CONCEPT AND PRINCIPLES OF WATERSHED MANAGEMENT

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Training Course on

HYDROLOGICAL INVESTIGATION TECHNIQUES FOR WATER RESOURCES DEVELOPMENT & MANAGEMENT

(26-28 August 2012)

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WATERSHED

A watershed can be defined as a geo-hydrological unit that drains to a common point by a system of drains. All lands on earth are part of one watershed or other. Watershed is thus the land and water area which contributes runoff to a common point.The words watershed, catchment, basin, drainage area, are synonymous, and in Indian usage, pertain to an area and not to a line. The terms micro, mini, sub-watershed or any variation of the terms indicate hierarchical division of the watershed of a stream, river or a drainage line.

WATERSHED MANAGEMENT

Watershed management may be defined as the process of formulating andcarrying out a course of action involving manipulation of natural,agricultural and human resources of a watershed to provide resources thatare desired by and suitable to the watershed community, but under thecondition that soil and water resources are not adversely affected.Watershed management is an integrated andinterdisciplinary approach. It generally requires land use adjustmentand soil and water conservation measures which contribute to enhancement of water resources, reduction in soil erosion rates, increased agricultural production, generation of employment andbalanced growth of national economy.

OBJECTIVES OF WATERSHED MANAGEMENT

The watershed managementmainly aims at:

(i) Protecting, conserving and improving the land resources for efficient and sustained production;
(ii) Protecting and enhancing water resources, moderating floods, reducing silting up of tanks/reservoirs, increasing irrigation and conserving rainwater for crops and thus mitigating droughts.
(iii) Utilizing the natural local resources for improving agriculture and allied occupation of industries (small and cottage industries) so as to improve socio-economic conditions of the local residents.

PERSPECTIVES ON WATERSHED MANAGEMENT

The land, water, vegetation, human and livestock population are components of a watershed. A perception of various aspects related with watershed components is useful for planning and successful implementation of a watershed management project.

Hydrological Aspects

The hydrological behaviour of a watershed is influenced by watershed conditions. The watershed treatment and management practices alter the slope and roughness characteristics of the watershed and tend to reduce the surface flow and peak flow. The management practices also reduce the rate and quantity of sediment erosion and their transportation, resulting in lower delivery of sediments into the reservoirs. The floods, though can not be eliminated completely, they can be greatly mitigated by sound watershed treatment and management. Similarly, the moisture conservation measures and sound land use programmes mitigate the drought severity in a watershed.

Environmental Aspects

There is an increasing awareness that environmental catastrophe is occurring by way of global warming, change in climate and hazard to health due to greenhouse effect. Ozone depletion is another feature of environmental concern. These ominous effects are caused by several phenomena like carbon dioxide accumulation and their interplay. It has been agreed by the scientists that greenery consumes the superfluous carbon dioxide, stores the deleterious gas, releases oxygen much in demand, provides the basic needs, plays a role in restoring climate and thus revives a better environment. Watershed development, applied locally for developing green foliage, enriches environment globally in due course of time. The local measure of micro-scale watershed development would have cumulative effect on environment when considered on a large basin or a global scale. Besides above, reduced onsite erosion and enhanced water quality in a well managed watershed also improve the natural ecosystem.

Socio-Economic Aspects

Watershed development is meant for growing biomass, the pipeline for prosperity of the people for bridging the gap between poverty line and per capita income. In achieving this objective, the viewpoint of individuals and communities, who live in the watershed, should be considered. The watershed treatment measures and management practices should be compatible with the people's need, their social stratification, occupation, economic status, customs values, livestock, farming practices and land holding size. The socio-economic factors also determine the motivation of the farmers to make necessary investment of labour and capital in watershed development.

Financial Aspects

The unit cost norms for watershed development normally range from Rs. 4500 to Rs. 6000 per hectare depending upon the nature and location of the watershed. The projects normally provide 100 percent grant for the management component as well as development component. However in case of development component the participating families are required to contribute a predefined percentage of cost for individual works and for community work.

Administrative and Political Aspects

Watershed management involves several disciplines and as such, the administrative aspects of the watershed development are innumerable in planning, programming and implementing. The enormity is further complicated by Central, State, District, Block and Project levels. A close collaboration is therefore needed between various planning and implementing agencies to achieve full benefits of the programme. Also, the planning should include only those measures/activities which are acceptable politically.

