MAT JOURNALS

Journal of Environmental Engineering and Studies
Volume 2 Issue 3

Catchment Area Treatment Plan for Thoubal Multi-Purpose Project, Manipur

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Abstract

Any type ponding whether natural or artificial generally leads to filling up the pond itself in due course of time mainly due to the process of sediment deposition and compaction. As far as ponding due to dam is concerned and its subsequent sedimentation, the catchment processes play major role and it becomes incumbent on the part of the planners and executors of projects to understand the processes of sediment production, its transportation and finally sedimentation/deposition, which in most of the cases is location specific. This is of concern because of the fact that prolonged and uncontrolled deposition of sediment in the reservoir greatly reduces the capacity of the reservoir to hold sufficient water required for the intended purposes. This is of even more importance as far as a multi-purpose project like the Thoubal project in Manipur as there are multiple stakeholders. Despite the fact that the catchment processes are difficult to model and the relations among the actor variables are not exactly amenable to mathematical prediction, sediment production models are important tools and help us formulate catchment area treatment (CAT) plans. In light of the same, preparation and subsequent execution of a well-designed CAT plan was felt to be of utmost importance to reduce the rate of siltation of the reservoir to be created as part of the multipurpose project planned by the Government of Manipur, India in the river Thoubal. The CAT plan was prepared based on the findings presented in the Environment Impact Assessment (EIA) report prepared separately for the project based on appropriate Guidelines of the Ministry of Environment & Forests, Government of India (Ref. 2).

Keywords: *Environment, Catchment area, sediment, reservoir, vegetation, watershed etc.*

INTRODUCTION

The Thoubal Multi-Purpose Project was conceived by the Govt. of Manipur to control the water of the river Thoubal and to harness the same for productive uses at the same time maintaining its quality as enunciated by UNCED (Ref. 1). Investigations were conducted by the State Govt. with the help of Central Water Commission (CWC), Central Soil and Materials Research Station (CSMRS) and Geological Survey of India. The Planning Commission approved the project in May 1980. The river Thoubal is one of the longest rivers of Manipur. It mainly flows through the Ukhrul district and Thoubal district lower down in the valley before joining river Imphal at Irong Lehil. The upper catchment of the river receives an average annual precipitation of about 1,500 mm (mainly during May-Aug). It drains an area of about 527 sq. km up to the dam site at Phayang.

Project Location

The river Thoubal Manipur originates from the western slopes of Siroi hills of Ukhrul district, adjoining the state of Nagaland at an altitude of about 2,400 m above MSL. The Upper Catchment of the river, which is completely hilly, is located between $24^0$50' and $25^0$30' North Latitudes and between $94^0$30' and $94^0$50' East Longitudes. The total catchment area of the river Thoubal up to its confluence with river Imphal is about 860 sq. km. Except for two villages falling in Senapati district, the catchment of river Thoubal lies in Ukhrul district, which is surrounded by Myanmar in the East, Senapati and Imphal districts in the West, Thoubal district in the South and Phek district of Nagaland in the North. The Thoubal catchment occupies about 527 sq km up to the dam site at Phayang.

