Types of water erosion

N. Evelpidou & A. Vassilopoulos

Faculty of Geology and Geoenvironment, University of Athens, Panepistimiopolis, 157 84, Athens, Greece, evelpidou@geol.uoa.gr

Geoenvironmental Institute, Flias 13, Maroussi, 151 25, Athens, Greece, vassilopoulos@geoenvi.org

Types of Erosion

Many natural phenomena cause physical erosion, which generates the transportation of the weathered elements or material of the earth surface. Erosion is the after effect of the chemical and physical weathering processes and has an interferes with the cohesion of the ground formations, leading to the formation of the weathering mantle. Erosion processes also influence human activities by causing socioeconomic, ecological, industrial and structural land use problems. The procreators that generate erosion may be discerned to natural and human.

Natural Factors causing erosion:

- Morphology
- Marine Processes
- Tectonic Features
- Climate
- Natural Disasters (e.g. fires)

Human Factors causing erosion:

- Agriculture
- Land Abandonment
- Deforestation
- Population Increase
- Urbanisation
- Tourism
- Existing Policy

Erosion is caused mainly by water and then by wind processes and human activity. Spatial dissimilarities in erosion products across different areas are due to climate, topography, hydrogeology and soil/rock characteristics. Erosion processes take place frequently at the upper soil and surface layers. The most

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common classification of erosion processes is related to the procreator factor and is the one listed below:

- Water Erosion
- Disturbance or Translocation Erosion
- Wind Erosion
- Coastal Erosion
- Landslides and Debris Flows
- Internal Erosion (provoked by groundwater flows)

The most important are wind and water erosion.

***Figure 1**: Coastal environment with both water and wind erosion present*

Water Erosion

Water erosion is best studied within the spatial context of a watershed. A small and simple watershed is composed of overland flow areas contiguous to single channel, while a large watershed comprises of smaller watersheds connected by a concentrated flow network.

The most important types of water erosion are caused by:

- Rainfall,
- Surface runoff from rainfall, and
- Surface runoff by irrigation

***Figure 2**: Raindrop impact and surface runoff from rainfall*

Among these, water flow and its course, that defines overland flow, is the most important factor to the study of water erosion. Water flows in two types of conduits; open channels and pipes. Pipe flow fills the conduit with water that flows under hydraulic pressure and takes place through the soil macropores in saturated soil. On the other hand, an open channel has a free-water surface open to atmospheric pressure, and takes place in rills, gullies and stream channels.

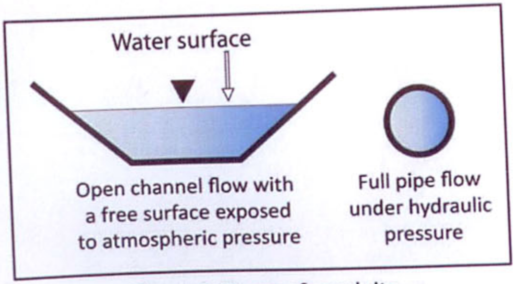

Figure 3: Types of conduits

The classification of subtypes of water erosion is based on spatial context and topographic position within a watershed, ranging in size from few square kilometers to thousands of square kilometers. The main factors affecting water erosion are described as follows.

Raindrop impact

The process known as '*Rainsplash*' is caused by the impact of raindrops hitting the bare soils that generates a shock wave, detaching particles of soil or small aggregates and dispersing them in all directions. The impact becomes more effective with the increase of rainfall intensity. For the largest drops, the final velocity may approach 10 m/s.

Figure 4: *The raindrop shockwave*

Flow traction

After *rainsplash*, the weathered material is transported by a small amount of overland water flow. This process is also known as '*Rainflow*'.