APPROACH FOR WATERSHED DEVELOPMENT AND MANAGEMENT

Participatory Approach for Empowerment of Community

People's participation is the key to watershed development programmes. This not only ensures longterm sustainability of the watershed development process through ownership of the programme by local communities, but also empowers the watershed communities to initiate activities on their own and take optimal advantage of other on-going development programmes of the Central and State Governments. The participatory approach enables the programme to evolve into a "National Movement of Watershed Development that fosters implementation ability at the local level and creates community infrastructure for micro watershed projects through active involvement of Gram Panchayats, Local Self Help Groups and NGOs"*. (* Finance Minister's Budget Speech 1999-2000)

Implementation of the Watershed Project through Watershed Community

The most critical step for empowerment of the local community and assurance of their active participation in the programme is to entrust the planning and execution of development works under the project to them. Under this approach it the watershed community should be informed about the total financial resources available to them.

Role of the Project Implementation Agency (PIA)

While the main development activities have to be carried out by the watershed community itself, the overall facilitation, coordination and supervision of the whole programme will be the responsibility of the PIA. The role of PIA shall be to motivate gram panchayats to pass necessary resolutions regarding implementation of watershed programmes; organize watershed communities at the village level; train office bearers and other community members on technological, management as well as accounting aspects; carry out Participatory Rural Appraisal (PRA) exercises for preparation of Watershed Plan; inspect and authenticate project accounts during implementation phase; undertake action research to identify low cost technology wherever possible; validate as well as build upon indigenous technical knowledge; create institutional arrangements for post project maintenance of the assets created under the project; assist community organizations in forging functional linkages with panchayats, credit institutions, research organizations and on-going programmes of line departments etc.

Selection of PIA

Success of the watershed programme will depend upon the selection of a suitable PIA as well as a responsive community. The selection of PIA should be through a process by which potential PIA's would be required to prepare project reports/ feasibility studies of identified watersheds. The project reports/ feasibility studies would include assessment of the responsiveness of the community on the basis of their willingness to contribute towards watershed development; promote equity for poor and women; and to participate in shramdan. These Project Reports and the PIAs should be assessed/ evaluated for strengths based on fixed criteria and the final selection should be made by a Selection Committee.

Project Proposals to be Demand Driven and Reflect Felt

To ensure that the involvement of watershed communities in the planning process does not remain merely passive, the formulation of the project proposal should be through a "bottom up" process. Subject Matter Specialists should orient the watershed community with respect to technological options and leave the final choice of technologies to the users. While exposing the participants to various options, particular attention should also be paid to indigenous innovations evolved by the community itself.

Replication of Successful Watershed Development Projects

A number of successful and sustainable watershed development projects both under Govt. and Non-Govt. efforts have demonstrated the strength and utility of the watershed approach. In addition, innovative members of the community have also created replicable techniques in management of natural resources. Such success stories should be shown to the potential watershed communities and the extension functionaries involved therein and the community members motivated through focused exposure visits to these examples. Action plans prepared by the community after exposure to such projects would incorporate elements of their demonstrated successes thereby ensuring a higher likelihood of sustainability.

Development of Common Property Resources (CPRs) and Sharing of Usufruct Rights

Wherever there exists community lands in micro-watersheds the development of such lands, especially the contribution of the community in the form of cash or labour, will depend upon the sharing of the usufruct likely to accrue as a result. The usufructs after meeting the needs of the beneficiaries should be sold. Of the net proceeds 10 % may be deposited in the village development fund of the Panchayat, 15% be deposited in the Watershed Development (Corpus) Fund of the Watershed Committee to meet future needs of maintenance of CPRs to ensure continuous generation of usufructs from such CPRs. The remaining 75% may be shared by the members of the Watershed Association, including the landless.

Development of Forest Lands in Watershed Areas

Some watersheds may encompass, in addition to arable land under private ownership, forest land under the ownership of State Forest Department. Since nature does not recognize artificial legal boundaries of forest and non-forest lands in watersheds, entire watershed should to be treated in an integrated manner. Though the criterion for selection of watersheds primarily remains predominance of non-forest lands, the forest lands forming part of such watersheds should also to be treated simultaneously as per prevailing guidelines.

Linkages of Watershed Community with Panchayat Raj Institutions

An important element of long term sustainability is to forge linkages with permanent institutions in the area. Efforts should be made to strengthen linkages between watershed community organization and Panchayat Raj Institutions (PRI). Since PRIs are in varying degrees of administrative effectiveness in the States, the latter are likely to follow different mechanisms for linkages between the watershed institutions and the PRIs. Wherever possible Panchayats should be encouraged to undertake direct implementation of the Watershed Project. Elsewhere linkages should be forged between the Panchayats and the watershed communities. Some of the mechanisms being adopted at present include: (i) provision of nominating two representative of the Village Panchayat into the Watershed Committee of which one is a woman; (ii) declaring Watershed Committee as a sub-committee of the Land Management Committee under the Panchayat Raj Act.

