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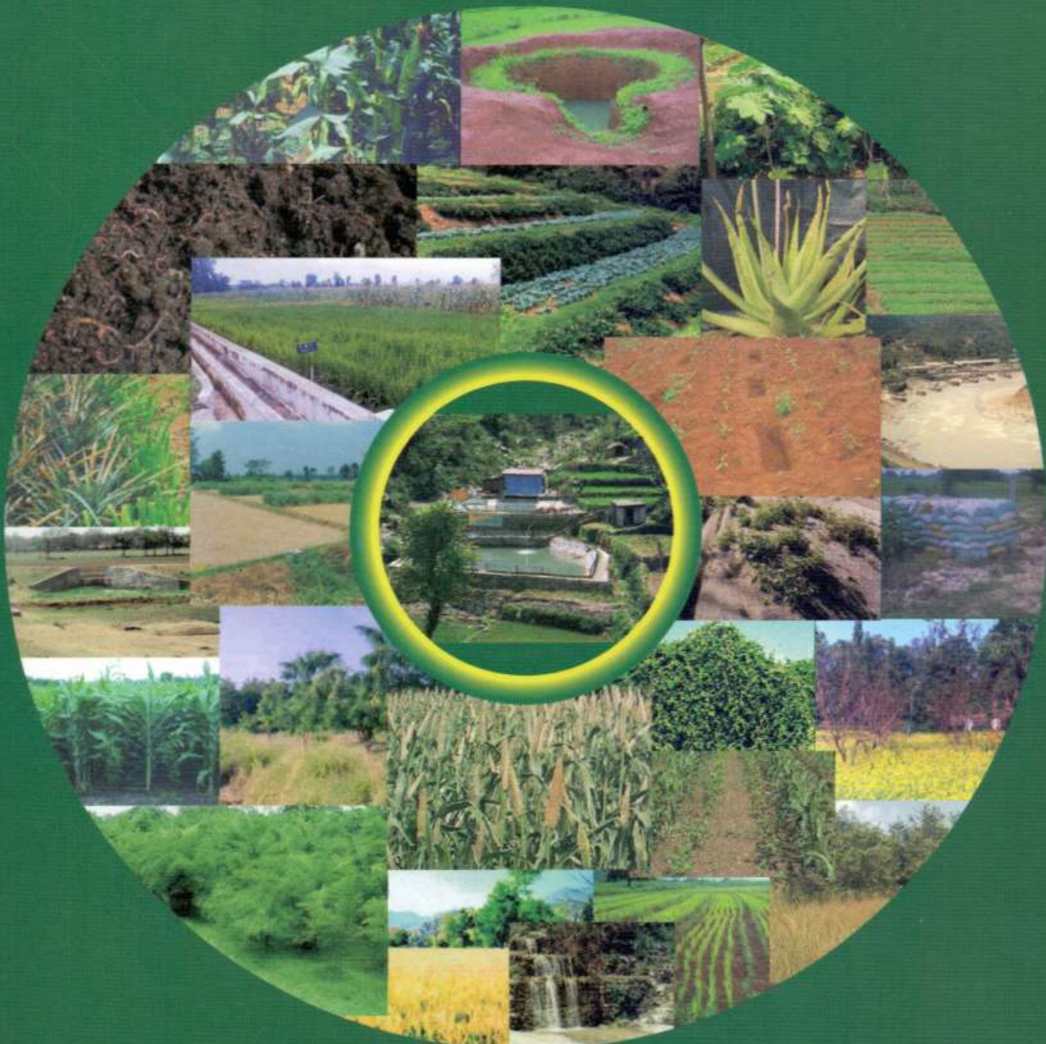
POTENTIAL TECHNOLOGIES FOR RESOURCE CONSERVATION & PRODUCTIVITY ENHANCEMENT



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218, Kaulagarh Road, Dehradun - 248195, Uttarakhand (INDIA)

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Foreword

Conservation of natural resources is an essential prerequisite for sustainable production of agriculture and other commodities in the country. Unscientific land use management practices and over exploitation of natural resources are causing enormous soil loss due to water erosion, which is the chief contributor (80%) to total land degradation in the country. High rates of water erosion cause deterioration in soil quality through loss of plant nutrients, reduction in soil organic matter content and water holding capacity and adverse changes in soil structure apart from decline in water table due to reduced infiltration rates. Water yield from streams/springs is declining and perenniality of flow in most of the river systems is being adversely affected due to land cover transformations and consequent high runoff and soil losses during the monsoon season. Deteriorating soil quality, declining availability of water resources coupled with faulty agricultural practices are mainly responsible for reduced productivity on arable and non-arable lands.

Many technologies have been developed in the past for increasing productivity on arable and non-arable lands, preserving productive potential of soils and ensuring environmental security. Unfortunately, many of these technologies are mostly available in the form of research papers, books, bulletins and other forms of literature, which are not readily available and understandable for adoption by user agencies and farmers in a 'ready-to-do' form at the grass root level.

I am very happy to learn that Central Soil and Water Conservation Research and Training Institute, Dehradun has compiled and documented the available potential technologies for efficient conservation and effective utilization of soil and water resources, to significantly improve crop and biomass productivity on arable and non-arable lands. I am sure this bulletin would immensely benefit the state agencies and farming community through wider dissemination of the potential technologies in different agro-climatic regions of the country for resource conservation and enhanced productivity. Adoption of these technologies will contribute very significantly towards drought proofing in the country and ensuring food security in a sustainable manner.

September, 2009

(Dr. A.K. Singh)
DDG (NRM)
ICAR, KAB-II,
New Delhi

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Introduction

Indian agricultural scenario is facing the challenge of realizing two divergent objectives of meeting the food demand of its ever growing population and sustaining its natural resources for future generations. India occupies 2.42% of world's land and 4% of its fresh water resources, but carries 16.8% of world's human population and 15% of its cattle. Steady growth of human as well as livestock populations and current phase of economic and trade liberalization are exerting heavy pressure on India's limited land and water resources. As per harmonized database on land degradation in India,120.72 million ha area is subjected to various forms of land degradation with erosion due to water contributing a maximum of 68.4% to the total degraded area followed by chemical degradation (24.68 million ha), wind erosion (12.40 million ha) and physical degradation (1.07 million ha). Soil erosion by water results in loss of top fertile soil and terrain deformation. The loss of plant nutrients through water erosion is estimated to be about 8.4 m t yr^{-1}.

In India, out of the 307 m ha of reported area, 142 m ha is presently being cultivated. Net sown area in the past 30 years has remained static between 138 and 142 m ha, though gross cropped area has steadily increased at a compound annual growth rate of 0.56% to 190.84 m ha in 2001-02. Managing soil and land resources, including the degraded ones, to meet the basic human and animal needs in terms of food, fibre, fodder, timber and fuel continues to be a major issue for policy makers, planners, conservationists and environmentalists. To meet the growing needs, though the net sown area may remain static at about 142 m ha, the cropping intensity needs to be increased from 137% in 2004-05 to 155% in 2025.

Water resources of the country, though vast, are not inexhaustible. Out of the estimated total precipitation of 400 m ha-m, the utilizable water resources are only 69.0 m ha-m of surface and 43.2 m ha-m of ground water resources. With fixed availability of water in the country, the demand-supply gap of water is widening and conflicts are increasing for sharing of water resources among different sectors. Water resources are being extensively used for increasing agricultural production and meet the demands of municipal, industry and energy sectors. Ground water is the source of four-fifths of the domestic water supply in rural areas. Over-exploitation of groundwater resources in intensive agriculture is causing its rapid decline and may convert many productive tracts of the country into deserts if the trend is not reversed.

The rainfall distribution in India is highly variable, the extremes ranging from less than 150 mm received annually in the western most part of the country to around 11,690 mm in the eastern most part. Spatially, about 30% area of the country receives less than 750 mm rainfall, 42% picks up between 750 and 1250 mm and 20% experiences between 1250 and 2000 mm on an average annual basis. In terms of temporal distribution, the total rainfall occurs in less than 150 hours and half of it descends in not more than 20 to 30 hours of heavy spells. Hence, runoff is a characteristic feature of the hydrologic cycle emanating mainly from high intensity storms. The variation in temporal and spatial distribution of rainfall causes frequent occurrence of floods and droughts in many parts of the country.

With monsoon season lasting over only a few months, agriculture in India is heavily dependent on supplemental irrigation, especially during critical stages of plant growth. Irrigation sector consumes as much as 83% of available water resources followed by drinking and municipal (4.5%), energy (3.5%) and industry (3%) sectors. Other uses account for approximately 6% of the total water use. With sustained and systematic development of irrigation in the country, gross irrigated area has increased from 22.6 m ha in 1950-51 to about 99 m ha in 2003-04. However, net irrigated area is only 53.1 m ha, which is about 30% of the gross cropped area (176 m ha) in the country.

Widening gap between demand and supply of land and water resources, both temporally and spatially, is a major hindrance in achieving the desired food production targets. The National Agriculture Policy of India has emphasized on attaining a growth rate of 4% per annum in agriculture sector, so as to achieve a target of 320 million tonnes of foodgrain production by the year 2025. This calls for most efficient allocation of our natural resources for production as well as environmental services. In the light of limited scope of increasing production from the irrigated sector, transforming rainfed farming into more sustainable and productive system through efficient use of natural resources provides the only viable alternative to the problem, which can be achieved through cutting-edge socially acceptable conservation and production technologies, well supported by appropriate and forward looking agricultural policies for promoting all round development of agriculture sector.

India was among the first few countries to have taken timely cognizance of the enormity of the soil erosion problems. Realizing the importance of soil and water conservation, the Government of India established several soil conservation research, demonstration and training centres in 1950s that were later reorganized into the present Central Soil and Water Conservation Research and Training Institute at Dehradun. The Institute's Headquarters at Dehradun and its eight Regional Centres are located in 9 states and 7 agro-ecological regions of India at an altitude ranging from 34 to 2217 m above msl and experiencing average annual rainfall varying from 510 to 1625 mm. The principal mandate of the Institute is conservation of natural resources dovetailed with maximizing production from arable as well as non-arable lands. To accomplish its mandate, the research activities of CSWCRTI have been organized into seven research programmes and twenty sub-programmes.

The R&D activities of the Institute and its Centres have focused on evolving strategies of soil and water conservation on watershed basis, tackling special problems such as ravines, landslides, mine spoils and torrents, demonstration of technology for popularization and imparting training. Reclamation technologies of torrents, gullies, landslides, mine spoils, gravelly / bouldery soils, sloping lands, watershed restoration, runoff harvesting, alternate land uses, diversification, biodiversity (ecological successions), bioremediation, management of common property resources and community participation were amply demonstrated with fairly good degrees of successes. Multi-disciplinary research agenda not only focuses on realizing higher productivity and food security, especially for small and marginal farmers, but also on maintaining, rather enhancing quality of natural resource base. The Institute has been the pioneer in evolving new paradigms of transparency, equity and equitable distribution of benefits and resources in integrated watershed development programmes. The Institute also conducts capacity building courses for policy makers, NGOs, field functionaries and farmers in soil conservation and watershed management.

Several technologies have been generated during the past five decades, first as a Soil Conservation Research, Demonstration and Training Centre, and later from 1974 onwards as a premier institute of soil and water conservation research and training in the country. These technologies have the potential to check land degradation, preserve soil's production potential, sustain productivity, conserve in-situ rainwater, minimize soil erosion, mitigate droughts, moderate floods downstream, harvest and recycle inevitable runoff and ensure environmental security. They include conservation technologies for arable and non-arable lands, techniques for mass erosion control, vegetative barriers, alternative land-use systems, water harvesting and integrated watershed management.

Despite development of these essential technologies, they could not be implemented on massive scale by the farmers, state departments, extension agencies and NGOs, due to their non-availability in the easily understandable and 'ready-to-do' form. Recently, the Institute brought out brochures of 33 such technologies developed by the Institute's Headquarters and Research Centres located in different agro-ecological regions, mostly during the last one decade. Stepwise procedure for execution of each technology has been described for speedy implementation at the grass root level. These brochures are readily available at the Institute giving detailed description of the technologies for use by the concerned agencies.

In this bulletin, broad outline of the technologies published as brochures at the Headquarters and 8 Research Centres of the Institute have been presented under the seven sections, *viz;* Moisture Conservation and Water Management, Agronomical Measures on Arable Lands, Mechanical Measures on Arable Lands, Vegetative Measures on Arable Lands, Water Harvesting and Groundwater Recharge, Mass Erosion Control, and Alternative Land Use and Farming Systems.

1

MOISTURE CONSERVATION AND WATER MANAGEMENT

1.1

Conservation Tillage for Management of Natural Resources and Maximizing Productivity in Maize - *Toria* Cropping System in Northern Hilly Region

Rainfed farming of maize in *kharif* season, followed by *toria* during *rabi* season, with conventional tillage is the most prevalent cultivation practice in the north-western Himalayas. Conventional tillage involves primary and secondary tillage operations for crop cultivation. Under the traditional tillage practices, the high intensity rains in the region result in high erosion losses due to topographical conditions in hilly and mountainous regions, leading to reduced soil fertility and crop productivity. An alternative low cost tillage practice, which reduces erosion losses, improves soil fertility and enhances crop productivity of maize-*toria* cropping system in north-western Himalayas is, therefore, needed.

Which Tillage Practice and Why?

- Conservation tillage i.e. minimum tillage with maintenance of crop residue cover on 30% soil surface is most suitable for management of natural resources and maximizing productivity in maize-*toria* cropping system.
- Under minimum tillage, disturbance of soil during tillage is minimum i.e. just enough for crop production, thereby reducing runoff, soil and nutrient losses.
- Since 30% of soil surface is covered with crop residue as mulch material, soil loss, runoff and nutrient loss is further reduced and a larger amount of moisture is retained in the soil, thus enhancing productivity.
- The conservation tillage practice is also more suitable as compared to conventional tillage due to its low cost.

Maize Cultivation

- For minimum manipulation of the soil, plough field with tractor drawn cultivator or bullock drawn *desi* plough immediately after harvest of previous crop. Second ploughing is to be done at the onset of monsoon, prior to sowing of maize.
- Recommended varieties of maize for the region e.g. Vivek, Kanchan, Makka Hybrid-9, VL-14, VL-42 and VL-88 should be sown 5-6 cm deep.
- Plant population of maize should be maintained between 55,000 to 65,000 plants ha^{-1}, using seed rate of 20 kg ha^{-1} for better yield and conservation of resources.
- Row to row distance should be 90 cm and plant to plant distance should be 20 cm.
- Residue of the harvested crop is saved for use as mulch material for *toria* crop.
- Standard package of practices should be followed.

Toria Cultivation

- One ploughing should be done just after maize harvest, and second just prior to sowing.
- *Toria* varieties T-9, PT-30, PT-303, PT-507 and Bhawani, recommended for the region are sown as early as possible just after maize harvest in 3rd or 4th week of September to ensure proper germination and establishment by using the residual soil moisture.
- *Toria* is sown 2-3 cm deep @ 5-6 kg ha^{-1} with plant population of 3.00-3.25 lakh plants ha^{-1}. Thinning should be done to maintain 30 cm row to row and 10 cm plant to plant spacings.
- Maize crop residue should be applied (@ 4-5 t ha^{-1}) as surface mulch to conserve soil moisture, and improve soil's physical and chemical properties.
- *Toria* residue obtained after its harvest (about 2-2.5 t ha^{-1}) should be applied as mulch during 1st week of March and incorporated into the soil by ploughing.
- Standard package of practices should be followed.

Conservation Efficiency

- Minimum tillage + crop residue incorporation reduces runoff by 12% and soil loss by 24% as compared to conventional tillage.
- Reduction in soil loss also results in low nutrient losses (Table 1).

Table 1: Effect of minimum tillage and crop residue mulching on runoff, soil and nutrients losses

Agricultural practice	Runoff (% of rainfall)	Soil loss (t ha yr^{-1})	Nutrients losses (kg ha yr^{-1})		
			N	P	K
Conventional tillage	23.3	18.0	32.1	0.56	13.3
Minimum tillage + crop residue	20.6	13.6	18.5	0.41	8.8

Improvement in Soil Properties

- The technology increased organic carbon, total N, available P and K by 21%, 16%, 22% and 8%, respectively over their initial status, which was also higher as compared to conventional tillage (Table 2).
- Bulk density improved from 1.36 to 1.30 g cm^{-3} and infiltration rate from 6.4 to 7.2 mm hr^{-1} over its initial status.

Table 2: Effect of minimum tillage + crop residue on physico-chemical properties and fertility of soil after 7 years

Agricultural Practice	pH	O.C. (%)	Total N (%)	Av. P (kg ha^{-1})	Av. K (kg ha^{-1})	B.D. (g cm^{-3})	Infiltration (mm hr^{-1})
Conventional tillage	5.4	0.63	0.07	32	135	1.38	6.8
Minimum tillage + crop residue	5.2	0.70	0.08	39	147	1.30	7.2
Initial status	5.1	0.58	0.58	32	136	1.36	6.4

Yield Enhancement

- Minimum tillage + crop residue incorporation yielded 2568 kg ha^{-1} of maize grain and 707 kg ha^{-1} *toria,* which were 8% and 9% higher, respectively as compared to conventional tillage (Table 3).

Table 3: Effect of minimum tillage and crop residue incorporation on yield of crops and net returns

Agricultural practice	Crop yield (kg ha^{-1})		Cost of cultivation* (Rs ha^{-1})	Gross returns* (Rs ha^{-1})	Net returns (Rs ha^{-1})
	Maize	*Toria*			
Conventional tillage	2387	647	18110	25300	7190
Minimum tillage + crop residue	2568	707	16440	25790	9350

*Based on 2006-07 prices.

Economics

- Conventional tillage is about 10% costlier than conservation tillage.
- Highest net returns of Rs. 9350 ha^{-1} (as per 2006-07 prices) were obtained by implementing the technology as compared to Rs.7190 ha^{-1} with conventional tillage.
- It is a 'zero input' technology which gives higher economic returns.

Scope

- The technology is highly suitable and can be adopted by marginal, small as well as other categories of farmers of Doon valley and hill and mountain agro-eco system under rainfed conditions covering Uttarakhand, Himachal Pradesh, Jammu & Kashmir and north-eastern states to conserve natural resources and enhance productivity of maize-*toria* cropping system.

Tillage Practices for Erosion Control and Enhanced Productivity in Yamuna Ravines

Alluvial soils occupy an estimated 75 m ha in the Indo-Gangetic alluvial plains and the Brahmaputra valley. A considerable area of this alluvial tract occurs in semi-arid region. Unscientific intensive cultivation in the area has led to development of a wide array of second generation problems, such as nutrient deficiencies, salinity, sodicity and sub-soil hardness. The soils of the semi-arid region are sandy loam, poor in water holding capacity, and rich in *kankar* granules with hard sub-soil. The bulk density of sub-soil is high, ranging from 1.6-1.72. The infiltration rate of these soils is low due to presence of impervious layer (*kankar*) of soil and, therefore, rainwater cannot penetrate into deeper layers. Low moisture content in soil profile severely affects the yield and water use efficiency of crops. The major crop sequence of the area (pearl millet-wheat) frequently fails due to poor storage of water in the soil profile. Since rain is a major source of water availability in semi-arid region, every drop of it must be conserved efficiently. To augment *in-situ* moisture conservation and improve yields of pearl millet and wheat, suitable modification and improvement in tillage practices is needed to enhance crop productivity.

Which Tillage Practice and Why?

- As rainwater cannot penetrate into deeper layers due to presence of impervious layer (*kankar*) of soil, it is mostly lost as runoff resulting in poor edaphic environment for crop growth even in rainy season.
- At the time of seed bed preparation, tillage depth is very important to ensure maximum *in-situ* rainwater conservation.
- Deep tillage is the practice of physical manipulation of soil to a depth of 20 cm by means of disc plough/chisel for providing ideal environment for plant growth. Adoption of deep tillage practice helps in higher turnover of below ground biomass.
- This results in greater storage of moisture in deeper layers (25-50 and 50-75 cm) of soil profile.
- Deep tillage (Photo 1) through disc plough (20

Photo 1: Deep tillage

cm) once in three years (only during *kharif* season) + one pass of cultivator every year enhances root growth/root biomass, soil organic carbon content and crop yield, suppresses weed growth, and reduces runoff to conserve maximum *in-situ* rain water in sandy loam deep alluvial soils of Indo-Gangetic plains.

Conservation Efficiency

- There is about two times higher storage of moisture in deeper layers (25-50 and 50-75 cm) of soil profile than the farmers' practice (wedge plough/cultivator twice every year at 7 cm depth).
- Runoff is considerably reduced (19%) as compared to farmers' practice (28%). However, no significant difference in soil loss is observed under deep tillage as compared to farmers' practice.
- The soil organic carbon content also increases from about 0.24% (zero tillage) to 0.45% in deep tillage in a span of five years due to continuous addition and decomposition of root biomass of crops.

Yield Enhancement

- Grain yield of pearl millet (Photo 2) is enhanced by about 50% as compared to farmers' practice. Highest yields of pearl millet (25 q ha^{-1}) and wheat (37 q ha^{-1}) can be obtained by adopting this practice.

Photo 2: Pearl millet crop under deep tillage

Economics

- The cost of tillage operations with deep tillage is slightly higher (Rs 300 ha^{-1} yr^{-1}) than the farmers' practice. However, imposition of the technology provides over two times higher net returns than the farmers' practice in pearl millet-wheat cropping sequence (Table 4).

Table 4: Yield and income from deep tillage technology and farmers' practice

Particulars	Deep tillage		Farmers' practice	
	Pearl millet	Wheat	Pearl millet	Wheat
Grain yield (q ha^{-1})*	25	37	14	27
Stover yield (q ha^{-1})*	34	40	21	30
Cost of cultivation (Rs ha^{-1})**	8300	14000	6500	14000
Gross income (Rs ha^{-1})**	16360	43000	9240	31500
Net income (Rs ha^{-1})	8060	29000	2740	17500

*Average of 6 years **Price-2007-08.

Scope

- Medium and large farmers are the likely beneficiaries of this technology. Deep tillage can be implemented where there is a problem of hard crust formation in the sub-soil layer. It is more common in areas where the soil pH is around 8 to 8.5, free $CaCO_3$ is abundant as evidenced by presence of *kankar* granules, and annual rainfall is 500 to 700 mm per annum. The technology can be adopted in Agra, Firozabad, Mainpuri, Etah and Etawah districts of Uttar Pradesh and identical agro-climatic regions of other states.

1.3

Vermi-Compost - An Effective Conditioner for Red Soils of Bundelkhand Region

Red soils of Bundelkhand region, developed mostly from granite and gneiss, are inherently low in fertility status due to coarse structure, poor water holding capacity, and low base saturation and organic carbon contents. The productivity levels of these soils, mostly rainfed, are among the lowest in India. These soils also have shallow depth, in addition to being vulnerable to erosion. Erratic rainfall and occurrence of frequent long dry spells cause water stress in *kharif* crops, often forcing the farmers to leave their land fallow during the monsoon season. Therefore, the cropping intensity in the region is less than 100%. In order to enhance and sustain the productivity of red soils in the region and increase the cropping intensity, it becomes imperative to adopt time-tested integrated plant nutrient supply systems, which advocate conjunctive use of inorganic and organic sources of plant nutrients, along with *in-situ* soil moisture conservation techniques. The best option for achieving both the objectives is the application of organics, preferably through composts (as they readily supply nutrients in addition to improving the soil quality) to supplement the inorganic fertilizers and improve physical (and biological) health of soil for better *in-situ* moisture conservation.

Which Composting Method and Why?

- In the series of composting, vermi-composting is one of the quickest methods, resulting in the production of nutrient-rich organic material. Vermi-composting is faster than conventional composting, with the former requiring 65 to 80 days as against four to six months required by the latter.
- Considering the fact that the region abounds in livestock population, application of vermi-compost is the best option.
- Vermi-compost serves both as a nutrient source and as a soil conditioner in the highly-permeable red soils of Bundelkhand. Applied as supplements to inorganic fertilizers @ 1 to 3 t ha^{-1}, it provides N, P_2O_5 and K_2O @ 1.8-2.1, 1.5-1.8 and 0.6-0.8 per cent, respectively. As a soil conditioner, it improves soil organic carbon, water stable aggregates, infiltration rate and soil water holding capacity (as vermi-compost can hold water almost twice its weight).

Vermi-composting Procedure

- Vermi-composting is a simple and rapid biotechnological process of composting farm wastes (e.g. straw from wheat, soybean, chick pea, mustard, vegetable wastes, leaves, twigs, etc.) with dung, brought about by some proven species of earthworms.
- The vermi-beds (Photo 3) should preferably be located under trees or in the vicinity of cattle sheds where there is shade. Non-cemented but compacted surfaces at the base of vermibeds are cost effective.

- Vermi-composting can be initiated any time of the year (preferably February-March) with one tractor-trolley of 15-20 days old cow dung (1850 kg on fresh weight basis), which is easily available in a farm house having 5-6 cattle heads.
- The dung is spread under shade and allowed to cool by spraying water. A series of six beds of 10ft x 3ft x 2ft can be laid with the cooled manure on previously compacted flat or brick-lined soil surface.
- Alternating layers (3-4 cm) of dung and residue-dung (1:1) slurry are piled up to a height of 2 ft. The earthworm species, namely *Eisenia foetida, Perionyx excavatus or Eudrillius eugiene* and their cocoons are introduced into the pits @ 4000-5000 adult worms per quintal of waste material.
- After their disappearance into the substrate, moist jute bags (gunny bags) are spread uniformly on the heap to facilitate aeration and maintain temperature.
- After 30 days, when the worms start appearing on the surface, a 2" thick layer of partially decomposed dung along with farm wastes such as straw, twigs or vegetable wastes are added to the heap. The materials are allowed to decompose for another two months.

Photo 3: Vermibeds

- The heaps are turned for aeration every 5-7 days and watered so as to maintain uniform moisture (50-60%) and temperature (28-32°C).
- Seven to ten days before the compost is ready, a fresh lot of cow dung is procured to prepare six more beds. On completion (65-80 days), the compost can be heaped in sunlight for the worms to go beneath the heap, which are then separated from the compost by sieving for introduction into the new vermibeds.
- By adopting this procedure, six cycles can be completed in one year.
- After one year, the population of earthworms becomes sufficient to decompose substrate in more than six vermibeds. A farmer can then opt to increase the number of beds and production.

Conservation Efficiency

- Vermi-compost applied @ 1 t ha^{-1} prior to sowing of *kharif* crop, in a green gram - mustard sequence on red soil increased soil organic carbon by 0.02% in three years, water stable aggregates from 45 to 50%, soil water holding capacity (as vermi-compost can hold water almost twice its weight), and infiltration rate from 3.2 to 3.5 cm h^{-1}.

Economics

- About 5000 kg of vermi-compost is produced with the above specifications and procedure, incurring a cost of about Rs 12,100 yr^{-1}.
- Substituting 50% inorganics in green gram-mustard sequence on red soil by vermi-compost applied @ 1 t ha^{-1} prior to sowing of *kharif* crop increased net returns by about 19% (Table 5).

Table 5: Economics of vermi-compost application in green gram-mustard in red soil

Particulars	Green gram	Mustard	Total
Cost of cultivation with traditional cultivation) (100% inorganics) (Rs ha^{-1})	7,100	7,740	14,840
Cost of cultivation (substituting 50% inorganics in green gram with vermi-compost @ 1 t ha^{-1}) (Rs ha^{-1})	10,620	7,740	18,360
Yield - traditional cultivation (kg ha^{-1})	725	1,145	-
Yield - with vermi-compost (kg ha^{-1})	985	1,285	-
Returns-traditional (Rs ha^{-1})	12,330	19,470	31,800
Returns-with vermi-compost (Rs ha^{-1})	16,750	21,850	38,600
Profit - traditional (Rs ha^{-1})	5,230	11,730	16,960
Profit - with vermi-compost (Rs ha^{-1})	6,130	14,110	20,240

Scope

- Vermi-composting has an immense potential in Bundelkhand region owing to the high cattle population, coupled with the poor edaphic conditions. The compost, owing to its higher soil aggregation potential is equally suited to both fine and coarse textured soils.
- However, the major limitation is the timely availability of substrate for decomposition. The harsh climatic conditions of the region, especially hot summers, increase the mortality of worms. Water is the most limiting factor for its production in drought years.

Indigenous Technologies for *In-Situ* Moisture Conservation and Rainwater Management in Semi-Arid Ravine Region

Out of an estimated 142.2 million ha net cultivated area of the country, 95.8 million ha (66.7%) is still rainfed, which contributes only 44% to the total food production of the country. In south-eastern Rajasthan, out of 2.1 million ha cultivated area, about 56% is rainfed. Water is the major limiting factor in rainfed agriculture due to occurrence of below normal and erratic rainfall over time and space. Since irrigated areas are already showing signs of fatigue and it is not possible to bring more area under cultivation, increased demand of food has to be met by improving the productivity of rainfed agriculture. *In-situ* moisture conservation and runoff management practices are vital for increasing production of rainfed cereal, pulse, oilseed and fodder crops to cope up with the increasing demand. However, most of the recommended modern conservation practices such as contour bunding, contour farming, vegetative barriers and mulching for *in-situ* soil moisture conservation and contour furrow, broad bed and furrow, graded bunding and contour ditching for runoff conservation measures are not explicitly and intensively adopted by the resource poor farmers on their own due to high cost and technological, operational, socio-economic and even psychological reasons. Farmers generally adopt their traditional methods for *in-situ* moisture conservation and efficient water management.

How to Improve Technological Adoption and Why?

- There is increasing realization that transfer of developed technologies should commensurate with traditional knowledge available at a given location as sustainability in agriculture depends upon the blending of indigenous knowledge of farming community with the modern technologies.
- Therefore, documentation of indigenous methods of *in-situ* moisture conservation and runoff management practices in south-eastern Rajasthan is essential for adoption, with little modifications (if necessary) and understanding farmers' perceptions on soil and water conservation practices.

In-Situ Moisture Conservation Practices

Summer ploughing

- Summer ploughing is generally done across the general slope of the field and some times across as well as along the slope in the months of April and May for increasing porosity and creating mini surface storage structures like ridges and furrows.

- Summer ploughing is very effective for *in-situ* moisture conservation during initial monsoon storms of low to moderate intensity. Moisture conservation is much greater in permeable soils than with relatively impervious soils for timely sowing of *kharif* crops.
- There is less runoff and soil loss due to more infiltration and less evaporation due to breaking off the capillaries and pulverization of soil.
- Availability of plant nutrients increases due to decomposition of crop residues, weeds etc.
- The summer ploughing with either *desi* plough (99%) or tractor drawn cultivator (1%) is one of the most common practices in rainfed farming areas of the region.

Kulying

- *Kulying* is a very common off monsoon season tillage operation by *kuly* for seed-bed preparation of *rabi* crops like chickpea, lentil, mustard, linseed etc. *Kulying* is started in *kharif* fallow land just after the recession of monsoon.
- *Kuly* is a bullock drawn blade harrow with blade of 75-90 cm length and weight of 15-20 kg (Photo 4). It can cover 1.5 ha land per day and has service life of 8 to 10 years.
- It is carried out at a depth of 5-7 cm at 8-10 days interval at least 5 to 6 times prior to sowing of *rabi* crops.

Photo 4 : ***Kuly***

- The cost of implement varies from Rs. 300-400 and annual maintenance is about Rs. 50-100.
- Due to repetitive ploughing, the soil is maintained in good tillth and weeds are controlled.
- *Kulying* reduces evaporation losses and maintains soil moisture level by breaking the capillaries and pulverization of soil.
- There is *in-situ* moisture conservation in subsequent rainfall events.

Kulphaing

- *Kulphaing* is a common intercultural operation carried out by *kulpha* in *kharif* crops cultivated in black soils. *Kulphaing* is generally done once or twice during crop growing season, when there is a dry spell.

- *Kulpha* is a modified form of *kuly* for intercultural operation and operated by a pair of bullocks (Photo 5). Generally, two *kulphas* are operated simultaneously to cover more area per unit time.

Photo 5 : *Kulpha*

- The working depth varies from 3-5 cm depending upon the soil condition at the time of operation. It can be manufactured by village artisans and weighs 15-20 kg.
- The cost of implement varies from Rs. 200 to 300 and annual maintenance cost is about Rs 50 to 100. Approximately 0.8 ha area is covered per day and it has service life of about 4 to 5 years.
- It is used by 80% farming community for intercultural operation in *kharif* crops like sorghum, soybean, maize, groundnut, etc.

Criss-cross ploughing

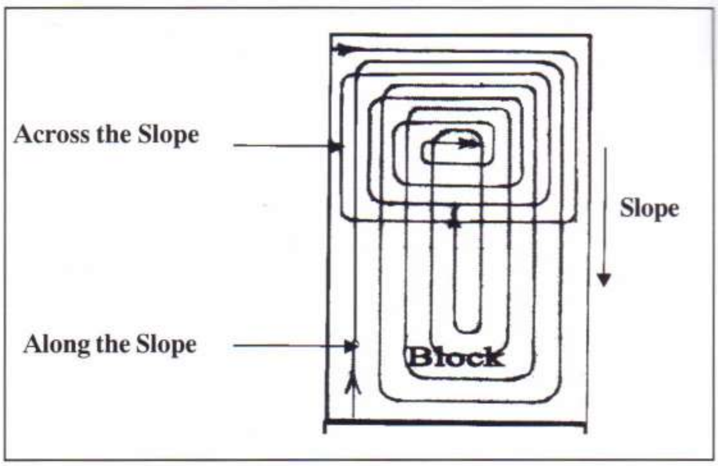


Fig. 1: Criss-cross ploughing

- In criss-cross system, ploughing is done twice, firstly along the slope and secondly across the slope (Fig. 1).
- The main objective of criss-cross ploughing is to leave no part of field unploughed, as unidirectional ploughing often leaves some unploughed land between two adjacent furrows, and creates a number of criss-cross mini surface water storage structures, which help in increasing the intake opportunity time for water to infiltrate into the soil, improve soil moisture and reduce runoff from the field.
- At the time of ploughing, farmer divides the whole field into a number of small blocks. The number and size depend upon the size of field and number of ploughs working in the field.
- The ploughing is started from the border of field and goes towards centre till a block/field is covered.

- Criss-cross ploughing is a very old indigenous tillage practice in the region, which helps in reducing run off and soil loss.

Bundhi (Earthen bund)

- *Bundhis* are heavy cross section earthen bunds constructed by a farmer across the slope at the lowest end of the field, with or without a *nikas* (waste weir) to dispose off excess runoff from one field to another field or *nalla* bed.
- These structures are generally used to retain upslope water and silt. Retention of water behind the *bundhi* increases infiltration in the field by enhancing opportunity time, increases soil moisture regime and reduces runoff and soil loss.
- If *bundhi* is intact, there is deposition of silt behind the *bundhi* due to retention of surface runoff, which converts undulating field into nearly plain/level land, and the reclaimed land becomes more fertile.
- *Bundhis* must be strengthened with grasses having good soil binding capacity like, *Dichanthium annulatum, Cenchrus ciliaris,* etc. These grasses apart from stabilizing the *bundhis* are also very good source of fodder for the cattle.
- It is a more common indigenous practice in ravinous tract of the region for soil and water conservation.