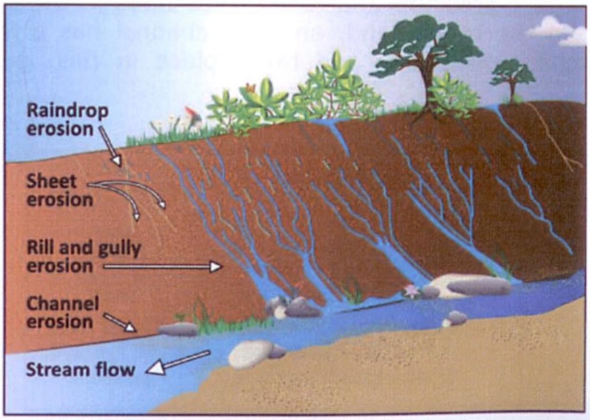

Figure 5: Types of water induced erosion

Combination of the aforementioned

The combination of *rainsplash* and *rainflow* is responsible for the creation of drainage systems which is the most important erosion factor in most landscapes across the earth. *Rainsplash* and *rainflow* processes are most significant in areas between small channels or rills, which are formed on a quickly eroding surface and are commonly grouped together as *inter-rill* erosion processes.

Runoff

The water that does not infiltrate, flows on the surface through streams, rivers or rainflow. As water flows on the surface, transports soil or land material along with it. The size of the material that is transported is relative to the slope and the speed of the flowing water.

The main water erosion types are:

- Sheet erosion,
- Interrill areas erosion,
- Rill areas erosion,
- Ephemeral gully erosion,
- Permanent, Incised gully erosion and
- Stream channel erosion.

Sheet erosion

Sheet erosion is defined as the even removal of soil from the surface and is the first phase of the erosion process with low erosion rates. When erosion becomes gradually more intense, rill erosion begins, which progresses to gully erosion, producing deeply carved channels. Interrill erosion is considered as sheet erosion as it is uniform over the interrill area.

***Figure 6**: Sheet erosion*

Rills

Surface runoff is consolidated in numerous small streams of water, which are known as rill areas. Rill erosion is the erosion caused by flow that occurs in these areas. When flow is adequately intense, it entrains the soil particles directly, forming small channels or rills on the surface and erodes material by '*rillflow*', which is concentrated along these drainage lines.

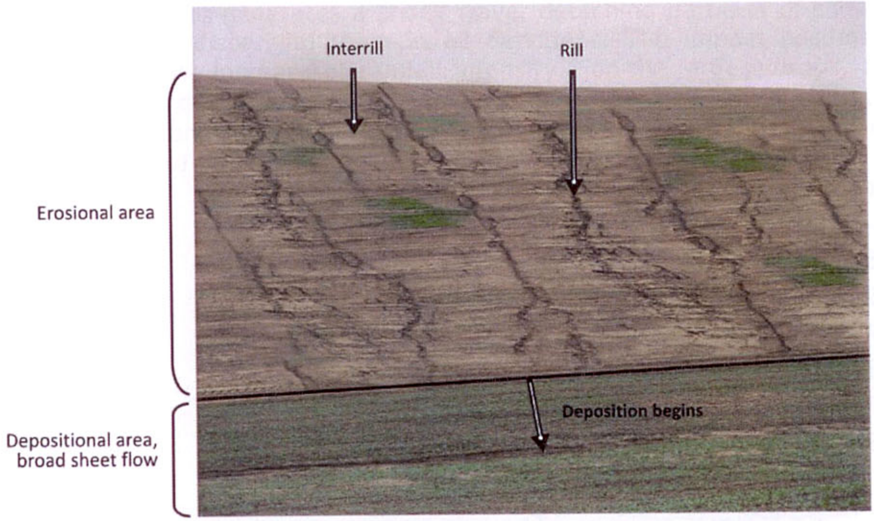

Figure 7: Erosional and depositional areas on hillslope.

The original pattern of the rivulets developed by tillage may evolve into network of rills and small channels. The location and pattern are studied by the microtopography of the soil surface on the hillslope. In theory, rills are channels that are so small that they may be eliminated by tillage. After elimination, rills have a tendency to be formed in new places. Surface runoff also takes place in rivulets on uncultivated hillslopes even if well-defined carved rills do not shape. Frequently, the pattern of surface flow is designated by plant stems and roots, debris, rocks and local depositions creating a not smooth surface, leading runoff to concentrate into small channels among the obstructions.

Interrills

Interrill areas exist between rills and the erosion that takes place on these areas is called interrill erosion. When rainfall intensity goes above the infiltration capacity of the soil on a certain area, surface runoff is developed.