Linkages with Credit Institutions

During the Project lifetime the PIA and WDT should work to develop linkages with the credit institutions such as the Regional Rural Banks, Cooperative Banks etc. The credit requirements of the Watershed Project should get reflected in the District Credit Plan.

Promoting Equity for Resource Poor and Women

In all watershed development projects thrust should be on improving equity through special efforts at strengthening socio-economic status of landless and women. The following specific steps may be considered while promoting equity under the watershed programme:

- Focus on development of poor quality and marginal lands owned by poor families
- Preferential allocation of usufruct rights over produce from the developed common land to landless households / women groups
- Equitable right to all households in new water resource developed under the project
- Construction of new water harvesting structures near the land / recharged wells including drinking water wells owned by resource poor
- Groundwater to be treated as a common property resource
- Equal employment opportunities and wage rates for implementating watershed works
- Due emphasis on livelihood support systems for landless households
- Utilizing the services of the landless poor and women in the post-project management of common property resources.

STEPS FOR PREPARATION OF INTEGRATED WATERSHED MANAGEMENT PLAN

Preparation of a watershed development plan includes (a) identification of watershed problems and setting up of objectives and priorities based on various surveys and base line data of the watershed, and (b) formulation of proposed development and management plan.

Identification of Problems and Data Collection/Surveys

The following steps and inventories are required for developing a watershed plan.

(i) Quick identification of watershed problems: Collection of first-hand information on the nature and extent of (a) physical problems (steep slopes, bad lands, slide-prone soils, weak geologic formation etc.), (b) resource use problems (shifting cultivation, forest destruction, fire, overgrazing, poor road and other infrastructural facilities), (c) end problems (soil erosion, landslides, heavy sedimentation, floods, droughts, water quality), (d) socio-economic and other problems that may be obstacles in carrying out watershed work (land tenure, poverty, lack of education, low acceptance of innovations, seasonal shortage of labour etc.).

(ii) Determining main objectives and priorities: Selection of priority (critical) sub-watersheds, setting up of development objectives based on the problems and management possibilities.

(iii) Detailed surveys, maps and data collection: Topographic survey and map; soil survey and land capability survey and maps; present land use map based on actual field survey or remote sensing data; an erosion and site degradation map, collection of available hydro-meteorological data, socio-economic survey, collection of information on infrastructural facilities, and any other information useful for planning the development works.

Formulation of Proposed Watershed Development and Management Plan

Based on the surveys and data, a comprehensive watershed development and management plan is formulated which consists of the following components.

(i) Foundation: Land and water development (i.e. soil & water conservation measures).
(ii) Superstructure: Sustainable production system (i.e. agriculture, forestry, grasslands, horticulture, animal husbandry, others).
(iii) Bio-industrial component: Processing industries for value addition, employment & enhanced income.
(iv) Infrastructure: Roads, markets, transport, communication, power etc.
(v) Organizational facility and People's institutions: A multidisciplinary organizational structure at national, state and district level; and Watershed Cooperatives, Associations, Panchayat Raj bodies, and NGOs at local level for implementation of the programme.
(vi) Project costs and financial plan: Cost of bench mark survey, project planning, project implementation (works), staff, training, research (if any), monitoring appraisal and evaluation, building, vehicles, stores, maintenance of works etc. and their phasing over the project duration.
(vii) Financial Plan: Sources of finance, budget financed items and credit financed items, mode of spending, rate of subsidies, recoveries etc.
(viii) Benefit-cost analysis: Analysis on short term and long-term basis.
(ix) Monitoring and evaluation: A built-in system of multi-point monitoring and evaluation e.g. gauging stations for hydrology and sediment monitoring.

SOIL AND WATER CONSERVATION MEASURES FOR WATERSHED TREATMENT

There are always strong links between measures for soil conservation and measures for water conservation. Many measures are directed primarily to one or the other, but most contain an element of both. Reduction of surface run-off by structures or by changes in land management will also help to reduce erosion. Similarly, reducing erosion will usually involve preventing splash erosion, or formation of crusts, or breakdown of structure, all of which will increase infiltration, and so help the water conservation. The basic principles of soil and water conservation are:

(i) Allowing more time for runoff to infiltrate into the soil and conserving as much rain water as possible at the place where it falls;
(ii) To restrict runoff velocity within permissible limits by breaking the long land slope into several short ones to prevent excessive soil and water losses;
(iii) To develop appropriate land use systems according to land capability;
(iv) Putting adequate vegetal cover on the soil during the rainy season;

(v) Drawing out excess water with a safe velocity and diverting it to storage ponds and store it for future use;
(vi) Avoiding gully formation and putting checks at suitable intervals to control soil erosion and recharge ground water;
(vii) Increasing cropping intensity through intercropping and sequence cropping;
(viii) Safe utilization of marginal lands through alternate land use system.

