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ON

**EFFECTIVE WATERSHED MANAGEMENT FOR
ENVIRONMENTAL HAZARD CONTROL/
MITIGATION IN NIGERIA**

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**APPLICATION OF GEOTEXTILES IN EROSION
CONTROL/MITIGATION**

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1.0 INTRODUCTION

While erosion is a natural process, human activities have increased by 10-40 times the rate at which erosion is occurring globally. Excessive (or accelerated) erosion causes both "on-site" and "off-site" problems. On-site impacts include decreases in agricultural productivity and (on natural landscapes) ecological collapse, both because of loss of the nutrient-rich upper soil layers. In some cases, the eventual end result is desertification. Off-site effects include sedimentation of waterways and eutrophication of water bodies, as well as sediment-related damage to roads and houses. It is most significant environmental problems world-wide (Blanco-Canqui et al., 2008), and (Toy, et al. 2002).

In earth science, erosion is the action of surface processes (such as water flow or wind) which remove soil and rock from one location on the earth's crust, then transport it to another location where it is deposited. Eroded sediments may be transported just a few millimetres, or for thousands of kilometres (Hallet, 1981). Typically, erosion proceeds fastest on steeply sloping surfaces, and rates may also be sensitive to some climatically- controlled properties including amounts of water supplied (e.g by rain), storminess, wind speed, wave fetch, or atmospheric temperature (especially for some ice- related processes).

Intensive agriculture, deforestation, roads, anthropogenic climate change and urban sprawl are amongst the most significant human activities in regard to their effect on stimulating erosion (Sklar, et al. 2004)

1.1 TYPES OF EROSION

i. Rainfall and surface runoff: Rainfall, and the surface runoff which may result from rainfall, produces four main types of soil erosion: They are (Zachar, 1982).

- ❖ **Splash Erosion:** The impact of a falling raindrop creates a small crater in the soil ejecting soil particles. The distance these soil particles travel can be as much as 0.6m

(two feet) vertically and 1.5m (five feet) horizontally on level ground.

- ❖ **Sheet Erosion:** This is the transport of loosened soil particles by overland flow. If the saturated, or if the rainfall rate is greater than the rate at which water can infiltrate into the soil, surface runoff occurs. If the runoff has sufficient flow energy, it will transport loosened soil particles (sediment) down the slope. (Jhreschkow, 2011).

- ❖ **Rill Erosion :** This refers to the development of small, ephemeral concentrated flow paths which function as both sediment source and sediment delivery systems for erosion on hillslopes. Generally, where water erosion rates on disturbed upland areas are greatest, rills are active. Flow depths in rills are typically of the order of a few centimetres (about an inch) or less and along-channel slopes may be quite steep. This means that rills exhibit hydraulic physics very different from water flowing through the deeper, wider channels of streams and rivers (Nearing et al., 1997).

- ❖ **Gully Erosion:** This occurs when runoff water accumulates and rapidly flows in narrow channels during or immediately after heavy rains or melting snow, removing soil to a considerable depth (Boardman et al, 2007, Poesenet al. 2002 and Borah et al. 2008).

ii: Rivers and Streams: This includes;

- **Valley or Stream Erosion:** This occurs with continued water flow along a linear feature. The erosion is both downward, deepening the valley, and head ward, extending the valley into the hillside, creating head cuts and steep banks. In the earliest stage of stream erosion, the erosive activity is dominantly vertical, the valleys have a typical V cross- section and the stream gradient is relatively steep. When some base level is reached, the erosive activity switches to lateral erosion, which widens the valley floor and creates a narrow flood plain (Ritter, 2006).

➤ **Bank Erosion:** Bank erosion is the result of melting away of the banks of a stream or river. This is distinguished from changes on the bed of the watercourse, which is referred to as scour. Erosion and changes in the form of river bank may be measured by inserting metal rods into the bank and marking the position of the bank surface along the rods at different times (Nancy, 2004).

