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WATERSHED MANAGEMENT BETTAHALASURU USING GIS AND REMOTE SENSING

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Abstract:

Satellite remote sensing data with geographic information system has a pragmatic approach to map and generate spatial input layers of predicting response behavior and yield of watershed. Hence, in the present study an attempt has been made to understand the hydrological process of the command area at the watershed level by drawing the inferences from soil loss estimation. The study area chosen for the present study is Bettahalasuru command area situated in Bengaluru North lies geographically between 13°10'8"N and 13°9'12"N latitude and 77°35'58"E and 77°37'35"E longitude and toposheet No:57 G/12. It covers an area of 3.8 Sqkm and perimeter of 7.89km. Top few centimeters of the soil will usually be fertile, which is very important for the agricultural practices. Soil loss estimation was carried out in order to assess the erosion rate. If the erosion rate is severe, immediate steps should be undertaken to conserve the soil. Several methods were suggested in the past but due to its robustness, USLE (Universal Soil Loss Estimation) model has been adopted in the present study. The weighted soil erosion estimated was 16.53 t/ha/year which is Moderate soil loss. Hence should adopt conservation practices to reduce soil loss.

Key Words: Watershed, Soil Erosion, Remote Sensing & GIS

1. Introduction:

Land and water are the two vital natural resources, the optimal management of these resources with minimum adverse environmental impact are essential not only for sustainable development but also for human survival. Watershed management is the process of formulating and carrying out a course of action involving manipulation of the natural system of watershed to achieve specified objectives. It implies the proper use of all land and water resources of a watershed for optimum production with minimum hazard to natural resources. Remote sensing and GIS techniques have emerged as powerful tools for watershed management programs. Top few centimeters of the soil will usually be fertile, which is very important for the agricultural practices. Soil loss estimation was carried out in order to assess the erosion rate. If the erosion rate is severe, immediate steps should be undertaken to conserve the soil. Several methods were suggested in the past but due to its robustness, USLE (Universal Soil Loss Estimation) model has been adopted in the present study.

2. Objectives:

- ✓ To protect and enhance the water resource originating in the watershed.
- ✓ To prepare different thematic maps using SOI topomaps and remotely sensed data.
- ✓ Soil loss estimation using Universal Soil Loss Equation (USLE).
- ✓ To check soil erosion and to reduce the effect of sediment yield in the watershed.

3. Scope of the Study:

- ✓ RS and GIS are being used as tools for planning and management of available natural resources within the watershed. Hence, in the present study an attempt has been made to use RS and GIS to estimate water balance component namely soil loss to understand the hydrological process of the watershed.
- ✓ Erosion models are necessary tools to predict excessive soil loss and to help in the implementation of an erosion control strategy.

4. Methodology:

- ✓ Collection of data.
- ✓ Preparation of different thematic maps.
- ✓ Soil loss estimation using Universal Soil Loss Equation (USLE).

Collection of Data:

- ✓ Survey of India (SOI) Topomap No. 57 G/12, on 1:50,000 Scale
- ✓ Indian Remote Sensing (Irs-1d, Liss Iii) Satellite in the form of FCC
- ✓ Soil Data-KSRSAC, Bangalore according to National Bureau of Soil Survey and Land Use Planning (NBSS and LUP, 1995) Standards.

Preparation of Different Thematic Maps:

- ✓ In order to know the different natural resources, terrain conditions, etc. in the study area, different thematic maps are prepared.

Universal Soil Loss Equation (USLE): Wischmeier and Smith, 1965 suggested USLE model to estimate soil loss from watershed it is an erosion model designed to compute longtime average soil losses from sheet and rill erosion under specified conditions. It is also useful for identification of construction sites and other non-agricultural conditions, but it does not predict deposition and does not compute sediment yields from gully, stream bank, and streambed erosion.