Bandha (Stone masonry)

- *Bandha* is a stone masonry drop structure with very long and heavy earthen embankment or masonry wall (extension wall) in different shapes and sizes (Photo 6). These structures are made of limestone masonry and constructed by resourceful farmers.

Photo 6 : *Bandha*

- Like *bundhis, bandhas* retain water and silt, enable uniform distribution of rainwater, which increases infiltration in the field by enhancing opportunity time, increases soil moisture regime, reduces runoff and soil loss, converts undulating field into nearly plain/level land, and makes the land fertile.
- Silt retention capacity of *bandhas* ranges from 42 to 60 t ha^{-1} yr^{-1} with 15-20% higher soil moisture regime than area without *bandha*.

- *Bandha* is the most common indigenous practice in the ravinous tract of south-eastern Rajasthan for soil and water conservation. It has been observed that 20% farmers of ravinous areas are practicing this system.
- Most of these structures are unscientifically constructed, which has resulted in side cutting and damage to the structures.

Runoff Management Practices

Talab (Pond)

- *Talab* is an embankment type pond of various sizes (smaller ponds called as *talai*) constructed near human settlements or at depression site of villages by providing huge cross section embankment around three sides of *talabs* with a provision of *nikas* (sluice gate) for removing the excess water, protecting the embankment from over topping/breaching and drawing irrigation water.
- The length of embankment of a *talab* varies from 200-500 m, with height 5-7 m, top width 5-8 m and bottom width 20-40 m. The embankments were strengthened by stamping and trampling by elephants and horses. In some *talabs*, stonewalls were constructed to protect upstream sides to avoid damage from wind wave action.
- Catchment area of these ponds ranged from 25 to 700 ha, the submerged area from 5 to 50 ha and ratio of catchment to storage capacity from 5 to 18.
- Most of these ponds have been laid in east-west direction to retain water for a longer duration due to less evaporation by easterly/westerly blowing winds.
- The structure harvests huge amount of surface runoff, otherwise going waste, and thereby reduces soil loss and increases ground water recharge down below the open/tube wells, and meets the water demand for irrigation, animal and domestic consumptions.
- In some *talabs*, different types of mechanisms have been provided to withdraw water for irrigation.
- Bed silt of the *talabs/talais* can be used for soil fertility improvement and construction/repair/ maintenance of mud houses by the farmers.

Sagar (Submergence bund)

- *Sagars* are large submergence bunds constructed as a barrier across the slope of catchment with a provision of *nikas* (sluice) for removing excess water and protecting the bund from over topping and breaching.
- The harvested runoff from catchment is retained during the monsoon season behind the bund to recharge the soil profile. The harvested water is either lost through seepage and evaporation or it is drained out by September/October for sowing of *rabi* crops like mustard, chickpea, wheat etc. in the submerged area.

- Percolation of runoff recharges the ground water and increases the water table downstream of open wells, tube wells, etc. Submergence bund is very effective for pervious soil.
- The size of bund is designed on the basis of rainfall, soil type and watershed characteristics. The minimum ratio of command to catchment area is 1: 20 to 25.
- Deposition of fertile soil and increase in moisture regime gives 70-80% higher *rabi* crop yields as compared to adjoining land without submergence bund. Average yield ranges from 25 to 30 q ha^{-1} of wheat, 10 to 12 q ha^{-1} of chickpea and 14 to 16 q ha^{-1} of mustard (Photo 7).

Photo 7 : Bumper wheat crop in the submergence area of a *sagar*

Anicuts

- Anicuts are stone masonry dams constructed across the perennial streams or *nallas* to harvest huge amount of surface as well as sub-surface runoff during or after the off monsoon season.
- Anicuts are also masonry drop structures with very long and heavy stonewalls.
- They help in meeting the water demand for animal, domestic and irrigation purposes.
- The retained water also percolates into soil profile and seeps down to recharge ground water, thereby replenishing the water level of downstream wells for irrigating the surrounding areas.

Scope

- The indigenous technologies can be adopted in the semi-arid ravine region of the country for improving *in-situ* moisture conservation and runoff management.
- Wide-scale adoption of the indigenous technologies in a participatory mode will help to increase and stabilize production in the region.

2

AGRONOMICAL MEASURES ON ARABLE LANDS

Contour Furrows for Enhancing Productivity in Medium Deep Black Soils of South-Eastern Rajasthan

Rainfed agricultural production systems in semi-arid region are primarily water limiting. Therefore, conservation of every drop of rainwater through improved land and water management practices is of utmost priority for increasing productivity and reducing the risk of crop failure during deficient rains. In the hot semi-arid region of south-eastern Rajasthan, occurrence of aberrant monsoon is a common feature. The medium deep black soils of the region either have inadequate soil moisture due to long dry spells or experience water stagnation due to improper drainage during consecutive rainfall events. Soil and water conservation practices which facilitate proper drainage along with promotion of in-situ rainwater conservation are essentially required for the predominant *kharif* crops of south-eastern Rajasthan to sustain productivity.

Why Contour Furrows?

- Considering compatibility with the predominant rainfed cropping systems, soil type and topography of south-eastern Rajasthan, contour furrows or inverted bunds are found to be one of the most suitable conservation measures to facilitate in-situ rainwater conservation as well as safe disposal of excess runoff during consecutive rainfall events in the region.
- Contour furrows are small ditches, 20-30 cm deep and 40-50 cm wide, laid along the contours across a natural slope. They break the length of slope into smaller segments, provide additional storage depression for impounding surface runoff and create a drainage net-work when connected to a graded drainage channel.
- The contour furrows technology was found to be the most effective as well as beneficial for rainfed farming in the region. Contour furrows are a better choice over contour or graded bunding as they often fail due to swelling / shrinking characteristic of black soils.
- Sorghum, pigeon pea, maize and soybean are important crops of the region. Intercropping of sorghum with pigeon pea using contour furrows technology produced highly encouraging results in terms of increase in agriculture production and reduction in runoff and soil loss.

Construction of Contour Furrows

- Field preparation is initiated immediately after the pre-monsoon showers.
- Deep plough (20cm) the field with mould board plough followed by two harrowings and a planking to have smooth surface.

- Sowing should be done across the general slope of the field to promote *in-situ* moisture conservation and reduce soil erosion.
- Adopting standard package of practices for cultivation of sorghum and pigeon pea, sow hybrid sorghum CSH9 (100-110 days duration) and local pigeon pea (230-240 days duration) in alternate rows, 30 cm apart.
- After every 10 rows of sorghum, skip a row of pigeon pea to accommodate a contour furrow between 2 rows of sorghum (Fig. 2).

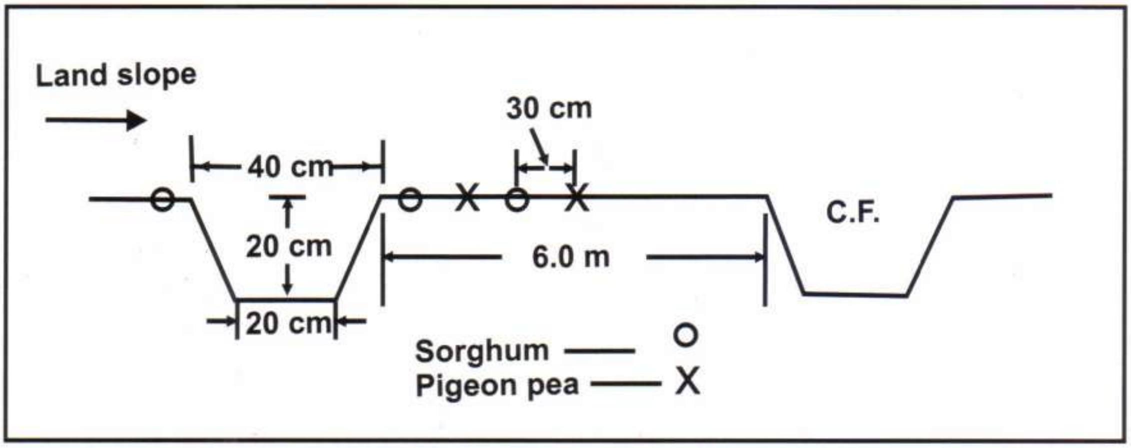


Fig. 2 : Schematic view of cross section of contour furrow

- Immediately after *kharif* sowing, furrows are made with single blade furrow plough or similar equipment which opens 40-50 cm wide and 20-30 cm deep furrow by pushing the excavated soil towards both sides of furrow (Photo 8).
- The excavated soil is pushed away from the furrow to avoid stagnation of water outside the furrows.
- Furrows must be placed on contours, to avoid them to function as drainage ditches, which otherwise collect runoff and accelerate erosion.
- For correcting the improper alignment along the contour furrows, and for storing water in the furrows, small earthen dykes are constructed for impounding water at 10-15 m interval.

Photo 8 : Single blade furrow opener

Conservation Efficiency

- The furrows create additional surface storage capacity of 11.25 mm ha^{-1}, which reduces runoff by about 22% and soil loss by 1.4 t $ha^{-1}yr^{-1}$. Furrows facilitate drainage during consecutive heavy rains and provide protection to crop during periods of water stagnation.

- The storage of optimum amount of runoff improves soil profile moisture, which mitigates the adverse impact of dry spells.

Yield Advantage

- Contour furrows consistently improve crop yield by about 30% compared to untreated plots in sorghum + pigeon pea intercropping system (Table 6).

Table 6: Effect of contour furrows on crop yields and returns from sorghum + pigeon pea intercropping

Particulars	Land treatment	
	Control	Contour furrow
Sorghum grain yield (q ha^{-1})	16.3	21.3
Pigeon pea grain yield (q ha^{-1})	2.2	2.9
Total crop (SGE*) productivity (q ha^{-1})	20.6	26.9
Cost of crop cultivation (Rs ha^{-1})	16000	16750
Gross return (Rs ha^{-1})	19593	24977
Net Return (Rs ha^{-1})	3593	8227

*SGE = Sorghum grain equivalent; Cost and return estimated based on 2007-08 market prices.

Economics

- The technology is relatively inexpensive (Rs. 750 ha^{-1} for 0.06 m^2 cross section contour furrows of 1600 m length constructed at 6 m horizontal spacing) compared to contour or graded bunding (Rs. 5000 ha^{-1}).
- Net returns of sorghum + pigeon pea intercropping with the technology (Rs. 8230 ha^{-1}) are 130% higher compared to under farmers' practice of constructing field funds (Rs. 3600 per ha^{-1}).

Scope

- The contour furrow is a suitable conservation technology for rainfed areas of hot semi-arid regions of the country having medium deep black soils. In south-eastern Rajasthan contour furrows can be implemented in Kota, Baran, Bundi, Jhalawar and part of Sawai Madhopur and Tonk districts and adjoining districts of Madhya Pradesh.

2.2

Maize + Cowpea Intercropping for Resource Conservation and Higher Productivity in Northern Hilly Region

Maize is an important *kharif* crop of the western Himalayas. It is widely cultivated under rainfed conditions. It allows more runoff and soil loss due to wider inter and intra spacings adopted for its cultivation and poor canopy cover. Therefore, in western Himalayan region, since agricultural activities are carried out on hill slopes where the soil depth is shallow, the runoff, soil and nutrient losses are high from maize fields during the frequent high intensity rains, and consequently the productivity loss is severe. This makes maize cultivation, in particular, and cropping system, in general, uneconomical as well as unsustainable in the region. Even after adoption of mechanical or land configuration erosion control measures like contour bunding, graded bunding etc., soil erosion by water continues. Therefore, to tackle this problem, suitable agronomic measures such as adequate crop cover in the inter spacings of the maize crop through intercropping for resource conservation and higher productivity need to be adopted.

Which Crop as Intercrop and Why?

- Out of the several crops evaluated, intercropping of maize with cowpea was identified as the best intercropping measure, which reduces runoff, soil and nutrient losses due to its luxuriant canopy cover (Photo 9), besides suppressing weed growth. It was also more productive and remunerative as compared to the traditional sole maize cultivation.
- The intercropping with cowpea, a leguminous crop, maintains soil's organic matter and improves its fertility, which, alongwith soil conservation brings sustainability in production.
- It helps to diversify crop cultivation, thereby reducing risk of crop loss and fulfilling diverse needs of the farmers for cereals and pulses.

Photo 9 : Intercropping of maize and cowpea

Intercropping Procedure

- Following standard package of practices, recommended varieties of maize (Vivek, Makka hybrid -9, VL Makka-88, VL Makka-42, VL Makka-14 and Kanchan) and cowpea (Pusa Komal and Pusa Rituraj) crops should be sown with the onset on monsoon (generally 3rd week of June) with row to row spacing of maize as 90 cm and plant to plant spacing of 20 cm (Fig. 3).
- A row of cowpea should be sown at a distance of 30 cm on both sides of a row of maize. Therefore, two rows of cowpea can be accommodated between two rows of maize with a 30 cm space between the cowpea rows (Fig. 3). Plant to plant distance between cowpea should be kept as 30 cm.

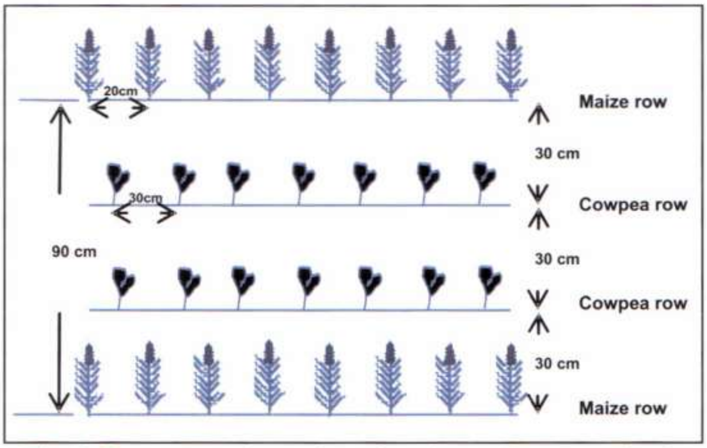


Fig. 3 : Lay out and spacing of maize and cowpea in the intercropping system

- An optimum plant density (55,000 plants ha^{-1}) of maize should be maintained.

Conservation Efficiency

- Maize (55,000 plants ha^{-1}) with cowpea as an intercrop forms thick canopy cover (up to 81%) in 50 days after sowing as compared to 59% in 70 days for sole maize.
- Higher vegetative cover is effective in controlling and reducing runoff by 10% and soil loss by 28% over pure maize.
- The legume crop of cowpea builds soil fertility.
- Intercropping reduces weed growth.

Yield and Economic Advantages

- Maize + cowpea (1:2) intercropping is more productive as it yields 34 q ha^{-1} of maize equivalent production as compared to 28 q ha^{-1} from pure maize (Table 7).
- By adopting maize + cowpea (1:2) intercropping technology, with additional cost of Rs. 3,000 ha^{-1} (21%), 17% higher net returns of Rs. 9,370 ha^{-1} can be generated as compared to Rs. 8,000 ha^{-1} with pure maize. The additional intangible benefits due to resource conservation help in improving sustainability of production systems, which more than compensate for the additional cost involved in the technology.

Table 7 : Effect of maize + cowpea (1:2) intercropping on yield of crops and net returns

Agronomical practice	Maize equivalent yield (kg ha^{-1})	Cost of cultivation (Rs ha^{-1})	Gross returns (Rs ha^{-1})	Net returns* (Rs ha^{-1})
Maize + cowpea (1:2)	3370	17,000	26,370	9,370
Pure maize	2760	14,000	22,000	8,000

*Based on 2007-08 prices.

Scope

- This resource conserving and easily implementable technology can be adopted in rainfed *kharif* maize crop by farmers of all the three north-western hill states, e.g. Jammu and Kashmir, Himachal Pradesh and Uttarakhand for enhancing productivity and obtaining higher economic returns.

Ragi + Pigeon Pea Intercropping for Higher Productivity in Tribal Areas of Orissa and Eastern Ghat Region

The Eastern Ghats Region of Orissa is rainfed and is characterized by varying slope and soil depth. It is highly vulnerable to water erosion due to rolling topography, spells of high intensity rainfall and faulty landuse. The area is dominated by tribal population, which practices traditional methods of crop cultivation, with predominantly *ragi* (finger millet) crop, thus accounting for heavy soil erosion and low productivity. Adverse weather conditions like delay in the onset of rains and / or failure of rains for few days to few weeks is very common in the rainfed *ragi* growing areas of this region. Tribals either cultivate sole crop of *ragi* or *ragi* with cereals / legumes/oilseed crops in mixtures with variable seed rates. Incompatible crop mixtures along with uneven sowing lead to improper plant spacing, unbalanced resource utilization, competition among crops and low crop yields. As a result, farmers face economic losses due to partial or total failure of the crops. To tackle this problem, an intercropping system needs to be designed in such a way that in case of unfavourable weather conditions, at least one crop survives to give economic yields to the resource poor farmers.

Why Intercropping of Pigeon Pea with *Ragi*?

- Economic losses to traditional rainfed *ragi* cultivating farmers of Orissa & Eastern Ghats Region due to frequent delay in onset or failure of rains can be significantly mitigated by adopting *ragi* + pigeon pea intercrop (6:2) as a technology to provide for efficient utilization of inputs, greater stability of yield, better control of pests and diseases, and erosion control.
- Pigeon pea is suitable for rainfed agriculture because it is drought tolerant, needs minimum inputs and produces reasonable yields. Being a nitrogen fixing legume, pigeon pea improves soil fertility, which augments crop's yield.
- Crops do not compete with each other as *ragi* matures in 90 days while pigeon pea in 120 days after sowing.
- Pigeon pea grain is highly nutritious and is a rich source of proteins (4.7%), carbohydrates, fiber and minerals. *Ragi* is known to be the richest source of calcium. The two crops together can provide nutritional security to the tribal community in the region.

Intercropping Specifications

- *Ragi* and pigeon pea are grown simultaneously in row ratio of 6:2 in the field following standard package of practices to provide higher yield stability as compared to mono-cropping.

- The field should be ploughed twice with soil turning plough (followed by planking) when there is adequate moisture in soil or at the onset of monsoon.
- Proper levelling of the field should be ensured to prevent water logging, as it may otherwise impede yield of the crops.
- Sowing should be done across the general slope to reduce soil erosion as per sowing specifications presented in Table 8.

Table 8: Specifications for sowing of *ragi* + pigeon pea intercropping

Particulars	*Ragi*	Pigeon pea
Intercropping rows	6	2
Row spacing (cm)	20-25	40-60
Plant spacing (cm)	8-10	10-20
Seed rate (kg ha^{-1})	4-5	2-3
Variety	Bhairbhi, local variety	UPAS-120, ICPH-8

Conservation Efficiency

- Better resource conservation in terms of runoff and soil losses i.e. 213.3% and 6.5 t ha^{-1}, respectively is achieved from the technology as compared to farmers' practices (18.6% and 11.1 t ha^{-1}, respectively).
- Loss of organic carbon was 132.8 kg ha^{-1} under farmers' practice as compared to 78.8 kg ha^{-1} under intercropping system.

Yield Enhancement

- *Ragi* + pigeon pea intercropping has the potential of producing 15.7 to 18.2 q ha^{-1} of *ragi* equivalent yield compared to 9.0 to 10.5 q ha^{-1} from farmer's practice of *ragi* + pigeon pea mixed cropping in lower, middle and upper hill slopes i.e. Dangar I, II and III (Table 9).
- Green straw of *ragi* is sweet smelling and is a suitable fodder for cattle. It is consumed by cattle without any wastage.

Table 9 : *Ragi* equivalent yields of *ragi* + pigeon pea intercropping in different hill slopes

Particulars	Crop yield (q ha^{-1})		
	Dangar I	Dangar II	Dangar III
Ragi + pigeon pea (6:2 rows)	18.2 (4030)	16.9 (3290)	15.7 (2570)
Farmers' practice (*ragi* + pigeon pea mixed cropping)	10.5 (1040)	9.4 (280)	9.0 (39)

Figures in parentheses are net returns (Rs ha^{-1}) at 2003 price level.

Economics

- The cost of cultivation of the improved technology is Rs 14,610 ha^{-1}.
- The technology of intercropping *ragi* + pigeon pea in 6:2 ratio was found to be the best in terms of crop yield, conservation of resources and net returns i.e. Rs. 3,460 ha^{-1} as compared to Rs. 2,370 ha^{-1} under farmers' practice at 2008 price level.

Scope

- It is a promising technology for red lateritic soils of Eastern Ghats High Land region of Orissa, where land is undulating, and due to erratic occurrence and uneven distribution of rainfall, agricultural production suffers. It is well suited to mildly sloping agricultural fields. Thus, this technology can be adopted in the Eastern Ghats High Land zone of Orissa having identical climatic and soil conditions.

2.4

Castor + Green Gram Intercropping for Delayed Onset of Monsoon in South-Eastern Rajasthan

The south-eastern region of Rajasthan experiences semi-arid climate, with average annual rainfall of 750 mm. About 90% of the rainfall occurs in the monsoon season, which is unevenly distributed over time and space with a delay of upto 2-4 weeks, i.e. upto first week of August, in the region. Under such conditions, fields are left fallow for raising *rabi* crops, and frequent shallow tillage operations are carried out during dry spells and post monsoon to conserve soil moisture in crop root zone, thus adding to the cost of production. However, many times, moisture in seeding zone is inadequate for germination and establishment of *rabi* crops. As a result, total failure occurs and returns are much lower than the cost of production. Intercropping systems have shown potential to reduce risk of such failures. These systems have been found to be more productive and remunerative as compared to sole cropping of individual crops.

Why Castor + Green Gram Intercropping?

- Recommended intercropping systems like sorghum + pigeon pea, pigeon pea + black gram and soybean + pigeon pea are promising only under normal monsoon conditions. Their productivity declines significantly if the monsoon gets delayed upto first week of August.
- Castor + green gram intercropping has been identified as an efficient intercropping system for delayed monsoon conditions upto 3-4 weeks in south-eastern Rajasthan.
- Castor (*Ricinus communis*) is a long duration (220-230 days) non-edible crop which grows well under rainfed as well as limited irrigation situations with little effect on its productivity due to delayed sowing up to first week of August than other *kharif* crops in the region.
- It is a widely spaced crop and its growth rate in early stages is slow which offers an excellent opportunity for intercropping of short duration and fast growing legumes for resource conservation, weed control, insurance against crop failure and maximizing production and returns (Photo 10).
- Unlike castor, green gram (*Mung bean*) is a fast growing (65-70 days duration) legume, which

Photo 10 : Intercrops at early stage

escapes competition with castor and is suited well for delayed monsoon conditions.

- Following standard package of practices for cultivation of castor and green gram in the region, castor and green gram should be sown in separate rows across the slope in 1:2 ratio i.e. 30 cm apart so that the distance between two castor rows remains 90 cm (Fig. 4). This would minimize erosion hazard under field conditions.

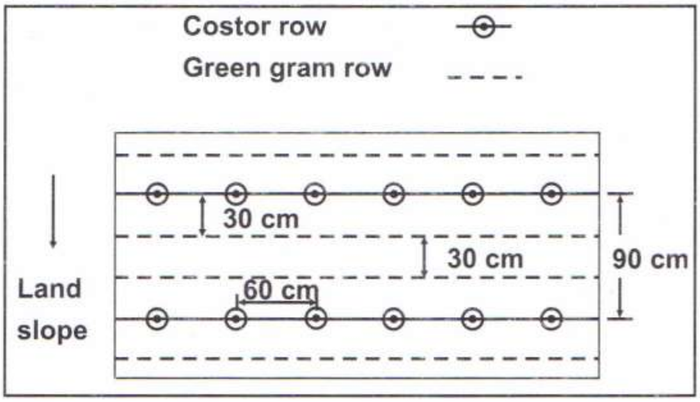


Fig. 4 : Field layout of intercropping system

Conservation Efficien cy

- This system provides excellent vegetative cover (Photo 11) on the ground and reduces runof f and soil loss by 22% and 30%, respectively over pure stand of castor apart from improving soil fertility status.

Photo 11 : Excellent vegetative cover on the ground

Yield Enhancement

- Under normal monsoon conditions, this system provides 26% (3.5 q ha^{-1}) and 248% (12.2 q ha^{-1}) higher castor grain equivalent yield than sole cropping of castor and green gram, respectively (Table 10).

Table 10 : Crop productivity under sole and intercropping systems

Cropping system	Grain yield (q ha^{-1})	CGE* yield (q ha^{-1})
Pure castor	13.6	13.6
Pure green gram	7.2	4.9
Castor + green gram (1:2)	14.3 (ct) +4.2 (gg)	17.1

ct - castor; gg - green gram; *CGE = Castor grain equivalent, calculated based on July 2008 market prices.

- This intercropping system is superior to other intercropping systems under delayed monsoon conditions upto 4 weeks as it recorded only 15% (4 q ha^{-1}) reduction in productivity against 48 - 58% (7.0 - 12.5 q ha^{-1}) reduction in other best recommended systems.

Economics

- The performance of the intercropping system was excellent under delayed monsoon conditions as it recorded only 31% reduction in net returns against normal onset, whereas other intercropping systems showed negative values.
- It is the only system which gave positive net returns as compared to the other intercropping systems (Table 11).
- The cost of the technology following standard package of practices is Rs 22,300 ha^{-1}.
- It provides employment for 93-95 man-days against 76-78 man-days in pure crop of castor.

Table 11 : Net returns (Rs ha^{-1}) under different intercropping systems under delayed monsoon situations

Intercropping system	Onset of monsoon		
	Normal	2 weeks delay	4 weeks delay
Sorghum + pigeon pea	18,850 (19.7)	15,150 (17.8)	-565 (8.9)
Pigeon pea + black gram	8,410 (14.4)	2,130 (10.8)	-3,200 (7.4)
Castor + green gram	20,400 (27.6)	20,540 (27.6)	14,140 (23.5)
Soybean + pigeon pea	19,060 (21.9)	9,250 (15.9)	-1,290 (9.3)

Figures in parentheses indicate pigeon pea grain equivalent yield (q ha^{-1}).

Scope

- This intercropping system is suitable for rainfed hot semi-arid region with medium black soils of Southeastern Rajasthan comprising districts of Kota, Bundi, Baran, Sawai Madhopur and Tonk for higher returns per unit area.
- It can also be adopted in northern Gujarat and western Madhya Pradesh having identical soil and rainfall conditions.

Sorghum + Pigeon Pea Intercropping for Stabilizing Productivity in South-Eastern Rajasthan

The south-eastern region of Rajasthan receives an average annual rainfall of 750 mm. Delayed onset of monsoon and intermittent dry spells are major limiting factors for rainfed crop production in the region. Ensuring stability in rainfed production systems in semi-arid regions continues to be a major concern for this region. The nature provides many viable alternatives for sustainable agriculture under adverse climate and soil conditions. The deep black soils of the region have the capacity to retain adequate moisture for at least one good harvest. In addition, crop diversification has enormous potential for reducing the risk of total crop failure experienced by sole cultivation of any crop. Under stressed conditions, crop diversification through intercropping is a viable option as it efficiently utilizes nutrients, moisture and other resources by selecting suitable component crops that have a marked variation in their growth pattern and duration. The peak growth period of component crops should not coincide, as higher yield advantages are directly proportional to differences in maturity period of component crops. Therefore, generally long and short duration crops are grown together for higher total yield advantage. In addition to ensuring stability in crop production, intercropping is more profitable than growing sole crop.

Why Sorghum + Pigeon Pea Intercropping?

- Sorghum is one of the prominent *kharif* crops of this rainfed region.
- As the rooting pattern and date of maturity between the sorghum and pigeon pea differ, the two crops show good compatibility when grown together. Sorghum is harvested after 100 to 110 days while pigeon pea matures in 230 to 240 days.
- The legume crop of pigeon pea helps in maintaining soil fertility.
- Sorghum + pigeon pea intercropping is the most promising cropping system for normal monsoon rainfall and even under aberrant weather conditions in semi-arid region of Rajasthan (Photo 12).

Photo 12 : Intercrops before harvest of sorghum

- Following standard package of practices for cultivation of sorghum and pigeon pea in the region, the crops should be sown in 1:1 row ratio during last week of June to first week of July as per monsoon occurrence. Delayed sowing progressively reduces the yield of crops.

Yield

- Under normal monsoon conditions, this system gives 30-35 q ha^{-1} sorghum grain and 10-12 q ha^{-1} pigeon pea grains with 60-70 and 10-12 q ha^{-1} fodder and fuel yield, respectively.
- The intercropping system gives 32% (11.3 q ha^{-1}) and 83% (21.1 q ha^{-1}) higher sorghum grain equivalent yield than sole sorghum or pigeon pea, respectively (Table 12).
- The cost of the technology following standard package of practices is about Rs 16,000 ha^{-1}.

Table 12: Crop productivity in sole and intercropping systems

Cropping system	Grain yield (q ha^{-1})	Sorghum grain equivalent * yield (q ha^{-1})
Pure sorghum	35.2	35.2
Pure pigon pea	13.1	25.4
Sorghum + pigeon pea (1:1)	32.2 (Sorghum) 7.4 (Pigeon pea)	46.5

*Calculated based on July, 2008 market price.

Economics

- The gross returns and net returns obtained with the technology are Rs 40750 ha^{-1} and Rs. 24,750 ha^{-1}, respectively.
- An additional 35-40 mandays of employment are generated with the technology as compared to sole cropping of sorghum or pigeon pea.

Scope

- The intercropping systems is suitable for rainfed farming in hot semi-arid region with medium deep black soils of south-eastern Rajasthan and adjoining areas of western Madhya Pradesh.

Integrated Nutrient Management Systems for Export Oriented Vegetable Crops in the Nilgiris

Land use pattern of the Nilgiris is primarily dominated by tea plantation and cultivation of annual vegetables (potato, carrot, cabbage, etc.). However, cultivation of tea has become uneconomical due to significant fall in prices resulting in serious economic stress to small and medium farmers. Cultivation of vegetable crops being highly market oriented, the farming community uses high amount of inorganic fertilizers, which does not yield the desired benefits. Instead, it has led to problems of soil degradation and pollution of water bodies. Cultivation of export oriented vegetables like Brussels sprout, broccoli and lettuce in the Nilgiris can provide better economic returns to the small and medium farmers. However, there is a need for developing a better nutrient package for these vegetable crops, as adoption of high doses of inorganic fertilizers as in the conventional vegetable crops may be cost intensive and may lead to further economic stress to the farmers.

What Nutrient Management Systems?

- Integrated nutrient management systems comprising of combinations of NPK and FYM, with and without liming, bio-fertilizers and crop residue recycling provide higher productivity of export oriented vegetable crops like Brussels sprout, broccoli and lettuce.
- Not only better yields, the combinations also improve soil health and reduce erosion.

Integrated Nutrient Management Systems

- Four integrated nutrient management (INM) systems encompassing different combinations of components were found to be superior in respect of soil health and conservation efficiency, crop yield, and economics:
  - **INM1:** FYM @ 22.5 t ha^{-1} yr^{-1}, bio-fertilizers (BF) Phosphobacteria and Azospirillium each @ 37.5 kg ha^{-1} $crop^{-1}$, lime @ 5 t ha^{-1} yr^{-1} and crop residue recycling (CRR)
  - **INM2:** NPK @ 75% of the recommended dose, FYM @ 3 t ha^{-1} yr^{-1} and BF, lime and CRR as under INM1
  - **INM3:** NPK @ 50% of the recommended dose, FYM @ 6 t ha^{-1} yr^{-1} and BF, lime and CRR as under INM1
  - **INM4:** NPK @ 25% of the recommended dose, FYM @ 9 t ha^{-1} yr^{-1} and BF, lime and CRR as under INM1.

- Recommended doses of NPK are 150:150:100 for brussels sprout, 50:100:30 for lettuce and 80:100:100 for broccoli.
- Application of lime (once in a year) and bio-fertilizers (in each crop) along with crop residue recycling should invariably be followed.
- Depending upon the availability of FYM (to be applied once in a year) with the farmer, he can optimize the dose of chemical fertilizers for each of the above mentioned crops.

Conservation Efficiency

- Soil quality improved in terms of higher pH values (4.86 to 5.26), and lower Exchangeable Al (2.25 to 3.75) and Exchange Acidity (0.29 to 0.75) under these INM systems.
- Increase in pH and organic carbon under these INM systems was in the range of 11 to 20 and 2 to 7 per cent, and decrease in Exchangeable Al and Exchange Acidity varied from 44 to 67 and 30 to 72 per cent, respectively when compared to farmers' practice of applying inorganic fertilizer mixtures (NPK @ 150:175:150 in Brussels sprout, 70:90:70 in lettuce and 100:120:100 in broccoli).
- Runoff and soil loss were significantly lower under INM1 (116.1 mm and 0.96 t ha^{-1}), INM2 (113.9 mm and 1.18 t ha^{-1}), INM3 (111.9 mm and 0.94 t ha^{-1}) and INM4 (115.8 mm and 0.96 t ha^{-1}) as compared to farmer's practice.
- Under the four INM systems, the over all reduction in runoff ranged between 23 and 25 per cent, while for soil loss it was between 25 and 40 per cent when compared to those recorded under farmer's practice.
- Relative soil and water conservation efficiency was highest under INM3 (65%) followed by INM1 (64%), INM4 (64%) and INM2 (56%). Nutrient losses through runoff water were also lower under these INM systems.

Yield Enhancement

- Significantly higher yields of Brussels sprout were obtained in under INM1 (7.9 t ha^{-1}), INM4 (7.2 t ha^{-1}), INM3 (7.1 t ha^{-1}) and INM2 (6.9 t ha^{-1}), which were higher by 38, 25, 24 and 21 per cent, respectively when compared to the yields obtained under farmer's practice (5.7 t ha^{-1}).
- Six to eight times higher yields of lettuce were recorded under INM3 (14.2 t ha^{-1}), INM4 (14.2 t ha^{-1}), INM1 (13.8 t ha^{-1}) and INM2 (12.1 t ha^{-1}) when compared to the yield obtained under farmer's practice (1.8 t ha^{-1}).
- Similarly, broccoli yields (Photo 13) were also higher under INM1 (3.9 t ha^{-1}), INM4 (3.7 t ha^{-1}), INM3 (3.5 t ha^{-1}) and INM2 (3.0 t ha^{-1}) which were higher by 71, 64, 53 and 33 per cent, respectively when compared to the yield obtained under farmer's practice (2.3 t ha^{-1}).