Each watershed has unique characteristics and problems. Its treatment and management would therefore require careful consideration of various site specific factors like topography, nature and depth of soil cover, type of rocks and their pattern of formation and layout, water absorbing capacity of land, rainfall intensity, land use etc. As watersheds also support a number of systems viz., agriculture, horticulture, grasslands and non-arable lands etc. besides being a catchment for tanks and reservoirs, the soil and water conservation measures specific to a system are needed for the good health of the watershed.

Soil and Water Conservation Measures for Agricultural Lands

Broadly speaking, the practical methods of soil and water conservation fall into two important classes, viz. mechanical measures and agronomic measures.

Mechanical Measures of Erosion Control on Agricultural Lands

Mechanical measures (also called engineering measures) play a very vital role in controlling erosion on agricultural lands. These measures mainly aim at: (i) increasing the time of concentration by intercepting the run-off and thereby providing an opportunity for the infiltration of water, (ii) dividing a long slope into several short ones so as to reduce the velocity of the run-off and thus prevent erosion, and (iii) protecting against damage owing to excessive runoff. The important mechanical soil conservation measures include contour bunding (also called level terraces, ridge terraces, absorptive-type terraces), graded bunding (channel terraces), bench terracing on steep slopes, land leveling and grading, and grassed waterways for safe disposal of runoff.

Contour bunding

Contour bunding consists of constructing narrow-based trapezoidal earthen embankment at intervals along the contour to impound runoff water behind them so that all the stored water is absorbed gradually into the soil profile for crop use. A series of such bund divide the area into strips and act as barrier to the flow of water. As a result, the amount and velocity of run-off are reduced, resulting reducing the soil erosion. Contour bunding is generally recommended for low rainfall areas (<600 mm) and for permeable soils up to slopes of about 6% in agricultural lands. The bunds can be either open ended or hooked up at the ends. If the ends are hooked up the intercepted water is made to impound on the upper edge till the water is absorbed into the soil. With the open ends the built up head of water causes the excess water to drain off slowly after giving opportunity to infiltrate into the soil. Bunds with hooked-up ends are adopted in low rainfall areas with highly permeable soils, while the open end type is used in moderately permeable soils. It is also necessary in contour bunding system to remove excess runoff resulting from high intensity storms and therefore, surplussing arrangements are provided wherever necessary. Contour bunds are protected by planting the useful grasses (fodder), and green manuring plants etc. on them. Contour bunding works are carried out over wide areas in many parts of India, notably in Andhra Pradesh, Gujarat, Karnataka, Maharashtra and Tamil Nadu.

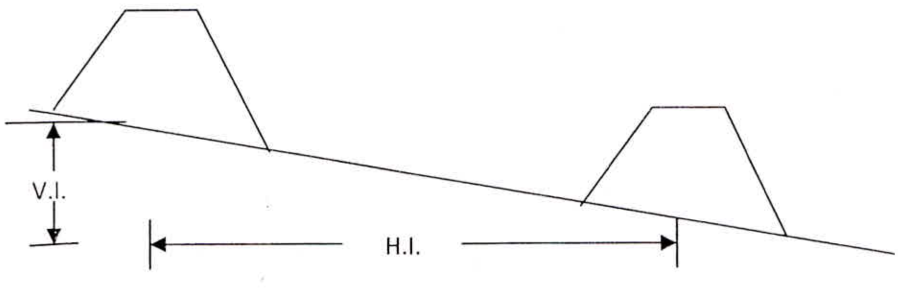

Figure 1.contourbunding

Graded bunding or channel terraces

Graded bunds or channel terraces are constructed in relatively high rainfall (> 600 mm) areas where the excess water is to be removed safely out of the fields to avoid water stagnation. Graded bunds are recommended even in lesser rainfall areas where the soils are highly impermeable or clayey nature like the deep black soils of Karnataka. In graded bunds the water flows in a graded channel constructed on the upstream side of the bunds at non-erosive velocities and is led to safe outlets or grassed waterways. It may be noted that the channel portion of the graded bunds is also put under cultivation, whereas in case of graded waterways they are kept permanently under grass.