The rill and interrill areas comprise the overland-flow areas of the surface and interrill in addition to rill erosion is the total water erosion that occurs on the overland flow areas of the landscape. The slope lengths of interrill areas are often short, less than one meter. Interrill areas are defined by the fact that all occurring detachment on them is caused by raindrop impact, while in rill areas it is due to surface runoff.

Gullies

When the rainfall is very heavy, and the slopes are, at least locally, steep, erosion may cause a greater opening, forming gullies of significance depth (>1.5 m) and width. If a new intensive rainfall occurs, the pre-existing gullies are going to become flowing streams and the water, charged with soil material is going to form a debris flow that builds up a high kinetic energy able to generate intense erosion and damages across the gully.

***Figure 8**: Gully at Somogy County, Hungary*

1. Ephemeral gully erosion

Ephemeral gullies are usually developed within areas of the size of a field, where farming and related land-disturbing actions take place. Ephemeral gully erosion is a feature unique to cultivated fields. Flow in concentrated-flow areas erodes rapidly the surface soil layer and reaches the resistant soil beneath. Erosion widens rather than deepens the channel.

The quantity of sediment produced by this type of erosion equals the quantity of sediment produced by interrill and rill erosion in the same field. In farm fields, ephemeral gullies are crossed as a part of routine farming operations and are filled routinely by tillage operations, which remove soil from the overland-flow areas adjacent to these channels.

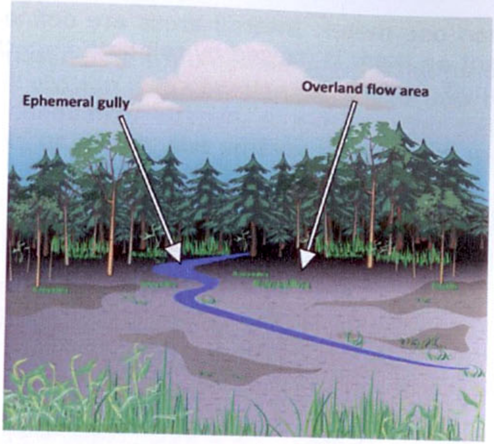

***Figure 9**: Blending of ephemeral gully areas with overland flow areas*

The macrotopography of the surface characterised by ephemeral gullies, is responsible for theirreformation in the same location after refilling by farming operations. Through time, gullies gradually become blended with the hillslopes rather than remaining incised with vertical sidewalls. This periodic refilling and reformation by erosion is the reason they have been named *ephemeral gullies*.

When soil is loosened because of tillage, the remaining soil layer in the ephemeral gully area is much more erodible than the untilled soil directly underneath the tilled zone. Water flow rapidly erodes the ephemeral gully to the depth of the non erodible, untilled layer, and then it erodes the side-walls of the gully, creating a wide, shallow channel with a high width-to-depth ratio.

2. Permanent, incised gully erosion

Erosion in permanent, incised gullies is episodic, varying from year to year. Permanent gullies normally are incised channels that are wide and deep relative to the flow in them. Permanent, incised gullies commonly are recent in age and are developed in just a few years. They also appear on natural but also on disturbed areas, which are defined as channels that are too deep to cross or to fill with normal farming activities. The progress of a gully into a field causes serious damages and gives high sediment loads.