➤ **Thermal Erosion:** This is the result of melting and weakening permafrost due to moving water. It can occur both along rivers and at the coast. Rapid river channel migration observed in the Lena River of Siberia, is due to thermal erosion, as these portions of the banks are composed of permafrost-cemented. (Costard, et al 2003 and Jone, et al).

iii Coastal Erosion: Shore line erosion, which occurs on both exposed and sheltered coast, primarily occurs through the action of currents and waves but sea level (tidal) change can also play a role (Glynn, 1997).

iv Chemical Erosion: Chemical erosion is the loss of matter in a landscape in the form of solutes. Chemical erosion is usually calculated from the solutes found in streams. Anders Rapp pioneered the study of chemical erosion in his work (Dixon et al., 2005).

v Glaciers: Glaciers erode predominantly by three different processes: abrasion/scouring, plucking, and ice thrusting. In an abrasion process, debris in the basal ice scrapes along the bed, polishing and gouging the underlying rocks, similar to sandpaper on wood. Glaciers can also cause pieces of bedrock to crack off in the process of plucking. In ice thrusting, the glacier freezes to its bed, then as it surges forward, it moves large sheets of frozen sediment at the base along with the glacier (Stuart, et al. 2010).

vi Floods: At extremely high flows, kolks, or vortices are formed by large volumes of rapidly

rusting water. Kolks cause extreme local erosion, plucking bedrock and creating pothole-type geographical features called Rock-cut basins. Examples can be seen in the flood regions result from glacial Lake Missoula, which created the channelled scablands in the Columbia Basin region of eastern Washington (Mitchell and Montgomery 2006).

vii Wind Erosion: Wind erosion is a major geomorphological force, especially in arid and semi-arid regions. It is also a major source of land degradation, evaporation, desertification, harmful airborne dust, and crop damage—especially after being increased far above natural rates by human activities such as deforestation, urbanization, and agriculture (Zheng et al. 2009 and Cornelis 2006)

viii Mass Movement: Mass movement is the downward and outward movement of rock and sediments on a sloped surface, mainly due to the force of gravity (Van Beek, 2008 and Gray et al., 1996). Mass movement is an important part of the erosional process, and is often the first stage in the breakdown and transport of weathered materials in mountainous areas. (Nicholas, 2009)

2.0: GEOTEXTILES

Textiles were first applied to roadways in the days of the pharaohs. Even they struggled with unstable soils which rutted or washed away. They found that natural fibres, fabrics or vegetation improved road quality when mixed with solids, particularly unstable soils. Only recently, however, have textiles been used and evaluated for modern road construction for prevention of erosion. In 1920's the state of South Carolina used a cotton textile to reinforce the underlying materials on a road with poor quality soils. Evaluation several years later found the textile in good workable condition. They continued their work in the area of reinforcement and subsequently concluded that combining cotton and asphalt materials during construction reduced cracking/ ravelling, and failure of road. When synthetic fibres became more available in the 1960's, textile were

considered more seriously for roadway construction and maintenance (Koerner, 2012).

Geotextile is any permeable textile material used with foundation, soil, rock, earth, etc. that is an integral part of a constructed project, structure or system. It is made of synthetic or natural fibres. Geotextiles are also technical textiles, designed for use in association with soil and for various civil engineering purposes serving the need for separation, filtration, reinforcement, protection or drainage (Barrett, 1966). In contrast, a geomembrane is a continuous membrane type liner or barrier. It must have sufficiently low permeability to control migration of fluid in a constructed project, structure or system. (Madison, 2003)

2.1: Geotextile Materials

Geotextile materials are fabrics formed into mats, webs, nets (geonets), grids (geogrids), or formed plastic sheets, geotube, meshes. This can be in the form of geomatrix and geosynthetic.

Geomatrix is a composite of geotextile and geotextile related materials which may be used in a variety of applications including: reinforcement of base materials, erosion or subsurface drainage control.

Geosynthetic is a fabric manufactured from synthetic fibres used in conjunction with foundation soil, rock, or earth on any constructed project, structure or system.