Estimation of Soil Loss:

The equation is as follows:

$$A = RKLSCP \text{ t/ha/year} \quad (1)$$

Where,

A = Computed soil loss (t/ha/year)
R = Rainfall erosivity factor
K = Soil erodibility factor
L = The slope length factor
S = The slope steepness factor
C = The cover and management factor
P = Conservation practice factor

The magnitude of soil erosion depends on two forces-the detachment of soil particles by the impact of rainfall energy called the erosivity of rain, and the ability of the soil to resist the detachment of its particles by this force called the erodibility of soil. This relation is expressed as shown below

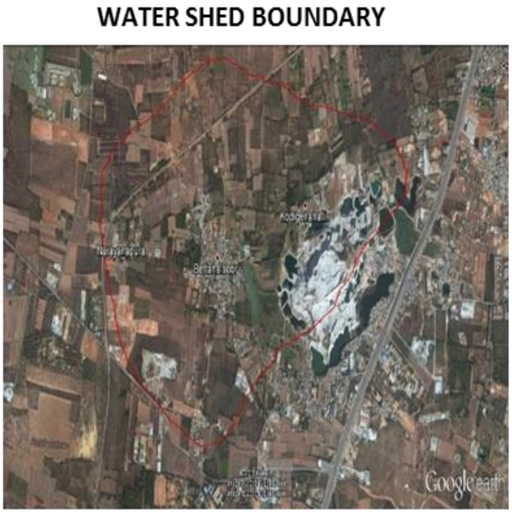

Figure 1: Watershed Boundary

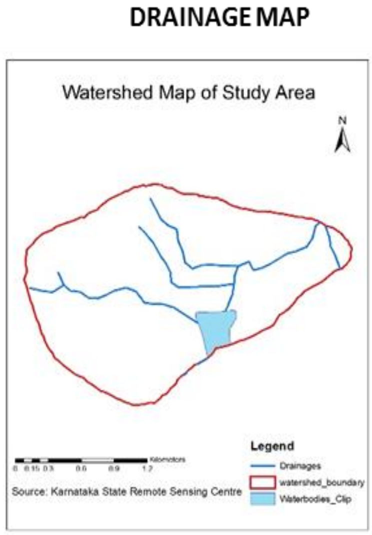

Figure 2: Drainage Map

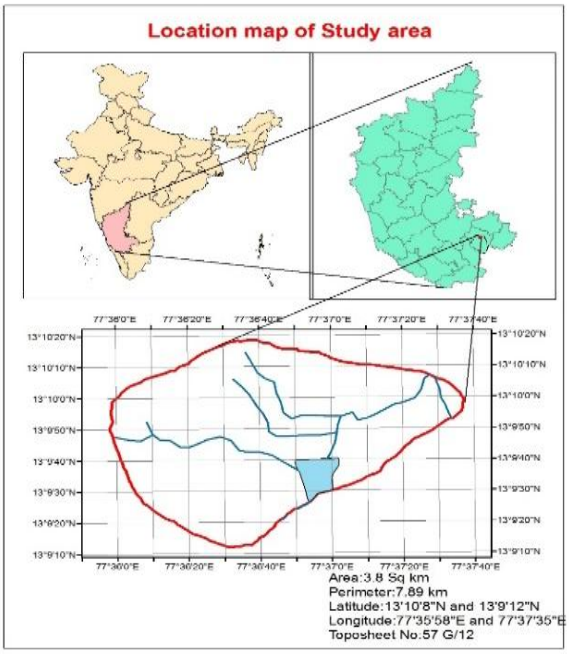