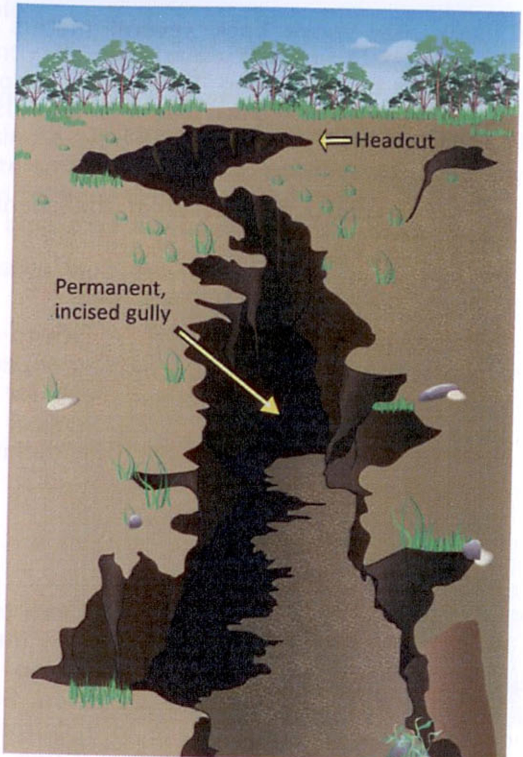

***Figure 10**: Permanent, incised gully in an agricultural field*

Stream channel erosion

Stream channels are an important part of the landscape when developed in the absence of human activities. However, human activities on upland areas and within channels may be of great significance to the stream-channel erosion. Channel features, along with grade and meander form, are the midstream modulating the flow and sediment load delivered to the channels from the upland areas. Thus, any changes in land use modifying runoff and sediment delivery may produce changes in the stream channels, which may be changing constantly by nature, but the change in stable stream channels can be almost imperceptibly slow.

On the other hand, unexpected changes in land use, like forestry to urban use or forestry to intensive agriculture, may increase upland runoff considerably and destabilize stream channels starting channel erosion, through widening of the channels, forming of headcuts that migrate upstream rapidly, producing large sediment loads and degrading the stream quality critically. The most energetic locations of stream-channel erosion generally occur on the outside of meander bends, where channel bank may move back several meters during intense storms.

Finally, some measurements for controlling channel erosion may be:

- the decrease of runoff rates with impoundments,
- the construction of enlarged channel cross sections,
- the installation of grade-control structures in the channel, addition to bank protection and,
- the placement of in-stream vanes to divert flow away from channel banks.

One simple way to calculate channel shape, is the width-to-depth ratio. For example, for a narrow channel the width-to-depth ratio is expected to be small (e.g., 1:1), while for a wide channel it exceeds 10:1 and for sheet flow it is countless. The drainage channels development is the physical evolution of the landscape. Areas between channels and the watersheds outline the channel's drainage basin.

Snowmelt erosion

Snow may be another significant erosion factor. In northern parts of the Earth where snowfall is dense, during early spring when the snow melts, the resulted erosion is intense. In these areas, the frozen soils during winter constrain infiltration increasing surface runoff and consequent erosion. Surface conditions may differ from an ice and snow-covered surface to a defrosted surface with frozen subsoil. The impregnate soil shows low shearing force and high erodibility, while high losses may occur when snow melts or when rain falls on partly frozen ground with thawed topsoil. In cases of heavy rainfall, the result will be rill and gully formations.

Erosion by overland flow resulting from snowmelt depends on a particular combination of factors. If snowmelt runoff starts when the soil is thawing, erosion may be considerable. If there is rainfall on thawing soil, it will cause very high rates of rill erosion, because the soil is highly erodibleand the rainfall although low, is steady producing very low runoff rates.

Bank erosion in rivers and lakes

This extreme type of erosion occurs only in constrained places, specifically, in river valleys and along lake shores. After an intense rainfall the volume of water increases, causing consequentlythe raise of the water level in the drainage channel and the increase of the speed flow, resulting to the fast undercutting of the banks, the collapse of the upper part of the bank soil and the change of the river's path. Thus, bank erosion may be stronger by quick runoff after an intense rainfall.

Erosion by piping

Water frequently flows through the soil just below the surface, which may contain macropores, other small openings and channels left by decaying roots, burrowing insects and animals, which may become pipes, and pipe flow may erode soil, causing a type of erosion known as piping. Initially, the diameter of the pipes is quite small, namely few millimetres, but when erosion occurs, they may be enlarged to diameters up to one meter. When a pipe is near the surface, the roof of the pipe may fall down, leaving an open rill or permanent, incised gully.

***Figure 11**: Erosion from simple pipe diversion*

Disturbance or Displacement Erosion

Tillage erosion

Plowing, either tansverse to hillslope or along the contours is responsible for a type of erosion known as tillage erosion. During plowing, soil transport occurs in both cases, but plowing transverse to contours causes 1,000 times bigger soil transport. The main factors that affect tillage erosion are the morphological slope change, the management scheme and the tillage type.

