomass transfer, contour bunds, and agro-forestry (Keely, 2001) [8]. This study focuses on soil erosion control technologies because soil erosion is the major form of land degradation in Uganda. The technologies used by farmers around Mt. Elgon to control soil erosion are: contours, terraces,

Trenches, and agroforestry and Napier grass for stabilising contours and terraces. These technologies are further elaborated on in the paragraphs that follow. Contours are constructed across the slopes on cultivated land to reduce the erosive power of runoff flowing through the cultivated land. They reduce soil erosion by intercepting runoff and reducing its speed. In a study done in the United States by Ripley *et al*. (1961), it was reported that contours can reduce soil erosion on gentle slopes by 25 to 80%. Trenches are dug along the contours to stop runoff, improve water infiltration and moisture storage capacity (Halmiton, 1997) [6]. Grass (such as Napier) and multipurpose trees can be planted along the contours to slow down runoff and catch sediments that have been eroded upslope. Planting vegetation along the contours and terraces stabilises the soil conservation structures, while contributing to improved productivity and biodiversity such as fodder, fuel wood, fruits and poles for building (Mati, 2005) [10]. On sloping lands, terracing is necessary for reducing overland flow rates thereby contributing to water and nutrient conservation. Some of the common terracing technologies used by farmers in Uganda are *fanya juu* and bench terraces. Bench terraces are commonly made on steep slopes and they are labour intensive. For this reason, bench terraces are rarely excavated directly but instead they are developed over time from fanya juu terraces (Thomas, 1997) [19]. *Fanya juu* terraces are made by digging a drainage channel and throwing the soil upslope to make a ridge. Just like in the case of contours, grass and multipurpose trees can be planted on the ridges to help stabilise the ridges, prevent erosion and provide fodder and tree products (Thomas & Biamah, 1991) [20].

Topographic Influences on Erosion

Slope steepness and length are critical factors controlling overland flow and erosion (Bryan and Poesen 1989) [3]. As the slope increases, so does the probability that splashed soil will move downslope (Ellison 1944) [5]. In a laboratory experiment, Quansah (1981) [16]. found that detachment rates increased slightly, and sediment transport capacity increased greatly on steeper slopes. Steeper slopes also enhance erosion via rill development due to increased shear velocities (Chaplot and LeBissonnais 2000) [4]. On sloping land, there is usually net transport of soil downslope because displaced soil can travel further downhill than uphill due to gravity and slope angle. On a 10 percent slope, up to 75 percent of the splashed soil can move downhill (Ellison 1944) [5]. Huang *et al*. (1999) [7]. found that slopes < 5 percent resulted in net sediment deposition during simulated rain events in a laboratory experiment. On relatively flat surfaces, raindrop splash causes essentially no net soil loss because displaced particles are replaced by nearby soil particles that were displaced by raindrop impacts (Troeh *et al*. 1999) [21]. Long slopes generally result in high amounts of soil loss (Troeh *et al*. 1999; Brooks *et al*. 2013) [21, 2]. However, the effects of slope length are complicated by the processes of seal development, rill development, and deposition. All of these processes have varying effects on infiltration and runoff and can occur simultaneously (Bryan and Poesen 1989) [3].

Erosion Control

Erosion control can take many forms in many different activities. Mechanical, physical, and biological methods all can be used to reduce erosion and control sedimentation or locations of sediment deposition. Many of these methods are generally considered under the umbrella term of best management practices (BMPs), and they are used in agriculture, construction, forestry, mining, and other land uses in which erosion is a concern. BMPs are designed to reduce erosion at optimized cost, and they are based on physical principles that influence the energy of water and the erodibility of soil (Stuart and Edwards 2006) [18]. Managers are well aware of the benefits of vegetation for soil stabilization, so revegetating disturbed sites is a fairly common BMP (Troeh *et al*. 1999; Kochenderfer 1970) [21, 9]. The revegetation process often includes soil amelioration (ripping compacted soils, fertilization, liming, etc.) and seeding followed by mulching, but also can be as simple as casting seed (Kochenderfer 1970) [9]. Vegetative species selected for erosion control usually are prolific, fast growing plants with fibrous root systems that are able to rapidly cover bare soil and hold it in place (Troeh *et al*. 1999) [21].

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