Bench-terracing

Bench terracing is normally practiced on steep hill slopes ranging from 16-33%. In the steep slopes, mere reduction of slope length will not be able to reduce the intensity of the scouring action of the runoff flowing downhill. In addition to reduction of slope length, degree of slope is also required to be modified. Bench-terracing, which involves converting the original ground into level step like fields constructed by half-cutting and half-filling, helps in considerably reducing the degree of slope. In addition, it also helps in the uniform distribution of soil moisture, retention of soil and manure and also helps in better application of irrigation water, all of which together help in increasing the productivity of the land.

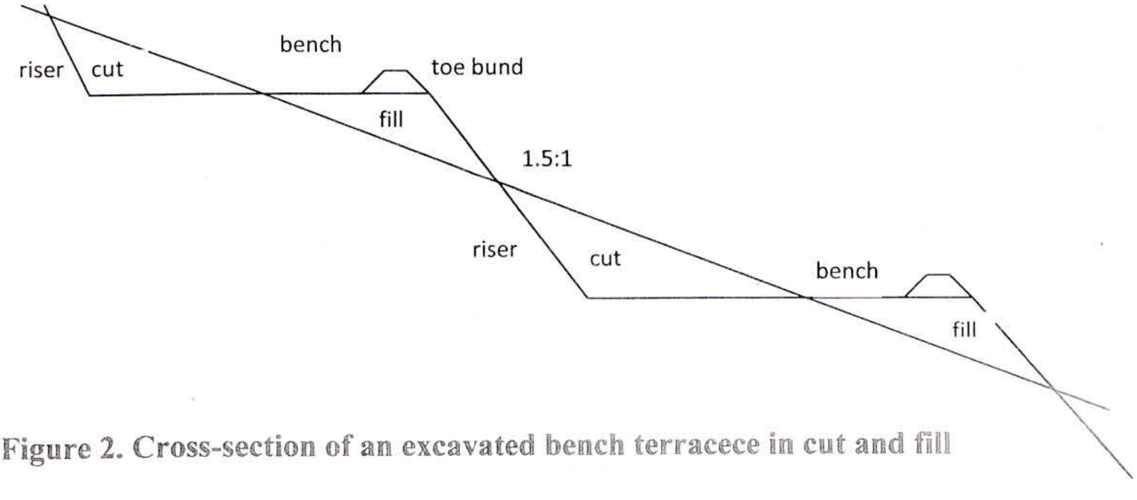

Figure 2. Cross-section of an excavated bench terracece in cut and fill

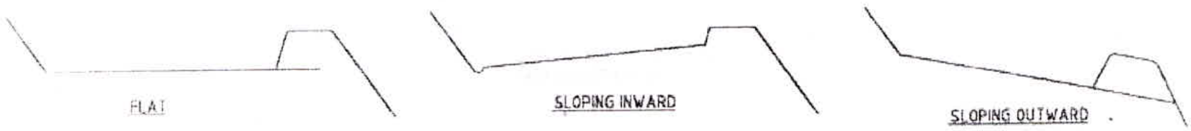

Figure3.Types of bench terracing

Grassed waterways

A grassed waterway is associated with channel terraces for the safe disposal of concentrated run-off, thereby protecting the land against rills and gullies. A waterway is constructed according to a proper design and a vegetative cover is established to protect the channel section against erosion because of the concentrated flow. Generally, the most ideal location for a grassed waterway is a natural depression or drainage line where the slope is the flattest in the watershed. Where grassed waterways cannot be located in natural courses, they are artificially constructed and should be located, if possible, along fence lines or hedgerows to avoid inconvenience to farming operations.

Land levelling and grading

Land leveling or grading is the process of preparing or modifying (i.e. reshaping) the land surface to a planned grade to provide a suitable surface. Land leveling usually requires cutting of high areas and raising of low spots, in order to remove the surface irregularities and unevenness to make a plane surface. It prepares a suitable field surface to control the flow of water, to check soil erosion and provide better surface drainage.

Agronomic Measures for Soil And Water Conservation

Agronomic practices for soil and water conservation on agricultural lands go hand in hand with mechanical measures. Agronomic measures help in reducing the impact of raindrops through interception and thus reduce splash erosion. These practices also help in increasing infiltration rates and thereby reducing runoff and overland flow through the use of contour cultivation, mulches, dense-growing crops, strip-cropping and mixed cropping. The various types of agronomic practices are briefly described below.

Use of vegetation

Crops and vegetables which cover the ground surface well and have extensive root system reduce soil erosion. Plant canopy protect the soil from the adverse effect of rainfall. The grasses and legumes produce dense sod which helps in reducing soil erosion. The vegetation provides organic matter to the soil. As a result, the fertility of soil increases and the physical condition of soil is improved.