Economics

- Among the different INM systems, brussels sprout crop had higher net returns per hectare under INM1 (Rs 1.47 lakhs), INM4 (Rs 1.22 lakhs), INM3 (Rs 1.17 lakhs) and INM2 (1.12 lakhs).
- Also for lettuce, INM systems had better economics with INM4 producing the highest net returns of Rs 0.68 lakhs ha^{-1} followed by INM3 (Rs 0.67 lakhs ha^{-1}), INM1 (Rs 0.65 lakhs ha^{-1}) and INM2 (Rs 0.51 lakhs ha^{-1}).

Photo 13 : Broccoli with INM

- In case of broccoli also, significantly higher net returns per hectare could be obtained under INM1 (Rs 0.81 lakhs), INM4 (Rs 0.76 lakhs), INM3 (Rs 0.67 lakhs) and INM2 (Rs 0.52 lakhs).

Scope

- The four integrated nutrient management systems have potential for adoption by vegetable growing farmers in the Nilgiris, especially under small and medium categories.
- Farmers who are engaged in the cultivation of export oriented vegetable crops like brussels sprout, lettuce and broccoli can select any one of the four options of integrated nutrient management for achieving higher crop yield and returns and ensuring better soil health and conservation in the Nilgiris.

Potassium Application for Resource Conservation and Enhanced Production in North-Western Himalayas

In the hill and mountain agriculture evolved over centuries with the application of farmyard manure ranging from 5-15 t ha^{-1} along with inorganic NPK application hardly exceeding 20 kg ha^{-1} yr^{-1} as against 105 kg ha^{-1} yr^{-1} national average, application of potassic fertilizers is virtually nil in the Himalayan states. Thus availability of potassium for plant growth is limited in the Himalayan soils. Imbalanced fertilization leads to scanty canopy cover, thereby causing high erosion. On the other hand, balanced fertilization provides better vegetative cover, which reduces soil erosion that in turn maintains crop productivity, soil health and water balance, and makes crop cultivation economical and sustainable. Potassium, being a macro nutrient, stimulates above and below ground bio-mass production, which changes into soil organic carbon. Therefore, there is a need for application of proper dosage of potassium nutrient through inorganic fertilizers to *kharif* and *rabi* crops cultivated in the hilly soils of the region.

What Dosage of Potassium?

- Application of a higher dose of potassium @ 120 kg K_2O ha^{-1} provides higher grain yield of maize, cowpea green pod, wheat, lentil and mustard than the recommended (40 kg K_2O ha^{-1}) dosage alongwith higher net returns.
- Among the crops, the productivity and BC ratio of cowpea-wheat/lentil/mustard cropping system is higher as compared to maize-wheat/lentil/mustard system.
- Application of the higher potassium dosage @ 120 kg K_2O ha^{-1} provides better canopy cover which reduces runoff and soil loss.
- Potassium fertilization also improves the nutritional value of harvested grain by higher protein and oil content.

Fertilizer Application

- Field should be ploughed once immediately after the harvest of previous crop with tractor drawn cultivator or bullock drawn *desi* plough followed by one planking (minimum tillage) with the onset of monsoon prior to sowing of maize to conserve the soil moisture.
- During second ploughing, 45 kg N, 60 kg P_2O_5 and 120 kg K_2O ha^{-1} for maize and 20 kg N, 80 kg P_2O_5 and 120 kg K_2O ha^{-1} for cowpea should be applied followed by planking. The remaining half of N i.e. 45 kg ha^{-1} should be applied to maize at the time of knee-high stage.
- About 20 kg seed of maize variety Kanchan and 2 kg seed of cowpea variety Pusa Komal should be sown with seed drill. For maize, 90cm x 20cm and for cowpea 45cm x 45cm plant to plant and row to row spacing, respectively should be maintained at the time of sowing.
- For *rabi* crops, wheat variety HD 2353, lentil variety PL-4 and mustard variety T-59 should be sown during the 1st fortnight of November.

- NPK (kg ha^{-1}) should be applied @ 60:40:30 for wheat, 20:80:30 for lentil and 20:40:30 for mustard, respectively. In case of lentil and mustard, full dose of NPK should be applied at the time of sowing. For wheat, half of N should be applied at sowing time and the remaining half at critical crown root initiation stage.
- Standard package of practices should be adopted for cultivation of the crops.

Conservation Efficiency

- Runoff and soil loss is reduced to the extent of 18.5 and 15.8 per cent under maize and 22.8 and 19.7 per cent under cowpea cover, respectively.
- The soil K status improved over the years as the average balance coefficient was 1.29, indicating that considerably higher K was applied than removed as compared to 0.67 in case of lower (recommended) rate where more K was removed than was applied.

Yield Enhancement

- Higher grain yield was observed in all the crops, *viz*; maize (28.3 q ha^{-1}) with wheat (17.9 q ha^{-1}), lentil (5.9 q ha^{-1}) and mustard (7.3 q ha^{-1}), and cowpea green pod (12.8 q ha^{-1}) with wheat (21.0 q ha^{-1}), lentil (7.1 q ha^{-1}) and mustard (8.4 q ha^{-1}) with higher doses (120 kg K_2O ha^{-1}) of potassium than recommended K (40 kg K_2O ha^{-1}).
- The water use efficiency of *rabi* crops increased with the increase in potassium dosage.
- Potassium fertilization also improved the nutritional value of harvested grain by elevating the protein and oil content.
- Cowpea based rotation exhibited higher productivity, soil health and water balance.

Economics

- The net returns for crop sequences of maize-wheat, maize-lentil and maize-mustard receiving 120 K_2O ha^{-1} were Rs.15130, 8520 and 9580 ha^{-1}, which were Rs. 7710, 5920 and 5500 ha^{-1}, respectively more than the same crop sequences with lower (recommended) dose of K_2O. The BC ratio of the crop sequences were 1.50, 1.31 and 1.36, respectively.
- The net return for crop sequences of cowpea-wheat, cowpea-lentil and cowpea-mustard receiving 120 K_2O ha^{-1} were Rs.19640, 12960 and 12920 ha^{-1}, which were Rs. 8270, 5670 and 6280 ha^{-1}, respectively more than the same crop sequences with lower (recommended) dose of K_2O. The BC ratio of the crop sequences were 1.73, 1.56 and 1.55, respectively.

Scope

- Potassium application @120 kg K_2O ha^{-1} with minimum tillage for first crop can be adopted by the farmers of Doon valley and hill and mountain agro-ecosystem, specifically in medium to light textured soils to conserve natural resources and check soil degradation due to K mining besides building up of organic matter and enhancing productivity of crops for higher returns under rainfed conditions.

2.8

Soil and Water Conservation Measures in New Tea Plantation Areas for Sustainable Production in Southern Hilly Region

Tea is an important plantation crop cultivated in four states, *viz*; Assam, Tamil Nadu, Kerala and Karnataka, covering 1.34 lakh ha area of India. In south India, tea is cultivated on hill slopes in an area of 0.55 lakh hectares (41%), of which the Nilgiri hills alone constitute about 85% of the total area under tea cultivation in the region. The crop is cultivated on sloping lands (10% to 100% slopes). In the initial years of plantation, canopy cover is sparse due to slow growing nature of the crop. In the absence of suitable conservation measures, high intensity rainfalls cause tremendous soil erosion from new tea plantations. Conservation measures are very essential for preserving valuable natural resources, *viz*; soil, water and nutrients. Considering the vast area of tea cultivation in the country, a technological package is essentially needed in new tea plantations for maintaining ecological balance and ensuring sustainable tea production along with economic and livelihood securities for more than 10 million people engaged in tea cultivation in the country.

Which Conservation Measures?

There are several conservation measures that are effective in preventing erosion in the newly established tea plantation areas:

- Contour planting
- Contour staggered trenching
- Vegetative barriers
- Contour stone wall and drains
- Mulching
- Cover crops

Field Preparation for Planting Tea and Shade Trees

- Remove unwanted weeds, shrubs from area selected for plantation and level / smoothen the land wherever needed to avoid water stagnation.
- Boundary and leader/vertical drains are laid along field boundary, if required, depending upon location and type of problem to prevent entry of water from upper reaches and safe disposal of runoff (Fig.5 & Photo 14).
- Boundary drain should by 0.6 m wide at the base, 0.45 m deep with sloping sides and

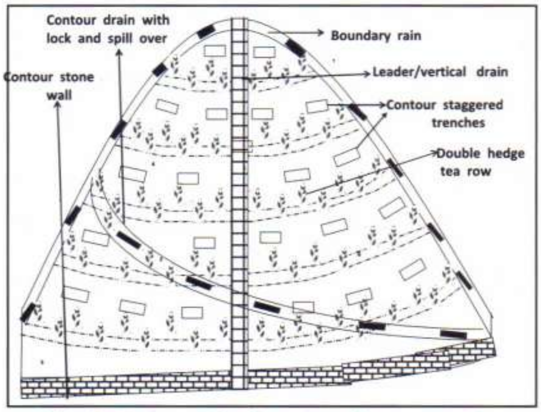


Fig. 5 : Schematic diagram of conservation measures in tea plantation

intermittent blocks of 0.3 m height and 0.3 m length at 2-3 m interval are constructed to reduce velocity of flowing water. This drain is connected to leader drain.

- Leader drain is constructed with stones along the slope and should be 0.6 m wide at the base, 0.45 m deep with 0.5 m deep and 0.5 m long drop pits to retard the velocity of water flow.
- Cost of laying drain comes to Rs. 60 - Rs. 90 for every running metre depending upon site condition.
- Follow double hedge contour planting for tea with the recommended spacing and planting techniques. Use A-frame for marking contour line before peg marking for pitting (Fig.6).

Photo 14 : Vertical drain in tea plantation

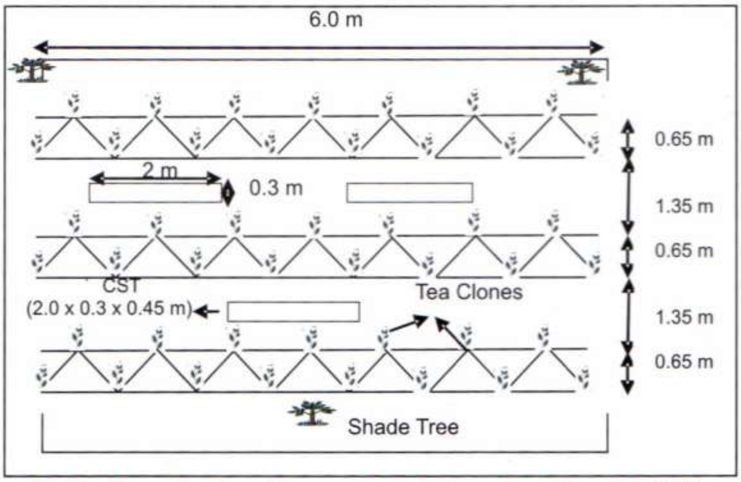


Fig. 6 : Layout of tea clones and shade tree planting with CST

- Silver Oak (*Grevillea robusta*) is commonly used and recommended species for shade in tea plantation in south India. Recommended spacing and planting techniques may be followed for planting shade tree in new tea plantation.
- Cost of planting tea with shade trees is Rs 70,140 ha^{-1} (at 2007 prices).

Contour stone wall

- Constructing a contour stone wall is optional and recommended if stones are available at the site.
- Wall should be generally 0.6 m wide and 0.8 m high, with 0.5 m and 0.3 m above and below the ground surface, respectively.
- If stones are readily available, provide one contour wall at every 6 to 8 double hedge rows of tea on land slope of <30% and for >30% slope, at every 4 to 6 double hedge rows of tea.
- Labour cost works out to Rs. 60 to 70 per running metre (unit cost of 2007).

Continuous contour trenches (CCT)

- CCT is recommended when construction of contour stone wall is not feasible due to non availability of stone at site.
- The trench should be 0.3 m wide, 0.45 m deep with lock and spillover (0.20-0.25 m height and 0.3 m length) arrangement after every 2 m. The spacing of CCT is similar to that of contour stone walls. Excavated soil is spread on downstream side of trench.
- CCT is connected to boundary / leader drain and it costs Rs. 8 to 9 per running metre at the unit cost of 2007.

Contour staggered trenches (CST)

- It is an essential conservation measure for tea plantations, irrespective of all other measures.
- Trenches are dug on contour lines after every 2 m distance. The trenches are 2 m long, 0.3 m wide and 0.45 m deep. Total number of trenches per ha is 1250.
- Trenches are dug in a staggered manner in walking rows between two paired rows. The excavated soil is spread on downstream side of trenches.
- Cost of trenching works out to Rs. 6,250 ha^{-1} as per unit price of 2007.

Cultivation of cover crops

- When tea canopy is sparse and there is not much competition for nutrients, short duration leguminous cover crops e.g. French bean (*Phaseolus vulgaris*), Touch me not (*Mimosa invisa*) etc. can be cultivated between tea rows of upto 3-4 years old plantation (Photo 15).

Photo 15 : Cover crop of beans + CST

- Seeds are sown at 0.45 m x 0.20 m spacing without disturbing the soil. For French bean 25 kg ha^{-1} and for Mimosa 5 kg ha^{-1} seed is required. Two crops of French bean can be cultivated in a year. Follow recommended practices for growing cover crops.
- Cost of cultivation of beans as cover crop is Rs 10,000 - 12,000 ha^{-1} per season at 2007 prices.

Mulching

- It is mostly done when cover crops cannot be cultivated. Locally available plant material is used as a mulch.
- Mulching should be done immediately after planting @ 5 t to 25 t ha^{-1} depending upon availability of mulch material (Photo 16).

Photo 16 : Mulching in tea plantation

Vegetative barriers

- Vegetative barriers are recommended in place of contour stone walls and CCT.
- Soil binding non fodder grasses e.g. Weeping love grass, Guatemala grass, Vetiver, Malabar / Lemon grass are planted between tea rows, edges of roads, drains and boundaries as vegetative barriers, which provide good soil cover and reduce soil erosion.
- To meet fodder needs, fodder grasses e.g. Hybrid Napier may be planted.
- On slopes upto 30%, two rows of vegetative barrier after every 6 to 8 double hedge rows is to be planted while on slopes > 30%, vegetative barrier is to be planted after every 4 double hedge rows.
- Spacing of 0.2 m to 0.3 m between plants and 0.3 m to 0.4 m between rows is followed for planting grasses in a staggered manner.
- Cost of plantation of a vegetative barrier with these specifications is Rs 11,000 ha^{-1}.

Maintenance

- Drains and trenches should be repaired / desilted at regular intervals.
- Infilling of tea clones, shade trees and grasses in vegetative barriers should be done during monsoon.
- Vegetative barriers must be trimmed at regular intervals so that they do not compete with tea clones for nutrients.

Conservation Efficiency

- Contour staggered trenches (CST) with cover crop of French beans reduced runoff by 51% and soil loss by 64% as compared to tea plantation without CST and bean crop.
- Planting of weeping love grass as a vegetative barrier on the edges of roads, drains and

boundaries reduced soil erosion to 0.19 t to 1.27 t ha^{-1} yr^{-1} as compared to 16.95 t ha^{-1} yr^{-1}, without any conservation measures.

- Implementation of conservation measures and their maintenance reduces siltation in dams and reservoirs.

Yield and Economics

- CST + cover crop of beans increased yield of green tea leaves by 37%.
- Tea plantation with CST + cover crop of beans gave BC ratio of 2.41, net present worth of Rs.1,96,440 ha^{-1}, payback period of 3 years with 59% IRR at 10% discount rate for a period of 8 years.
- Conservation measures of CST + beans alone gives B:C ratio of 2.39, net present worth of Rs.35,190 ha^{-1}, payback period of 2 years with 66% IRR at 10% discount rate.
- Minimum additional net returns of Rs. 24,000 yr^{-1} ha^{-1} can be obtained for initial 3 years from cover crop of beans.
- Apart from generating high monetary returns, the conservation measures will provide additional employment to workers in the tea industry.

Scope

- The technology can be implemented in all the Southern hilly states of the country, i.e. Tamil Nadu, Kerala and Karnataka where tea is cultivated. All the conservation measures are most suitable for tea cultivation in Southern region and are economically viable.

3

MECHANICAL MEASURES ON ARABLE LANDS

Compartmental Bunding for *In-Situ* Rainwater Conservation in Medium to Deep Black Soils

About 60% cultivated area of the country is rainfed, but it produces only 40% of the total food grain production. Productivity of rainfed crops varies from 400 to 900 kg ha-1 depending upon climatic and physiographic features. In medium to deep black soils of arid and semi-arid regions, water is the major limiting factor for crop production due to low rainfall (400-650 mm). Its uneven distribution, with unpredictable occurrences of dry spells, results in frequent droughts of different intensities causing reduction in productivity of major crops. Efficient utilization of rainwater is essential for the improvement and sustainability of agriculture in the dryland agro-ecosystem. In addition, low infiltration rate due to high clay content in black soils generates in 10-30% runoff with loss of top fertile soil, leading to productivity loss. The farmers in the dryland black soil regions of south India need to harvest every drop of rainwater and increase the water use efficiency for higher crop productivity.

Why Compartmental Bunding?

- Compartmental bunding conserves rainwater *in-situ*, recharges soil profile uniformly, reduces runoff, soil and nutrient losses and increases crop yields on sustainable basis in medium to deep black soils of southern region. The beneficial effect of *in-situ* rainwater conservation through compartmental bunding is more pronounced during drought years with enhanced yields compared to normal and above normal rainfall situations.
- Compartmental bunding is more beneficial in medium to deep black soils with high clay content (>45 %) and low infiltration rate (0.8 to 1.2 mm h^{-1}) to raise post monsoon crops with conserved soil moisture available at different stages of crop growth.

Bund Formation

- The compartmental bunds are formed after preliminary tillage operations are completed during monsoon i.e. between June to July (Photo 17).
- Different sizes of compartments are formed with the bund former (Photo 18) depending

Photo 17 : Compartmental bunds in the field upon soil type and slope to conserve *in-situ* rainwater. The size of the compartments with land slope of >2% and <2% is 5 m x 5 m and 10 m x 10 m, respectively.

- For a bund of cross section 0.06 m^2 the specifications are- bottom width 0.5 m, top width 0.1 m, height 0.2 m and side slope 1:1.

Photo 18 : Compartmental bund former

Yield Enhancement

- Laying out of farmers' fields with compartmental bunding increases yield of *rabi* sorghum, Bengal gram, sunflower and safflower by 5 to 30% in areas receiving < 650 mm annual rainfall.
- The increase in *rabi* sorghum grain yield is 28% higher during moderate drought year as compared to only 16% during normal rainfall year. The same trend can be observed in water use efficiency (9.86 kg ha^{-1} mm^{-1} and 8.20 kg ha^{-1} mm^{-1}, respectively) during the two rainfall situations.

Economic Efficiency

- Cultivation of sorghum with this technology provides higher net returns of Rs. 2000 and Rs. 2090 in Bellary and Kurnool districts, respectively from fields with compartmental bunds, as compared to fields without (Table 13).

Table 13 : Impact of compartmental bunding in Bellary and Kurnool districts (average of three years)

State/District	Treatment	Sorghum grain yield (q ha^{-1})	Net returns* (Rs. ha^{-1})
Karnataka/ Bellary	Control Compartmental bunding	11.48 13.00 (13)	5200 7200
Andhra Pradesh/Kurnool	Control Compartmental bunding	11.48 13.03 (13)	5210 7300

Figures in parentheses indicate percent increase over control.

* Estimated at March 2008 rates.

- It is a low cost technology, which does not require any major input.
- Cost of laying out compartmental bunds of 10m x 10m is Rs. 550 ha^{-1} (Rs. 250/- is cost of hiring a pair of bullocks + one bund former for a day and Rs. 300/- is labour cost of 3 labourers for one day). When compartments of 5m x 5m are formed, an additional Rs. 200/- are required per ha. Since the number of compartments formed is higher, the labour cost is more.

Scope

- This technology is simple and can be easily adopted by farmers.
- It is applicable in medium to deep black soils (Vertisols), which fall in the semi-arid tropical region of India with less than 750 mm annual rainfall, especially:
  - Akola and Sholapur districts of Maharashtra
  - Gulburga, Bijapur, Bagalkot, Gadag, Dharwad, Haveri, Davanageri, Chitradurga, Koppal and Bellary districts of Karnataka,
  - Kurnool, Anantapur, Kadapa and Mehabubnagar districts of Andhra Pradesh
  - Dindigul district of Tamil Nadu.

Conservation Ditching for Efficient Resource Conservation and Enhanced Productivity of Semi-Arid Vertisols

Vertisols and associated soils constitute 22.12% (72 million hectares) of total geographical area of the country. They are mostly confined to semi-arid region of the Deccan Plateau, a large part of which receives low annual rainfall (< 750 mm), but is characterized by few high intensity (32 mm to 120 mm h^{-1}) storms. This causes sheet erosion (an average of 12.5 t $ha^{-1} year^{-1}$ on 1-2% land slopes) in easily erodible black soils due to low infiltration rates, poor aggregation and sparse vegetative cover. To overcome erosion problem in such soils and to conserve rains water, contour bunding and graded bunding are generally adopted in the region. However, contour bunds in black soils reduce crop yield by 25% to 30% due to water stagnation in about 16% of the inter-bunded area besides problems of breaching due to swelling and shrinking characteristics. Graded bunds (without properly designed farm pond), on the other hand, drain out the excess rainwater without being recycled for crop production. To overcome the structural and functional limitations of contour and graded bunding, an alternative measure is needed in black soil region.

Which Technique and Why?

- Conservation ditching is a potential technology that can help farmers in overcoming the structural and functional limitations of contour bunding, graded bunding and farm pond construction to conserve rainwater at field level and increase productivity of vertisols of semi-arid region.
- As a terrace structure, a well designed conservation ditch stores the inter-terrace design runoff within its confines; thus drastically reducing its capacity to initiate/accelerate soil erosion on the downstream side of the ditch.
- As a storage structure, due to low infiltration rates in the deep black soils, sufficient volume of the stored water is available in the ditch for about a week to ten days after every ditch-filling rainfall. The water is available for irrigation at different stages of crop growth and also for pre-sowing irrigation.
- Since the water is available at low lifts (0.6-0.9 m), traditional low-lift and low-cost hand operated lifting devices (swing basket and Archimedean screw) can be used for lifting the water. The downstream area can be easily irrigated by gravity to augment the soil profile moisture and stabilize yields of dryland crops.

Ditch Formation

- Conservation ditch (Photo 19) is a shallow trapezoidal dugout trench constructed on contours to serve the dual purpose of soil conservation and water storage structure at individual field level in low rainfall areas of deep black soils.

- The ditch is designed to store 200 to 300 m^3 of water from one hectare of inter terrace land.
- Depth and bottom width of the conservation ditch is kept within the range of 0.6 m to 0.9 m, depending upon storage volume and soil depth.

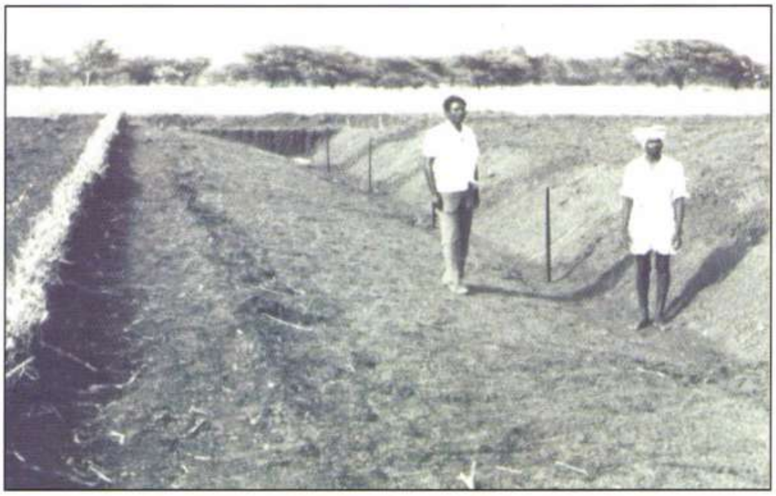


Photo 19 : Conservation ditch in the field

- Upstream slope of 5:1 is recommended to avoid scouring while downstream slope is kept at 1.5:1 to conform to angle of repose (Fig. 7).
- With a top width of 4.58 m and bottom width and depth of 0.6 m each, the cross section of the conservation ditch [=0.5 x (top width + bottom width) x depth] would be 1.55 m^2 and, therefore, the design capacity would be 1.55 m^3 per running metre length.
- Length of conservation ditch may vary from 30 m to 300 m. Long ditches are excavated in segments of 100 m. When ditches are to be excavated in a series, unditched stretches of 4-5 m are left in a staggered manner between ditches for effective erosion control.
- Embankment is made at the lower side of the ditch to maintain depth of storage.

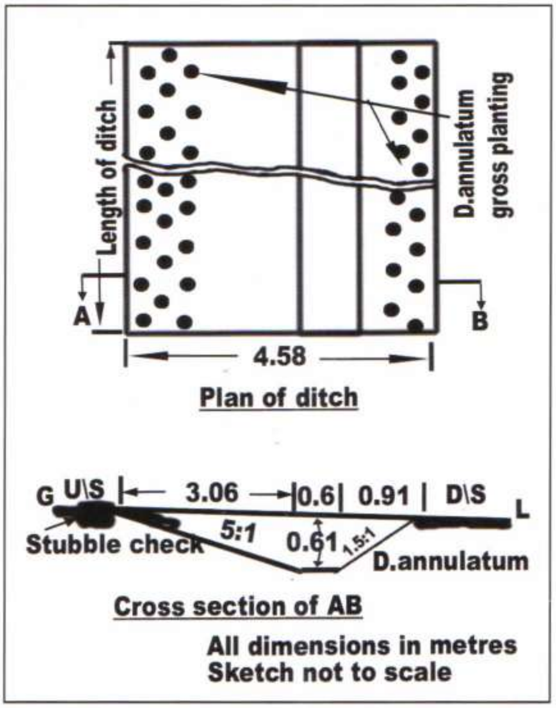


Fig. 7 : Cross section design of conservation ditch

- In black soils, overland flow causes rill erosion, which should be properly checked as otherwise it would cause erosion towards the ditch, thus damaging its shape. Vegetative barrier of 2 rows of *Agave* species planted in a staggered manner at 60cm x 60cm spacing (Fig. 8) on the upstream side to arrest the soil and allow only runoff water to flow into the ditch with safe velocity is, therefore, recommended to effectively check rill erosion and siltation of the ditch.
- Rooted slips of *Dicanthum annulatum*, which has high survival percentage (90%) should be planted on the side slopes of the ditch (Fig. 7) which is addition to yielding fodder for

cattle would also prevent the soil from caving in, thus maintaining proper shape of the conservation ditch.

- For utilizing the builtup soil moisture on the downstream side of the ditch, horticulture plants e.g. mango, *sapota*, *ber*, *anjura*, orange, drumstick etc. can be planted. Leguminous species, which serve as green manure, can also be grown on downstream side.
- Desilting of the ditch may be required once in three years.

Fig. 8 : *Agave* barrier for protection of conservation ditch

- The stored water should be used at the earliest to avoid unproductive seepage losses.

Conservation Efficiency

- The conservation ditch holds entire runoff during below normal years and 70-90% of annual runoff during normal rainfall year. It is effective in mitigating drought conditions.
- Besides harvesting and use of runoff, the nutrient rich silt deposited on the bed of the ditch can be harvested back to the cultivated land @ 4.5 t ha^{-1} yr^{-1} in the first year, 2.6 t ha^{-1} yr^{-1} in next 4 years and 1.8 t ha^{-1} yr^{-1} after 4 years. The harvested soil is clay to clay-loam in texture. The nutrients @ 357 kg ha^{-1} of N, 38.5 kg ha^{-1} of P_2O_5 and 851 kg ha^{-1} of K_2O are retained along with silt in the ditch.

Yield Enhancement

- Charging of downstream area with water from the conservation ditch helps to realize 5-7 times higher yield as compared to withering of crops in drought years.
- Conservation ditch irrigation resulted in additional yield of 650-850 kg ha^{-1} of sorghum and 298 kg ha^{-1} of safflower i.e. 35-48% increase over rainfed situation without ditching.
- Under normal rainfall conditions, maximum yield of 16 t ha^{-1} yr^{-1} of *Dicanthium annulatum* was obtained from second year onwards.
- Runoff stored in conservation ditches between May and June when recycled to grow green gram downstream, gave a yield of 6 q ha^{-1}, which is a bonus income for the farmers.

Economics

- The cost of laying a conservation ditch amounts to Rs 55 m^{-3} for earth work and Rs. 55 m^{-1} for plantation on banks. Therefore, for a conservation ditch of 200 m length, the total cost would amount to Rs. 20,270/-.
- On an average, additional yield of sorghum is 628 kg ha^{-1} amounting to additional net benefit of Rs. 2,840 ha^{-1} yr^{-1} at 10% discount rate considering 10 year life span with sorghum as test crop.

Scope

- Conservation ditching is primarily adaptable in deep black soils having low infiltration rates (<1 mm hr^{-1}) and receiving low annual rainfall (< 750 mm).
- This technology is suitable for implementation in black soil region of Karnataka, Andhra Pradesh, Maharashtra and Tamil Nadu.

3.3

Bench Terracing - An Effective Soil Conservation Measure for the Nilgiris

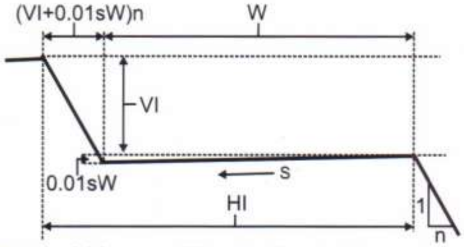
The Nilgiris region has great ecological importance as it is one of the thirteen biosphere reserves in the country and the only one in southern India. This hilly eco-system is fragile and bestowed with rich and diversified natural resources but is subjected to many land degradation problems, the major being soil erosion due to faulty land use and management practices, which hinder the development of sustainable production system in the area. In any hilly area, suitable soil and water conservation measures are essential to prevent soil erosion from the steep slopes where cultivation of annual crops is most common. Bench terracing is being practiced in the steep hill slopes, where agriculture has replaced the natural forest cover, since times immemorial. Bench terraces may be level (table top), outward sloping or inward sloping depending upon different conditions of land slope, soil type, rainfall, farming systems, etc. Therefore, selection of proper terrace system suitable for high rainfall area with deep permeable soil like that of the Nilgiris is essential for sustainability of production systems and conservation of fragile agro-ecosystem.

Which Terrace System and Why?

- Inward sloping terraces are suitable for high rainfall areas with deep permeable soils, like that of the Nilgiris.
- These are especially suited for steep slopes, where it is essential to keep the excess runoff towards the hill side (original ground) rather than on the valley side.
- The formation of bench terraces on steep slopes not only retards soil erosion but also makes cropping operations on these slopes easy and economical.

Terracing

- Determine the land slope of the area to be terraced using Abney's Level or measuring tape.
- Determine permissible depth of cut in area selected for terracing depending upon soil depth, which can range upto a maximum of 0.9 m in the Nilgiris. It should be ensured that a soil depth of at least 15 cm is available in the field for crop cultivation.
- Riser slope should be 0.5:1 or 1:1 for heavy textured and light textured soil, respectively.
- After ascertaining the above three parameters, vertical interval (Fig. 9)



W = Terrace width HI = Horizontal interval
VI = Vertical interval s = Inward slope of the bench (%)
n:1 = Riser slope (n is the HI of the riser when VI is 1.0 m)

Fig. 9 : Cross section of bench terrace

between two benches according to slope per cent can be selected from the ready reckoner given in Table 14. Vertical interval of more than 2 m should be avoided as it may lead to riser instability.

Table 14: VI (m) for different permissible depths of cut and slope

Slope	Depth of cut (m) when n=0.5						Depth of cut (m) when n=1.0					
(%)	0.4	0.5	0.6	0.7	0.8	0.9	0.4	0.5	0.6	0.7	0.8	0.9
10	0.8	1.1	1.3	1.5	1.7	1.9	0.9	1.1	1.3	1.6	1.8	2.0
12	0.9	1.1	1.3	1.5	1.7	1.9	0.9	1.1	1.4	1.6	1.8	2.0
14	0.9	1.1	1.3	1.5	1.7	1.9	0.9	1.2	1.4	1.6	1.9	2.1
16	0.9	1.1	1.3	1.5	1.7	2.0	1.0	1.2	1.4	1.7	1.9	2.1
18	0.9	1.1	1.3	1.5	1.8	2.0	1.0	1.2	1.5	1.7	2.0	2.2
20	0.9	1.1	1.3	1.6	1.8	2.0	1.0	1.3	1.5	1.8	2.0	2.3
22	0.9	1.1	1.3	1.6	1.8	2.0	1.0	1.3	1.5	1.8	2.1	2.3
24	0.9	1.1	1.4	1.6	1.8	2.0	1.1	1.3	1.6	1.8	2.1	2.4
26	0.9	1.1	1.4	1.6	1.8	2.1	1.1	1.4	1.6	1.9	2.2	2.4
28	0.9	1.2	1.4	1.6	1.9	2.1	1.1	1.4	1.7	1.9	2.2	2.5
30	0.9	1.2	1.4	1.6	1.9	2.1	1.1	1.4	1.7	2.0	2.3	2.6
32	1.0	1.2	1.4	1.7	1.9	2.1	1.2	1.5	1.8	2.1	2.4	2.6
34	1.0	1.2	1.4	1.7	1.9	2.2	1.2	1.5	1.8	2.1	2.4	2.7

- Terrace width at different land slopes and vertical intervals can also be determined from a ready reckoner presented in Table 15. Bench width of < 4.0 m should generally be avoided for agriculture, except when narrow benches are used for some specific purposes like raising horticulture nurseries, floriculture, etc.

Table 15 : Bench width (m) for different VI and slopes

Slope	Vertical interval (m) when n=0.5						Vertical interval (m) when n=1.0					
(%)	1.0	1.2	1.4	1.6	1.8	2.0	1.0	1.2	1.4	1.6	1.8	2.0
10	9.5	11.4	13.3	15.2	17.1	19.0	9.0	10.8	12.6	14.4	16.2	18.0
12	7.8	9.4	11.0	12.5	14.1	15.7	7.3	8.8	10.3	11.7	13.2	14.7
14	6.6	8.0	9.3	10.6	12.0	13.3	6.1	7.4	8.6	9.8	11.1	12.3
16	5.8	6.9	8.1	9.2	10.4	11.5	5.3	6.3	7.4	8.4	9.5	10.5
18	5.1	6.1	7.1	8.1	9.1	10.1	4.6	5.5	6.4	7.3	8.2	9.1
20	4.5	5.4	6.3	7.2	8.1	9.0	4.0	4.8	5.6	6.4	7.2	8.0
22	4.0	4.9	5.7	6.5	7.3	8.1	3.5	4.3	5.0	5.7	6.4	7.1
24	3.7	4.4	5.1	5.9	6.6	7.3	3.2	3.8	4.4	5.1	5.7	6.3
26	3.3	4.0	4.7	5.4	6.0	6.7	2.8	3.4	4.0	4.6	5.1	5.7
28	3.1	3.7	4.3	4.9	5.5	6.1	2.6	3.1	3.6	4.1	4.6	5.1
30	2.8	3.4	4.0	4.5	5.1	5.7	2.3	2.8	3.3	3.7	4.2	4.7
32	2.6	3.2	3.7	4.2	4.7	5.3	2.1	2.6	3.0	3.4	3.8	4.3
34	2.4	2.9	3.4	3.9	4.4	4.9	1.9	2.3	2.7	3.1	3.5	3.9

- The number of terraces that can be formed is obtained by dividing the total vertical distance with the selected vertical interval (VI). If number of terraces is in fraction, round it off to the nearest whole number and accordingly readjust the vertical interval.
- To facilitate proper drainage of excess water, longitudinal grade of 1% and an inward grade of 2.5% should be provided. Length of terrace should be limited to 100 m for operational efficiency and preventing erosion. A vertical disposal drain of 0.3 m bottom width, 0.2-0.3 m depth and 1:1 side slope should be provided at the end of the terrace.
- Mark terrace lines with 1% longitudinal gradient and 2.5% inward grade at the chosen / adjusted vertical interval with the help of a hand level or A-frame (Fig.10). Ease out all the sharp and pointed curves before starting the earth excavation.
- After marking, commence earth excavation from the middle and push the excavated soil towards the lower slope until the desired level is obtained.
- Give proper slope to the riser and plant perennial crops for stability (Photo 20).