Modern geotextiles are usually made from synthetic polymers such as polypropylenes, polyesters, polyethylenes and polyamides. They do not decay under biological and chemical processes. This makes them useful in road construction and maintenance. Geotextiles can also be made of natural fibres such as raffia vinifera (dried raffia palm frond) and coir (coco nut fibre), but the synthetic materials are most commonly used.

2.2 Types of Geotextile

There are two types of geotextiles.

i The woven Geotextile: The woven geotextile looks like burlap, is a sheet made of two sets of parallel strands systematically interlaced to form a thin, flat fabric. The strands may be slit film which are flat, or monofilaments which are round. The ways these two sets of yarns are interlaced determine the weave pattern of the fabric which in turn determines the best application for that woven fabric. Woven fabric has the following advantages:

- High strength
- UV Resistant
- Rot Resistant
- Resists Biological Degradation
- Chemically inert
- Increases the life of roads.

ii Non-woven Fabric: Non-woven fabric looks like felt fabric, is an arrangement of fibres either oriented or randomly patterned in a sheet. These fabrics can be manufactured in a variety of ways, bonding fibres together using chemical, thermal or mechanical processes. The bonding methods do not significantly change the function of the fabric. Non-woven geotextile fabric has a lower tensile strength than woven geotextiles, and is more likely to stretch. It has the ability to let water flow laterally within itself. Non-woven geotextile is ideal for use with roads, roofs, rail, roads, ponds, dams, trenches and landfills. Advantages of non-woven fabric:

- 100% propylene staple fibres
- Needle-punched shape
- UV Resistant
- Rot Resistant
- Biological Degradation Resistant. (Renfrew, et al. 2004)