Contour farming

During intense rainstorms, the soil cannot absorb all the rain as it falls. The excess water flows down the slope under the influence of gravity. If farming is done up and down the slope, the flow of water is accelerated, because each furrow serves as a rill. The major part of the rain is drained away without infiltrating into the soil. The top fertile soil, along with plant nutrients and seeds, is washed off. All this results in a scanty and uneven growth of a crop. Contour farming is a practice of conducting farming operations such as ploughing, planting and cultivating land across the slope rather than up and down. The operations are carried out as nearly as practical on the contour. The ridges and the rows of the plants placed across the slope form a continual series of miniature barriers to the water moving over the soil surface. The barriers are small individually, but as they are large in number, their total effect is great in reducing run-off, soil erosion and loss of plant nutrients.

Strip cropping

Strip cropping consists of a series of alternate strips of various types of crops laid out so that all tillage and crop management practices are performed across the slope or on the contours. Strips of erosion-permitting crops are always separated by strips of close-growing or erosion-resisting crops. Strip cropping is not a single practice rather it is a combination of several good farming practices such as crop rotation, contour cultivation, proper tillage operations and cover cropping. When strip cropping is combined with contour tillage or terracing it effectively divides the length of the slope, checks velocity of runoff, filters out soil from runoff water and facilitates absorption of rains. For small land holdings as in India, mixed cropping is a better substitute for strip cropping. Mixed cropping is a practice of growing more than one crop in the field simultaneously. Generally, legume is used as one of the crops. Mixed cropping gives better cover on land, good protection from the beating action of the rain, protection from soil erosion and assurance of one or more crop to the farmers.

Mulching

Surface mulches are used to minimize splash, to prevent soil from blowing and being washed away, to reduce evaporation, to increase infiltration, to control weeds, to improve soil structure and eventually to increase crop yields. Mulching of open land surface in a cropped area is achieved by spreading stubble trash or any other vegetation. Trash farming, in which crop residues are cut, chopped and partly mixed in the ground and partly left on the land surface is also a form of mulching. Mulching with maize residues, paddy husk and grass can be used.

Sub-soiling

This method consists in breaking with a subsoiler the hard and impermeable subsoil to conserve more rain-water by improving the physical conditions of a soil. This operation, which does not involve soil inversion and promotes greater moisture penetration into the soil, reduces both run-off and soil erosion. The subsoiler is worked through the soil at a depth of 30-60 cm at a spacing of 90-180 cm.

Vegetative hedges and buffers

The main purpose of raising live vegetative hedges in and around farmland is to protect soil and crops against wind and water. The choice of shrubs and grasses to be used for live hedges depends on the varying agro-climatic conditions of the region concerned. A plant suitable for vegetative barrier needs special characteristics. It should have deep and aggressive roots, but not a tendency to spread out of line; it should be tough and unattractive to animals and pests; and its flowers should be sterile to prevent it from spreading. Vetiver grass is known to meet all these requirements. It also tolerates a wide range of soils and climate, is simple to propagate and needs no maintenance except for the first year during very long drought periods, and will establish a hedge within three growing seasons. Vetiver is also cheap to plant and can be established by the farmer alone without any need for expert advice or expansive machinery. The live hedges can be used alone or in combination with mechanical measures. The vegetative hedges or a grass strips of about 1 m width planted across the slope at 1m vertical interval are very effective to slow runoff velocity, cause temporary ponding of runoff water and allow time for settling of suspended sediment. In due course of time, the accumulation of silt behind the barriers gradually achieves a bench terracing effect.

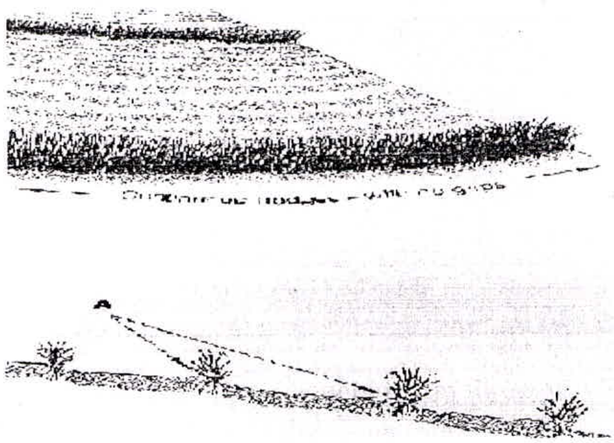

Figure4.continuous hedges of vetiver grass with no gaps

Erosion Control Measures for Non-Agricultural Lands

The non-arable lands include the lands which fall under land capability classes V, VI, VII, and VIII as their use is restricted largely to pasture, forest, wildlife and recreation due to one or more limitations of slope, erosion, stoniness, rockiness, shallow soils, wetness, flooding, and climate etc. The denuded forest lands and waste lands form a major source of sediment and runoff and cause environmental hazards like formation of gullies and ravines, landslides, and siltation of reservoirs and canals. To prevent degradation of these lands through concentration of flows, following engineering soil and water conservation measures are adopted which are supplemented with proper afforestation techniques, horticultural practices and grassland developments etc.