Figure 3: Location Map

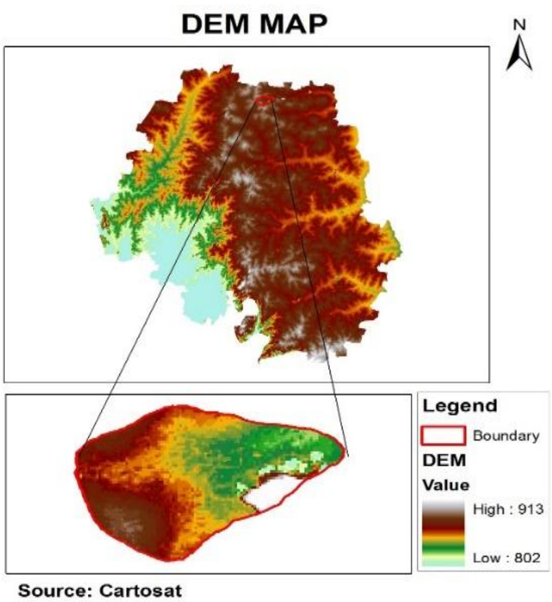

Figure 4: Dem Map

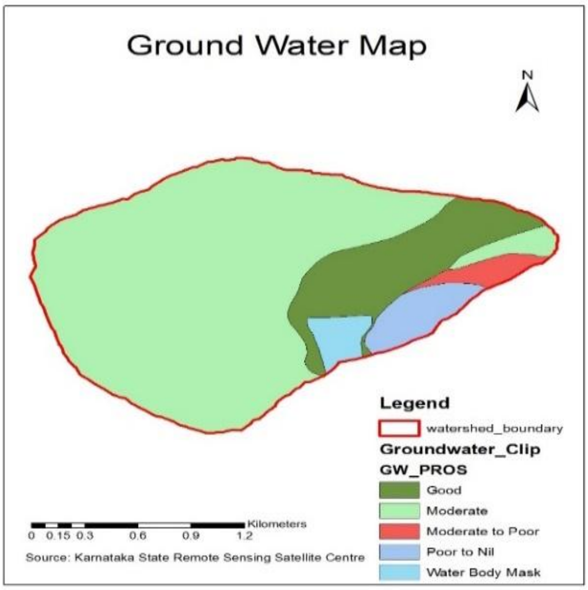

Figure 5: Ground water map

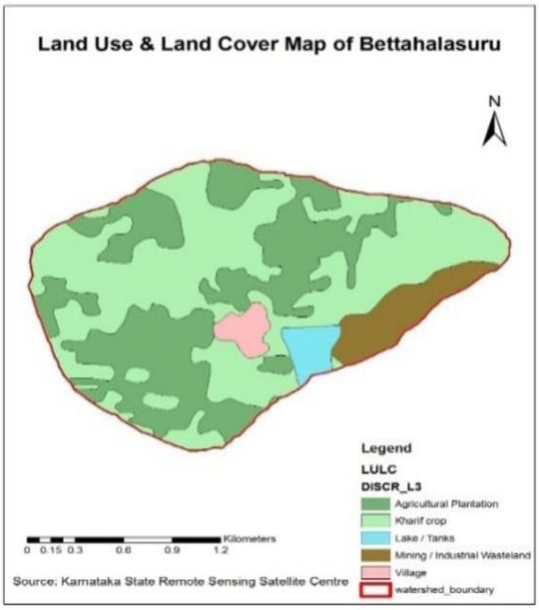

Figure 6: Land use & land cover map

$$\text{Soil erosion} = f\,[(\text{erosivity of rain}) \times (\text{erodibility of soil})] \quad (2)$$

The USLE is also based on similar principles. The erosivity of rain is represented by the factor R and the erodibility of soil surface system by the multiples of the factors KLSCP. In systems terminology considering the watershed as a system represented by the multiples of the factors KLSCP, the input force is represented by the rainfall erosivity factor R and the output (the response to the input), which is the soil erosion is represented by the letter A.