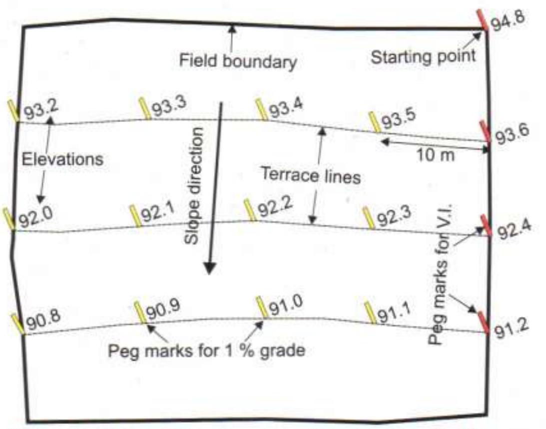


Fig. 10 : Marking terrace lines in the field

Photo 20 : Perennial beans on terrace riser

- Provide toe drain at the inner edge of each terrace and join all the toe drains to the vertical disposal drain with a drop pit (0.3m x 0.3m x 0.3m) at the junction.
- The total earthwork volume involved in bench terracing (inward slope of 2.5%) including vertical disposal drain (0.1375 m^2 - cross sectional area) and drop pits for different combinations of vertical interval, and land slope are presented in Table 16 to serve as ready reckoner for different users.
- The cost of terracing using bulldozer with unit cost of Rs 38.5 m^{-3} at 2008 price level is presented in Table 17.

Terrace Maintenance

- Tillage operations should be done along the length of the terrace to ensure minimum disturbance to the slope.

Table 16 : Earth work volume ($m^3 ha^{-1}$) for different slopes and vertical intervals

Slope	Vertical interval (m) when n=0.5						Vertical interval (m) when n=1.0					
(%)	1.0	1.2	1.4	1.6	1.8	2.0	1.0	1.2	1.4	1.6	1.8	2.0
10	1477	1770	2065	2358	2653	2947	1386	1661	1938	2212	2489	2765
12	1412	1693	1974	2256	2536	2817	1309	1570	1829	2091	2350	2611
14	1363	1634	1905	2175	2447	2719	1248	1496	1744	1991	2240	2489
16	1322	1586	1849	2112	2374	2638	1196	1434	1671	1908	2145	2383
18	1288	1545	1800	2058	2313	2570	1150	1378	1606	1835	2063	2292
20	1259	1509	1759	2009	2260	2510	1108	1328	1548	1768	1988	2208
22	1232	1477	1722	1967	2212	2458	1070	1282	1494	1706	1918	2131
24	1208	1448	1689	1929	2169	2409	1033	1238	1444	1649	1854	2058
26	1186	1422	1657	1893	2128	2365	999	1197	1395	1593	1791	1990
28	1165	1397	1628	1859	2091	2322	966	1158	1349	1541	1733	1924
30	1145	1373	1600	1827	2055	2283	934	1120	1305	1490	1675	1861
32	1126	1350	1573	1797	2021	2245	904	1082	1261	1441	1620	1799
34	1108	1328	1548	1769	1988	2209	874	1047	1219	1393	1565	1739

Table 17 : Cost of terracing (Rs '000 per ha) for different slopes and vertical intervals

Slope	Vertical interval (m) when n=0.5						Vertical interval (m) when n=1.0					
(%)	1.0	1.2	1.4	1.6	1.8	2.0	1.0	1.2	1.4	1.6	1.8	2.0
10	56.8	68.2	79.5	90.8	102.1	113.5	53.3	63.9	74.6	85.2	95.8	106.5
12	54.4	65.2	76.0	86.8	97.6	108.5	50.4	60.4	70.4	80.5	90.5	100.5
14	52.5	62.9	73.3	83.8	94.2	104.7	48.0	57.6	67.1	76.7	86.2	95.8
16	50.9	61.1	71.2	81.3	91.4	101.6	46.0	55.2	64.3	73.5	82.6	91.8
18	49.6	59.5	69.3	79.2	89.1	99.0	44.3	53.1	61.8	70.7	79.4	88.2
20	48.5	58.1	67.7	77.4	87.0	96.6	42.7	51.1	59.6	68.1	76.6	85.0
22	47.4	56.9	66.3	75.7	85.2	94.6	41.2	49.3	57.5	65.7	73.9	82.1
24	46.5	55.8	65.0	74.3	83.5	92.7	39.8	47.7	55.6	63.5	71.4	79.2
26	45.7	54.7	63.8	72.9	81.9	91.0	38.5	46.1	53.7	61.3	69.0	76.6
28	44.8	53.8	62.7	71.6	80.5	89.4	37.2	44.6	51.9	59.3	66.7	74.1
30	44.1	52.9	61.6	70.4	79.1	87.9	36.0	43.1	50.2	57.4	64.5	71.6
32	43.4	52.0	60.6	69.2	77.8	86.4	34.8	41.7	48.6	55.5	62.4	69.2
34	42.7	51.1	59.6	68.1	76.6	85.1	33.6	40.3	46.9	53.6	60.3	67.0

n - riser slope.

- If some crops are to be cultivated on ridges, the ridges should be oriented on contours during the season when rainfall intensity is expected to be low. When rainfall intensity is expected to be high, then they should be made along the bench slope.

- As bench terracing involves lot of top soil disturbance, integrated nutrient management should be followed to restore soil fertility.
- Desilting of the vertical drain should be done at regular intervals.

Conservation Efficiency

- Reduction in soil loss from 44 to 71% and runoff from 21 to 64% was observed by forming bench terraces on steep slopes in the Nilgiris.
- Moisture availability in soil increases apart from conservation of nutrients.

Yield Enhancement

- Through terrace renovation, yield of potato increased in the range of 57 to 103% in the Nilgiris.
- Integrated nutrient management along with terrace renovation enhanced yield of potato in the range of 37 to 223%.
- Yield of potato, carrot and broccoli increased in the range of 66 to 84% in a Nilgiris watershed where either new terraces were constructed or old terraces were renovated.

Scope

- There is good scope of applying this technology in the Nilgiri hills and identical areas of Western Ghats in the states of Kerala, Karnataka, Goa and Maharashtra where high rainfall and steep slopes prevail and crops requiring proper drainage are cultivated.

Conservation Bench Terrace System - A Viable Alternative to Conventional System in Sub-Humid Climates

Sloping lands are vulnerable to soil erosion by water. Mechanical measures are generally recommended on arable lands to dissipate the energy of the flowing water either by reducing the length and/or degree of slope. A number of slope-control practices are being adopted in sub-humid regions of the country for managing agricultural production systems on mildly sloping lands in order to maximize the benefits and sustain them for secured livelihood. However, due to erratic and uneven distribution of rainfall, moisture availability is often a limiting factor for assured crop production on sloping agricultural lands under rainfed conditions, thereby adversely affecting their productivity. Under such situations, scope for diversified agriculture is often limited and viable alternatives are required to conserve every drop of water and minimize the risk of crop failure.

Why Conservation Bench Terrace System?

- The Conservation Bench Terrace (CBT) is one of the potential technologies which helps in stabilizing the slope, prevents soil erosion and enhances the moisture availability in soil profile for sustaining crop growth under adverse weather conditions.
- CBT is a relatively new land-forming system designed to conserve soil and water. CBT system has been developed to harvest the runoff from a sloping area for the benefit of water demanding crops like paddy grown in the lower leveled portion of the field. Crops such as maize, sorghum or *bajra* which require good drainage are cultivated on the sloping area.
- The inevitable runoff can be efficiently conserved and utilized by adopting the CBT system in comparison to the conventional system. Thus, even in low rainfall conditions, assured crops can be taken on conserved moisture.
- It enhances crop productivity and diversity while conserving the soil and water resources.

Establishment of CBT System

- The CBT system consists of a terrace ridge (shoulder bund) to impound run-off on a level bench (recipient area) and a donor watershed, which is left in its natural slope and produces run-off that spreads on the level bench (Fig.11).
- If the quantity of runoff generated from the contributing area is greater than that can be absorbed or stored in the level terrace, an outlet is constructed at appropriate height in the shoulder bund of CBT system for safe disposed of runoff from the system into a pond/waterway.
- A field bund is constructed on the upper boundary of the contributing area, which acts as a ridge of the contributing area (Fig. 12). When CBT system is constructed in series on a

continuously sloping land, the shoulder bund (terrace ridge) acts as a field bund on top of the contributing area for the subsequent lower CBT system.

- CBT technology is suitable for deep permeable soils upto 6% slope so that impounded water is absorbed quickly and runoff is minimized.
- Ratio of donor to recipient area may vary from 1:1 to 3:1 depending upon the rainfall and water requirement of the crop to be cultivated.
- Form a bund at the end of CBT system with soil scrapped from the levelled portion. Shoulder bunds of cross sectional area between 0.35-0.5 m2 for red and lateritic soil and 1.2 - 1.5 m2 for black soils are recommended at a vertical interval of 1.0-1.5 m. Normally shoulder bund with top width 0.03 m, height 0.5 m, upstream slope of 1:1 and downstream side slope of 1.5:1 are recommended. Recipient area is given grade of 0.1 - 0.5%.

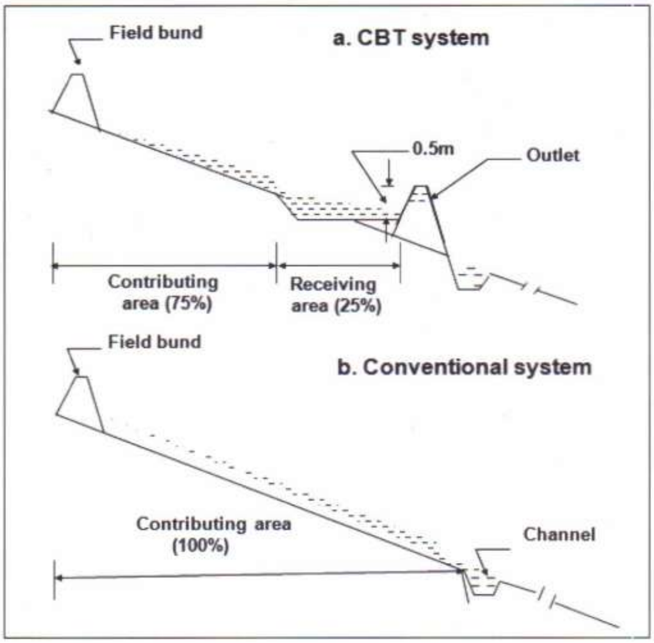


Fig. 11 : Sectional view of CBT and conventional systems

- Depth of water impoundment in levelled or recipient area may be kept as 10-20 cm depending upon rainfall pattern, crop requirement and intended amount of runoff to be harvested. Locate an outlet at appropriate place in the bund to drain off excess runoff.
- A channel with bottom width 0.3 m, depth 0.3 m, upstream side slope 1.5:1 and downstream side slope 1:1 is constructed for safe disposal of water at toe of the shoulder bund with 0.1 to 0.4% gradient, which drains into water harvesting structure like pond for recycling purpose. For sustained crop productivity, CBT system in conjunction with suitable water harvesting and recycling techniques gives the best results.

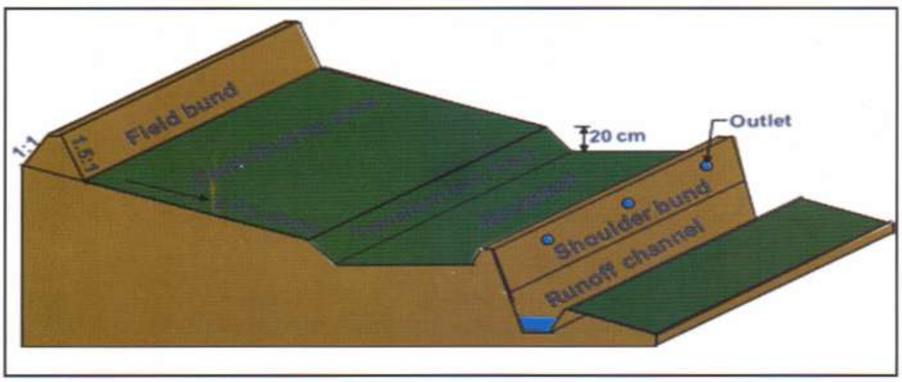


Fig. 12 : Schematic view of CBT system

- At junction of donor and recipient area provide transition zone with 1.5:1 slope.
- Grass sodding (with local grasses) on bunds, transition zone and channels is essential to stabilize the slopes and protect them from erosion.

- Select crops/cropping sequence for donor and recipient areas. In the upper portion, rainfed crops like maize, sorghum or bajra, requiring good drainage are grown whereas in the level bench, water demanding crops like paddy are cultivated with arrangement of supplemental irrigation from harvested rainwater.

Conservation Efficiency

- At Dehradun, a CBT system constructed at 2% slope with 3:1 ratio of the donor to recipient area and 20 cm depth of impoundment significantly reduced runoff and soil loss by over 80% and 90%, respectively as compared to conventional system of maize-wheat rotation.
- The CBT system registered 7.4% of rainfall as runoff and 1.19 t ha^{-1} of soil loss as compared to 36.3% of runoff and 10.1 t ha^{-1} of soil loss in the conventional system of sloping borders.

Yield Enhancement

- The analysis of yield data of maize, rice and wheat crops has revealed that the CBT system was about 19.5% more productive in terms of maize-equivalent yields

Economics

- The analysis of yield data of maize, rice and wheat crops revealed that the CBT system was about 71.7% more remunerative over the conventional system due to better in-situ rainwater conservation in sub-humid region of outer Himalayas.
- Net Present Value of about Rs. 26,500 ha^{-1} can be realized from CBT system as compared to only Rs.16,700 ha^{-1} from the conventional system (Table 18).

Table 18 : Economics of CBT as compared to conventional systems

Evaluation parameter	Maize-wheat (rainfed)	Conventional system	CBT system
NPV (Rs ha^{-1})	15,400	16,700	26,500
BCR	1.22:1	1.13: 1	1.20:1
PBP (years)	2	12	10
IRR (%)	NA	15.4	17.0

NPV- net present value; BCR-benefit cost ratio; PBP- pay back period; IRR- internal rate of return.

- Conventional and CBT systems in the ratios of 50:50 or 25:75 were found to be the best choices to maximize economic returns, ensure food security, minimize soil and nutrient losses, and produce sufficient runoff for harvesting and recycling under rainfed cropping systems in sub-humid climates.

Scope

- The CBT system has great potential for adoption in mildly sloping lands, of upto 6% slope, and having silty loam to silty clay loam soils. It can be profitably applied in conjunction with conventional system of maize-wheat rotation in the sub-humid climate of Jammu and Kashmir, Himachal Pradesh, Uttarakhand and the north-eastern states. The technology can also be implemented in arid and semi-arid regions by suitably deciding the ratios of sloping (contributing) and flat (receiving) areas, depending upon rainfall, crop and soil conditions.

4

VEGETATIVE MEASURES ON ARABLE LANDS

Vegetative Barriers for Erosion Control in Western Himalayan Region

In the Western Himalayan region, agricultural activities are mostly carried out on gentle to steep slopes causing high losses of soil, nutrients and productivity due to water erosion. Although mechanical measures like bunding and terracing are effective for soil and water conservation, but their high cost and frequent maintenance inhibit the farmers for their wider adoption. As an alternative to bunding, planting slips of suitable grass species along the contour line and creating a vegetative barrier for runoff flowing along the slope is one of the important conservation techniques, which helps in reducing soil and water losses and improving soil fertility, crop productivity and fodder availability. The benefits of vegetative barriers have been exceedingly realized as an alternative to earthen bunding for soil and water conservation and erosion control, being relatively cheaper, eco-friendly and pro-farmer. Vegetative barriers reduce the velocity of flow and act as a filter to trap the silt, which gets deposited behind the barrier (Fig.13). Sediment deposition results in the formation of bench terraces over a period of 3-4 years. Generally farmers are not accustomed to planting grasses as vegetative barriers on sloping lands.

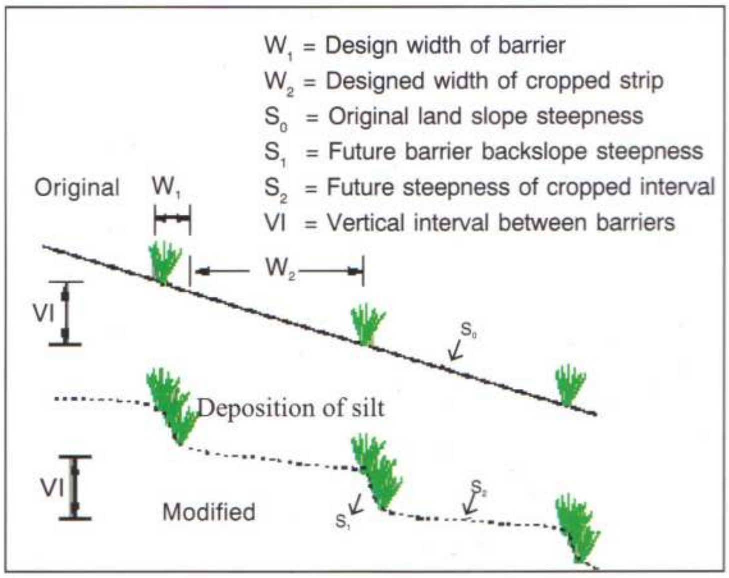


Fig. 13 : Silt deposition and slope reduction by vegetative barriers

Which Grasses as Vegetative Barriers?

- For vegetative barriers, economically important grasses that give dense and perennial cover should be selected. Locally available grasses like *Panicum maximum* (Guinea grass), *Vetiveria zizanioides (Khus khus)* and *Eulaliopsis binata* (*bhabar*) have been found promising for this purpose in Shivaliks and lower Himalayan region.
- These three species form an erect, stiff and uniformly dense hedge (Photo 21) that offers high resistance to overland flow with high root binding capacity to prevent rilling and scouring near the barrier. The three grasses are adapted in a wide range of soils.
- They survive moisture and nutrient stress and get established as soil cover quickly after rains.

- They cause minimum loss of crop yield and do not proliferate as a weed, do not compete for moisture, nutrients and light, are not a host for pest and diseases, and supply products of economic value to the farmers.
- *Bhabar* grass is used for making rope, strings and mats. Young shoots are also used as fodder.

Photo 21 : Vegetative barriers of Guinea grass

- Guinea grass is nutritious, palatable and free from oxalates. The crude protein and the crude fibre content of this grass vary from 8 to 14% and 28 to 36%, respectively.
- *Khus khus* is also used for handicrafts, roof thatch, mushroom growing, animal fodder, feed stuff and herbals etc.

Establishment of Vegetative Barriers

- None of the three grasses require any special land preparation. The selected grass is planted as seed or preferably root slip along with field crops after two or three ploughings and one leveling. Land should be free from all kinds of weeds and fertilizer application is similar to that of field crops.
- About 2000-3000 root slips are required for planting a paired row of 100 m running length of a barrier. About 4000-6000, 8000-12000 and 16000-24000 root slips are required per ha for 2, 4 and 8% slopping land, respectively. Row to row spacing of 75 cm and plant to plant spacing of 20 cm is recommended for all the grasses. A vertical interval of 1 m is kept between two paired rows of vegetative barriers.
- For each row out of a paired row of vegetative barrier, the grasses are planted along a contour line in furrow of 10 cm width and 20 cm depth excavated by using country plough or small agricultural implement. Planting in the two rows of a vegetative barrier should be done in a staggered fashion.
- Planting is done during first or second week of July (start of monsoon) for all the grasses.
- The soil excavated from contour furrows is heaped on downstream side to form a bund.
- All the grass species require at least two cuts in a year, first just before the onset of monsoon (May/June) and second in October/November to encourage tillering.
- For an effective live barrier, trimming to a height of 15-30 cm annually along with hoeing in between rows with every cut is recommended.

Calculation of Number of Barriers and Distance between Barriers

Horizontal (surface) distance between the barriers

$$= \frac{\text{Length (along the slope) of the field (m)}}{\text{Slope (\%)}}$$

$$\text{No. of barriers} = \frac{\text{Length (along the slope) of sloping field (m)}}{\text{Horizontal (surface) distance between two barriers (m)}}$$

Conservation and Yield Advantages

- In general, vegetative barriers can reduce runoff and soil loss by 18-21% and 23-68% respectively, on slopes varying from 2-8%.
- Maize and wheat yield increased by about 23-40% and 10-20%, respectively through conserved moisture. From the system, nearly 6-17 q ha^{-1} yr^{-1} dry grass yield is obtained as fodder from the barrier, in addition to maize crop (grain + stalk).

Economics

- The cost of different components of barrier plantation is Rs. 2480 ha^{-1}, Rs. 4960 $ha^{-1}$and Rs. 9920 ha^{-1} on 2, 4 and 8 per cent slopes, respectively, which is approximately one third of the cost of contour bunding on corresponding slopes.
- The return from grass species varies from Rs.750-850 ha^{-1} yr^{-1} as a biomass. The net return with crop rotation of maize - wheat with the adoption of vegetative barriers varies from Rs. 7,000 to 21,500 ha^{-1} yr^{-1} on different slopes. Additional return of Rs. 8030, 5660 and 3130 ha^{-1} yr^{-1} on 2, 4 and 8 per cent slopes, respectively have been realized by adopting vegetative barriers over traditional practices on slopping lands.
- Onsite fodder availability, particularly during winter season, would be an additional advantage without sacrificing yields of maize and wheat crops.

Scope

- The technology is easily applicable on 2-8% sloping lands in high rainfall zones of Jammu and Kashmir, Himachal Pradesh and Uttarakhand. It is quite cheap and easily adoptable conservation measure for the resource poor hill farmers.

4.2 Mixed Vegetative Barrier of Pineapple and Grass - An Effective Soil and Water Conservation Measure for Western Ghats Region

The Western Ghats region is endowed with rich natural resources but is a fragile eco-system. Intense and erosive rains coupled with steep and / or longer lengths of slope and faulty land use management practices lead to washing away of top soil and nutrients, loss of productivity, siltation of ponds and reservoirs, floods and droughts. Several soil and water conservation measures have been recommended to check and restore degraded lands. Among these, mechanical measures demand high capital cost and technical skill for their execution and maintenance. On the other hand, vegetative barriers are cost effective. Since the region is rich in bio-diversity, farming community has the choice of plant species having economic importance and serve as a vegetative barrier. Use of grasses alone as a barrier is most common but mixed vegetative barrier formed from combination of two or more plant species increases the acceptability by the farming community and improves its efficiency for resource conservation.

Why Pineapple along with Grass as a Vegetative Barrier?

- Pineapple (*Ananas comosus L. Merris.*) is one of the important fruit crops grown in the region, which, having high conservation value, can be exploited along with other grass species as a vegetative barrier for soil and water conservation in annual and perennial plantation crops.
- Pineapple is grown extensively on wide range of soils in plains and upto 900 m in the Western Ghats region since it provides better returns compared to other crops.
- Planting material (sucker) is available locally, and being not grazed and browsed by animals, having no serious pest and diseases problems and high economic value through sale of fruits and suckers, it is more acceptable as a vegetative barrier.
- A suitable grass species when planted in a single or double row makes the vegetative barrier highly effective right from the initial stages. Grasses propagated through root slips or cuttings are preferred for quick establishment. Guatemala (*Tripsacum laxum*) or Hybrid Napier (*Pennisetum typhoides* x *P. purpureum*) grasses are recommended along with two rows of pineapple.
- This mixed vegetative barrier is most suited to both annual and perennial crops of the region for resource conservation at reasonable initial investment.

Barrier Establishment and Maintenance

- Following standard package of practices for cultivation of pineapple, planting of pineapple suckers is done in paired rows with a distance of 60 cm between rows and 30 cm between suckers. The planting is done in a staggered manner on contours for ensuring higher conservation efficacy of the vegetative barrier. About 667 suckers are required for planting one paired row of 100 m.

- Grass species - Guatemala (*Tripsacum laxum*) or Hybrid Napier (*Pennisetum typhoides or P. purpureum*) is planted along with two rows of pineapple on downstream side (Photo 22). Guatemala grass is planted through root slips while Hybrid Napier is established through cuttings.
- Distance between root slips / cuttings is kept as 15-20 cm and 30 cm from pineapple row to retain the eroded soil and increase soil moisture availability which helps in better establishment of pineapple. About 500 root slips / cuttings are required for planting a single row of 100 m.
- After planting, a 15-20 cm deep furrow is dug on upstream side of barrier to trap sediments and conserve moisture for better establishment of suckers.
- The suggested surface distance between barriers based on slope of the field and vertical interval (VI) is presented in Table 19. It is convenient to have a vertical interval of 1.0 m so that the barriers can be easily established on the risers after the terraces are formed.

Photo 22 : Two rows of pineapple and one row of Guatemala grass

- The number of barriers to be established is worked out with the formula :

$$= \frac{\text{Length of the sloping field (m)}}{\text{Surface distance between two barriers (m)}}$$

- The number of pineapple suckers and grass slips required for planting in an area is calculated as:

$$= \frac{\text{Area (m}^2\text{) x No. of rows in a barrier}}{\text{Surface distance between two barriers (m)} \times \text{Spacing between plants in a row (m)}}$$

Or

$$= \frac{\text{Length of barrier (m)}}{\text{Spacing between suckers/ slips in a row (m)}} \text{ x Rows in a barrier}$$

- Prior to planting the barriers, contour lines are marked in the field using A-frame (Fig.14).
- Planting is taken up at the onset of monsoon and suckers / slips are planted in 10-15 cm deep holes.

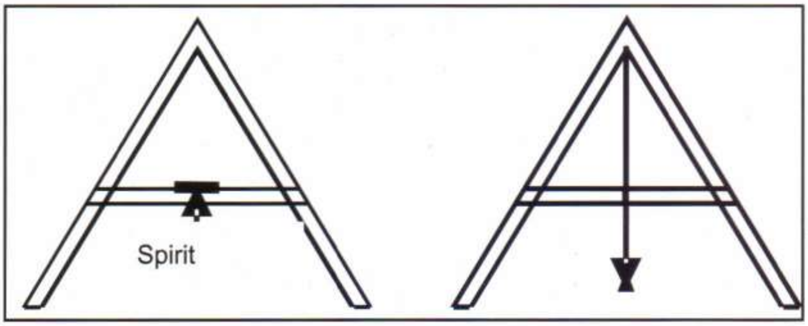


Fig. 14 : A-frame

- Gap filling is to be done till the barrier is completely established.

Table 19 : Suggested surface distance between barriers based on slope of the field and vertical interval (VI)

Slope (%)	Surface distance between barriers (m)		
	VI=1.0 m	VI=1.25 m	VI=1.5 m
8	12.5	15.7	18.8
10	10.1	12.6	15.1
12	8.4	10.5	12.6
14	7.2	9.0	10.8
16	6.3	7.9	9.5
18	5.6	7.0	8.4
20	5.1	6.4	7.6
22	4.7	5.8	7.0
24	4.3	5.3	6.4
26	4.0	4.9	5.9
28	3.7	4.6	5.5
30	3.5	4.3	5.2
32	3.3	4.1	4.9

- Grass is to be cut at intervals when it is about 20 cm high so that it does not affect the crop in the field / terrace and more number of slips are produced to form a dense barrier.
- Excess suckers should be removed after first harvest, which can be used as a planting material.

Conservation Efficiency

- Mixed vegetative barrier of one row of Guatemala grass and two rows of pineapple at 1.0 or 1.5 m vertical interval is the best treatment for cassava cultivation on 25% sloping lands in terms of reduction in runoff (52%) and soil loss (33%) and conserving 4.4 kg, 1.19 kg and 6.83 kg of N, P and K per ha, respectively compared with the no vegetative barrier.

Economics

- The cost of establishing the mixed vegetative barrier is only Rs. 26 per running meter.
- Due to the barrier, Rs. 403 ha^{-1} can be saved on cost of fertilizers, and Rs. 18,085 on land leveling over a period of three years.
- Minimum return of Rs. 25,000 ha^{-1} yr^{-1} is possible from sale of pineapple fruits after two years of planting as a vegetative barrier.
- A total benefit of Rs. 80,070 could be realized in three years period due to the barrier in addition to biomass yield of grass and suckers.

Scope

- The technology is applicable in the entire Western Ghats region, covering the states of Kerala, Tamil Nadu, Karnataka, Maharashtra and Goa where pineapple is commercially cultivated under plantation crops.
- Since the initial investment is low (Rs 26 per running meter), this measure can be easily adopted by even resource poor farmers and hence it is a 'scale neutral' technology.

4.3

Tea Plantation for Economic Utilization and Stabilization of Terrace Risers in the Nilgiris

The Nilgiris is a fragile hilly eco-system, which due to steep slopes, undulating topography, heavy and erratic rainfall pattern, and faulty landuse and crop management practices suffers from heavy soil loss and runoff. In this hilly region, inward sloping bench terraces with risers slope of 0.5:1 or 1:1 is a recommended soil conservation measure in cropped areas for reducing runoff and soil loss. However, terrace riser maintenance is accorded very less priority by the farmers of the region who tend to make the risers as vertical as possible in order to accommodate more crop rows and minimize the loss of cultivable area due to terracing. This leads to improper terrace conditions, thereby increasing the erosion hazards and defeating the very purpose for which the terraces are initially constructed. In order to overcome this problem, if some perennial crops having economic value are grown on terrace risers, the area lost can be converted into additional area for cultivation purposes.

Which Perennial Crop on Terrace Risers and Why?

- Growing tea on terrace risers in the Nilgiris is a profitable proposition with the added advantage of riser protection since tea possesses good canopy cover (Photo 23) and has high crop duration.
- Nutrients lost from cropped terraced area through runoff are utilized by the tea plants on risers, thus preventing uneconomical wastage of applied nutrients.
- Planting and establishment of tea is easier on risers without much disturbance of soil.
- Low maintenance is required by the crop with minimal pest and diseases problems.

Photo 23 : Tea on risers of terraces cultivated with annual crops

Tea Planting on Risers

- Terrace riser slope should be of 1:1 or 0.5:1. Before planting of tea, all weeds must be removed, without disturbing the soil.

- One year old seedlings of UPAS1-3, UPAS1-15, CR-6017, or B-6/61 varieties of tea should be planted in 2 or 3 parallel rows on terrace risers (Fig. 15) during onset of either south-west monsoon (June-July) or during north-east monsoon (September-October).
- Rows are marked at a spacing of 0.75 m and planting is also done at a spacing of 0.75 m. About 267 tea seedlings/clones are required for planting 100 m length of a paired row.

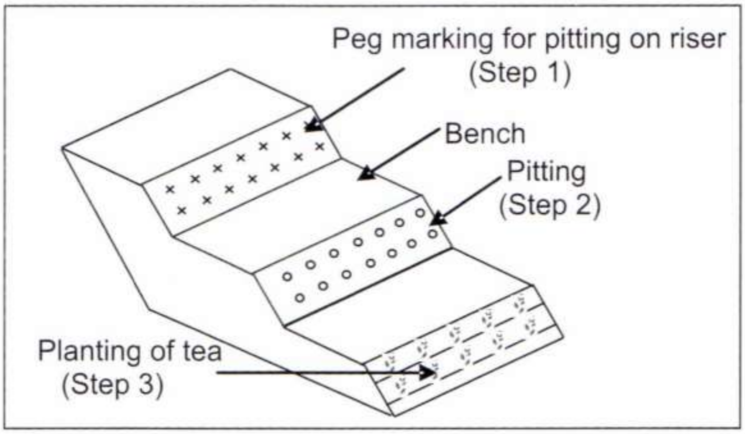


Fig. 15 : Steps for planting tea on risers

- Planting is done in 20 cm deep and 15 cm diameter holes.
- Planting should be done in the lower row first so that the displaced soil from the upper row(s) does not fill the holes in the lower row.
- After planting, if dry spell prevails, life saving irrigation should be provided with the help of sub-soil injector @ 1-2 litre per plant.
- Standard package of practices for raising of tea and its maintenance should be followed.

Conservation Efficiency

- The fertilizers applied to the crops on bench terraces leach down and are utilized by the tea planted on the risers.
- Tea is planted 1 to 2 feet below the level of the bench terrace. The roots of tea are, therefore, able to utilize the sub-soil moisture effectively and give higher yield in lean period as compared to tea cultivated under the conventional system.
- Tap root of tea plant goes about 45 cm deep into the soil and spreads to about 30 cm laterally, thus anchoring itself well and holding the riser soil firmly.
- Tea canopy also provides cover to riser soil from direct impact of rain drops and thus runoff and soil loss is brought down to 27.4 mm and 0.33 t $ha^{-1}yr^{-1}$.

Yield and Employment Potential

- An average yield (15 years average) of 5.8 t $ha^{-1}yr^{-1}$ is obtained from double rows of tea on terrace risers.
- Over a period of 16 years, 4670 mandays (292 mandays yr^{-1} ha^{-1} of terraced land) of employment can be generated.

- Since area occupied by risers is used for plantation, therefore, instead of reduction in area of cultivation by bench terracing, actually there is increase in area of cultivation.
- If prices of annual crops cultivated on bench terraces continuously remain uneconomical for a large number of years, then tea can be cultivated on the bench terraces, without dismantling the terraces. There is also the option for switching back to agriculture on bench terraces, if tea price remains low over a long period.
- Grasses and weeds growing on risers harbor rodents, which are eliminated if tea is cultivated on risers.
- Risk of loss due to failure of crops cultivated on terraces is minimized with crop diversification by cultivation of tea on terrace risers.
- In later stages of tea crop, leached out nutrients from agricultural crops, cultivated on the bench terraces will be sufficient for the tea raised on risers.