Contour and Staggered Trenches for Hill Slopes and Wastelands

Contour trenching is excavating trenches across the slope and as nearly on contour as possible in the upper reaches of the catchment. Bunds are formed downstream along the trenches with material taken out of them. Plantation is done on the bund to stabilize the bund. The trenches retain the runoff and help in establishment of the plantations made on the bund. The main idea is to create more favourable moisture conditions and thus accelerate growth of vegetation. Contour trenches also break the velocity of runoff. The rainwater percolates through the soil slowly and travels down, and benefits the better types of land in the middle and lower reaches of the catchment. Where the lower fields are bunded, these trenches also protect the bunds from the runoff from upper reaches of the catchment. Contour trenches may be of continuous or interrupted type. Continuous trenches store more water but their cost is high. They are essentially used for moisture conservation in low-rainfall areas and require careful layout. Interrupted or intermittent trenches are adopted in high-rainfall areas.

Staggered trenching is excavating trenches of shorter lengths in a row along the contour with interspace between them. The trenches in successive rows will be staggered, while in alternate rows the trenches will be located directly below one another. The depth and top width of the trenches may be taken as 0.3 m and 0.6 m with side slopes as 0.5:1 or 1:1.

Figure5. Staggered contour trenches

Gully Control Structures

Gully erosion generally starts as small rills and gradually develops into deeper crevices. Ravines are a form of extensive gully erosion. Gully erosion not only damages the land resources but at the same time contribute larger amount of sediment load to river system. For controlling the gully erosion, the erosive velocities of runoff are reduced by flattening out the steep gradient of the gully by constructing a series of structures across the gully bed, known as gully plugs or check dams. These check dams transform the longitudinal gradient into a series of steps with low risers and long flat treads. Besides reducing the velocity and erosive activity of the runoff, these check dams also arrest the sediment and store the runoff. The stored water improves the soil moisture of the adjoining area and allows percolation to recharge the aquifers. The vertical interval between check dams is kept equal to the height of a check dam which may normally vary from 0.5 to 1.5 m depending on the gully size and type of the check dam.

The check dams, depending on the material used and the functional requirement, may be of three types: (i) temporary check dams (ii) semi-permanent check dams and (iii) permanent check dams. Temporary check dams constructed across gullies with no significant runoff are intended only to function until the vegetation in the gully becomes well established to provide necessary protection. Check dams of this type are usually made of brush wood, wire and poles, or loose rocks. There are no standard principles of the design of these structures. These are to be designed and constructed based on the needs and availability of materials in a given situation. These check dams have to be repaired annually or after every heavy storm.

The semi-permanent check dams have a longer life and usually do not require any maintenance. These dams are very effective in steep gullies traversing hilly and mountainous regions. The earthen dam, woven wire rock-fill dam, Gabion structure, log dams and rough stone dry packed dams fall in this category and are suitable for control of medium-deep gullies (about 2-2.5 m deep) with a width of about 6 m and a contributory watershed of about 40 ha or more.

For large gullies in which excessive runoff from the top is expected and a high degree of safety and permanence are desirable, permanent gully control structures of masonry and concrete are constructed. These structures have a main function to safely dispose peak runoff for a given frequency, from higher to lower elevation. These should have arrangements to dissipate the kinetic energy of discharge within the structure, in a manner and degree that will protect both, the structure and downstream channel from damage. There are three principal types of spillways, viz., drop spillway, drop inlet spill way and chute spillway.