Rainfall Erosivity Factor (R):

The rainfall erosivity factor is a function of falling raindrops and the rainfall intensity. Wischmeier and Smith (1958) found that the product of kinetic energy of the raindrop and the maximum intensity of rainfall over duration of 30 minutes, in a storm, is the best estimator of soil loss. This product is known as the Erosion Index (EI) value. For a given storm the EI value is determined by multiplying the kinetic energy of the storm to the maximum 30-minute for that storm. The EI values for all the storms occurring in a given year for location are added to obtain an annual erosivity index. The EI30 can be expressed as follows:

$$EI_{30} = \frac{(KE)I_{30}}{100} \quad (3)$$

Where,

EI_{30} = Erosion index
KE = Kinetic energy of storm
I_{30} = Maximum 30 minute rainfall intensity of the storm

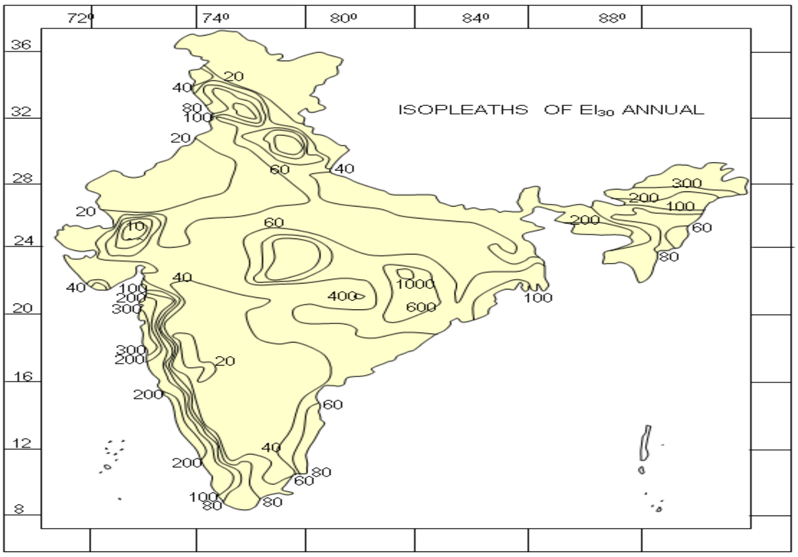

Figure 7: shows the Isopleath Map of India used for soil loss estimation.

Kinetic energy can be expressed as:

$$KE = 210.3+89 \log_{10} \quad (4)$$

Where,

KE = Kinetic energy in ton/ha-cm

I = Rainfall intensity in cm/hr

The rainfall factor (R) for the present study has been taken from the published Isopleath Map of India (Raghunath et al., 1982). This map has prepared, based on 50 years of weather cycles, provides information on erosive forces of rainfall. For the present study, rainfall factor was taken directly as 40 for all watersheds from the Isopleath Map of India.

Soil Erodibility Factor (K):

The soil erodibility factor K is a measure of standard plot 22.1m long, on a 9% slope maintained in a continuous fallow, tilled up and down hill periodically to control weeds and break crust that are formed on the soil surface. The soil erodibility factor (K) relates the rate at which different soils erode under the conditions of equal slope, rainfall. Some soils erode more easily than others due to inherent soil characteristics such as texture, structure, permeability and organic matter content. The soil erodibility factor (K) calculated from the following equation (Wischmeier and Smith, 1978)

$$100\,K = 2.1\times10^{-4}(N1.N2)^{1.14}(12\text{-}OM)+3.25(S\text{-}2)+2.5\,(P\text{-}3) \quad (5)$$

Where

K = soil erodibility factor.

N1, N2 = particle size parameter (% silt + % very fined sand).

OM = percent organic matter content.

S = soil structure code (very fine granular = 1; fine granular = 2; medium or coarse granular = 3; blocky, platy, or massive = 4).

P = profile permeability class (rapid = 1; moderate to rapid = 2; moderate = 3; slow to moderate = 4; slow = 5; very slow =6).