Economics

- In the first two years, there are no returns from tea cultivated on risers. From the third year onwards returns are obtained, and by the seventh year, the cumulative returns exceed the cumulative cost. The payback period of the system is about seven years.
- By the ninth year of plantation, net returns of Rs. 33,530 ha^{-1} are obtained considering 2008 prices.
- Saving on fertilizer cost due to no fertilization is required in later stages of tea since it utilizes the leached down nutrients from the terraces.

Scope

- This technology can be adopted in Southern hilly regions where tea is being grown and bench terracing is essential for annual crop cultivation. It is beneficial for small and marginal farmers.

4.4

Bio-Fencing Technology for the Vertisols of Semi-Arid Region

In semi-arid rainfed agro-ecosystem, domestic cattle are let loose to graze due to fodder scarcity during most part of the year, resulting in damage to standing crops in the range of 20 to 80%. In the black soil areas of semi-arid region, high intensity rains coupled with low water infiltration rate due to high clay content generate 10-30% runoff and associated losses of nutrient rich topsoil. Unrestricted cattle grazing in cultivated fields further enhance soil degradation and disturbs the agro-ecosystem, thus affecting the crop yields. The investment required for either constructing a long cement wall surrounding a plot of land or barbed wire fencing is quite high. Small and marginal farmers cannot invest a huge sum for erecting such a fence. Therefore, farmers of the region have been following the practice of bio-fencing. i.e. planting of perennial shrubs and trees on boundaries of agricultural farms to form a fence, which prevents entry of human and stray animals. For fencing, farmers use living as well as freshly pruned thorny bushes, shrubs and trees. However, this type of fencing material provides no tangible benefit to the farmers. It only serves to protect the field from stray cattle and human encroachment, besides reduction in runoff, soil and nutrient losses. Therefore, an alternative technology is needed, especially for the marginal and small farmers, whereby in addition to protecting the standing crop and reducing runoff, soil and nutrient losses, the bio-fence also provides additional economic returns through its by-products.

What Alternative Technology?

- Scientifically raising perennial shrub agave (*Agave sisilana*) or tree *Euphorbia tirucalli* of economic value on boundaries of agricultural farms to form a bio-fence not only tackles the problem of crop production losses caused by stray animals through damage of standing crops and soil erosion, it also enhances crop diversification to meet food, fodder and fuel needs, especially during prolonged drought periods.
- These bio-fences also protect the crops from dust, especially in the mining areas, which otherwise causes loss of production.
- In addition to reduced losses of crop yield and soil, additional income is generated through their by-products.

Establishment of a Bio-fence

- A field bund, if existing, is made weed free before onset of monsoon and a trench (20 cm wide x 30 cm deep) is excavated on the outer side of the bund. If no bund exists, then soil excavated from the trench may be used to form the bund.

- Locally available bio-fencing species e.g. *Agave sisilana* or *Euphorbiia tirucalli* should be planted on field bund in two staggered rows at a spacing of 50cm x 50cm (Fig. 16)

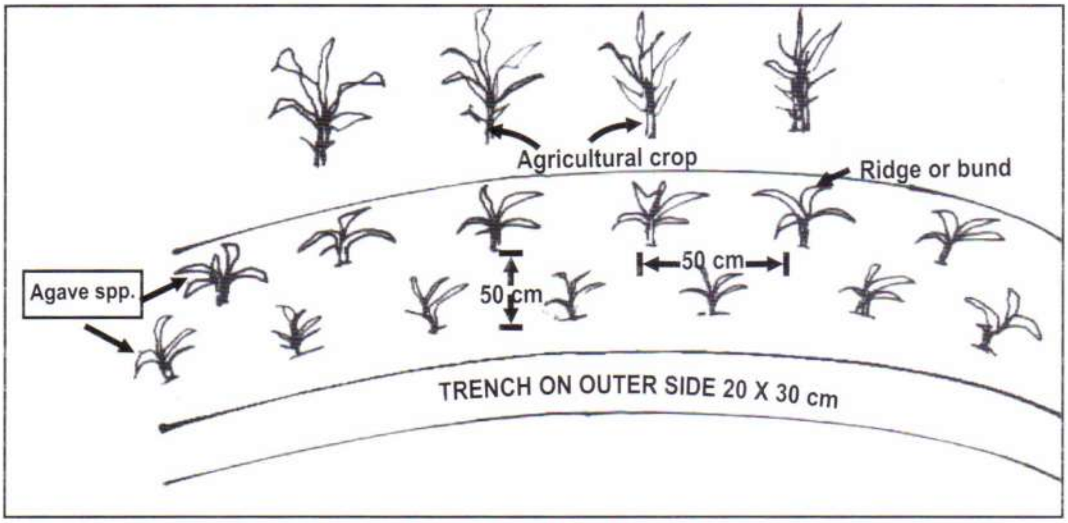


Fig. 16 : Bio-fence planted on ridge

- For Agave, generally root suckers are used as planting material while for *E. tirucalli*, stem cuttings serve as a planting material.
- A fence gets well established in 3-4 years (Photos 24 and 25) following standard package of practices for raising of agave and *E. tirucalli*.

Photo 24 : Bio-fence of *Agave sisilana*

Photo 25 :Bio-fence of *Euphorbiia tirucalli*

- Plants of *E. tirucalli* should be pruned after they attain a height of 1.5 m, otherwise it may affect crop growth and reduce productivity by 20 to 30%.

Conservation Efficiency

- In addition to proper demarcation of field boundary and protection from livestock damage, planting of bio-fence on bunds provides stability and prevents breaching of field bunds.
- Ridge planting of bio-fence recorded 7% higher soil moisture compared to planting on flat land.
- Soil moisture was 6% higher in cropped area at a distance of 2-4 m from bio-fence as compared to within 2 m from the bio-fence.
- Soil moisture was higher by 17% and 12% when *A. sisilana* and *E. tirucalli,* respectively were planted as a bio-fence.
- *A. sisilana* and *E. tirucalli* reduced runoff by 56% and 58% and soil loss by 73% and 75%, respectively over control (without bio-fence).
- Pruned material can be placed in compost pit, which turns into rich manure.

Yield Enhancement

- Yield of sorghum was higher by 26% and 20% when cultivated in a field with bio-fence of *A. Sisilana* and *E. tirucalli,* respectively as compared to control.
- Grain yield of sorghum 2-4 m away from bio-fence was higher by 6% (11.5 q ha^{-1}) as compared to near (<2 m) the bio-fence (10.9 q ha^{-1}) which indicates that the bio-fence and crop compete with each other for nutrients, soil and water. However, the loss is well compensated by increased grain production at 2-4 m distance from bio-fence and also by prevention of loss by grazing animals.
- In mining areas, bio-fences protect the crop and reduce crop yield loss by 5% to 10%.
- Bengal gram yield was 27% and 20% higher with bio-fence of *A. sisilana* and *E. tirucalli,* respectively as compared to field without bio-fence (control).

Economics

- The cost of bio-fencing varies from Rs. 14 per running metre (*A. sisilana*) to Rs. 20 per running metre *(E. tirucalli)*.
- Additional income from bio-fencing varies from Rs. 10 per running metre *(A. sisilana)* to Rs. 4 per running metre *(E. tirucalli)*.
- The net returns from bio-fenced plot with *A. sisilana* and sorghum was Rs. 6800 ha^{-1} yr^{-1} compared to Rs. 4500 ha^{-1} yr^{-1} from sorghum cultivated in a plot without a bio-fence (Table 20). With *E. tirucalli* as a bio-fence, the net returns were Rs 6180 ha^{-1} yr^{-1}.
- Compost formed from pruned material of bio-fence gives an additional income of Rs. 3 to Rs. 5 per running metre of bio-fence.

Table 20 : Net returns (Rs. ha^{-1} yr^{-1}) due to bio-fencing

Plot details	Bio-fence species	
	Agave sisilana	*Euphorbia tirucalli*
Bio-fence	1170	600
Sorghum crop in bio-fence plot	5630	5580
Bio-fence + sorghum crop	6800	6180
Sorghum + crop without bio-fence	4500	4500

Scope

- Bio-fencing technology is highly beneficial for implementation in semi-arid regions to conserve moisture, soil and nutrients and enhance crop productivity.

5

WATER HARVESTING AND GROUNDWATER RECHARGE

Dugout Pond for Deep Black Soils of Deccan Plateau Region

Vertisols and associated black soils cover about 72 million ha area in the country. The semi-arid black soil region in the dryland tract receives low rainfall varying from 500 to 700 mm, which is spread over a relatively longer period of seven months from May to November with an uneven, unpredictable and erratic distribution both in terms of amounts and intensities. Inspite of low rainfall, occurrence of a few intense storms is a common feature, which account for 20 to 30% of annual rainfall. Rainwater is invariably lost as runoff during these intense storms on account of low infiltration rate. Proper utilization of the excess water is required for sustaining production of rainfed crops in the region, which have poor and unstable yield due to moisture stress during crop growth as a result of low and uncertain rainfall and poor crop management practices.

Why Farm Pond in Black Soils?

- Black soils, which constitute 23% of rainfed area in India, have great production potential, if managed properly. These soils are generally put under cultivation in winter (post-rainy season) mostly on stored moisture.
- Studies on erosion control structures till date have indicated the suitability of drainage terraces with grassed waterways for disposing off the inevitable runoff. To mitigate this problem, water harvesting through dugout farm ponds in every 10 ha catchment is required to stabilize crop production.
- There exists immense potential in semi-arid black soil region to harvest a substantial amount of runoff into farm ponds (with negligible seepage loss) and periodically recycle the stored water for protective irrigation of crops for enhanced production.

Construction of Dugout Pond

- Depending upon topographic conditions, three types of farm ponds, *viz*; excavated farm pond for flat land, excavated-cum-embankment pond for mildly sloping topography and embankment type farm pond for hilly and rugged terrain are recommended.
- In the black soil region with flat to mildly sloping land, excavated (dugout) type ponds are suggested.
- Site for excavating a pond is selected in a participatory mode with farmers.
- The size of the catchment should be optimum to ensure storage of substantial amount of water for longer period. A pond should be located on one side of the watercourse to avoid rapid siltation.

- The command area should be free from salinity / alkalinity and the site should require little or no land shaping around the pond.
- The nature of the base of the pond is important, since pond base with shale, basalt or shattered rock is likely to lose more water due to seepage.
- In designing a dugout pond, apart from points mentioned above, parameters/components such as storage capacity, shape of pond, inlet and outlet should be suitably planned (Fig. 17).
- In the black soil region, the capacity of the pond should generally be 250 m^3 ha^{-1} of catchment area and pond dimensions can be decided with the help of Table 21.

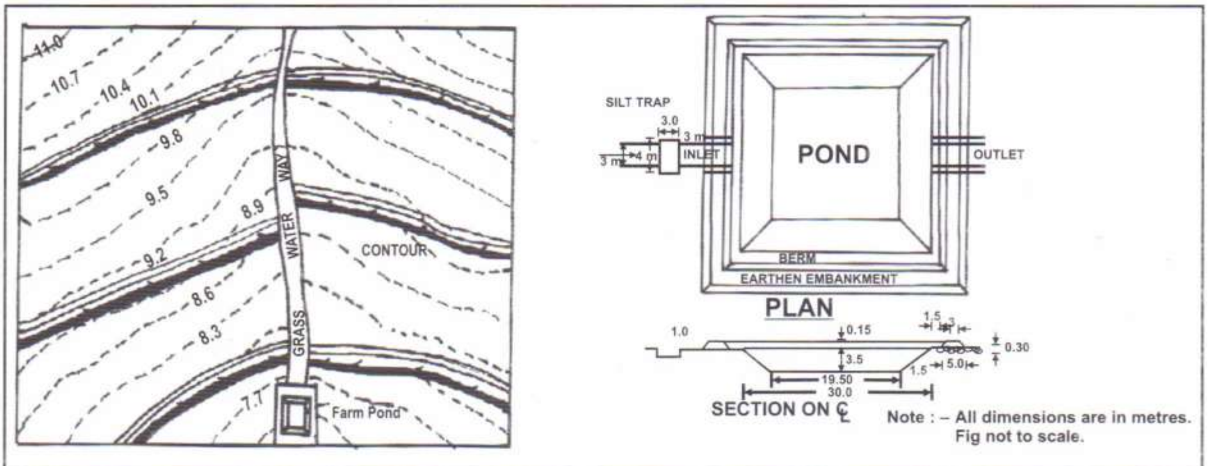


Fig. 17 : Line diagram of a typical farm pond showing the location in a field with contour lines and graded bunds

Table 21: Dimensions of dugout farm ponds of different capacities (V) and depths (D) in Vertisols with side slope (Z) 1.5:1

Design capacity (cum)	For 2.0 m depth		For 3.0 m depth	
	Bottom side of square section (X) (m)	Top side of square section (X1) (m)	Bottom side of square section (X) (m)	Top side of square section (X1) (m)
250	7.8	13.8	3.4	12.4
500	12.5	18.5	7.6	16.6
750	16.1	22.1	10.7	19.7
1000	19.2	25.2	13.2	22.2
1250	21.8	27.8	15.4	24.4
1500	24.2	30.2	17.4	26.4
1750	26.4	32.4	19.2	28.2
2000	28.5	34.5	20.9	29.9
2250	30.4	36.4	22.5	31.5
2500	32.2	38.2	24.0	33.0

- After clearing bushes, shrubs and other unwanted materials from the site and demarcation of four corners of farm pond, segment wise excavation (stepping method) of the pond is done to get the required shape and side slopes.
- Generally square pond (Fig. 18) should be excavated since it is easier to excavate and evaporation and seepage losses are lower than that from a rectangular pond. Side slopes are decided by the angle of repose of the sub-soil. Usually side slopes of 1.5:1 are sufficient for the *murrum* obtained under deep black soils. Dimensions of the square dugout shape farm pond are given in Table 21.

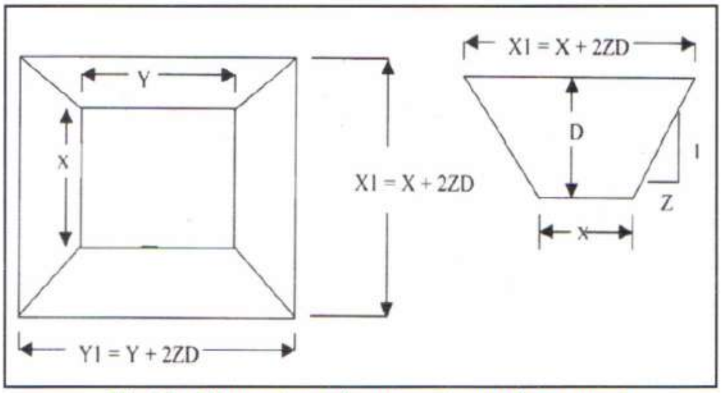


Fig. 18 : Dimensions of square dugout farm pond

- Inlet to the pond is a chute spillway for diverting runoff into the pond in a controlled manner. The entry section is a rectangular broad crested weir. Peak discharge rate for 10 years return period in deep black soils is taken as 0.15 cum sec^{-1} ha^{-1} and accordingly width and height of the crest is designed with 20% extra height as free board.
- The outlet should be lower in elevation than inlet to avoid back water effect. Its discharge capacity should be half of the inlet capacity at peak rate of runoff.
- Shoulder bund with a small toe drain should be provided to avoid rills and to allow collection of water into the pond or take it out through earthenware pipes.
- A silt trap slightly greater in length than width of the water course, 0.75 m to 1.0 m deep with side slopes of 1:1 is made at the entrance of the inlet to check the silt load entering into the pond.

Maintenance

- Pond in deep black soils may be silted up @ 5-6 t ha^{-1} yr^{-1}, hence periodic desiltation of the pond is essential.
- Silt from the silt trap should be removed periodically.
- Since black soil swells and shrinks excessively, therefore, to avoid collapse of constructed structure (inlet and outlet), a firm base of *murrum* is to be provided prior to construction.
- Breaches and rills formed in the shoulder bunds and spoil bank should be promptly plugged.
- Aquatic weeds/plants growing in the pond should be periodically removed since not only do they transpire large quality of water, but on decay, they affect quality of pond water.
- Fencing may be provided around the farm pond if required.

Yield Enhancement

- Crop yield increased by 55% and 90% on providing 5 cm and 10 cm of water, respectively as protective irrigation.

Economics

- On providing 5 cm and 10 cm of protective irrigation, the gross returns increased by 55% and 86%, respectively.
- The expected annual benefit from different sizes of farm ponds along with design capacity, water availability and irrigated area is presented in Table 22.

Table 22 : Expected net benefit per year from different sizes of dugout farm ponds with sorghum as the test crop

Catchment area (ha)	Expected runoff (cum)	Design capacity (considering two fillings during the rainy period) (cum)	Water availability after accounting for evaporation and seepage losses (cum)	Area irrigated with two irrigations of 5 cm each (ha)	Net benefit (Rs)
1	500	250	400	0.4	9109
2	925	460	740	0.7	16852
3	1350	675	1080	1.1	24595
4	1710	855	1370	1.4	31199
5	2075	1038	1660	1.7	37803
6	2400	1200	1920	1.9	43724
7	2730	1365	2184	2.2	49645
8	3030	1365	2424	2.4	55110
9	3330	1665	2664	2.7	60576
10	3600	1800	2880	2.9	65586

Scope

- The technology can be implemented in black soil region where seepage is negligible. The technology has become highly popular in semi-arid region of Andhra Pradesh and Karnataka. Watershed development department is practicing this technology which is also highly beneficial to the farmers.

Jhola Kundi - A Low Cost Water Harvesting Technique for Augmenting Production in Eastern Ghats High Land Region of Orissa

Low lands of the eastern Ghat High Lands (EGHL), locally called *jhola* lands, are wide terraced gully beds. *Jhola* lands, which comprise 5% of the EGHL landscape, are at 1 to 1.5 m lower elevation than the adjoining medium slopping lands and uplands. The *jhola* lands are highly productive due to presence of perennial water resources. Paddy is the major crop grown in this ecosystem. However, there exists scope for cultivation of water intensive but more remunerative vegetable crops through efficient utilization of this perennial water. The adjoining medium slopping lands and hill slopes (locally called as *donger* lands) lack remunerative crop production due to lack of proper water harvesting techniques. Eastern Ghats High Land zone of Orissa is densely inhabited with tribal populace, and inspite of the region being rich in water resources, agriculture is of subsistence level, since the tribals have not been able to tap the water resources for increasing agricultural productivity. Cultivation of vegetables has been found to be more remunerative in this tribal belt compared to cereal crops like paddy and *ragi*. As there is ample scope for utilizing *jhola* stream water as a source of irrigation for medium slopping lands, a cost effective suitable water harvesting technology is required for production of remunerative vegetable crops such as tomato, cabbage, cauliflower, brinjal, pepper etc. in sloping medium and uplands in summer and post monsoon season, as well as *jhola* land, suiting to individual small and marginal farmers.

Which Water Harvesting Technology?

- *Jhola Kundi,* a cost effective water-harvesting device, is a promising technology for irrigating vegetable crops during post monsoon and summer seasons.
- It is a shallow open well dug manually for easy lifting of water through traditional water lifting devices (Photo 26).
- The technology is quite affordable as it is cost effective.
- *Jhola Kundi* is absolutely maintenance free, only precaution required is not to allow surface runoff water to enter from the surface, thereby preventing siltation.

Photo 26 : *Jhola kundi*

Construction of a *Jhola Kundi*

- For cultivation of vegetable crops e.g. tomato, cabbage, cauliflower and brinjal, approximately 450 mm depth of water is required for average growing period of 100 days. Thus for irrigating 0.5 ha area, 22.50 ha-cm (2250 cum) water is required. If irrigation of crops is carried out in rotation, water requirement would be 0.225 ha-cm per day (22.5 cum per day).
- To meet the irrigation requirement of the vegetable crops, depth and diameter of a *jhola kundi* should be 4 m and 3 m, respectively. While deciding the depth and diameter of a *jhola kundi,* convenient suction head for easy lifting of water (through traditional water lifting devices) should also be considered.
- For above dimensions of a *jhola kundi*, suitable location along the periphery of *jhola* system is selected for digging a *jhola kundi*.
- *Jhola kundi* is dugout manually like an open well. Since sub-surface flow occurs continuously in the sub-surface soil strata, water needs to be removed continuously during excavation.
- Soil obtained after excavation of *jhola kundi* is deposited around the kundi 0.5-1.0 m away, forming a bund. The bund prevents entry of surface runoff water into the *jhola kundi* and keeps a check on it getting silted up.
- Traditional water lifting device (locally called as tenda) with optimum operation lift of 1.2 to 4.0 m (Photo 27) or paddle operated Krishak Bandhu Pump with optimum operation lift of 5-7 m can be used for lifting water from *jhola kundis*.

Photo 27 : *Jhola kundi* with traditional water lifting device

Operational Advantages

- Traditional water lifting devices can be fabricated by the farmer himself by using the local material.
- *Jhola kundi* technology of water harvesting is almost maintenance free.
- The traditional water lifting devices and Krishak Bandhu Pump are easy to operate and even women can use them to irrigate their fields.

Yield Enhancement and Economic Advantages

- The harvested water from one *jhola kundis* can be used to irrigate 0.5 to 1.0 ha area during *rabi* season and 0.2 to 0.4 ha area during the summer season. Thus post monsoon and summer season vegetables can be cultivated, resulting in increase in cropping intensity and yield (Table 23).

- The traditional practice of cultivation of non-remunerative cereal crops like paddy and finger millet can be replaced with cultivation of highly remunerative cash crops of vegetables and flowers (Table 24).
- Net income from cash crops ranged from Rs.23,030 to Rs. 64,700 ha^{-1} (Table 24).
- Cost of excavating a *jhola kundi* of 30 m^3 is only Rs.2000, which a farmer can afford.
- Paddle operated Krishak Bandhu Pump costs Rs.1,200 to Rs. 1,500 only.

Table 23 : Crop diversification and overall productivity

Attributes \ Crops	Before project - Millets, maize, vegetables (in small patches), maize etc.	After project - Cash crops (vegetables, ginger, fish, flowers)
Yield (q ha^{-1})	49	172
Net returns (Rs $ha^{-1}year^{-1}$)	4900	52180
Cropping intensity (%)	127	270
B:C ratio	-	2.80

Table 24 : Yield and net income from vegetables irrigated with water harvested in *jhola kundi*

Crop	Yield (q ha^{-1})	Net returns (Rs ha^{-1})**
Cabbage	235	37710
Cauliflower	218	64700
Chillies	40	53280
Brinjal	208	60290
Pea	52	55700
Tomato	216	63575
Maize + chillies	164*	23025
Maize + cauliflower + beans	288*	59145

*Maize equivalent yield; **At 2008 price level.

Scope

- The small and marginal farmers of the Eastern Ghat High Land region having *jhola* lands and medium lands in their possession can suitably adopt *jhola kundi* water-harvesting technology for harvesting water from water rich *jhola* ecosystems for growing off-season remunerative vegetable crops.

Recharge Filter - A Cost Effective Technology for Augmenting Groundwater in Arid and Semi-Arid Regions

In India 75% of total irrigated land (65 m ha) is being irrigated by groundwater from wells and tubewells. By 2025, irrigated land is expected to increase to 100 m ha of which 85% would rely on ground water utilization. Unchecked over exploitation during the last fifty years to meet the burgeoning demand of water for human and cattle population has led to decline of water table by 1-2 m in many states of India. In the state of Gujarat, it has dropped by 0.5 m to as high as 9.5 m in the recent past. Recharge of the aquifers from natural resources like rainfall, seepage from canals, ponds etc. is only 15-20% of seasonal rainfall in the Indo-Gangetic plains and in the hard rock peninsular region it is 5-10%. In areas where groundwater is extracted beyond natural recharge, artificial recharge is essentially required. Conventional methods of augmenting ground water recharge like percolation tanks, farm ponds and check dams are generally adopted in all watershed development programmes. However, artificial recharge techniques like recharge pits, shafts etc. have not gained much prominence. Hence, there is a need to identify suitable cost effective artificial recharge techniques.

Which Recharge Technique?

- Recharge filter technique helps in augmentation of ground water recharge and conservation of water resources.
- The runoff going waste from arable and non-arable lands is first filtered by a three tier system for removing the sediment load and then the sediment free runoff is directly conveyed to the aquifer through a buried pipe line, which enables quick recharging of ground water.
- Two types of recharge filters have been developed for use as per the size of the catchment area. Type I recharge filter is suitable for <4.5 ha area in arable land, while Type II recharge filter is recommended for higher heads of ponding near the drainage channel in non-arable lands.

Construction of Recharge Filters

Type I recharge filter

- Surface area of recharge filter pit to be constructed in agriculture land is calculated on the basis of volume of runoff expected from the contributing area considering 24 hours maximum rainfall of 2 years return period, so that the design runoff is drained / recharged in 24 hours to prevent water logging of crops. The suitable size of the recharge filter for various catchment sizes with 2% slope is presented in Table 25.
- A square pit of required size is excavated 1 m deep into the soil and is lined with Low Density Polyethylene film (LDPE) of 250 micro thickness. However, to suit the site condition, the length and width of recharge filters can be changed by maintaining the same surface area.

Table 25 : Size of recharge filter surface area for various catchment area (Type - I)

Catchment area (ha)	Size of filter (m x m)	Interceptor bund height (m)	Volume of recharge (m^3)	Height of waste weir (m)	Length of waste weir (m)
1.0	2.9 x 2.9	0.95	425	0.24	2.0
2.0	4.0 x 4.0	1.24	943	0.29	2.0
3.0	4.9 x 4.9	1.43	1495	0.34	2.0
4.0	5.6 x 5.6	1.67	2061	0.38	2.0

- Base of the filter is graded towards the middle where a perforated pipe leading to the recharge well is placed (Fig.19).
- A wire mesh (2cm x 2cm openings) box casing filled with suitably graded stones/geo-textile is fixed around the collecting pipe to ensure dirt and sediment free water.
- Graded filter materials are spread in layers of 30 cm thickness each over the perforated pipe and LDPE sheet (250 microns thick), which lines the pit. Bottom layer is of graded stones / gravel of 40 mm size. Middle layer has finer gravel of 20 mm size, while the upper layer is of coarse (clean) sand of 2 mm grain size (Table 26).

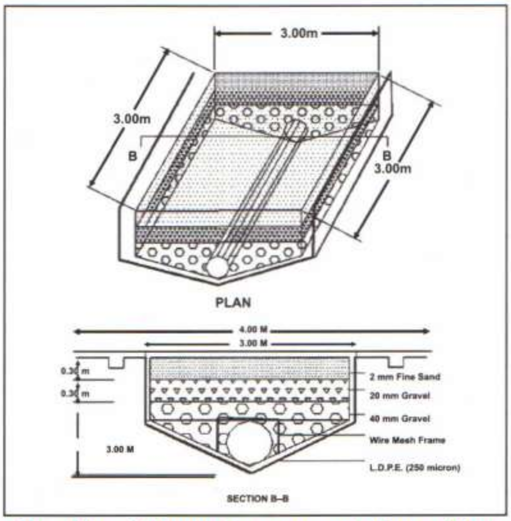


Fig. 19 : Schematic representation of low cost LDPE lined graded recharge filter (Type-I) for arable land

Table 26 : Materials required for construction of Type-I recharge filter unit

Surface area (m x m)	LDPE sheet (m^2)	PVC pipe (m)	Wire mesh (kg)	Coarse sand (2 mm) (m^3)	Graded stone (20 mm) (m^3)	Graded stone (40 mm) (m^3)	Agro-net/ geo-jute (m^2)
2.9 x 2.9	35.0	2.9	14.5	2.8	2.8	3.5	15.2
4.0 x 4.0	50.5	4.0	20.0	5.3	5.3	6.7	25.0
4.9 x 4.9	65.2	4.9	24.5	8.0	8.0	10.0	34.8
5.6 x 5.6	77.9	5.6	28.0	10.5	10.5	13.1	43.6

- Top of the recharge filter can be covered with agro-net/geo-jute (0.25 mm opening) to prevent sediments from clogging the sand surface.
- The recharge filter should be supported by an interceptor bund to harvest runoff water and a suitable ramp-cum-waste weir must be provided to remove excess runoff, if any.

Type II recharge filter

- The most suitable size of filter, after construction of water retention structures (check dams / earthen dams), should be based on the depth of available recharge in non-arable lands / drainage channel. The depth of ponding over the recharge filter must not be less than 1.0 m to induce maximum recharge. Table 27 shows the volume of water directly recharged through the filter based on the depth of ponding and size of filter.

Table 27: Rate of direct recharge through the filter for different depths of ponding in Type II recharge filter

Ponding depth (m)	Recharge rate through the filter ($m^3 h^{-1}$) for diferent filter sizes (m x m)					
	3 x 3	4 x 4	5 x 5	6 x 6	7 x 7	8 x 8
1.0	24.5	43.5	67.9	97.8	133.1	173.8
1.5	30.9	54.9	85.8	123.5	168.1	219.5
2.0	37.3	66.3	103.6	149.2	203.1	265.3
2.5	43.7	77.8	121.5	174.9	238.1	311.0
3.0	50.2	89.2	139.3	200.7	273.1	356.7

- The procedure for the construction of Type-II filter is similar to Type I filter with the difference that instead of LDPE lining, the pit is lined with brick wall (9") with inner face and base plastered (1:6).
- The perforated pipe laid at the base joining the recharge well through an under ground pipeline is enclosed in a wire mesh box containing stones of suitable size / geo-textile to surround the pipe (Fig. 20).

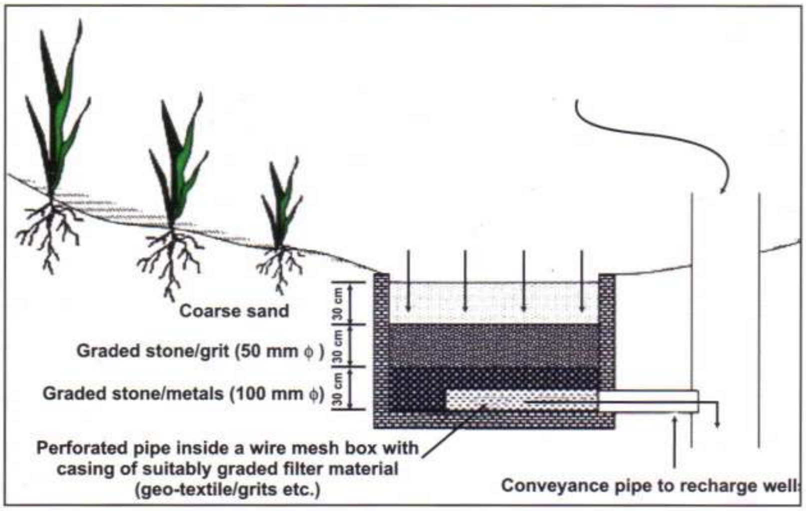


Fig. 20 : Schematic representation of a recharge filter (Type-II) for non-arable land

- Base of the recharge filter is covered with 30 cm thick layer of stones / gravel of 100 mm size. Over this layer is the middle layer (30 cm thick) of stones / gravel of 50 mm size and the upper layer (30 cm thick) is of coarse sand (Table 28).

Table 28 : Material required for construction of Type - II recharge filter unit

Surface area (m x m)	Cement (Bag)	Sand (m^3)	Brick ballast (m^3)	Brick (no.)	Graded stone (50 mm) (m^3)	Graded stone (100 mm) (m^3)
3 x 3	12	4.38	1.99	748	3	3
4 x 4	19	7.35	3.18	978	5	5
5 x 5	27	11.08	4.64	1208	8	8
6 x 6	36	15.58	6.38	1438	11	11
7 x 7	46	20.84	8.40	1668	15	15
8 x 8	58	26.86	10.69	1898	19	19

Cost

- The cost of two types of recharge filters of different sizes designed for various sizes of catchment are given in Table 29. These costs are exclusive of cost of the pipe for delivering water to the wells. Cost of pipe (160 mm for Type-I and 200 mm diameter for Type-II, each for 6 kg cm^{-2} pressure) along with excavation and laying cost of Rs. 332 and Rs. 476 per running metre length should be added to the cost of construction of Type I and Type II recharge filter, respectively.
- The cost of construction for diversion units such as field bunds, waste weir arrangements, check dams or earthen dams to create a favorable ponding depth for both types of recharge filters is the additional cost to be incurred based on the site conditions.

Table 29 : Cost of construction of recharge pit of 1 m depth (Type-I and Type-II)

Size of filter (m x m)	Arable land (Type-I) (Rs.)	Size of filter (m x m)	Non-arable land (Type-II) (Rs.)
2.9 X 2.9	16,250	3.0 X 3.0	21,340
4.0 X 4.0	28,200	4.0 X 4.0	34,090
4.9 X 4.9	40,450	5.0 X 5.0	49,830
5.6 X 5.6	51,550	6.0 X 6.0	68,560
--	--	7.0 X 7.0	90,280
--	--	8.0 X 8.0	1,14,990

Filter Treatment

- The material in the recharge filter only checks entry of suspended material into the aquifer. However, to check entry of undesirable dissolved / soluble material into the aquifer, the following treatments are needed:

- For removal of metals - add additional layer of peat
- For removal of organics - add activated carbon / wood charcoal
- For removal of phosphorus - add calcite dolomite and iron fillings
- For removal of metals - add soybean hulls
- For removal of dissolved metals - coat the top layer of sand with oxides of iron, manganese or aluminum.

Benefits

- Due to construction of 23 recharge filters and 17 check dams in Antisar watershed in Kheda district of Gujarat, the water table in the wells increased by over 14 m in the pre-monsoon period and over 22 m in the post monsoon period during five years of monitoring.
- The benefit due to increased crop production by the use of recharged groundwater (4,05,160 m^3) during the five years period was estimated as Rs. 11,25,840. Estimated value of the groundwater ranged from Rs. 4,17,310 to 42,25,800, depending upon the crops to be grown.

Scope

- This cost effective and easily implementable technology is highly suitable for arable and non-arable lands in the arid and semi-arid regions of Gujarat and Rajasthan having moderate to heavy textured soils.

5.4

Supplemental Irrigation from Harvested Rainwater for Higher Crop Production in Shivalik Region

Shivalik region falls under the sub-humid zone, which receives > 1000 mm annual rainfall. However, since the monsoon rains recede much before the sowing of *rabi* crops, the moisture level in the seed zone is quite low thereby affecting crop yields adversely. Moreover, a major part of the region lacks assured irrigation facility, which is essentially required for realizing the full yield potential of crops and sustaining agricultural production. Therefore, the area is mostly rainfed, and the crops suffer heavily due to lack of required moisture at critical stages of plant growth. Hence, available rainwater needs to be properly utilized through appropriate conservation techniques for boosting agricultural production in the region.

What Technology Needed for the Region?