Fig.1: Woven and Non-woven Geotextiles

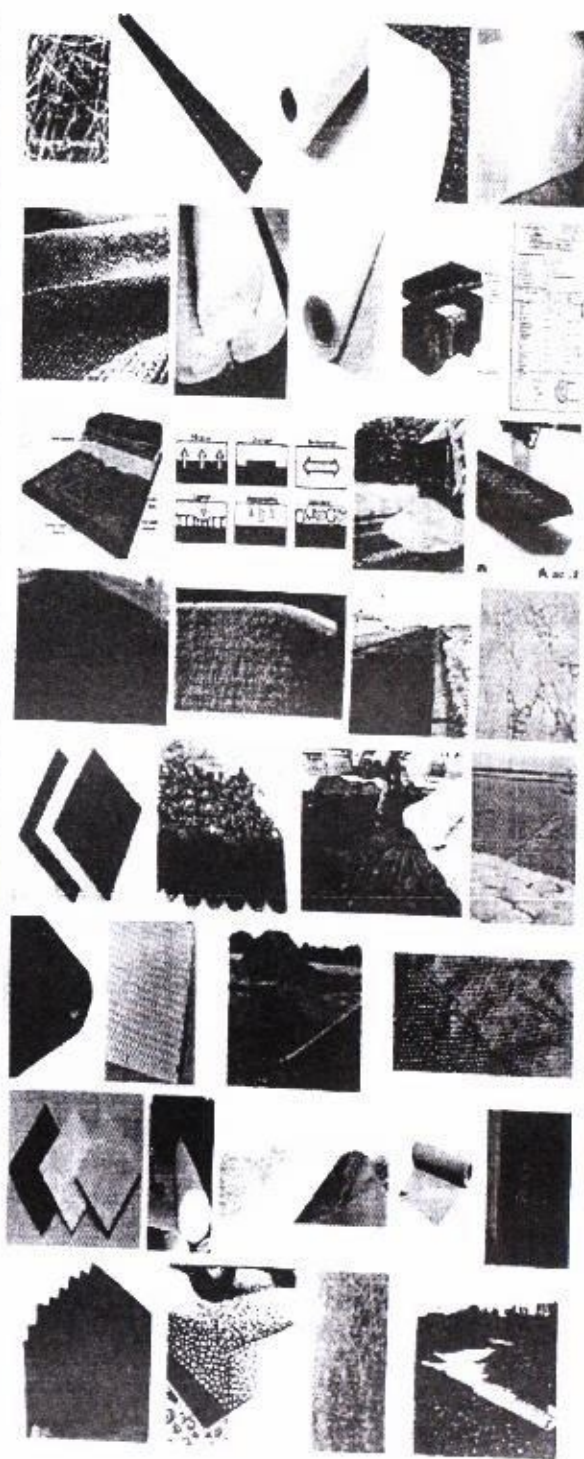


Fig.2: Woven and Non-woven Geotextiles

3.0 APPLICATIONS OF GEOTEXTILES IN EROSION CONTROL

Geotextiles can help to mitigate the negative impact of soil erosion. Wind and water erosion can be absolutely devastating to property. Sometimes the erosion happens very quickly and catastrophically due to a major storm event such as a hurricane or tropical storm. More often it develops slowly as the ocean's tide, the current of a river, or years of storm water runoff work with time to eat away at land and property with similarly devastating results. The choice comes down to controlling the soil erosion before it takes place or dealing with the aftermath (Koerner, 2012). Geotextiles are used for sand dune armouring to protect upland coastal property from storm surge, wave action and flooding. A large sand-filled container (SFC) within the dune system prevents storm erosion from proceeding beyond the SFC. Using a sloped unit rather than a single tube eliminates damaging scour.

Geotextile sand-filled units provide a "soft" armouring solution for upland property protection. Geotextiles are used as matting to stabilize flow in stream channels and swales (Madison, 2010). Geotextiles can improve soil strength at a lower cost than conventional soil nailing. In addition, geotextiles allow planting on steep slopes, further securing the slope. Coir (coconut fibre) geotextiles are popular for erosion control, slope stabilization and bioengineering, due to the fabric's substantial mechanical strength (Richard, et al. 2006). Coir geotextiles can last 3 to 5 years depending on the fabric weight. The product degrades into humus, enriching the soil. There are four primary applications of geotextiles in erosion control.

i. separation: In separation application, inserting a properly designed geotextile will

keep layers of different sized particles separate from one another. The aim is to prevent the mixing of two materials such as a soft sub grade with a clean base aggregate.

ii. Drainage : Water is allowed to pass either downward through the geotextile into the subsoil, or laterally within the geotextile which functions as a drain. How it is used depends on the drainage requirements of the application. The amount of drainage is proportional to the thickness of the fabric.

iii. Filtration: The fabric allows water to move through the soil while restricting the movement of soil particles.

iv Reinforcement: The geotextile can actually strengthen the earth or it can increase apparent soil support. For example, when placed on sand it distributes the load evenly to reduce rutting.

The four applications of geotextiles are shown below:

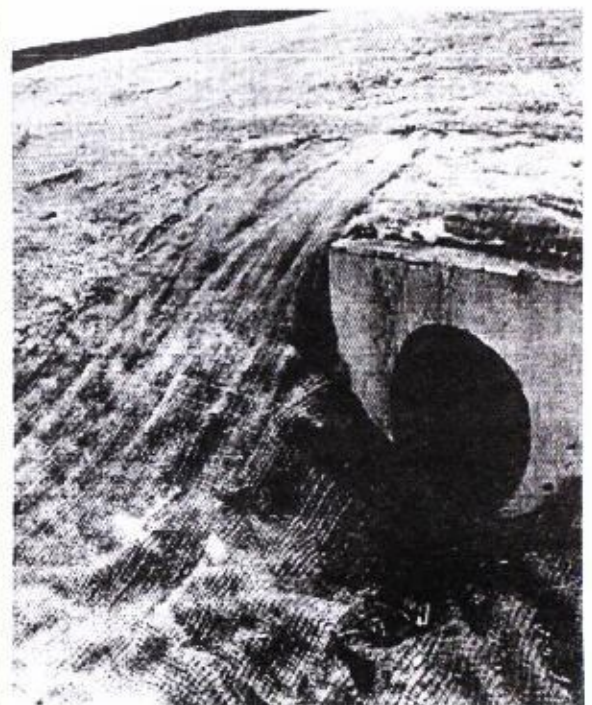




Fig. 3: Separation and Drainage Applications of Geotextile.