Land levelling

The mechanical soil removal in order to alter the surface slope for agriculture, using bulldozers causes this type of erosion.

Soil lack due to harvest

Moreover, during mechanical and manually harvest, soil removal takes place causing erosion.

Erosion due to animal living

The animals' hoofs may destroy vegetation when grazing by the pressure applied on surface, leaving a nude pedologic surface, susceptible to water erosion.

Erosion by irrigation

When irrigation water is applied to the land by overhead sprinklers, or subsurface emitters erosion is not a problem. When irrigation water is applied with surface-applied systems erosion may be important, because surface water is introduced at the head of furrows to flow down the field and infiltrate into the soil. This irrigation system produces large erosion rates, especially at the upper ends of the furrows, where erosion rate may be four times the average erosion rate for the field.

Overland and concentrated flow areas on a landscape

Sediment yield is the measure of average net erosion for the watershed and is calculated as the sum of the sediment produced by all erosional sources (counting that from overland flow, ephemeral gully, permanent, incised gully and stream channel areas) less the amount of sediment deposited on these areas and on the valley floodplains.

Erosional and depositional areas on a hillslope

Erosional and depositional areas may be recognised for hillslopes with concave segments on which deposition takes place. Soil loss, which defines net erosion, takes place on the upslope part, whereas net deposition takes place on the downslope part of the hillslope. The amount of sediment that is lost from the depositional section of a hillslope is less than the soil loss from the erosional section. The erosional area is the entire length of consistent and convex-shaped hillslopes, and the quantity of sediment leaving these hillslopes equals the soil loss. Moreover, on hillslopes with only slight concavity, net deposition does not take place and the amount of sediment leaving the hillslope also equals the soil loss.

Hillslope shape does not induce deposition, but dense vegetation and other barriers that slow runoff dramatically, may induce deposition on any slope shape.

Figure 12: *Cases where deposition on slope change may be induced*

The rainfall amounts, as well as slope degree, control the erosion rates. As a consequence of the slope degree effect, for rainfall less than 20 mm, the runoff and sediment transportation in the gentle slope is higher, but for rainfalls above 20 mm, it is the steeper slope which has greater sediment transportation.

Erosion is maximum at the rill-interrill boundaries. The sediment concentration/ precipitation relationship may be drawn as an envelope curve demonstrating that any rainfall event of a given amount and intensity, has a maximum runoff sediment concentration limit, which is interpreted to be a function of the runoff sediment transport capacity, depending mainly on the slope steepness.

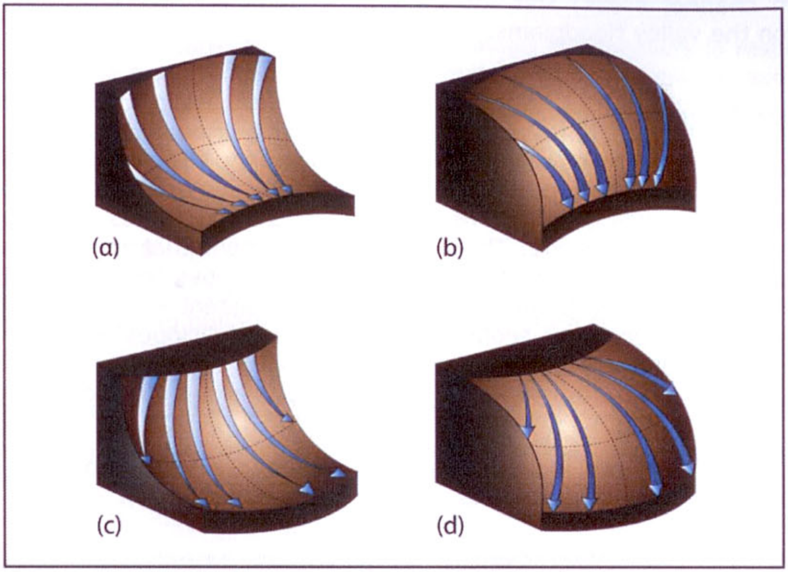

***Figure 13**: The influence of curvatures and geometric forms of relief on mass flows: (a) concave-concave form, (b) convex-concave form, (c) concave-convex form, (d) convex-convex form.*