- Under the prevailing situation, the inevitable runoff generated, from good amount of annual rainfall, and wasted needs to be harvested and stored in tanks / ponds. The harvested runoff needs to be judiciously utilized to get maximum production per unit of available water.
- For this, most critical growth stages of major *rabi* crops of the region, such as wheat, at which supplemental or life saving irrigation must to be provided need to be identified.
- Further, life saving irrigation must be provided as per available quantity of water and the importance of the identified critical crop growth stages of the *rabi* crop.
- Emphasis should be given to bring more area under irrigation rather than increasing the number of irrigations for higher production advantage.
- It would help in significantly boosting agricultural production in the Shivalik region.

Critical Irrigation Scheduling

- Following standard package of practices, short duration varieties of wheat like Raj-3765 and PBW-175, which have low water requirement and can withstand moisture stress condition, should be cultivated in the region.
- Irrigation scheduling need to be followed depending upon availability of harvested rainwater:
  - Only pre-sowing irrigation, when there is sufficient water for one irrigation.
  - Irrigation at pre-sowing and crown root initiation (CRI) stages, when water is available for two irrigations.
  - Irrigation at pre-sowing, CRI and tillering stages, when water is available for three irrigations.
- Utilize stored rainwater as early as possible to minimize evaporation and seepage losses.

Conservation Efficiency

- Three irrigations at critical crop growth stages, i.e. one each at pre-sowing, CRI and tillering stages, results in a saving of nearly 2250 cum of water per hectare.

Yield Enhancement

- At Chandigarh, the yield of wheat increased from 760 kg ha^{-1} (control) to 2660 kg ha^{-1} (223% increase) with sole irrigation at pre-sowing as compared to control.
- Two irrigations, one each at pre-sowing and CRI stages, increased the yield by 307%. Three irrigations, one each at pre-sowing, CRI and tillering stages, increased the yield by 347%.

Economics

- The cost of cultivation without any irrigation was Rs 7880 ha^{-1}, which increased by 8, 15 and 23 per cent with 1, 2 and 3 irrigations as per importance of crop growth stages (Table 30).
- The negative net returns obtained without irrigation, turned positive with irrigations provided as per water availability to wheat at critical growth stages.
- Net returns obtained from three irrigations, one each at pre-sowing, CRI and tillering stages, recorded 15% higher net returns (Rs.17,330 ha^{-1}) as compared to two irrigations, one each at pre-sowing and CRI stages (Rs. 15,130 ha^{-1}).
- Two irrigations, one each at pre-sowing and CRI stages, recorded 42% higher net returns (Rs.15,130 ha^{-1}) as compared to irrigation at pre-sowing stage only (Rs.10,690 ha^{-1}).

Table 30 : Net returns (Rs ha^{-1}) from wheat under different supplemental irrigation(s)

Critical crop growth stages for irrigation	Cost of cultivation (Rs ha^{-1})	Net returns* (Rs ha^{-1})
Control	7875	(-)1250
Pre-sowing	8475	10,690
Pre-sowing + CRI	9075	15,130
Pre-sowing + CRI + tillering	9675	17,330

* Based on year 2005.

Scope

- The technology of providing supplemental irrigation has great potential in those areas of entire Shivalik region where no assured sources of irrigation exist but have ample possibilities of rain water harvesting and recycling.

6

MASS EROSION CONTROL

6.1

Geotextiles for Slope Stabilization and Erosion Control in Himalayan Region

The Himalayan region is highly prone to landslides and slope failures due to its fragile geology, high rainfall and steep topography. Developmental activities like road constructions and mining have further aggravated land degradation problems. Quite often, plantations done on these degraded slopes do not survive due to poor soil moisture conditions and mass movement of the top soil. These slopes need to be stabilized by preventing washing away of the top soil and the vegetation by runoff. Construction of costly and massive mechanical structures is not desirable on these slopes due to fragile geology of the ecosystem. Therefore, a suitable alternative technology is needed to stabilize such highly erosion prone areas.

What Alternative Technology for Slope Stabilization?

- Geotextiles have been used quite extensively for erosion control and slope stabilization purpose in USA and Europe.
- Geotextile (*Bhoovastra*) is a woven/non-woven knitted structure of natural / synthetic textile fibres generally used for various geo-technical, civil engineering and soil conservation works.
- When laid on ground surface of the affected area (Photo28) and anchored with suitable devices such as wooden pegs, it provides innumerable miniature checkdams absorbing the impact and kinetic energy of falling raindrops (splash erosion) and checking velocity of surface runoff.
- Geotextile helps to establish vegetation on such highly degraded lands which can not be stabilized by normal methods, by:
  - Providing mechanical strength to land surface
  - Holding the vegetation in place through its open mesh
  - Conserving moisture and fine soil through its netting structure

Photo 28 : Vegetation plantation with geojute

- In due course, the geotextile material biodegrades in about two years period by which time the vegetation gets established and takes control of the soil erosion. Organic nutrients are added to the soil with the degradation of geo-textile.

- Application of geotextile material, alongwith suitable bio-engineering measures can help in controlling soil erosion and stabilizing degraded slopes, landslides, minespoil areas and cut slopes along roadsides.

Material Specifications

- Geotextile materials are generally available in rolls of 50 m length and 1.22 m width. Materials of following specifications may be used for slope stabilization and erosion control.

Geotextile	Weight (g m^2)	Mesh size
Geojute (soil saver)	500	16 mm x 22 mm
Coir geonet		
a) H2M6	400	25 mm x 25 mm
b) H2M8	700	10 mm x 10 mm

- Coir geonet (H2M8) may be used for stabilizing highly degraded sites.

Application Method

- Before onset of monsoon, implement suitable conservation measures as shown in Fig.21.
- Excavate a diversion drain above the problem area to drain out excess runoff.
- Construct need based soil conservation structures, e.g. gully plugs, stone barriers etc. at the problem site.
- Dig pits of recommended size at specified spacings for plantation of recommended trees.
- Dig anchor trench of 0.3 m x 0.3 m on the upper side of the geotextile application site and anchor one end of the geotextile in it by filling back the trench with the excavated soil.

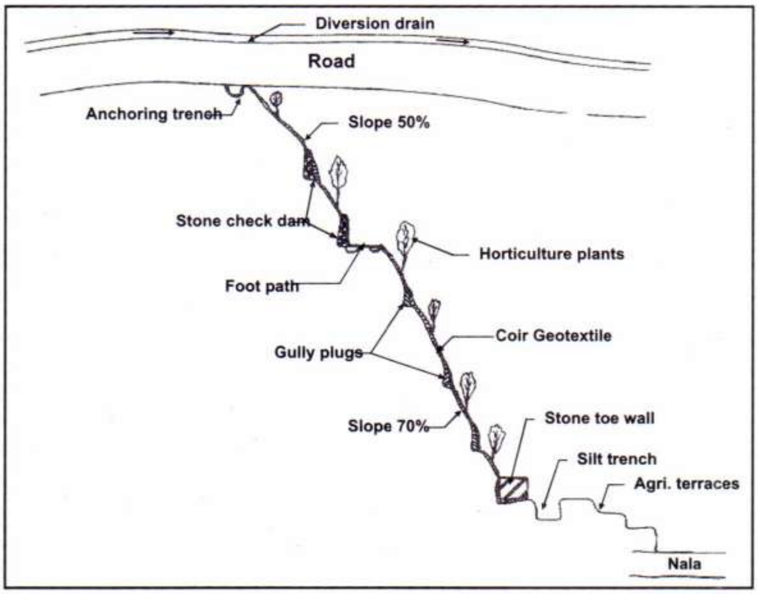


Fig. 21 : Profile showing conservation measures for a typical landslide area

- Open the roll of geotextile down the site. The adjacent rolls should overlap each other by about 20 cm along the entire length (Fig.22).
- Drive wooden sticks to hold the geotextile securely in its place.
- Plant rooted slips of local grasses like *Saccharum spontaneum* (*Kans*), *Thysanolaena maxima* (Broom grass) and cuttings of bushes like *Ipomoea carnea* (*Beshram*), *Vitex negundo* (*Simalu*), and *Arundo donax* (*Narkal*) in the openings of the net of geotextiles at 0.5 m x 0.5 m spacings.

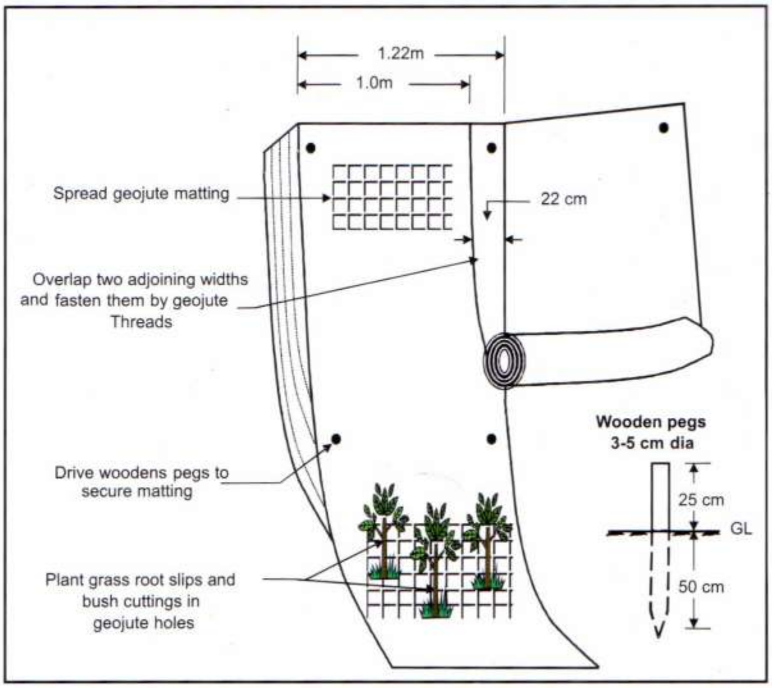


Fig. 22 : Technique of geotextile application

- A trench (0.3 m x 0.3 m) and a toe wall, if required, may also be excavated at the lower end of the geotextile roll to anchor it firmly.

Application Cost

- Cost of laying jute geotextile works out to almost Rs.27 per sq m and for coir geotextile about Rs.53 per sq m including cost of construction of small soil conservation structures and plantation (Year 2008 price level).
- Being costly, the geotextile application, it should be used at critical spots only where stabilization by normal soil conservation measures is not feasible.

Scope

- The geotextile technology can be suitably used for landslide/slip control along hill roads (there are more than 44000 km of hill roads in India).
- Highly degraded minespoil slopes covering almost 25,000 ha of area in the Himalayan region can be rehabilitated.

6.2

Katta-Crate Technology - A Cost Effective Measure for Rehabilitation of Torrent and Minespoil Areas

Torrents affect about 7500 sq km of land in Shivaliks spread over in the states of Uttarakhand, Uttar Pradesh, Haryana, Punjab, Himachal Pradesh, Jammu & Kashmir and the Union Territory of Chandigarh. Besides, vast tract of land (over 25000 ha) are degraded and erosion prone due to mining activity in the Himalayan region, which need to be rehabilitated by proper soil conservation measures. Stone-wire-crate gabion structure is the most commonly used soil conservation measure. However, where stone has to be transported over a long distance, cost of the gabion structures becomes exhorbitant. Therefore, an alternative low cost technology based on locally available material is needed, which can serve the purpose of training the torrents and rehabilitating minespoil sites similar to by the conventional gabion structures.

What Alternative Technology?

- *Katta*-crate technology uses disposable or used polythene cement bags (*katta*) and the locally available material - sand, gravel, pebbles, minespoil etc. mixed with a small quantity of cement. The mortar is filled in the *kattas* and laid as per design.
- The laid out bags become a solid mass in due course of time and are as good as stones.
- Such structures were field tested at minespoil and torrent control project sites and were observed to perform satisfactorily.
- The technology can be implemented with ease in much less time compared to the conventional gabion structures.
- The *katta*-crate structures are more economical than the conventional gabion structures, where stone is not readily available.

What is *Katta*-Crate?

- Locally available *nala* (stream) bed sand/gravel, pebbles; minespoil etc. are mixed with a small quantity of cement (1:18 ratio) and the mortar is filled in disposed (used) synthetic cement bags (locally known as *katta*). The filled bags are used for construction of soil conservation structures such as spurs, check dams/barriers, retaining walls etc.
- The bags may be encased with a GI (Galvanized iron) wire mesh made of 10 SWG (3.15 mm dia) wire for greater stability.

Construction of *Katta*-Crate Spurs

- Spurs are needed for torrent training works in order to protect the surroundings from damage by flooding.

- Spurs are structures constructed on the bank(s) of torrent and protruding towards the flow at an angle to channelize the flow.
- Disposed synthetic cement bags filled with the mortar of cement, sand and gravel (1:6:12 ratio) are laid over one another as per the design of spur (Photo 29).

Photo 29 : A *katta*-crate spur

- Length of spur should be less then 1/3rd of the torrent width. The height of spur is decided as per maximum depth of flow in the torrent, which normally does not exceed 1m.
- Spurs may be constructed upto a length of 3 m with bottom width of 1.5 m and top width of 1m. Height of super structure is kept as 1 m with foundation depth of 0.5 m, thus making total height of the structure as 1.5 m.
- The whole structure may be encased in a wire mesh for greater stability.

Cross Barriers for Minespoil Stabilization

- For stabilization of limestone minespoil slopes, cross-barriers may be constructed by filling cement, sand and minespoil/gravel mixture (1:6:12 ratio) in disposed synthetic cement bags and the filled up bags are laid across the slope in the rows one over another in three layers upto a height of about 0.6 m (Fig.23).
- On unstable slopes, mixed mortar filled bags encased in GI wire mesh are recommended.

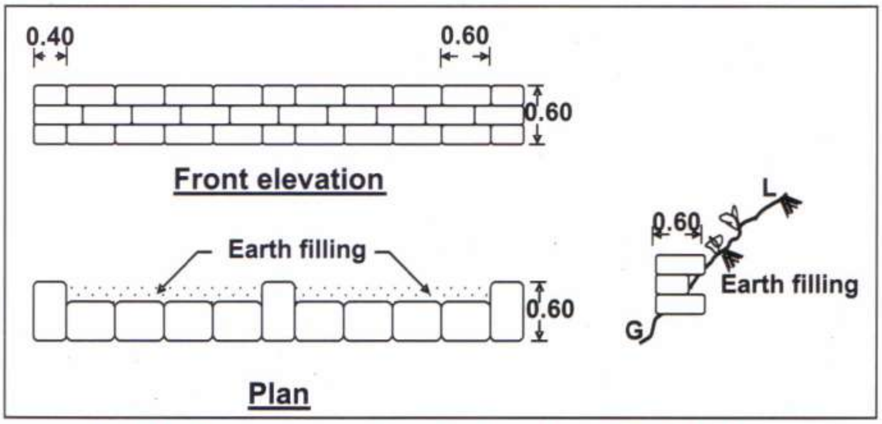


Fig . 23 : *Katta*-crate cross-barrier for minespoil stabilization

Economics

- The *katta*-crate construction (Rs.624 cum^{-1}) worked out to be cheaper by 20% as compared to gabion construction (Rs.784 cum^{-1}) in a typical case study where stone had to be supplied from a distance of about 20 km by road transport and headload. In case GI wire mesh is not used, then *katta*-crate is cheaper by 46% than the gabion structure.

Scope

- *Katta*-crate technology can be used for construction of structures for torrent training and minespoil stabilization at sites where big size stones are not available in the near vicinity.
- The technology is useful for State Departments of Soil Conservation, Watershed Development, Irrigation and Flood Control, Forests, Mining industry, NGOs and farmers.

6.3

Rehabilitation of Minespoil Areas in Northern Hilly Region

In India, mining is spread over an area of 9,43,380 ha, and surface mining is adopted in more than 90% of mines. The Himalayan region is bestowed with a large variety of mineral resources, mostly limestone. The mineral deposits occur mostly on forest lands and hilly regions having delicate ecological balance. Indiscriminate and large scale commercial mining carried out in this eco-sensitive region has posed a serious threat to the environment in the form of heavy soil erosion, drying of water sources, land degradation, disruption of communication system etc. Mining invariably entails removal of all plant cover on the land surface and the productive topsoil, and destruction of the habitat of all flora and fauna. Mining operations leave behind huge overburden or debris dumps, which are easily subject to erosion. Ill effects of the mining activity are reflected far downstream in the form of polluted water bodies, streams and rivers by toxic substances and heavy sedimentation. Some mines produce various type of waste waters like acid mine drainage water, tail pond discharge, runoff from waste dumps etc. These waters degrade both the surface and underground water resources. In order to avoid adverse effect of mining on the environment, scientific methods of mining should be adopted.

What Combination of Conservation Measures?

- Bio-engineering technology comprising of an appropriate combination of small engineering and vegetative measures is very effective for rehabilitation of highly degraded lands such as minespoils.
- As a result of reclamation, the highly degraded area is rehabilitated with many environmental externalities such as drastic reduction in the debris/sediment flow, attenuation of flood peaks, increased lean period (sub-surface) flow and improved water quality within a short period. The degraded land becomes productive, the vegetation density improves, and flor a and fauna gets restored.

Engineering Measures

Engineering measures are generally needed to stabilize eroded slopes and create conducive environment for plant growth by arresting fertile soil and improving moisture status.

Slope stabilization measures

Diversion drains

- Diversion drains (0.3m x 0.3m) are constructed across the slope at 0.5% grade on top of the degraded area to divert runoff water away from the unstable area and discharge it safely into a natural waterway or vegetated water course.

Trenches

- Continuous/staggered contour trenches are provided to reduce the velocity of flow, conserve moisture and trap sediment to support better vegetation establishment on sloping lands.
- Generally, staggered contour trenches (SCTs) are preferred, as they do not require high skill for construction and exact laying out on contours. Moreover, the chances of breaches of staggered trenches are less as compared to continuous trenches.
- SCTs of 2-3 m length with cross-section of 0.3m x 0.3m and intra trench spacing of 2-3 m are excavated at horizontal spacing of 4-6 m.
- About 200 to 400 trenches/ha can be made in a hilly areas at a cost varying from Rs.4000-8000 (2008 price level).

Crib structures

- Steep slopes of more than 40% can be stabilized by constructing log wood crib structures filled with stone/brush wood.
- Poles of 2 to 3 m length and 8 to 12 cm diameter are driven to a depth of 50-75 cm and erected in two lines, 1 m apart line to line and pole to pole, which are nailed together by providing horizontal braces of poles (Fig.24).
- The cost of crib structure is about Rs.700 per cum (2008 price level).

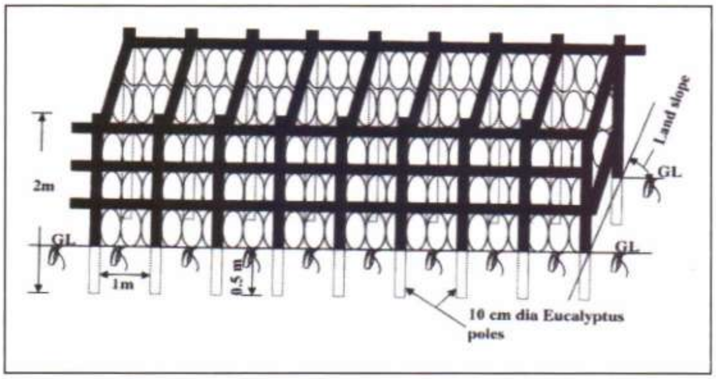


Fig. 24 : A logwood crib structure

Retaining walls

- The retaining walls are constructed for stabilizing precipitous hill slopes. Normally, the bottom width of a gabion wall is taken as two-third of its height (Fig.25). The width is reduced to 1 m at the top in steps.
- The cost of gabion wall construction is about Rs.500-600 per cum (2008 price level).

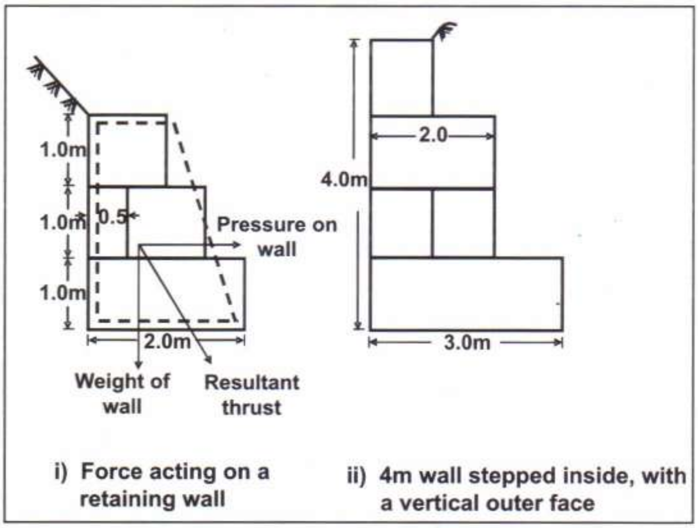


Fig. 25 : A typical gabion retaining wall

Geotextile

- Geotextile (*Bhoovastra*) made of jute/coir fibres (generally available in rolls of 50 m length and 1.22 m width) can be used effectively for stabilizing highly degraded minespoil slopes. It helps in establishment of vegetation by holding the seeds/vegetation in place from washing away by runoff, and conserving moisture and fine soil for better growth.
- The technique of geojute application includes: (a) spreading of geojute by overlapping and joining adjacent widths, (b) driving wooden sticks to secure the net in place, and (c) planting rooted slips of local grasses and cuttings of bushes in openings between the geojute strands at close spacing (Fig. 22).
- Life of a natural geotextile is 2-3 years and cost of geotextile application varies from Rs.27 per sqm (geojute) to Rs.53 per sqm (coir geotextile) (2008 price level).

Katta-crate structures (cross barriers)

- For stabilization of limestone minespoil slopes, barriers formed by filling minespoil material (debris) in disposed cement bags (*katta*-crate structures) can be successfully used. For longer durability of the structure, cement and sand / gravel mixture may be used in the ratio of 1:18.
- The filled bags are laid in a row over one another in three layers to make a height of about 0.6 m (Fig. 23).
- On unstable slopes, gunny bags encased in GI wire crates are recommended.
- The cost of construction of *katta*-crate structures is about Rs.625 per cum with GI wire cage (2008 price level).

Drainage line treatment

Temporary check dam

- First order gullies / channels receiving small quantities of runoff and sediments in upper reaches of watershed can be stabilized by temporary check dams constructed of loose stone masonry, brush wood, log wood etc.
- Their design life is usually 3-5 years, during which vegetation gets established.

Gabion check dams

- Gabion check-dams are constructed in main drainage channels receiving relatively large quantities of runoff and debris load (Fig. 26).
- Gabion structures are made with stones/boulders packed closely in wire mesh cages made with G.I. wire of 10 gauges thickness.
- The boxes may be fabricated with dimensions of 3m x 1m x 1m or any other suitable dimensions with a mesh opening size of 10-20 cm depending on the stone size.

- Height of the check-dams can be raised in stages. Initially, it is kept as 1 m, when it gets filled up with debris, it may be raised by another 1 m and so on, if required, restricting the maximum height to 3 m.
- As a general rule, the check dams should be so located that the compensation gradient (the slope between the bottom of one structure to the top of immediate structure down below) is within the permissible limits, which is usually upto 3-5%.

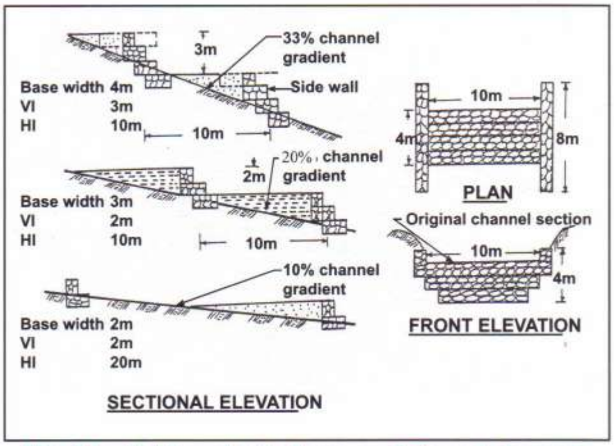


Fig. 26 : Gabion check-dams on different channel gradients

- Cost of construction of gabion check dam is about Rs.500-600 per cum (2008 price level).

Vegetative Measures

- The engineering measures must be followed by vegetative measures so that both of them act in unison as a bio-engineering measure, supplementing each other.
- The vegetative species should have following characteristics:
  - Should be suited to climatic and soil conditions of the area. Vegetation species should be suitable to the particular minespoil characteristics and site situations. For example, *Salix* (Willow) can come up well under moist conditions, while *Khair* (*A. catechu*) is a lime loving plant and *Ipomoea* (*Beshram*) can establish better under bouldary conditions.
  - Is fast growing, has primary colonizing nature, provides quick green cover, and has soil binding capacity and good erosion control characteristics.
  - Can fix atmospheric nitrogen and ameliorate the soil by addition of organic matter through plant litter.
  - Can attract birds, butterflies and other forms of wildlife and also encourage soil fauna.
  - Is of social and economic value to the local population and serves their requirements in terms of fuel, fodder and minor forest products.

Conservation Efficiency

- An abandoned lime stone mined watershed of 64 ha at Sahastradhara in Doon valley (Uttarakhand) rehabilitated by application of various bio-engineering measures (Fig. 27) reduced debris outflow from 550 to 6 t/ha/yr.
- Monsoon runoff reduced drastically from 57% to 37% with reduced flood peaks and increased base flow.

- The increase in base flow rejuvenated the dry streams thus making them perennial (Photo 30).
- The water quality improved significantly, bringing it to potable standards. Farmers are now using this water for irrigation and drinking purposes.
- The soil properties registered an increase in organic carbon, available phosphorous, and excessive calcium carbonate and pH decreased to normal limits.
- The structural measures retained a huge quantity of debris (62,000 cum), which would have otherwise moved down the watershed, causing road blockage and other damages.

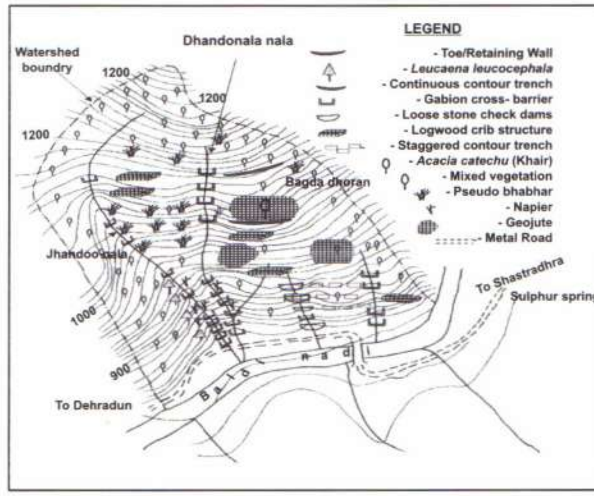


Fig. 27 : Different bio-engineering measures for treatment of Sahastradhara mined watershed

Economics

Photo 30 : Rejuvenation of dry streams at mined watershed after treatment

- The average cost of rehabilitation of mined area in the Himalayan region is about Rs. 50,000 ha^{-1} (2008 price level).
- The bio-engineering measures are cost effective and sustainable as compared to conventionally adopted pure engineering measures.
- Within a period of about 7-8 years, the highly degraded mined watershed was rehabilitated at a cost that would have otherwise been spent by the Public Works Department on clearance of debris alone coming from the catchment area on to the road.

Scope

- The evolved technology for minespoil rehabilitation was later applied by concered development departments (Forest and Eco-Task Force) for rehabilitating minespoil areas (95 abandoned mines) in the Mussoorie hills of Doon Valley.
- The technology can be successfully applied in 25,000 ha area reported under various mines in the Himalayan states of Assam, Himachal Pradesh, J&K, Meghalaya and Uttarakhand.

6.4

Bio-Engineering Technology for Treatment of Torrents in Shivaliks

Torrents (*choes*) or fast flowing seasonal hilly streams, which descend to mildly sloping foothills, are prominent geomorphological features of Shivalik region. They are meandering in nature, have a wide bed and ill defined banks, and often change their course during high intensity rainstorms of the monsoon causing flash floods with water overflowing their banks. Torrents carry with them heavy sediment load and cause considerable damage to agricultural land, property, and cattle and human population during monsoon every year. The Shivalik region suffers extensively from damage by torrents. About 1517 km^2 area is under course of torrents and about 7,500 km^2 area adjoining the torrents in the states of Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Haryana, Punjab and Union Territory of Chandigarh is affected by torrents. In the past, either only civil engineering measures or only vegetative measures were undertaken to tame the torrents. Huge amounts were spent on channelization of torrents but the results have not been very encouraging. Therefore, cost effective torrent training technology consisting of bio-engineering measures is needed to tame the torrents of the Shivalik region.

What Combination of Mechanical and Vegetative Measures?

- Different engineering measures, *viz;* spurs, embankments and revetments are used as per the requirement e.g. flow guidance, flood control, prevention of bank erosion, meandering etc. to tame the torrents.
- These engineering measures are well supported by vegetative measures like planting of suitable shrubs and grasses in the vicinity of the spur and at its nose, planting of locally available grasses for bank protection, vegetative reinforcement of the structures and stabilization of earthen embankments, and planting of suitable tree species on reclaimed land along torrents.
- The cost effective combination of mechanical and vegetative measures helps in mitigating flood damages, reclaiming land along the torrents and improving agricultural income of the affected farmers.

Engineering Measures

Prior to implementation of engineering measures, the following surveys and investigations are required to be conducted.

Survey and investigations

- Delineate the catchment area of the torrent in the toposheet and find out its area, drainage pattern and other morphological characteristics.
- Estimate the peak discharge and sediment flow from the catchment.

- Carry out a survey of torrent and land adjoining it. Find out the difference in levels between torrent bed and adjoining land.
- Identify critical eroding areas for priority treatment along the torrent where bank erosion or overtopping of flow occurs.
- Ascertain the highest flood level at different reaches of torrent in order to fix height of structures accordingly (embankments, spurs etc.)
- Draw a plan of torrent and determine its meandering characteristics.
- Survey the local vegetation suitable for plantation in the catchment area and along the torrent.
- Identify the type of debris (sand, boulders etc.) to have an idea about the deposits in the torrent.
- Gather information from the local community about places where damage to life and property occurred / may occur in future and about previous measures undertaken, indigenous technical knowledge, if any, for torrent training, nature of torrents, etc.
- Select appropriate measure for torrent treatment as per site condition after survey:
  - Spurs for flow diversion and bank protection
  - Earthen embankments and gully protection walls for prevention of overtopping of banks by flood water.
  - Channel rectification by excavation, where excessive sedimentation in the torrent / excessive meandering occurred.

Spurs

- Spurs are the structures constructed on the banks which extend towards the flow at an angle. They deflect current away from stream bank; protect riverbanks including land, houses and reclaim land along the torrent banks.

Types

- **Attracting :** They make acute angle (upto 45°) with torrent bank on their downstream side. They experience scour on upstream side and sedimentation on downstream side (Fig.28).
- **Deflecting:** Such spurs are constructed at right angle (90°) to the bank. They are short in length and are closely spaced for quick sedimentation, which occurs on both upstream and downstream sides of the spur (Fig.29).
- **Repelling :** They make obtuse angel (95° to 100°) with the bank

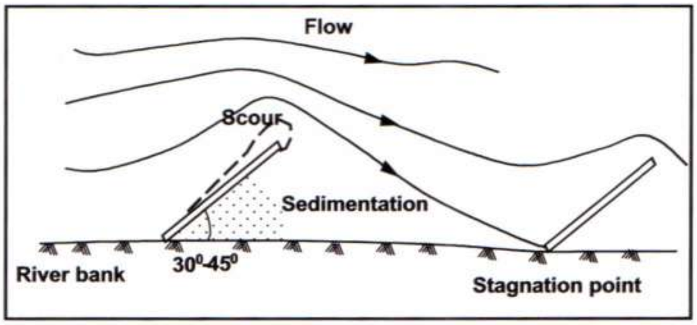


Fig. 28 : An attracting spur

from downstream side. They experience excessive scouring near the spur nose and structural failure is quite common, hence, rarely used.

Design

Length of spur: Projected length of a spur should not be more than 1/3rd the width of torrent i.e. blockage ratio should not exceed 0.3 (Fig.30). However, for safety reasons, it should not be greater than 12 m. Use nomograph for finding out spur length (m) for a given torrent width (Fig.31). Also use nomograph for finding out spur length (m) corresponding to catchment area of torrent (Fig.32). For a given angle of spur and total length (L), the projected length of spur (b), which is also effective length for hydraulic purpose, can be known by using the nomograph given in Fig. 33.

Spacing of spurs: In a straight stretch of torrent, spacing between spurs may be 4 to 6 times the projected length of spur. However, in case of a curved stretch, spacing should be closer, i.e. 2 to 2.5 times the projected length.

Cross section of spur

- Height of spur is generally kept 0.3 m above the highest flood level (HFL). However, when height of spur cannot be kept more than HFL, the spur is said to be a 'submerged spur'.
- For spurs up to 2 m height, trapezoidal cross section is adopted, with side slope of 1:3 to 1:4. When spur height is up to 3 m, stepped shapes of the spur (width reducing with each step) should be adopted.
- Base width of a spur may vary from

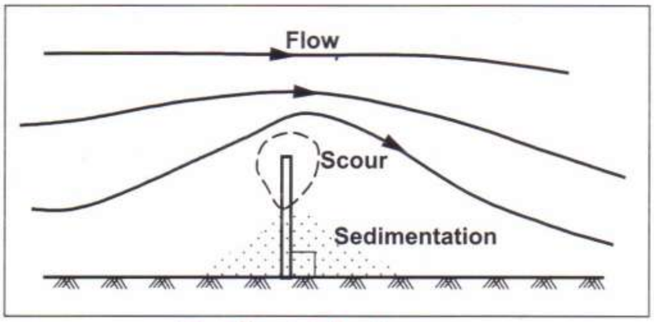


Fig. 29 : A deflecting spur

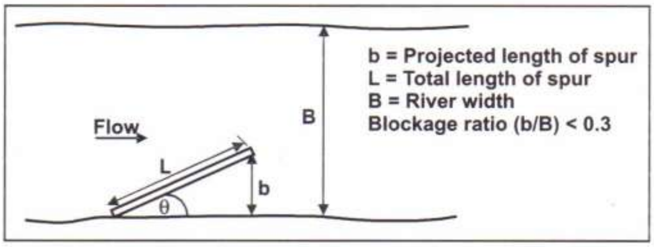


Fig. 30 : Length of a spur

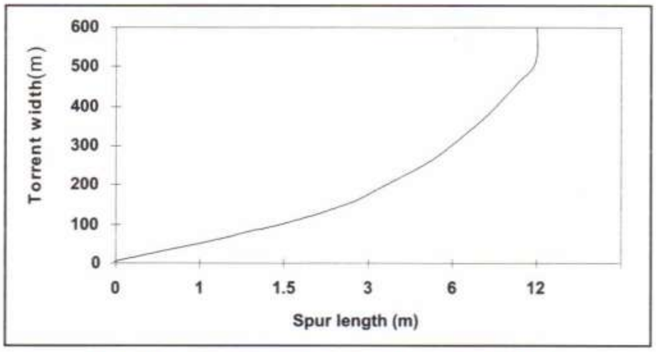


Fig. 31 : Spur length versus torrent width

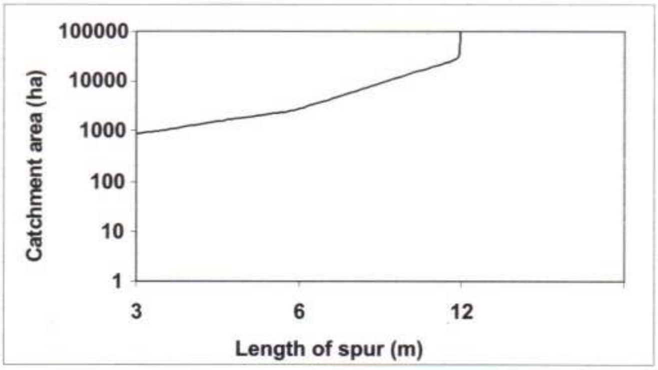


Fig. 32 : Spur length versus catchment area

1.5 m to 8 m, depending upon the catchment area. However, top width of a spur is generally kept as 1 m.