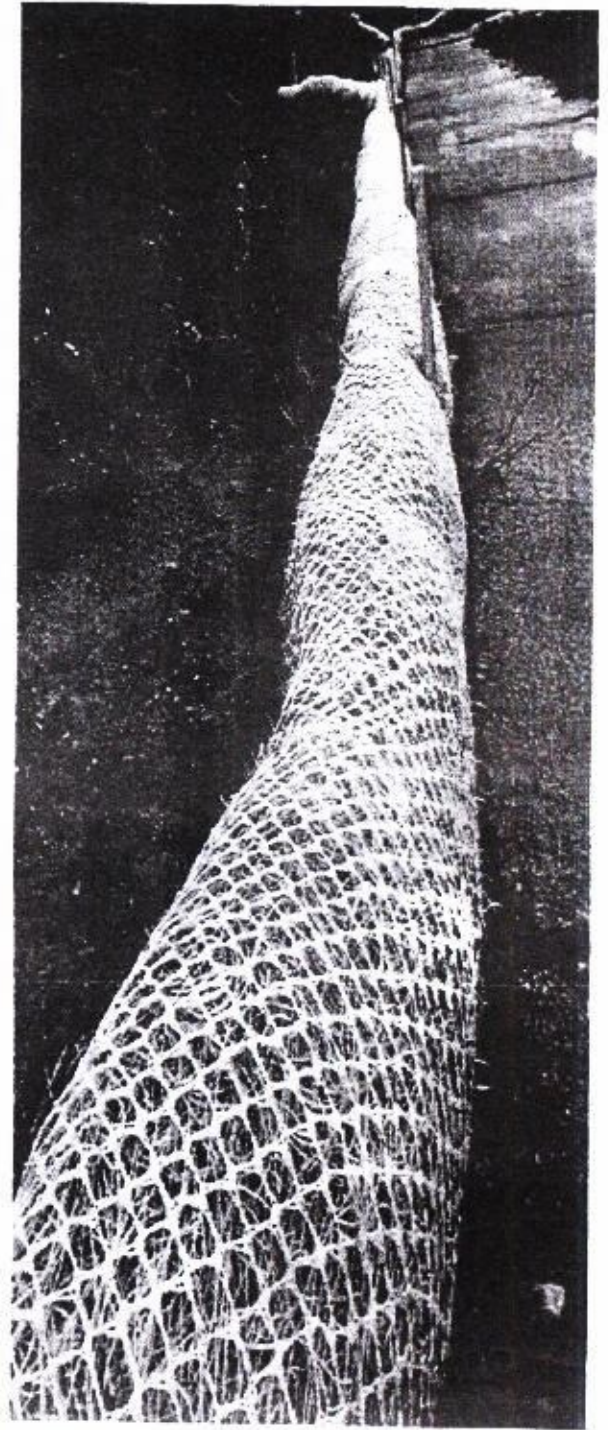


Fig. 4: Filtration Application of Geotextile

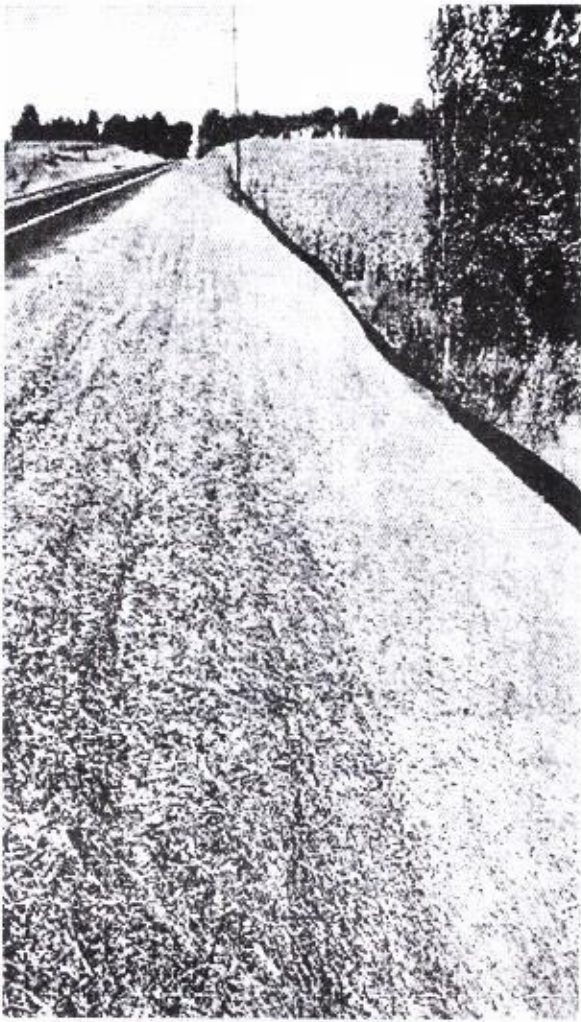


Fig: 5: Reinforcing Application of Geotextile

Geotextiles now are most widely used for stabilizing road through separation and drainage. When the native soil beneath a road is very silty or constantly wet and mucky, for example, its natural strength may be too low to support common traffic loads, and it has a tendency to shift under those loads. Although the subgrade may be reinforced with a base course of gravel, water moving upward carries soil fine or silt particles into the gravel, reducing its strength. Geotextiles keep the layers of subgrade and base materials separate and manage water movement through or off the roadbed.

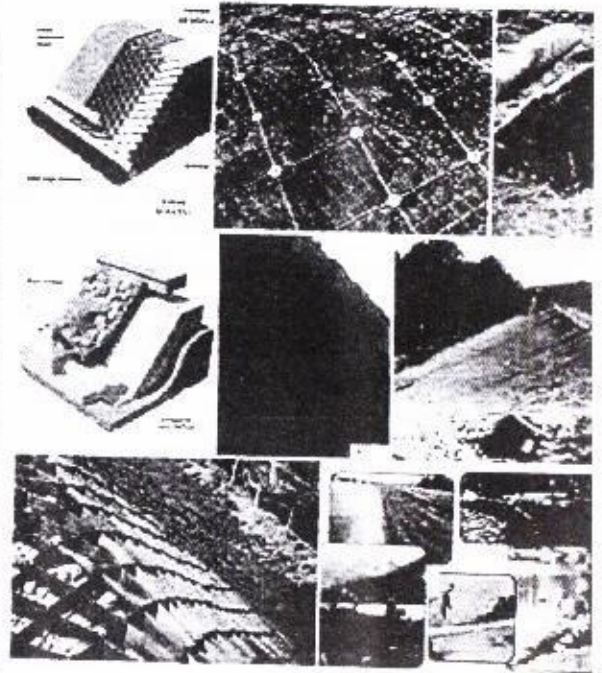


Fig.6: Erosion control on steeply sloping surfaces

CONCLUSION

Geotextiles can be used in many ways for erosion control. Geotextile recommended for erosion control should have permeability, resistance to abrasion, and high resistance to ultraviolet rays as primary consideration. Erosion control cover a variety of conditions from high velocity stream flow to heavy wave action, to less severe conditions. The Properties of soil must be known and the conditions that will face the geotextile.

In many installations, resistance to bursting, puncturing and tearing should be considered. In Other installations, such as a separator where the geotextile will be subjected to severe loads, durability is of concern. Permeability should also always be considered in separation uses to allow moisture to move freely through the system. This avoids excessive hydrostatic pressures which cause soil failure.

Most geotextile system failures result from improper installation, improper selection of fabrics, a change of conditions from the original design, or a combination of these factors.

Many countries have successively used geotextiles for erosion control. Here, too we should carefully determine the type and frequency of usage for our roads since heavy, high speed traffic could cause premature failure of the system.