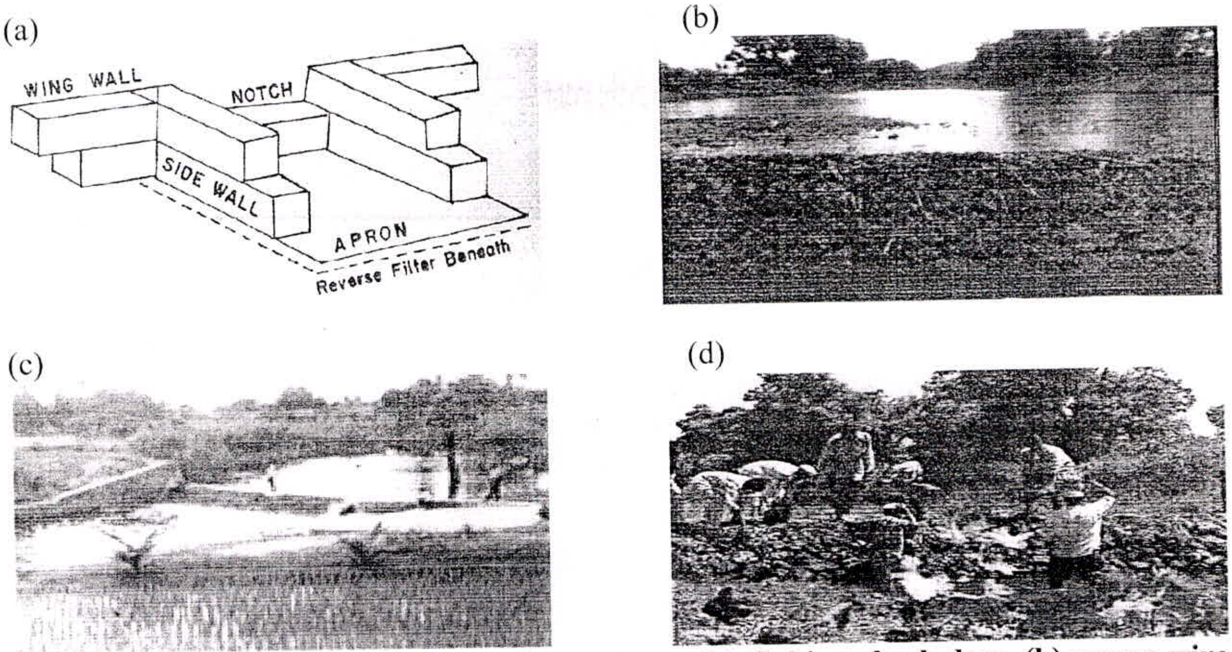

Figure6.various types of gully control structures: (a) Gabion check dam, (b) woven wire boulder check dam (c) drop spillway, and (d) loose boulder check dam.

Diversion Bund

The uncontrolled discharge from hills causes heavy soil erosion in uplands down below. So, a diversion bund is provided along the foothill zone across the slope on a slight gradient to intercept the runoff from upper reaches and to conduct it laterally safe into a naturally or protected watercourses.

Control of Gullies and Their Reclamation

The practices described below are arranged in the order in which they should be adopted; the cost of their execution increases progressively.
Closure to grazing and other biotic interference: Studies at different locations in India have indicated that when gullied areas are closed to grazing and other biotic interference, not only do the soil and water losses progressively decrease but there is marked qualitative and quantitative improvement in the growth of grasses.

Contour and peripheral bunding: After the closure of the gullied lands, the protection of adjacent tablelands from getting converted into ravine and gully lands constitutes the next step. The encroachment of gullies is to be reduced by retaining maximum of the rainfall in the catchment itself by constructing contour bunds/terraces. Peripheral bunds or diversion bunds are provided above the gullies to divert the excess water away from the gully heads so that gully head extension is stopped.

Gully plugging: The eroding and deepening of gully beds can be prevented with gully plugs. Gully plugs of suitable materials, e.g. brushwood, live hedges, earth, sand bags, brick masonry and boulders can be used.

Rain Water Harvesting and Groundwater Recharge

Farm ponds

In any watershed management programme farm ponds are important components and useful in storing water for irrigation. They also retard sediment and flood flows to the downstream river system. A good pond site should have a narrow gorge for earthen bund construction so that a small amount of earthwork provides large storage. The drainage area above the pond should be large enough to fill the pond in 2 or 3 spells of good rainfall. The pond location should be near where the water is to be used, e.g. for irrigation, it should be above the irrigated fields and for sediment control it should intercept the flow from the most erodible parts of the catchment. The land surface should not have excessive seepage losses unless it is meant to serve as a percolation tank for groundwater recharge.

Percolation tanks

A percolation tank, like an irrigation tank, has a structure to impound rainwater flowing through a watershed, and a waste weir to dispose of the surplus flow in excess of the storage capacity of the tank. Percolation tanks are generally constructed on the small streams or rivulets with adequate catchment for impounding surface runoff. These tanks are used entirely for recharging the aquifer through percolation. In comparison to ponds, percolation tanks conserve water to a greater extent because the filling and recharge occur mostly during the monsoon when the evaporation rate is about the half of potential rate in summer through which ponds contain water. Selection of suitable site for the construction of percolation tanks and subsequent maintenance is crucial for its effective functioning. Where hydro-geological conditions are favorable, percolation rates may be increased by constructing recharge (intake) wells within percolation tanks.

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