Apron

To protect attracting spur from scouring, apron is to be made towards the nose on the upstream side (Fig. 34) as scouring occurs along this side only, while for a deflecting spur apron is to be constructed towards the nose only, but of larger dimension. Apron depth may vary from 0.5 to 2 m.

Construction of gabion spurs

- Use 10 gauge (3.15 mm dia) galvanized iron (GI) wire for fabricating the wire mesh (15cm x 15cm) for the apron and the super structure as per the design.
- Excavate the foundation as per the design of spur and upto apron depth.
- Spur should be firmly anchored into the bank (0.5-1.0 m).
- Lay the apron first upto the ground level as per the design. Construct the superstructure above it. The apron should project outward (0.5 m to 1.0 m) depending upon the size of the structure.
- Apron and superstructure should be firmly tied together to function as a monolith structure. Series of spurs constructed to protect a torrent bank reach are shown in Photo31.
- The cost of construction of gabion spurs is about Rs.800 per cum (2008 price level).

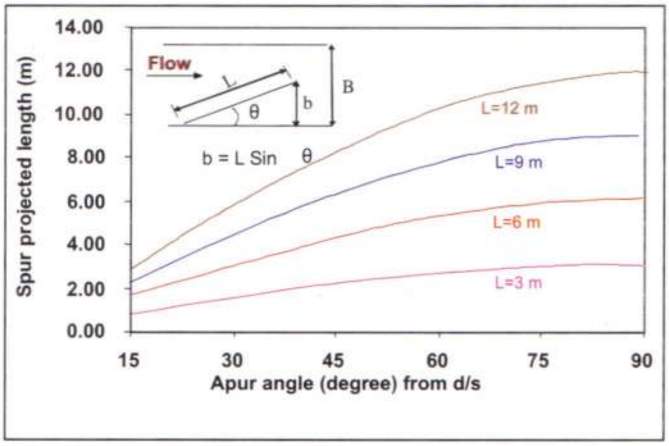


Fig. 33 : Spur angle versus spur projected area

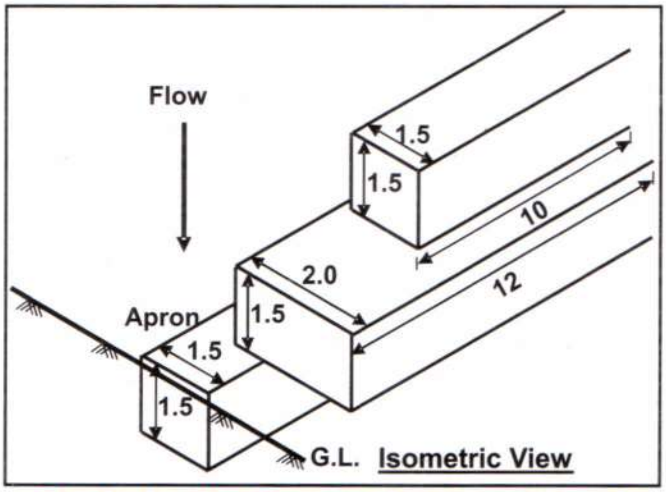


Fig. 34 : An attracting spur showing apron towards upstream side

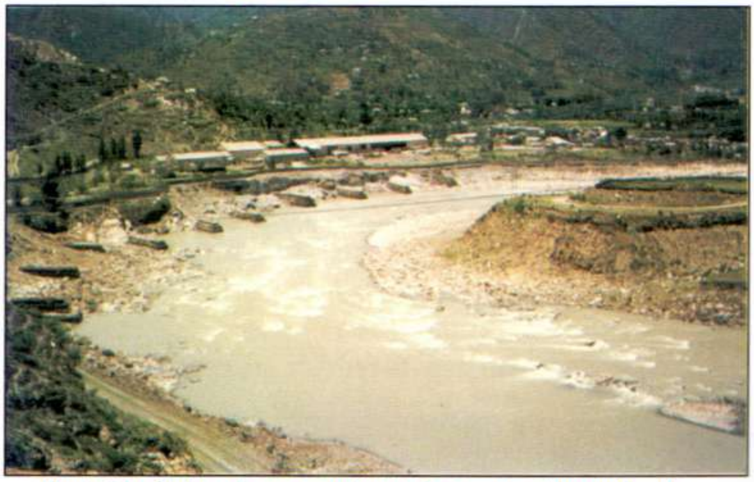


Photo 31 : Series of spur constructed to protect torrent bank

Katta-crate spurs

- In situations where stone is not readily available at site, *katta*-crate technique for construction of spurs can be used. Cement, sand and torrent bed gravel material are mixed in the ratio of 1:6:12 and the mortar is filled in disposed cement gunny bags (*kattas*). The filled bags are laid out one over another as per the design of spur (Photo 29). The whole structure can be encased in a wire-net for greater stability. Cost of construction of *katta*-crate spur is about Rs.624 per cum (2008 price level).

Embankments

- They are constructed to save adjoining land from torrent when maximum flow depth of torrent is more than bank height. Generally two types of embankments are constructed.
- ***Earthen embankment***: It is constructed when soil is readily available at the site. Height of the embankment is kept more than the highest flood level. Side slope of embankment depends upon soil type, but in no case it should be steeper than 1:1.
- Sodding of embankment with local grasses e.g. *munj, kans* and *dub* should be done to reinforce the embankment.
- A 0.5 m deep gabion toe wall should be constructed in the foundation below the ground level along the base of the embankment towards the flow to check scouring and undermining of the base.
- If needed, both spurs and embankment may be constructed (Photo 32).
- ***Gabion embankment:*** It is a protection wall made of stones, if stones are available at the site. It is generally made when torrent is narrow and it is not possible to construct an earthen embankment. A toe wall of 0.5 m depth should be provided in the foundation below the ground level.
- If height of gabion embankment is more than 1 m, it should be constructed in steps to provide greater stability to the structure (Photo 33).

Photo 32 : An earthen embankment planted with grass

Channel rectification

If the width of torrent bed is narrow and has silted over time, it is desilted and deepened to increase its cross-sectional area at the desired site to protect the adjoining land. In certain situations, course of the torrent can also be altered.

Vegetative Measures

- The vegetative species selected should have fast growth rate; high survival rate; good soil binding capacity; heavy root biomass with an extensive and deep root system and not prone to animal damage.

Photo 33 : A gabion protection wall (with steps)

- In between spurs along the torrent bank and particularly in the vicinity of the spur and at its nose, suitable shrubs and grasses locally adaptable and hardy in nature should be planted to prevent scouring (Photo 34).

Photo 34 : Vegetative reinforcement of spurs

- Species like *Arundo donax* (*Narkul* or *Nada*), *Vitex negundo* (*Shimalu*), *Ipomoea carnea* (*Besharam*), bamboo, Napier (*Hathi ghas)*, *Saccharum munja* (*Munj ghas*) etc. are suitable for bank protection and vegetative reinforcement of the structures.
- *Munj, Kans* (*Saccharum spontaneum*) and *Dub* (*Cynodon dactylon*) grasses are suitable for stabilization of earthen embankments.
- On reclaimed land along torrents, tree species like *Khair* (*Acacia catechu*), *Shisham* (*Dalbergia sisoo*) and bamboo have been found promising. For Shiwalik region of Punjab and Haryana *Vilayati Babool* (*Prosopis juliflora*), *Kikar* (*Acacia nilotika*), *Jungle jalebi* (*Pithocellobium dulus*), Eucalyptus spp. are specially suitable and for Uttarakhand Shivaliks *Shahtoot* (mulberry) and Bamboo are promising.
- If reclaimed lands are to be used for cultivation, initially pulse crops (e.g. *urd*, *tur*, lentil etc.) should be taken with application of bio-fertilizers/organic manures/FYM in order to improve the soil fertility.
- Vegetative spurs composed of species like Nada, *Munj,* Bamboo etc. can also be used for low flow situations and away from the main torrent flow.

Time of planting: The best time for planting vegetation should be mid of June to beginning of July for better establishment of plants during rainy season. Planting during the early monsoon period is better for replacing the vegetation damaged due to floods, if any.

Conservation Efficiency

- As a result of torrent training measures, land along the torrents was reclaimed to the extent of 4-20 ha/km of torrent length depending upon the catchment area and torrent size.
- In Sabhawala torrent watershed (area - 1174 ha) at Dehradun (Uttarakhand), torrent treatment measures were effective in protecting 36 ha land, 151 houses, 264 cattle and 1360 human population.
- Technology developed was instrumental in alleviating the sufferings of people due to flood damages during monsoon period and provided protection to human and cattle population and their assets.
- Monetary value of land adjoining the torrent increased by 4-5 times after treatment.
- In Narayanpur torrent watershed, district Panchkula (Haryana), the gross income from agricultural land after the treatment increased from Rs. 3,43,834 to Rs.12,51,216, registering an increase of 263 percent. The annual agricultural income on per hectare basis increased from Rs.4280 to Rs.16,220.

Economics

- The developed bio-engineering technology for torrent treatment was effective in cost savings of about 77% compared with a continuous gabion wall all along the banks, as per the conventional practice.
- The improved torrent training structures were 23% cheaper than the conventional ones besides being more effective and eco-friendly.
- The average cost of torrent treatment was estimated as Rs.3-10 lakhs per km depending upon the problem and torrent size.
- The benefit cost ratio varied from 2 to 2.65:1, which proves that torrent-training measures are highly cost effective.

Scope and Application of Technology

- The technology has the potential to be applied in the torrents occupying a bed area of about 1517 sq km in the Shivalik region, which would benefit about 7500 km^2 area affected by the torrent problem.
- The technology has been transferred to different state departments (Soil Conservation, Watershed Management, Forest etc.) and over 500 spurs have been constructed in the field with varying degree of success.

7

ALTERNATIVE LAND USE AND FARMING SYSTEMS

Peach Based Agri-Horticultural Practices for Utilization of Marginal Lands in North-Western Himalayas

About one third area (one lakh hectares approximately) of Doon Valley, situated on the periphery of the outer Himalayas, is either occupied by gravelly marginal lands that are virtually barren or are inhabited by perennial bushes of *Lantana camara* or seasonal grasses and shrubs during the rainy season. These lands are inherently poor in fertility because of high gravel content and cannot be used for cultivation of crops. With the shrinking per capita availability of cultivated land, there is a need to bring such marginal and bouldary areas under cultivation through a suitable combination of annual and perennial crops to boost agricultural production of the region.

What Combination of Crops and Why?

- The climatic conditions of the north-western lower Himalayan foothills favour cultivation of a wide variety of fruit crops in agri-horticultural systems, which are most prevalent in the region.
- Peach (*Prunus persica*) (Hindi - *Aadu*) is an important and popular fruit crop of the sub-tropical zone in the foothills and mid-slopes of Himalayas and can be cultivated at elevations ranging from 500-1200 msl, most preferably in the sub-tropical regions with warm summers and moderate winters.
- It can be raised successfully even on gravely marginal lands with poor fertility by suitably modifying the root environment by adopting good soil and manure mixture techniques.
- The plant is winter deciduous and thus provides an opportunity to raise suitable hardy intercrops in the inter and intra tree spaces all round the year, especially during the first six years of its growth when the plant canopy is not fully developed, and later shade loving crops like turmeric can be cultivated on these lands.
- Thus the gravelly marginal lands on which raising of traditional agricultural crops is uneconomical can be profitably brought under agri-horticulture systems, with the added advantage of providing vegetative cover on the degraded lands.
- Besides providing food security in the form of pulses and income from fruits and cash crops, turning over of biomass also improves the soil properties. In the long run, these areas can be utilized for growing other crops economically.

Peach Plantation and Intercropping

- Select the marginal land having mild slope and soil depth between 30-40 cm, containing coarse textured soil with small and medium sized stones and gravel.
- Clear all unwanted vegetation from the area and dig 1 m^3 pits at 7m x 7m spacings by December since peach plants are planted in January before new flush of leaves appear.
- For planting, use one year old saplings.

- Fill back pits with 75% sieved soil and 25% gravel (< 10 mm diameter) for aeration and drainage. Gravel allows sufficient aeration and space for root growth and does not allow water stagnation, since peach is very sensitive to water logging and dies of gummosis. Each plant should be watered with 10 litres of water, immediately after planting.
- Young peach plants at the time of planting should be at least one year old nursery raised budded plants. They require 40 kg FYM per pit, with 80 g N, 40 g P and 80 g K, 20 g zinc and 25 g borax powder in each pit. This can be supplied through 160 g urea, 85 g DAP and 135 g Muriate of Potash per plant.
- Follow standard agro-techniques for raising, training, pruning, controlling pests and diseases, and better management of peach orchard.
- In the *kharif* season, black gram can be cultivated as an intercrop followed by *toria* as an inter crop in the *rabi* season.
- For black gram, plough the interspace between peach plants upto plough sole depth after first monsoon shower. For *toria*, it should be similarly done during the first week of October.
- Both crops can be sown by broadcasting method with standard package of practices. Stover of *toria* crop harvested in January should be ploughed back into the soil.

Conservation Efficiency

- Gravelly marginal lands are provided with vegetative cover. The turning over of biomass improves soil physico-chemical properties and in the long run these lands could be used for growing traditional crops economically.

Yield Advantages

- Average fruit yield of 30 kg tree-1 can be expected during the 4^{th} and 5^{th} years of peach orchard establishment. Economically viable yield can be expected from 6^{th} to 15^{th} year @ 45 kg $tree^{-1}$.
- During *kharif*, 3.55 q ha^{-1} of black gram and during *rabi*, 3.58 q ha^{-1} of *toria* can be harvested as intercrops in marginal lands brought under peach orchard.

Economics

- Cost of orchard establishment of a peach orchard in one ha of marginal land using nursery raised budded plants is Rs.36,280. With *in-situ* budded plants, it is Rs. 30,180 ha^{-1}.
- Evaluation of a peach based agri-horticulture system revealed that the practice is economically viable with a B:C ratio of 3.50, calculated for a period of 20 years life of peach trees.
- With black gram-*toria* cultivation in the initial 6 years, the pay back period is 7 years.

Scope

- The technology is very much suited to the lower western Himalayas with elevations upto 1200 above msl, where peach and agricultural crops can be grown together.

Aonla Based Land Use Systems for Degraded Shivaliks

Shivaliks are one of the eight most degraded and highly fragile agro-ecosystems of the country. The region suffers heavily from soil erosion due to undulating topography, erratic rainfall pattern, excessive biotic pressures on natural resources, inadequate vegetative cover and unscientific landuse practices. Lack of irrigation facilities, mismanagement of resources, and rapidly depleting soil fertility status lead to frequent crop failures resulting in scarcity of food, fodder and fuel, besides environmental degradation. The unpredictability of weather due to global warming and climate change impacts has further aggravated the problem. Under such a situation, there is need to develop farming systems, which are more adaptable to the inclement weather conditions, and may sustain cultivation on marginal and degraded lands of the region. Various land use systems, *viz;* agri-silviculture, agri-horticulture, agri-silvi-horticulture, horti-pastoral, silvi-pastoral, horti-silvi-pastoral and silvi-medicinal can be adopted for enhancing production and to conserve natural resources in the region.

Which Land Use System?

- Among the prominent fruit species of the region, Indian gooseberry or *aonla (Emblica officinalis)*, a medicinal plant, can be profitably grown in the degraded Shivaliks, because of its hardy nature, i.e. low water requirement, and adaptability to tolerate a wide range of temperature (0°C- 44°C).
- *Aonla* based horti-pastoral and agri-horticultural landuse systems provide viable options for production in the degraded soils of the Shivalik region and salt affected wastelands where other fruit plants and cereal crops fail to provide sustainable production due to lack of moisture during the peak growth period, which is the major constraint in the region.
- Low growing grasses which are less competitive, shallow rooted and which enhance the fertility of soil, can be intercropped with *aonla* plantation for conservation of natural resources.
- *Aonla* + *Chrysopogon fulvus*, *Aonla* + napier and *Aonla* + perennial pigeon pea reduce runoff and sediment loss, besides enhancing fruit yield, as compared to pure *aonla* plantation.
- These horti-pastoral and agri-horticultural models of agro-forestry system have the potential to meet the ever-increasing demand of food, fodder, and fuelwood in the region alongwith conservation of natural resources.

Orchard Establishment and Intercropping

- Following standard package of practices, *aonla* plantation should be done either in January-February or July-August with one year old budded / grafted saplings of *aonla* cultivars which are most suited for the region (Chakaiya, Banarasi, NA-5, NA-6, NA-7 and NA-10) at a spacing of 6m x 6m or 8m x 8m (depending upon the type of land and purpose) in pits of one m^3 filled, about one month prior to plantation, with good quality soil, 25-30 kg farm yard manure and 50-100 gm phorate powder (to control termites).

- Young *aonla* plants must be irrigated at 15 days interval during winter and at 7-10 days interval during peak summers.
- Dholu *(Chrysopogon fulvus)*, napier and bhabbar grass should be planted at a spacing of 50cm x 50cm during 2nd year of plantation away from the *aonla* saplings after their proper establishment.
- Perennial pigeon pea should be planted at a spacing of 150cm x 100cm.
- After the orchard is 5-6 years old, canopy cover of the trees increases. Therefore, pulse crop should be replaced by shade loving crops like colocasia or turmeric as an intercrop.

Conservation Efficiency

- Under pure *aonla*, runoff from degraded lands may vary from 10 to 46%, depending upon rainfall.
- On an average, runoff is reduced to 8, 13 and 19% by *aonla* + *dholu* grass, *aonla* + napier grass and *aonla* + perennial pigeon pea combinations, respectively.

Yield Advantages

- In addition to conservation of natural resources, intercropping of fruit crops with perennial pulse crop and fodder grasses enhances yield per unit area.
- *Aonla* can yield a maximum of 130 kg $tree^{-1}$ under *aonla* + pigeon pea combination and minimum of 97 kg $tree^{-1}$ under *aonla* + napier combination (9-10 year old plantation).
- *Dholu* and napier grass in association with *aonla* yield up to 23.8 q ha^{-1} and 113.1 q ha^{-1} (fresh weight), respectively.
- Pigeon pea can yield 18.2 q, 7.9 q and 84.1 q of fodder, grain and fuelwood, respectively per ha in combination with *aonla*.
- Commercial yield of *aonla* commences after 9-10 years of plantation and continues upto 50-60 years.

Economics

- An *aonla* orchard can be established by investing Rs. 23,500 ha^{-1}. However, this cost can be further reduced to Rs. 17,180 ha^{-1} by *in-situ* budding technique, where one can save Rs. 6,320 ha^{-1} (27%) based on the price index of year 2003.

- The discounted net returns of pure *aonla*, *aonla* + *dholu* grass, *aonla* + napier grass and *aonla* + perennial pigeon pea vary from Rs. 11,05,620 to Rs. 11,28,500 ha^{-1} (Table 31).
- The system becomes profitable after 4-5 years of establishment.

Table 31: Economic parameters of different Horti-pastoral land use systems (1991-2003)

Economic parameters	Land use systems			
	***Aonla* pure**	***Aonla* + napier**	***Aonla* + *dholu***	***Aonla* + perennial pigeon pea**
Net present value (Rs.)	11,22,800	11,28,500	11,05,620	11,26,640
Pay back period (years)	44	5	4	
Internal rate of return (%)	52	53	52	52

Scope

- *Aonla* based agro forestry systems have vast scope for their replicability in degraded and marginal lands where other fruit plants and crops fail to provide sustainable production.
- Since *aonla* plants have wide adaptability and can tolerate freezing as well as high temperature up to 44°C, *aonla* cultivation has the potential for commercial growing on salt affected wastelands, which cover an area of 7 million ha in the country.

7.3

Ber Based Agri-Horticultural Systems for Marginal Lands in Shivaliks

The soils of Shivalik ecosystem are structurally degraded, and have high concentration of boulders coupled with low fertility. Soil erosion is a serious problem in the region. Cultivation of conventional cereal crops in the region is not very remunerative. Further, to meet the growing demands of food and fodder, the marginal lands are also being exploited and brought under cultivation, posing serious threat to already fragile rainfed agro-ecosystem. There is thus an urgent need to make the best use of available resources, to meet the long term goals of sustainability in the region. Agri-horticultural systems provide higher returns on a sustainable basis compared to arable farming systems. Therefore, suitable agri-horticultural systems for the region need to be identified to prevent land degradation and fetch high economic returns.

Which Agri-Horticultural System and Why?

- *Ber (Zizyphus mauritiana)* based agri-horticultural system has been identified as one of the most promising system for marginal lands of the region.
- The system increased productivity and gave higher economic returns on a sustained basis, as compared to conventional farming systems in the region.
- *Ber* is a promising fruit which can be raised with annual crops, and can resist moisture stress and adverse climatic conditions. It grows well even in soils having poor fertility status.
- Cultivation of suitable annual crops such as black gram in the tree interspaces as an agri-horticultural system exploits the underutilized inter-tree spaces of the fully developed and mature *ber* orchards to enhance productivity and higher returns.

Plantation of *Ber*

- One year old grafted / budded healthy saplings of recommended varieties for commercial cultivation (Umran and Sanaur-2) should be planted in pits of size $1m^3$, at 8m x 8m spacing in the months of February-March or August-September.
- Standard package of practices should be adopted for establishing the *ber* orchard and its maintenance.
- Trench of size 1m x.0.5m x 0.5m is dug on downstream side of sapling to conserve and store sufficient rain water in soil near the root zone of plants. Grass mulching is also beneficial for moisture conservation.

Intercropping of Field Crops

- Short duration legume crop varieties with low water requirement should be selected. Black gram varieties Mash-338 and T-9 are suitable for the region.
- Prepare field with one deep ploughing followed by two harrowings with local plough and planking either by tractor or with bullocks.
- Seed @ 20 to 25 kg ha^{-1} should be sown in lines at 30 cm row to row spacing, leaving a minimum of 1 m area clear in surroundings of the *ber* plants.
- Standard package of practices should be adopted for cultivation of annual crops.

Conservation Efficiency

- *Ber* + black gram based intercropping system induces minimum runoff (24%) and soil loss (2.7 t ha^{-1}) as compared to pure ber plantation (runoff, 32% and soil loss 3.7 t ha^{-1}).

Yield Advantages

- Under *ber* + black gram system, the growth and yield of *ber* plants was not much affected as compared to pure *ber* plantation.
- The average fruit yield in fifth year of plantation was 40.6 q ha^{-1}, as compared to 41.1 q ha^{-1} under pure *ber* plantation (Table 32).

Table 32 : Net returns from different *ber* based agri-horticultural systems

Cropping System	*Ber* fruit yield (q ha^{-1})*	Net returns (Rs ha^{-1})**
Pure *ber*	41.1	25640
Ber + sesamum	30.5	20720
Ber + black gram	40.6	35920
Ber + maize	30.5	23930

*Fifth year of plantation; **Based on 2001-02 prices.

Economics

- Cost of establishing a *ber* orchard in 1 ha area amounts to Rs. 14,000 (based on year 2001-02 cost) and thereafter from the second year an expenditure of Rs. 6000 to Rs. 8750 is incurred yearly on fertigation and maintenance of the orchard. However, within 2-3 years after plantation, fruiting commences in *ber* trees.

- *Ber* + black gram system gave highest net returns (Rs. 35,920 ha^{-1}) as compared to pure *ber* plantation (Rs. 25,640 ha^{-1}).

Scope

- The technology is suitable for Shivalik region comprising states of Punjab, Haryana and lower hilly belt of Himachal Pradesh, and Jammu & Kashmir.
- The technology has a wider scope for its replicability in the degraded and marginal lands in other states also, as *ber* plants have wider adaptability and can tolerate freezing as well as high temperatures.

7.4

Drumstick Based Agri-Horti System for Replacing Tobacco in Central Gujarat

Tobacco mono-cropping system is traditionally practiced in the Central Gujarat region. The tobacco crop is an erosion permitting widely spaced row crop, which has high cost of cultivation and high irrigation water requirement, though the area receives low rainfall, being in the semi-arid region. Though, tobacco is an important cash crop of the region, its cultivation is being discouraged in many parts of the country, since consumption of tobacco is injurious to health and environment. Hence, there is, an urgent need that farmers in the state diversify their cropping system, which is environment friendly, more profitable and highly sustainable in the long run.

Which Cropping System for Diversification?

- Crop diversification from the predominant tobacco mono-cropping system to drumstick or drumstick based green gram-fennel agri-horticulture system can reduce irrigation water requirements significantly in Central Gujarat region.
- Drumstick (*Moringa oelifera Linn.*) is a rainfed horticultural crop and does not require additional irrigation water for normal growth and development.
- Green gram (*Phaseolus radiatus L.*), a rainfed cover crop grown in *kharif* season, helps in reducing soil erosion.
- Fennel (*Foeniculum vulgare Mill.*) crop has a shorter growth period and requires lesser quantity of irrigation water than tobacco.
- The new cropping systems are more productive and provide higher net returns as compared to traditional tobacco cultivation.

Establishment of the Cropping Systems

- For establishing pure block plantation of drumstick, 25-30 days old nursery raised seedlings are transplanted in well manured and fertigated 75cm x 75cm x 75cm pits dug at 4m x 4m spacing in July after rains, following standard package of practices. For alley cropping, the seedlings are planted in 16 m apart rows, with plant to plant distance of 4 m.
- Green gram cultivar K-851 is cultivated in *kharif* season as a rainfed crop, following standard package of practices, between 2 rows of drumstick plantation.
- Fennel cultivar GF-1 is cultivated in *rabi* season after harvest of green gram.

Conservation Efficiency

- Drumstick cultivation, purely as block plantation as well as with green gram-fennel, enriches soil fertility by augmenting soil organic carbon, P_2O_5 and K_2O content to a higher extent than tobacco cultivation during five year cropping cycle (Table 33).
- Growing of drumstick as alternative crop for tobacco in the region may save 100% irrigation water.
- Green gram, being a rainfed cover crop grown in *kharif* season, does not require irrigation.
- Fennel crop matures in 100 days and requires four irrigations of 45 mm each, where as tobacco crop matures in 180 days and requires eight irrigations of 75 mm each upto maturity. Growing of green gram-fennel would, therefore, save about 70% water.

Table 33 : Soil organic carbon, P_2O_5 and K_2O content after five year cropping cycles

Crop sequence	Organic carbon (%)	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})
Green gram-fennel	0.38	61.5	257
Drumstick + green gram-fennel	0.41	70.0	289
Drumstick	0.48	76.9	310
Tobacco	0.39	55.3	295

Yield Advantages

- Alley cropping is a biological insurance against crop failure, which is frequently experienced with mono-cropping.
- Drumstick is a perennial crop having high medicinal value and export potential. Leaves, roots, seeds, bark, fruits, flowers and immature green pods act as cardiac and circulatory stimulants and possess anti-tumor ulcer, diabetic, oxidant, fungal and bacterial properties.
- Drumstick leaves are rich in beta carotene, vitamin C, proteins, iron and potassium. It is highly effective in checking malnutrition in children and women. Fresh leaves are consumed as curry and dried leaf powder is used in soups and sauces. Leaves are also used as fodder for cattle.
- Drumstick begins to fruit within 5 months after transplanting.
- The cropping system is more productive as compared to traditional tobacco mono-cropping as there is larger number of outputs including foodgrain, green vegetable, spice, fuel wood and green fodder (Table 34). Thus there is better use of land with this cropping system.

Table 34 : Crop yield and net returns under crop diversification

Crop sequence	Yield (q ha^{-1})					
	Green gram	Fennel/ Tobacco	Drumstick			Net returns (Rs. ha^{-1})
			Green pods	Fuel	Green fodder	
Green gram-fennel	5.94	3.32	-	-	-	17900
Drumstick + green gram-fennel	6.21	3.29	13.88	13.32	15.56	31080
Drumstick	-	-	58.33	37.79	47.91	56540
Tobacco	-	13.77	-	-	-	14060

Economics

- Pure drumstick plantation fetches highest returns (Rs. 56,540 ha^{-1}) followed by drumstick + green gram-fennel crop sequence (Rs. 31,080 ha^{-1}), as compared to sole tobacco cultivation with least returns (Rs.14,060 ha^{-1}) (Table 34).
- Pure drumstick and drumstick + green gram-fennel are thus 4 and 2.2 times more remunerative, respectively than the traditional tobacco cultivation.
- Total area under tobacco cultivation in Gujarat is 33,400 ha (2003-04). If 20% of this area is replaced with drumstick + green gram - fennel, total gain in net returns would be Rs. 112 millions. If 20% area under tobacco is replaced with drumstick alone, than total gain in net returns would increase to Rs. 280 million.
- In addition to production of 38,964 t of green pods, 25,243 t of fuel wood and 32,004 t of green fodder will also be produced, if tobacco crop is replaced by drumstick in 20% area of Central Gujarat.

Scope

- The alternative land use system developed for replacing traditional tobacco mono-cropping is suitable for small farmers of central Gujarat where limited irrigation facilities are available.

Aloe vera Cultivation in Interspaces for Supplementing Productivity of *Ber* Orchards in Reclaimed Yamuna Ravines

Ravines constitute about 1.23 million ha land in the state of Uttar Pradesh. The ravine lands are subjected to various forms of natural as well as anthropogenic degradation. Vegetation of the region experiences a variety of stressed environment such as nutrient deficiency, inadequate moisture availability and biotic stresses. The semi-arid climatic conditions coupled with very high summer temperature further aggravate the problems and makes farming an uneconomical venture. In such harsh edapho-climatic conditions, *ber* (*Zyziphus mauritiana*) has the potential to grow well as an important fruit crop of the region. However, cultivation of sole crop of *ber* on reclaimed ravine lands is not very remunerative. Technological interventions are required to exploit the underutilized inter-tree spaces of the fully developed and mature *ber* orchards in order to enhance its economic viability. In these interspaces, growing of a stress tolerant hardy crop having high market value can be useful in generating additional income from *ber* orchards. With the increase in age of trees, the tree canopy spreads and tends to merge, which does not allow the profitable utilization of the tree inter spaces with the conventional light demanding crops. In such conditions, shade loving, and low water and nutrient demanding crops hold promise in withstanding the stress conditions while sustaining farm income.

Which Crop to Cultivate in *Ber* Tree Interspaces?

- Cultivation of *Aloe vera*, in the tree interspaces of a *ber* orchard, as a two tier system, has potential to sustain productivity and provide alternative source of income to the farmers of the ravine region.
- *Aloe vera* is suitable for degraded soils of Yamuna ravines and its growth is not affected due to canopy closure of *ber* trees (Photo 35).

Photo 35: *Aloe vera* in tree interspaces of *ber* orchard

- The xeric medicinal crop of *Aloe vera* is a low nutrient demanding, but a highly remunerative crop (Photo 36).
- *Aloe vera* fetches a good price due to its high demand by the cosmetic and pharmaceutical industry.

Photo 36 : *Aloe vera*

Plantation of *Aloe vera* in *Ber* Orchard

- Following standard package of practices, recommended *ber* cultivars (Banarasi, Ponda Safeda and Gola) should be planted at 8m x 4m spacing at the onset of monsoon. The rows of the plantation should be aligned in the east-west direction to minimize the shade effect on the intercrop.
- *Aloe vera* suckers of 6 to 8 inches length are planted following recommended package of practices in thoroughly tilled inter-tree spaces, after the onset of monsoon, at a spacing of 50cm x 50cm (Fig. 35).
- After every 2 rows of *Aloe vera*, 1 m space is left for convenience in carrying out intercultural operations and harvesting. Plant population of 19,000 to 20,000 can be accommodated in one hectare of *ber* orchard.
- The crop gives economic yield upto 3 to 4 years, after which it should be replaced with a new plantation.

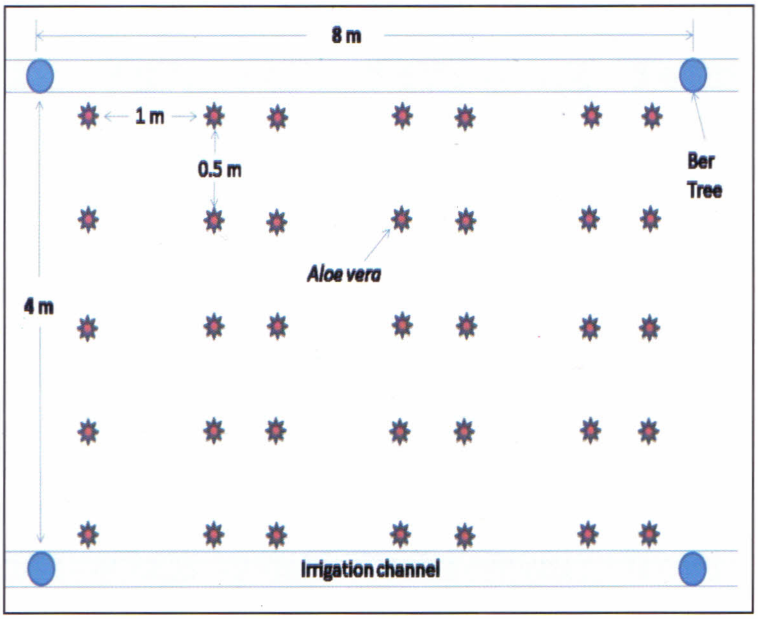


Fig. 35 : *Aloe vera* planting layout plan in inter tree spaces of *ber* orchards

Yield

- *Ber* with *Aloe vera*, can yield the same quantity of fruits (75-80 q ha^{-1} yr^{-1}) as the sole crop of *ber* (Table 35).
- Without affecting *ber* fruit yield, three cuttings of *Aloe vera* taken in a 4 years cycle, on an average, give fresh leaf yield of 300 q ha^{-1} yr^{-1}.