REFERENCES

- Barrett, R.J. (1996). Use of plastic Fillers in coastal Structures, International Conference Engineers, Toyota, 1048-1067.
- Blanco-Canqui, H., and Rattan, L. (2008). Soil and water conservation, Principles of Soil conservation and Management, Dordrecht- Springer, 55-80.
- Boardman, J. and Poesen, J. (2007). Soil Erosion, Chichester, John Wiley & Sons ISBN 978047085911.
- Borah, Deva K. et al. (2008). Watershed sediment yield, In Garcia, Marcelo H. Sedimentation Engineering ASCE publishing, 828.
- Boston, M. (2003). Massachusetts Erosion and Sediment Control, Environmental Protection, 73-74.
- Cornelis, W. (2006). Hydroclimatology of wind erosion in arid and semi-arid environments, Dryland Ecohydrology, Springer, 141.
- Costard, F., Dupeyrat, L., Gautier, e. and Carey, E. (2003). Fluvial thermal erosion investigations along a rapidly eroding river bank, Earth Surface processes and Landforms 28(12).
- Dixon, J. Thorn, C. and Colin, E. (2005). Chemical weathering and landscape development, Geomorphology, 67, 127-145.
- Food and Agricultural Organization (1965). Types of Erosion Damage, Soil Erosion by water United Nations, 23-25.

- Glynn, P.(1997).Bioerosion and Coral-reef growth: a dynamic balance, Life and of coral reef, 68-95.
- Gray, D. and Sotir, R. (1996).Surficial erosion and mass movement, Biotechnical and soil Bioengineering Slope Stabilization, A Practical Guide for Erosion Control,20.
- Hallet, B. (1981).Glacial abrasion and sliding: Their dependence on the debris concentration in basal ice, Annals of Glaciology, 23-28.
- Jones, B.Hinkel, K. and Eisner, W.(2008).Modern Erosion Rates and Loss of Coastal Features and Sites,Alaska. ARCTIC, 61, 4,,361-372.
- Julien, p. (2010). Erosion and Sedimentation, Cambridge University Press, 1
- Koerne R. (2012).Gesigning with Geosynthetic, 6th Edition, Xlibris Publishing, Co.,914.
- Madison, W.(2007).Dane Country Erosion Control and storm water Management Manual Report.
- Nancy,D.(2004). Erosion and Scour. Stream hydrology: an introduction for ecologists,4.
- Nearing, M.Norton, L., Bulgakov, D.Larinov, G.and Dontsova, K. M. (1997) Hydraulics and erosion in eroding rills, Water Resources research, 33, 865-876.
- Nichol, G.(2009). Sedimentology and Stratigraphy. John Willy & Sons.
- Obreschkow (2011).Confined Shocks inside Isolated Liquid- A New Path of Erosion.
- Poesen, J., Vandekerkhove, J.Nachtergaele, d., Ostwoud, W. and Wesemael (2002). Gully erosion in dry land environments. Dryland Rivers: Hydrology and Geomorphology of Semi Arid Channel, 229-262.
- Richards, D. (2006). Coir is sustainable alternative to peat moss in the garden. Garden Hints.,6.
- Ritter, M.(2006).Geologic Work of Stream, The Physical Environment,4.
- Sklar, L. abd William(2004).A mechanistic model for river incision into bedrock by salting bed load. Water Resource Research, 40,Stuart, N. Thomas, Mark, T.Jonathan, H. and Peter W. (2010)., Glaciation as a destructive and constructive control on mountain building, Nature467,313..
- Toy, T.Forest, G., Forster,George,R. and Rechar, K. Soil Erosion (2001).Soil erosion: processes, prediction .New York.
- Zachar, D.(1982), Soil Erosion Elsevie,48.
- Staurt N., Mark, T.Jonathan H. and J. Nelson(2010).Glaciation as a destructive and Constructive contro on mountain building. Nature,7313.
- Van,B.(2008).Hillside processes:mass wasting, slope stabilityand erosion control, In Norris. Springer.6675-7.
- Zheng and Huang, N.(2009).Mechanism of wind Blown Sand Movements, Springer, 7-8.