The particle size distribution of soils to evaluate 'K' values uses the grain size as (0.1-2.0) mm for sand, (0.05-0.10) mm for very fine sand and (0.002-0.05) mm for silt. In order to use the above Wischmeier's equation, it is necessary that the grain size of the soils in the watershed area brought down to above sizes. The soil in the watershed consists of coarse (medium) granular, blocky platy or massive type of soil structure. The soil erodibility factor K estimated for different soils in the watershed is shown in Table 1. The K-factor estimated for the watershed is shown in Table 2.

Union of soil map and watershed map were used to identify the different soil types constituting in the watershed. Therefore, dominant soil series in watershed has been taken for calculating the 'K' factor values. If the percentage of sand is more, then there will be voids between the particles and hence it will allow the water to pass through the voids. From this, it is observed all the soils series in the watershed have good permeability.

Weighted average value of K was calculated using the following equation

$$K=\frac{A_1K_1+A_2K_2+\dots\dots+A_nK_n}{A_1+A_2+\dots\dots\,An} \quad (6)$$

Where,

A_1, A_2, A_3… A_n =area of subwatershed 1, 2, 3…n

K_1, K_2, K_3, … K_n= K-factor for subwatershed 1, 2, 3,…n

Slope Length Factor (L):

The slope length and gradient are represented in the USLE as L and S respectively. However, they are often evaluated as single topographic factor as LS. Slope length is defined as the distance from the point of origin of overland flow to the point where either the slope gradient decreases enough that deposition begins or the runoff water enters a well defined channel that may be a part of a drainage network or a constructed channel. However, slope length has been considered as average length of overland flow. The effect of slope length on annual runoff per unit area of cropland may generally be assumed negligible. However, the soil loss per unit area generally increases substantially as slope length increases. The greater accumulation of runoff on the longer slopes increases its detachment and transport capacities.

Slope length factor, can be computed from the following equation

$$L= \left(\frac{l}{22}\right)^m \quad (7)$$

Where,

L = slope length factor

l = slope length (m)

m = dimensionless exponent = 0.5 for slopes > 4 %; 0.4 for 4% slope; 0.3 for slopes < 3%

Slope Steepness Factor (S):

The slope gradient factor is expressed as the ratio of soil loss from a plot of known slope to soil loss from a unit plot under identical conditions. On steep slopes the flow velocity is more, which leads to scouring and cutting of soil. As per Wischmeier and Smith (1978), slope gradient factor is determined by the formula.

$$S = \frac{0.43 + 0.3(\theta) + 0.043(\theta)^2}{6.574} \qquad (8)$$

Where,

S = slope steepness factor, θ = field slope in percent

Table 3 shows the LS values calculated for the watershed.

Crop Management Factor (C):

Factor C in the soil loss equation is the ratio of soil loss from land cropped under specified conditions to the corresponding loss from clean tilled, continuous fallow. This factor measures the combined effect of all the interrelated cover and management variables.

To calculate crop management factor C the whole crop duration is divided into four stages. Therefore the cover and management effects can be considered approximately uniform.

The major crops in the study area include paddy, maize, sugar cane, coffee & tea. However, the C factor is taken from the literature (Dhruva Narayana, 1996) i.e., paddy = 0.28; maize = 0.40; sugarcane = 0.60 and so on and the average value 0.42 was taken for the study.

Conservation Practice Factor (P):

Conservation practice factor is the ratio of soil loss with a specific supporting practice to the corresponding loss with up and down cultivation. In general, whenever sloping land is to be cultivated and exposed to erosive rain, the protection offered by soil or close growing crops in the system needs to be supported by practices that will slow runoff and thus reduce the amount of soil it carries. The most important support practices are contour cultivation; strip cropping, terrace system and waterways for the disposal of excess rainfall. The values are selected based on the recommendations of Wischmeier and Smith (1958). Since the study area comprised of only field bund conservation P factor was taken as unity. The soil loss estimated from the USLE for all watersheds is shown in Table 4.

Below figure shows the soil erosion map of Bettahalasuru.