Table 35 : Economics of *ber* with *Aloe vera*

Particulars	*Ber* with *Aloe vera*		Sole *ber*
	Aloe vera	*Ber*	
Yield (q ha^{-1} yr^{-1})	300*	75 to 80	75 to 80
Cost of cultivation (Rs ha^{-1} yr^{-1})**	20000	12500	12500
Gross income (Rs ha^{-1} yr^{-1})**	60000	48000	48000
Net income (Rs ha^{-1} yr^{-1})	40000	35000	35000
Net income from the system (Rs. ha^{-1} yr^{-1})	75000	35000	

*Yield of *Aloe vera* is based on three harvestings in a 4 year life cycle. **Base year 2008.

Economics

- An additional cost of Rs 20000 ha^{-1} is required for establishment of *Aloe vera* in a *ber* orchard (Table 35).
- Sole crop of *ber* in the region generates a net income of Rs 35,000 ha^{-1} yr^{-1}. An additional net income of Rs 40,000 ha^{-1} yr^{-1} can be obtained from the same piece of land by cultivating *Aloe vera* as an under-storey crop in the tree interspaces (Table 35).

Scope

- The technology requires fairly large initial investment. The return from *Aloe vera* is accrued after a gestation period of 1½ year. Therefore, this technology is more suitable for medium and large farmers who have fairly large holdings, greater capacity of capital investment and better access to credit facilities.
- The technology is applicable for light textured soils, including reclaimed ravine lands where water and nutrient resources are limited and in the cultivable wastelands having well drained soil, with an average annual rainfall of 700 mm.
- The technology is suitable for medium and large farmers of Agra, Etah, Firozabad, Mainpuri and Etawa districts of Uttar Pradesh and Jodhpur, Jaipur, Bharatpur and adjoining districts of Rajasthan.

7.6

Silvipastoral Systems for Wasteland Utilization in Foothills of Western Himalayas

In the Western Himalayas, livestock rearing for milk, meat and wool is an integral component of the farming systems adopted by small and marginal farmers, which contributes significantly to their farming income. Also, these farmers are dependent on draught power for most of the important agricultural activities like tillage and threshing. The farmers meet the fodder requirement of their stall fed livestock from straw of cereal and millet crops they cultivate alongwith green fodder from weeds, grasses and trees growing naturally within/on their field boundaries and the fodder they obtain from forest on daily basis as per availability. All the non-milch animals, except buffaloes, are also grazed during the day time. The number of livestock reared by a farmer depends mainly on the quantity of fodder and family labour at his disposal. During lean periods before the *kharif* season, the region experiences acute shortage of fodder due to exploitation of the natural sources of fodder, mainly forests and village community (*civil soyam*) lands, by over grazing or lopping of trees over the past years and inadequate area under pastures and fodder crops. Further, the natural pastures are heavily infested with inedible weeds such as *Lantana camara*. These forests are not only sources of green fodder but also main source of fuelwood for the whole village community. Acute shortage of fodder and fuelwood, not only in the region but also all over the country, can be mitigated by effective development and productive utilization of *civil soyam* and waste lands through various combinations of fodder yielding trees and grasses. The practice of growing trees and grasses on the same unit of land for producing required biomass constitutes a silvi-pastoral system.

Why Silvipastoral System?

- Silvipastoral system is the practice of growing trees with fodder grasses simultaneously on the same piece of land. Silvi-pastoral systems are promising alternative land use systems that integrate multi-purpose trees, grasses and legumes on non-arable and marginal lands to optimize land productivity.
- The trees and grasses are raised at a suitable spacing so that both trees and grasses get equal opportunity to grow. Since the rooting and growing patterns of both the types of vegetation are different, there is very little competition for natural resources.
- The systems help in conserving soil, nutrients and water besides providing fodder material, top feed, firewood and timber to the resource poor farmers.
- Over a period of time, trees recycle nutrients by leaf fall, which on its decomposition enriches the soil. The systems naturally improve the soil properties after several years.

Establishment of Silvipastoral System

- Site for development of a silvipastoral system could be land with shallow soils (< 40 cm) or coarse textured soil. The system can also be raised on old river bed lands (Photo 37).
- Selected tree species should be capable of growing on poor soils and tolerant to water stress (moisture and frost) for most part of the year.
- Canopy should be evergreen or deciduous and capable of withstanding frequent loppings. Tree leaves should be non-toxic at all stages and should have least lignin content at ripening stage. Fodder should be capable of being stored for 4-5 months under dry conditions, without loss of nutrients.

Photo 37 : An old river bed - a degraded site selected for the establishment of a silvipastoral system

- Ideal fodder yielding species for the region are *Bahunia purpurea* (*kachnar*), *Albizzia lebbek* (*siris*), *Grewia optiva* (*bhimal*), *Gmelina arborea* (*gamhar*), *Alianthus execlsa* (*maharukh*) and *Morus alba* (*shahtoot*). For timber production, Eucalyptus species is suitable for the region.
- Suitable grass species for the region are *Chrysopogon fulvus* (*gorda*), *Cenchrus ciliaris* (*anjan*), *Setaria kazangula* (*sita*), *Setaria anceps* (cv. *Nandi*), *Panicum maximum* (*Guinea*) and *Eragrostis curvula* (*Love grass*).
- For tree planting, pits of 60 cm^3 are dug in April - May at a spacing of 4m x 4m.
- Remove stones and gravel from the pit soil and add 2 kg FYM, a little sand (0.5 kg in case of clayey soil to make it porous) and 5 g of chloropyriphos (in case of termite infestation), mix well and fill back the pit with this mixture.
- Plant one year old saplings of about 1 m height in each pit in the first week of July. Make a basin around the sapling to collect rainwater.
- Tall growing grasses like *P. maximum* and Napier should be planted at a spacing of 0.75m x 0.75m in small pits, 7-10 cm deep. Other grasses can be planted at a spacing of 0.50m x 0.50m.

- Raise the trees and grasses following standard package of practices, and broadcast 25 kg DAP ha^{-1} two weeks after planting of grasses for improvement in vegetative growth.
- Tend the trees in the second and third year by removing unwanted branches and repair the basin around the plant for collecting rain water.
- In September of the second year, grass can be harvested manually at a height of 10 cm from the ground level. Second harvesting of grass can be done in February in the third year.
- Trees other than *Grewia* can be lopped to a maximum of 50% in June from 4th year onwards and by the 7th year, 75% lopping can be done. *Grewia* is lopped in winters.
- Well established 5 year old *Grewia* and Morus trees can be pollarded at a height of 1.5 m above the ground level (Photo 38).
- New shoots emerging from the cut portion are allowed to grow and biomass is harvested in winter (November-December) or during scarcity of fodder. Shoots emerging from buds on the stem are also retained.

Photo 38 : Pollarded *Grewia* trees with harvested napier grass

- Grasses need to be replaced after 7 years under poor soil and rainfall conditions, and by the 10th year under normal conditions, when their production begins to decline. However, trees once established will continue to provide green leaves as top feed and woody biomass from annual lopping cycles. Where timber is available on a rotation cycle of 15-20 years, benefits accrued will be much higher.

Yield and Economic Advantages

- The systems are economically viable due to production of three products i.e. fodder and fuelwood or timber over a period of time (Table 36). The systems were estimated to have a BC ratio of 1.6, when calculated for 18 year cycle at 12% discount rate. The IRR of the systems was estimated to be around 25%.

Table 36 : Suitable tree and grass combinations for silvipastoral systems in the lower Western Himalayan foothills

Species	Spacing (m)	No. of trees/slips	Produce (ha)	Time (years)	Fodder ($t\ ha^{-1}\ yr^{-1}$)
Eucalyptus hybrid with	3.5 x 3.5	816	Timber	12	-
Chrysopogon fulvus (*Gorda*)	0.75 x 0.75	17,800	105.7^{a} cum ha^{-1}	-	5.0 green
Dalbergia sissoo with	9 x 9	123	Firewood	19	-
Chrysopogon fulvus (*Gorda*)	0.75 x 0.75	17,800	64 t ha^{-1}	-	5.4 green
*Grewia optiva** with	4 x 4	625	Firewood	**	262 kg $ha^{-1}\ yr^{-1}$**
Chrysopogon fulvus (*Gorda*)	0.75 x 0.75	17,800	754 kg $ha^{-1}\ yr^{-1}$	-	4.3 green
Bauhinia purpurea with	4 x 4	625	Firewood	**	362 kg $ha^{-1}\ yr^{-1}$**
Chrysopogon fulvus (*Gorda*)	0.75 x 0.75	17,800	629 kg $ha^{-1}\ yr^{-1}$	-	2.6-3.6 green

* From pollarded Grewia trees; ** Average value of 14 years from lopped trees as top feed;
a - *Eucalyptus* wood rate - Rs.3300/- per cum @ 2008 prices.

Scope

- The technology can be implemented on mildly sloping waste lands in foothills of Jammu & Kashmir, Himachal Pradesh, Uttarakhand and Shivalik region. These silvipastoral systems have immense potential of utilizing wastelands which occupy a large area in north-west Himalayan region. Wastelands occupy 2.94 lakh ha in the Uttarakhand Himalayas and the area affected by torrents in the state is nearly one lakh hectares.
- Community owned lands (*civil soyam*) and village wastelands can be rehabilitated using this simple technique.
- Small and marginal farmers who own cattle can greatly benefit from this practice.

Bamboo and *Anjan* Grass for Enhancing Productivity of Mahi Ravines

The cultivable land area is limited in the country. With the rising human population, this area is under tremendous pressure due to expansion of urban and industrial sectors, as well as higher demand for food, fodder and fibre. This calls for reclamation of degraded lands to obtain better economic returns while ensuring environmental security. In Gujarat, ravines occupy an area of 0.4 million hectare. Dairy farming is one of the major agricultural enterprises in the state and demand of fodder is increasing over the years. Earlier, part of arable land was readily available for fodder cultivation. However, with increased human demand for food, fodder cultivation, though a necessity, is not a priority on arable lands. This has increased pressure on marginal lands and warrants reclamation of degraded lands for their productive utilization to meet fodder requirements in a sustained manner. These non-arable lands in general, and ravine wastelands in particular, have the potential to meet the much needed fodder and fuel needs by establishing silvi-pastoral systems besides protecting the reclaimed wastelands.

Which Silvi-pastoral System and Why?

- Deep ravines can be successfully reclaimed by planting bamboo on gully beds and anjan grass on side slopes.
- This technology checks water erosion, thus preventing soil loss from ravines.
- In addition to protecting the ravines, the technology provides fodder and as well as regular supplementary income.
- Productive utilization of these lands for fodder and commercial cultivation of bamboo not only meets fodder needs and provides maximum returns but also converts the degraded ravine lands into a lush green valley of bamboos and grass (Photo 39).

Photo 39 : Erstwhile ravine converted into lush green valley

Planting of Bamboo and Grass

- Following standard package of practices, one year old bamboo (*Dendrocalamus strictus*) seedlings are planted after rains in staggered contour trenches of 0.6m x 0.6m x 1.8m (w x d x l) size dugout before rains in the gully bed at 5m x 5m spacing across the slope of gully bed with the excavated soil heaped on the downstream side of the trench to retain moisture after rains (Fig.36).

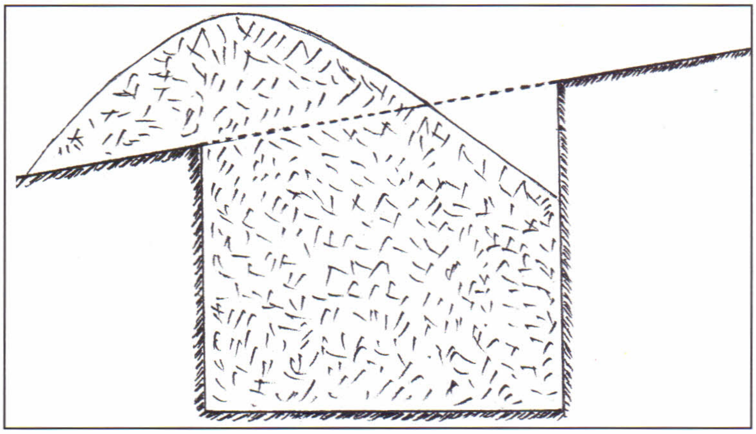


Fig. 36 : Contour trench with raised soil fill towards down slope

- Medium gullies (3-9 m gully depth and 18 m bed width) having slopes of 8-15% are reclaimed by sodding of a local grass species, *anjan* (*Cenchrus ciliaris*), which establishes and thrives well, to provide protective ground cover.
- Grass slips are planted across the slope after rains in staggered manner on contours, in 50 cm apart rows with standard package of practices (Fig. 37). Grass can also be planted in the interspaces of bamboo plantation in the gully bed.

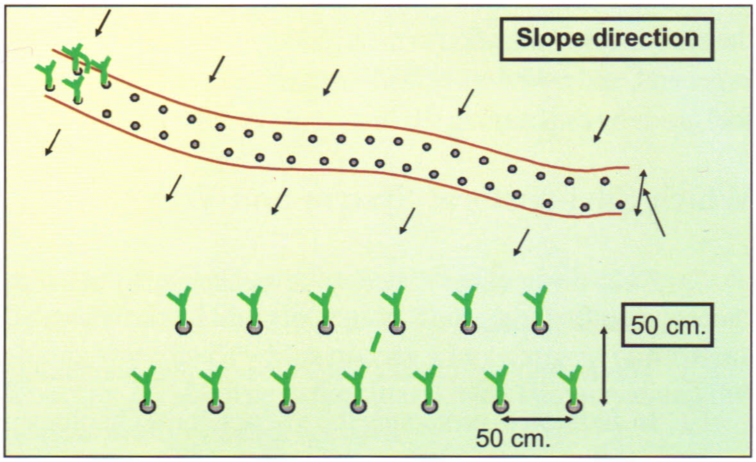


Fig. 37 : Grass planting across slope at 50cm x 50cm

Conservation Efficiency

- With this silvi-pastoral system, the ravinous watershed absorbs more than 80% of rainfall, which is either utilized by the plant or gets percolated deep into the soil profile to recharge the groundwater.
- Due to less runoff, soil loss is reduced from about 20 t ha^{-1} yr^{-1} prior to plantation of this system to less than 1 t ha^{-1} yr^{-1} only in the degraded ravines.

Yield

- Depending upon the amount of rainfall and its distribution during the year, 5.7 to 8.3 t ha^{-1} yr^{-1} of green fodder can be obtained from anjan grass planted on slopes.

- During the initial 5 years, grass yield from bamboo plantation interspaces can be 10 t ha^{-1} yr^{-1}, but thereafter it declines by 7th year to 3 t ha^{-1} yr^{-1} due to growth of bamboo.
- About 30% (1000 nos. ha^{-1} yr^{-1}) old culms can be harvested from a 7 year old bamboo plantation.

Economics

- The cost of planting bamboo and sowing grass slips in a ravine works out to about Rs. 22,000 per ha (at 2008 prices).
- Anjan grass fetched an income of Rs. 3,000 to 6,000 ha^{-1} over 5 years.
- Bamboo provided an income of Rs. 6,000 to 27,000 ha^{-1} yr^{-1}.
- The net present value of the bamboo and grass system was estimated as Rs. 36,353 per ha with a BC ratio of 1.60 for 20 years project life at 10% discount rate.

Scope

- The technology can be applied over an area of 980,000 ha (1996-97) in the ravine lands along the course of various river systems in Gujarat, particularly in Ahmedabad, Khedda, Anand and Vadodara districts.

7.8 Water Mill Based Integrated Farming System for North-Western Himalayas

Most of the hill farmers in north-western Himalayas are small and marginal with limited resources and income and, therefore, practice subsistence agriculture and animal husbandry. Under limited resource availability situation, judicious use of the available resources becomes imperative for meeting food and income needs. Therefore, farming systems that foster such concepts are very much the need of the hour. Integrated farming systems (IFS) are more efficient in resource use by recycling wastes of one component of the system in a synergetic way as an input, such as fodder and manure, to the other component to economize on the cost of inputs. Limited water resources in north-western Himalayas are generally being used for a single purpose like irrigation, drinking or running water mills, though the hilly regions due to their typical topography provide ample opportunities for multiple uses. In the present scenario of water crisis, IFS that emphasize optimal use of natural water resources, by fostering multiple water uses to enhance productivity and income opportunities are invariably advantageous over monoculture systems, which are generally constrained due to input shortages, water scarcity, fodder availability, dependence on costly inputs and growing incidence of diseases and pests, leading to poor yields and benefits.

What Components of IFS?

- Integration of cohesive farming components like fish farming, agriculture, poultry, piggery, rabbitry, goatry, water mill, irrigation network etc. with each other depending upon their local availability, feasibility and needs of the people would eliminate most of the problems of monoculture systems.
- Small and marginal resource-poor hill farmers who largely depend on water mills and traditional agriculture for their livelihood may supplement their income and achieve food and economic security if enterprises like fish farming, poultry and piggery are integrated with the water mill by harnessing their synergetic benefits.
- An IFS comprising of water mill, fish farming, poultry, pig rearing and agriculture was developed and found promising for the hill farmers.
- Widespread availability of watermills in north-western Himalayas provides regulated oxygen rich water supply to fishponds, poultry, piggery and agriculture crops besides an opportunity for grinding feed ingredients locally and supplying mill waste as feed for farm animals including fish, poultry birds and pigs in the system.
- Poultry and piggery integrated with fishponds form a significant source of nutrients in the form of poultry wastes, animal dung, and waste feed for fish production, reducing input costs in fish feed and pond fertilizer.
- Nutrient-rich fishpond water can be directly ploughed into agriculture to economize on the cost of manure and fertilizers.

Features of Integrated Farming System

- An IFS comprising of water mill (6 m^2), fish farming (100 and 160 m^2), poultry (10 - 12 m^2), pig rearing (5 - 7 m^2) and agriculture (2000 m^2) was developed (Photo 40).

Photo 40 : An overview of the IFS

Water Mill Component

- The traditional water mill operates through perennial stream flows supplies dissolved oxygen rich water to pond conducive for better fish growth.
- It is used in grinding food grains and remnants from mill going waste can be used as faced for fish, poultry birds and pigs.
- It yields net return of Rs. 10000 annually to the farmer through grinding of 200-300 given table of food grains.

Fish Farming

- Excavate an off-stream rectangular fishpond with size 100 - 250 m^2 and depth of 1 - 2 m, preferably on a flat area having soil of low porosity and assured perennial flow for over six months duration in a year.
- Line the bottom and side walls of pond with LDPE sheet or other suitable sealant material to control seepage, if required. In case pond bottom is lined with stone or brick masonry, layer of fertile soil of 15-20 cm thickness be laid on the pond bottom to promote better fish growth.
- For mid-Himalayan region, exotic carps such as silver carp, grass carp and common carp are more suitable than Indian Major Carps (IMC) such as *catla, rohu* and *mrigal*. However, all the above six species may perform well in the foothills.
- Prepare the pond by end of February to release fingerlings by March and harvest by November-December.
- Treat pond surface with 5 - 10 kg lime. Then, fill the pond with water and add 3 - 5 kg lime to it and apply 10 - 15 kg animal dung or poultry manure. Dissolve 1.5 kg urea and 0.75 kg triple super phosphate in water and apply uniformly throughout pond water.

- After 10 - 12 days, especially after getting good plankton (natural fish food) growth as indicated by light-green to green or light-brownish watercolour, release 100 - 200 fish fingerlings of bigger size (20 - 50 gm), into the pond.
- Feed fish with poultry wastes (mainly wasted poultry feed) at 2 - 4% fish biomass. If insufficient poultry waste is obtained, give supplementary feed of rice polish and mustard oil cake in 1:1 ratio, prepared in the dough.
- Add 150-200 gm per 100 m^2 in pond corners as feed fertilizer every alternate day.
- Release water into fishpond once in 10 days to maintain water level and temperature, instead of continuous through-flow.
- Adopt recommended package of practices to protect fish from diseases.
- Average individual fish weight of 400 - 500 gm is obtained in mid-hill Himalayas in a period of 6 - 8 months.
- About 45 - 60 kg fish per culture season can be obtained fetching an annual net profit of Rs. 2000 - 2500 per 100 m^2 with a BC ratio of 3.7:1.

Poultry

- A poultry hut of 10 - 12 m^2 suitable for 100 - 150 birds is constructed near the pond at least 0.5 m above the maximum water level and 10-20% of its area should protrude over the pond. Floor of the hut should be made of bamboo strips with 1-1.5 cm gaps.
- Culture high yielding poultry birds like *Kroiler* (hybrid of *desi* fowl x broiler) and guinea fowls, which are resistant to diseases and are more profitable.
- Culture one-day old poultry chicks and feed chicks/birds with commercial poultry feed in feeders as per body size. Supply fresh clean water twice every day.
- Initially, 0.2 kg per 100 birds per day poultry waste is generated, which increases gradually up to 7 kg during 8^{th} - 10^{th} weeks.
- About 3 - 4 poultry cycles, each lasting for about 8 - 10 weeks, can be accommodated in a year.
- Net profit of about Rs. 8000 - 10,000 from 100 - 150 birds in 10 - 12 m^2 coop and 3 - 4 cycles per year is obtained with BC ratio of 1.5: 1. *Kroiler* yields over 4 times higher profit than normal Bebcobb broiler variety.

Pig Rearing

- For 3 - 4 pigs (large white Yorkshire), 5 - 7 m^2 pigsty in dry condition with a manger (0.6 m^2) and drinking trough (10 - 12 litre) is needed.
- Two crops per year at average slaughter age of 6 - 7 months with live body weight of 45 - 60 kg can be produced.

- Feed pigs with poultry wastes or mixture of ground maize (25%), mustard oil cake (15%), rice polish/bran (30%) and press-mud (28.5%) along with 0.5% each of bone powder, mineral mix and table salt. Always ensure fresh clean water in the water trough.
- About 6 - 7 quintal wet pig dung and wastes are produced annually by 3 - 4 pigs for recycling as fish feed and fertilizer in fishpond/agriculture fields.
- A net profit of Rs. 2500 - 3500 per cycle with 3 - 4 pigs and Rs. 5,000 - 7,000 in two cycles annually with a BC ratio of 1.5:1 can be obtained.

Agriculture

- Hybrid and high yielding paddy and vegetable crops in about 1000 - 2000 m^2 agriculture fields can be ideally integrated with the system.
- Use pig/poultry dung as fertilizer in agriculture fields at 300 - 400 kg per 1000 m^2. Irrigate and fertilize fields with fishpond water.
- Yield of paddy can be enhanced by about 20% over the non-integrated fields.
- Net profit of about Rs. 1000 -1500 per year from paddy and vegetables in 1000 m^2 is obtained with a BC ratio of 1.5:1.

Conservation Efficiency

- Water requirement for culture of fish, poultry and pigs and agriculture is greatly reduced by at least 50% since the recycled water from the mill is utilized.
- Feed requirement for fish and pigs and fertilizer requirement for fishponds and agriculture crops is almost halved due to the recycling of system generated wastes. Wastes from about 100 - 150 poultry birds and 3 - 4 pigs suffice the feed and fertilizer needs of 150 - 200 fish and crops in 1000 m^2 area with minimum external feed and fertilizers.

Overall economics of the system

- Annual net profit of Rs. 26,000 - 31,000 is realized from the system as additional benefits instead of only about Rs. 10000 achieved annually from water mill and within 3 years, the initial cost of the IFS can be recovered with overall BC ratio of 1.9:1.

Scope

- The developed IFS has ample scope of application in the states of Uttarakhand, Jammu and Kashmir and Himachal Pradesh, which have over 2 lakh traditional water mills and terraced agriculture. Suitable modifications may be incorporated as per the resource availability, needs and preferences of local farmers. This system at individual and community level has tremendous potential to boost economy of small and marginal farmers.

Epilogue

The National Agriculture Policy has set a target of 4% growth in agriculture for generating massive employment opportunities, liberating millions of households from poverty, reducing inequality and achieving higher overall prosperity. It is sincerely hoped that this bulletin would immensely help the user agencies to achieve the targeted agricultural growth in the country, by conserving *in-situ* rainwater, minimizing soil erosion, sustaining soil fertility and crop productivity, harvesting and recycling runoff, mitigating droughts and moderating floods through wider dissemination of the technologies.

As technology generation is a continuing process and an inevitable output of research, the Institute would be happy to revise the bulletin as more technologies become available in the near future for better management of our natural resources and providing livelihood, economic, social and environment securities to the rural masses.

Further Reading

Technical Brochures

Adhikari, R.N. and Mishra, P.K. (2009). Dugout Pond for Deep Black Soils in Deccan Plateau Region. CSWCRTI, Research Centre, Bellary. Raman Prints, Bangalore : p11.

Biswas, H., Narayan, Dev and Tiwari, S.P. (2009). Vermi-compost - An Effective Conditioner for Red Soils of Bundelkhand Region. CSWCRTI, Research Centre, Datia. Allied Printers, Dehradun : p8.

Dass, Anchal, Gore, K.P. and Jakhar, Praveen (2009). *Ragi* + Pigeon Pea Intercropping for Higher Productivity in Tribal Areas of Orissa and Eastern Ghat Region. CSWCRTI, Research Centre, Koraput. Allied Printers, Dehradun : p7.

Ghosh, B.N. (2009). Vegetative Barriers for Erosion Control in Western Himalayan Region. CSWCRTI, Dehradun. Allied Printers, Dehradun : p8.

Jha, Pramod, Mohapatra, K.P. and Dubey, S.K. (2009). Tillage Practices for Erosion Control and Enhanced Crop Productivity in Yamuna Ravines. CSWCRTI, Research Centre, Chhalesar, Agra : p6.

Juyal, G.P. and Arya, R.K. (2009). *Katta*-Crate Technology : A Cost Effective Measures for Rehabilitation of Torrent and Minespoil Areas. CSWCRTI, Dehradun. Allied Printers, Dehradun : p7.

Juyal, G.P., Katiyar, V.S. and Dadhwal, K.S. (2009). Technology for Rehabilitation of Minespoil Areas in Hilly Region. CSWCRTI, Dehradun. Allied Printers, Dehradun : p16.

Juyal, G.P., Sharda, V.N. and Chandra Prakash (2009). Geotextiles for Slope Stabilization and Erosion Control. CSWCRTI, Dehradun. Allied Printers, Dehradun : p12.

Juyal, G.P., Tiwari, A.K. and Sharda, V.N. (2009). Bio-engineering Technology for Treatment of Torrents in Shiwaliks. CSWCRTI, Dehradun. Allied Printers, Dehradun : p20.

Kurothe, R.S. and Pande, V.C. (2009). Bamboo and *Anjan* Grass for Enhancing Productivity of Mahi Ravines. CSWCRTI, Research Centre, Vasad. Anand Press, Anand (Gujarat) : p12.

Kurothe, R.S., Sena, D.R. and Kumar, Gopal (2009). Recharge Filter : A Cost Effective Technology for Augmenting Groundwater. CSWCRTI, Research Centre, Vasad. Anand Press, Anand (Gujarat) : p12.

Madhu, M. and Khola, O.P.S. (2009). Mixed Vegetative Barriers of Pineapple and Grass : An Effective Soil and Water Conservation Measure for Western Ghats Region. CSWCRTI, Research Centre, Udhagamandalam, Tamil Nadu : p12.

Madhu, M. and Sahoo, D.C. (2009). Soil and Water Conservation Measures in New Tea Plantation Areas for Sustainable Production. CSWCRTI, Research Centre, Udhagamandalam, Tamil Nadu : p16.

Mishra, P.K. and Patnaik, U.S. (2009). Conservation Ditching for Efficient Resource Conservation and Enhanced Productivity of Semi-Arid Vertisols. CSWCRTI, Research Centre, Bellary. Raman Prints, Bangalore : p11.

Mohapatra, K.P. and Jha, Pramod (2009). *Aloe Vera* Cultivation in Interspaces for Supplemental Productivity of *Ber* Orchards in Reclaimed Yamuna Ravines. CSWCRTI, Research Centre, Chhalesar, Agra : p6.

Muruganandam, M., Sharda, V.N. and Arora, C.P. (2009). Water Mill Based Integrated Farming System (IFS) for North-Western Himalayas. CSWCRTI, Dehradun. Allied Printers, Dehradun : p16.

Nalatwadmath, S.K. and Patil, S.L. (2009). Bio-Fencing Technology for the Vertisols of Semi-Arid Region. CSWCRTI, Research Centre, Bellary. Raman Prints, Bangalore : p11.

Panda, R.K., Sudhishri, Susama and Dass, Anchal (2009). *Jhola Kuldi* : A low Cost Water Harvesting Technique for Augmenting Production in Eastern Ghat High Land Region of Orissa. CSWCRTI, Research Centre, Koraput. Allied Printers, Dehradun : p7.

Patil, S.L and Nalatwadmath, S.K. (2009). Compartmental Bunding for *In-Situ* Rainwater Conservation in Medium to Deep Black Soils. CSWCRTI, Research Centre, Bellary. Raman Prints, Bangalore: p11.

Prasad, Ram (2009). *Aonla* Based Land Use Systems for Degraded Shivaliks. CSWCRTI, Research Centre, Chandigarh. Azad Offset Printers (P) Ltd., Industrial Area, Phase-I, Chandigarh : p12.

Prasad, S.N. and Kumar, Ashok (2009). Castor + Green Gram Intercropping for Delayed Onset of Monsoon in South-Eastern Rajasthan. CSWCRTI, Research Centre, Kota. Priya Print Shop, Kota Jn. (Raj.).

Raizada, A. and Singh, Charan (2009). Silvipastoral Systems for Wasteland Utilization in Foothills of the Western Himalayas. CSWCRTI, Dehradun. Allied Printers, Dehradun : p10.

Rathore, A.C. and Raizada, A. (2009). Peach Based Agri-Horticultural Practices for Utilization of Marginal Lands. CSWCRTI, Dehradun. Allied Printers, Dehradun : p8.

Selvi, V. and Singh, D.V. (2009). Bench Terracing - An Effective Soil Conservation Measure for the Nilgiris. CSWCRTI, Research Centre, Udhagamandalam, Tamil Nadu : p12.

Sharda, V.N., Kumar, Ambrish and Juyal, G.P. (2009). Conservation Bench Terrace System - A Viable Alternative to Conventional System in Sub-Humid Climates. CSWCRTI, Dehradun. Allied Printers, Dehradun : p12.

Sharma, N.K. and Mohan, S.C. (2009). Maize + Cowpea Intercropping for Resource Conservation and Higher Productivity. CSWCRTI, Dehradun. Allied Printers, Dehradun : p6.

Singh, H.B. and Pande, V.C. (2009). Drumstick Based Agri-Horti System for Replacing Tobacco in Central Gujarat. CSWCRTI, Research Centre, Vasad. Anand Press, Anand (Gujarat) : p11.

Singh, Pratap and Prasad, Ram (2009). *Ber* Based Agri-Horticultural Systems for Marginal Lands in Shivaliks. CSWCRTI, Research Centre, Chandigarh. Azad Offset Printers (P) Ltd., Industrial Area, Phase-I, Chandigarh : p12.

Singh, Pratap, Tiwari, A.K. and Sharma, Pawan (2009). Supplemental Irrigation from Harvested Rainwater for Higher Crop Production in Shivalik Region. CSWCRTI, Research Centre, Chandigarh. Azad Offset Printers (P) Ltd., Industrial Area, Phase-I, Chandigarh : p9.

Singh, R.K. and Sethy, B.K. (2009). Contour Furrows for Enhancing Productivity in Medium Deep Black Soils of South-Eastern Rajasthan. CSWCRTI, Research Centre, Kota. Priya Print Shop, Kota Jn. (Raj.).

Singh, Ratan and Sharma, N.K. (2009). Conservation tillage for Management of Natural Resources and Maximixing Productivity in Maize-*Toria* Cropping System. CSWCRTI, Dehradun. Allied Printers, Dehradun : p8.

Somasundaram, J. and Kumar, Ashok (2009). Sorghum + Pigeon Pea Intercropping for Stabilizing Productivity in South-Eastern Rajasthan. CSWCRTI, Research Centre, Kota. Priya Print Shop, Kota Jn. (Raj.).

Sundarambal, P. and Singh, D.V. (2009). Tea Plantation for Economic Utilization and Stabilization of Terrace Risers in the Nilgiris. CSWCRTI, Research Centre, Udhagamandalam, Tamil Nadu : p11.

Books and Bulletins

Anonymous (2006). Handbook of Agriculture. Indian Council of Agricultural Research, New Delhi, M/s Chandu Press, Delhi: p1346.

Chandra Prakash, Raizada, A., Samra, J.S. and Sastry, G. (1999). Vegetative Barriers for Resource Conservation. CSWCRTI, Dehradun, Allied Printers, Dehradun: p111.

Dhyani, S.K., Sharda, V.N. and Juyal, G.P. (2007). Conservation Forestry and Watershed Management (Vol.III). Training Manual on "Soil Conservation and Watershed Management". Allied Printers, Dehradun: p311.

Juyal, G.P., Katiyar, V.S., Dadhwal, K.S., Joshie, P. and Arya, R.K. (2007). Mined Area Rehabilitation in Himalayas - Sahastradhara Experience. Research Bulletin No.T-53/D-34, CSWCRTI, Dehradun, Saraswati Press, Dehradun: p104.

Juyal, G.P., Singh, Gurmel, Katiyar, V.S., Joshie, P., Sastry, G. and Arya, R.K. (1991). Geojute for Rehabilitation of Steep Mine Spoil Areas. CSWCRTI, Dehradun, Allied Printers, Dehradun: p22.

Mohan, S.C., Samra, J.S., Srivastava, A.K. and Sharda, V.N. (2007). Soil Agronomy and Socio-Economic Aspects (Vol.I). Training Manual on "Soil Conservation and Watershed Management". Saraswati Press, Dehradun: p330.

Samra, J.S., Chandra Prakash, Sastry, G. and Raizada, A. (2004).Technical Manual on Contour Trenching for Rehabilitation of Degraded Lands. CSWCRTI, Dehradun. Allied Printers, Dehradun: p61+iix.

Samra, J.S., Sharda, V.N. and Sikka, A.K. (2002). Water Harvesting and Recycling - Indian Experience. CSWCRTI, Dehradun. Allied Printers, Dehradun: p347.

Ali, Shakir, Singh, K.D., Prasad, S.N., Kumar, Ashok and Mewara, Suresh (2003). Indigenous Technical Knowledge on *In-Situ* Moisture Conservation and Runoff Management Practices in South-Eastern Rajasthan. Central Soil and Water Conservation Research and Training Institute, Research Centre, Kota: 55p.

Sharda, V.N., Juyal, G.P., Chandra Prakash and Joshi, B.P. (2006). Soil and Water Conservation Engineering (Vol.II). Training Manual on "Soil Conservation and Watershed Management". Saraswati Press, Dehradun: p410.

Sharda, V.N., Juyal, G.P. and Naik, B.S. (2008). Watershed Development in India - Status and Perspective. CSWCRTI, Dehradun. Allied Printers, Dehradun: p219.

Sharda, V.N., Sikka, A.K. and Juyal, G.P. (2006). Participatory Integrated Watershed Management - A Field Manual. CSWCRTI, Dehradun: p366.