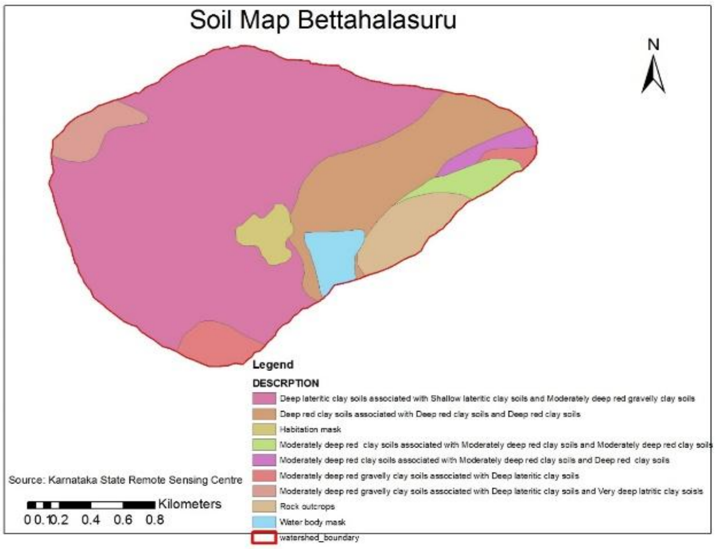

Figure 8: Soil map of Bettahalasuru

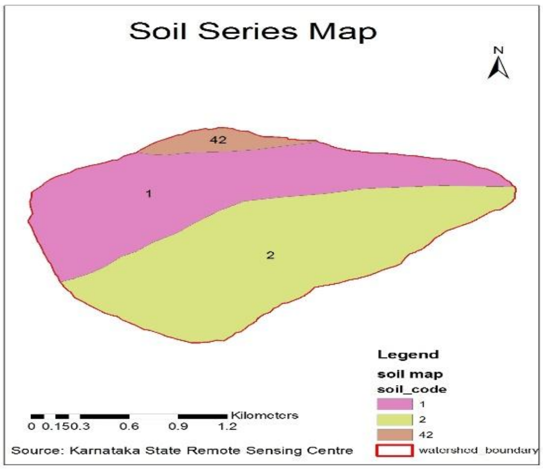

Figure 9: Soil series map

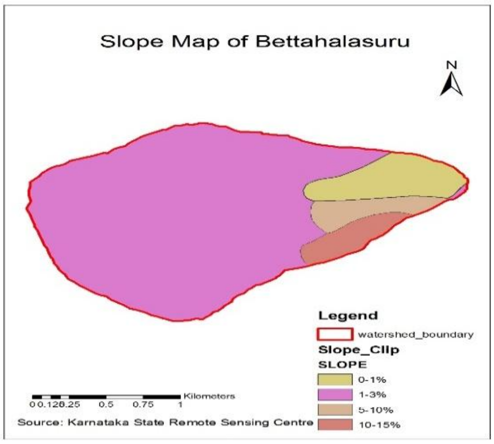

Figure 10: Slope map of Bettahalasuru

5. Results and Discussions:

Utilization of the Arc GIS software, along with some other associated extensions, has resulted in delineating watershed in Bettahalasuru Command Area (Fig 2).The weighted soil loss for the study area is estimated to be 16.53 t/ha/year, which is a moderate loss (ISRO-NNRMS-TR-103 2002). The limits of the soil loss are shown in the Table below.

Table 1: K – Factor for different soils in the watershed

Soil Code	Soil Type	sand (%)	Silt (%)	clay (%)	Sand + Silt (%)	OM (%)	Structure code	Permeability code	K-Factor
1	Silty Clay loam	20.00	38.00	30.00	58.0	0.20	3	3	0.125
2	Clay loam	39.10	27.30	33.60	66.4	1.14	3	3	0.133
42	loam	50.10	40.30	9.60	90.40	0.94	4	5	0.102

Table 2: K – factor for watershed

Watershed No.	1
Area (sq.km)	3.80
K – factor	0.12

Table 3: Topographic factors 'LS' for the watershed of Bettahalasuru

Watershed No.	Area (sq.km)	Length (m)	Difference in elevation (m)	Slope (%) $\theta = \tan^{-1}(y/x)$	LS Factor
1	3.80	691.65	111	9.117	0.33

Table 4: Soil loss estimated for watershed

Watershed No.	Area (Sq.km)	LS Factor	K	R	C	P	Erosion(t/ha/Year)
1	3.80	0.33	0.180	40	0.42	1	16.53

Table 5: Soil loss limits

S.No	Particulars	Soil loss (t/ha/year)
1	Nil to slight	Less than 5
2	Slight to moderate	5 to 10
3	Moderate	10 to 25
4	Severe	25 to 50
5	Very severe	Greater than 50

(Source: ISRO-NNRMS-TR-103-2002)

6. Conclusion:

In the present study the estimation of soil loss using USLE will provide informations about the vulnerability of area, which are more prone to soil loss and conservation of natural resource within the catchment for sustainable management of soil resource for better crop yield. The soil loss for watersheds in the Bettahalasuru was estimated using Universal Soil Loss equation (USLE) which consists 6 major factors i.e., RKLSCP. Rainfall erosivity factor, R was taken 40 for the watershed which is taken from the published Isopleath Map of India. The rainfall erodibility factor (K) obtained was found to be 0.180, the slope length and slope steepness was calculated and found to be 5.74.The crop management factor (C) was taken as the average values for various crops grown in watersheds by considering the dominant crop and the average value obtained was 0.42. Since, the catchment comprises only bunds around the agricultural lands and no conservation were followed, the conservation practice factor P was taken as unity. The weighted soil erosion estimated for the Bettahalasuru command area was 16.53 t/ha/year which is Moderate soil loss (ISRO-NNRMS-TR-103-2002).

7. Conservation Practices to Reduce Soil Loss:

- ✓ Agriculture utilizes the soil for growing crops. This creates loose soil that can be easily eroded. Several management practices can be implemented to reduce soil erosion.
- ✓ Plant on the contour-This involves planting around slopes rather than up and down them. This helps slow the flow of water and allows it to be absorbed.
- ✓ Rotate crops-Planting different crops on land from one year to the next helps reduce soil erosion. It leaves residue on the surface to help hold the soil in place.
- ✓ Terraces-A terrace is a ridge or row of earth mounds placed across a slope. Terraces allow a gradual drop for the flow of water. This helps prevent rapid water flow and aids in holding soil in place.
- ✓ Grassed strips-Small strips covered with grass may be left near plowed areas. This slows the flow of water and helps keeps gullies from forming.

- ✓ Diversion ditches-Small ditches may be built across slopes to slow water movement and divert it in to a safe outlet. They are similar to grassed waterways, but may be lined with riprap or other material.
- ✓ Vegetative covers-Fields may be planted in winter-cover crops after fall harvest. The cover crop adds fertility and protects the soil from erosion.
- ✓ Conservation tillage involves planting crops with little or no plowing. Crop residue from the previous year is left on the surface to protect the land.
- ✓ Wind breaks-Rows of trees may be planted to slow blowing wind and help prevent wind erosion.
- ✓ Mulching is placing a layer of straw, burlap, or other material on the top of soil to protect it from wind and water. Mulch helps hold water and reduce the impact of
- ✓ Silt fences are placed at the bottoms of slopes to hold the soil yet allow the water to flow. This keeps sediment out of streams and lakes and prevents the loss of soil. Silt fences may be made out of bales of hay, plastic strips, or other materials.
- ✓ Cover crops-Vegetation can be planted on excavated soil to hold it in place. Winter grass can be planted in the fall on new lawn areas to prevent erosion until the following spring when a permanent sod can be established.

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