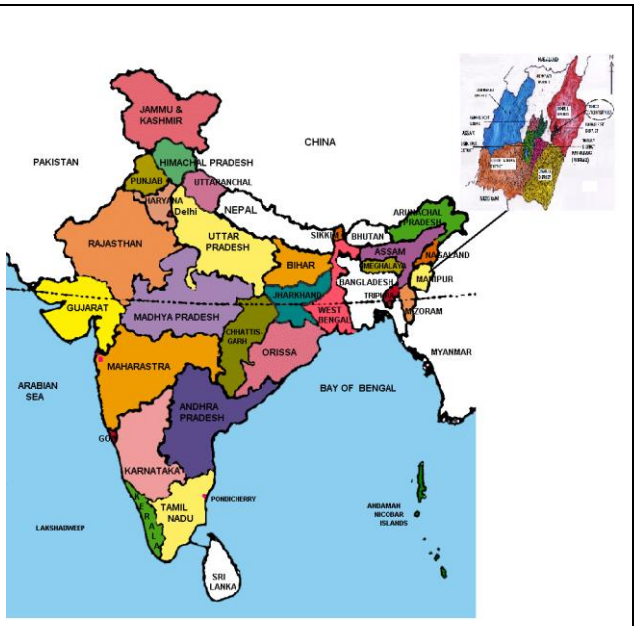

Fig. 1: *The state of Manipur in India*

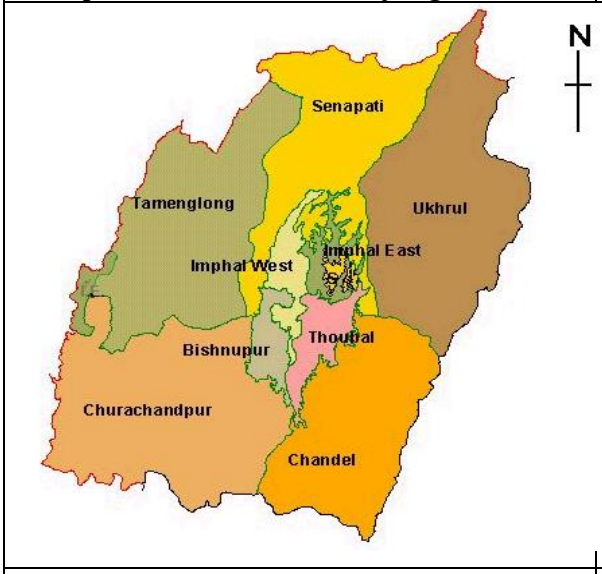

Fig. 2: *District map of Manipur*

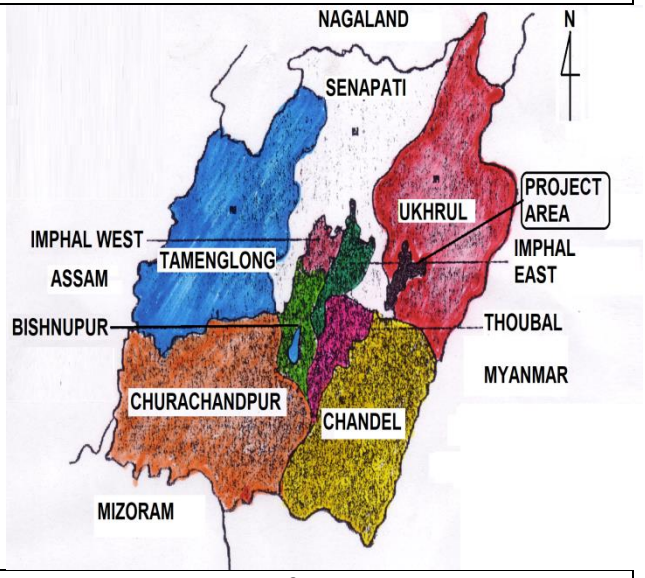

Fig. 3: *Location of the project catchment*

Objective of the Intervention

The objective of the study was to bring about a symbiotic relationship between man and the nature in the catchment area, by utilising its endowments for improvement in production and productivity and restoration of ecological balance. The aim of the project was to:

- Checking soil erosion and land degradation by taking up adequate and effective soil conservation measures in erosion prone areas (very severe and severe).
- Rehabilitation of degraded forest areas through afforestation and facilitating natural regeneration
- Reduction/control of cultivation practices in the catchment area through suitable and appropriate alternatives acceptable to the villagers.

Highlights of the CAT Plan

The Catchment Area Treatment Plan highlights the management techniques to control erosion in the catchment area of the Thoubal project to reduce reservoir siltation as preventive measures. This is intended to stabilize the catchment processes against future erosion. The directly draining catchment area has been considered for treatment and the study was done on watershed basis as per guidelines on Soil Conservation in the Catchment of River Valley and the National Watershed Development Project for Rainfed Areas of the Soil and Water Conservation Division (Ministry of Agriculture and Co-operation, Govt. of India (Ref 3 & 4).

Drainage Discharge and Silt Load of River Thoubal

The discharge of river Thoubal and silt load were analysed by Central Water Commission at Thoubal Bazaar Monitoring Station during 1976-77. It reveals the following:

- Monthly Average Discharge = 1.828 Mm^3 (Maximum= 7.88 Mm^3 and Minimum= 0.22 Mm^3)- 1976
- Monthly Average Discharge = 1.83 Mm^3 (Maximum= 5.86 Mm^3 and Minimum= 0.088 Mm^3)- 1977
- The Monthly Silt Yield = 28,541.58 MT (1977) and 37,462.24 MT(1976)

Mention may be made that there is no hydrological station either of the Central Water Commission or the Brahmaputra Board, Govt. of India or any other agency in Manipur to monitor silt load and discharge of the river Thoubal. Hence, current observed data could not be presented.

Status of Land Use

The hilly catchment is extensively drained and run-off and soil erosion are high. The shifting cultivation is practiced extensively in the catchment without having regard to its damaging the area. Much of the soils are already exposed to erosion hazards. The catchment is inhabited by 40,619 people who live in 44 villages. The population mainly belongs to Naga and Kuki tribes. Land use details are as follows.

Table 1: District-wise particulars of land falling within the catchment area

Sl. No.	Particulars	Ukhrul District (Sq. km)	Senapati District (sq.km)	Total Area (sq. km)
1	Dense forest area	70.00	0.00	70.00 (13.28%)
2	Degraded forest area	319.40	2.10	321.60 (61.02%)
3	Highly/very degraded area	50.00	5.00	55.00 (10.44%)
4	Others areas	79.75	0.65	80.40 (15.26%)
5	**Total watershed area**	**519.25**	**7.75**	**527.00 (100%)**

Source- Divisional Forest Officer, Working Plan Div. No-II, Govt. of Manipur

Land Tenure System

No settlement survey has been done in the Hills districts of Manipur**.** Therefore no statistics on land use is available. There are two categories of land in the catchment area viz. un-surveyed hill areas inhabited by Naga Tribes (Tangkhul), which belong to the Village Council or the Community of the respective villages and un-surveyed hill areas inhabited by Kuki tribes, which belong only to the Kuki chiefs.

Due to such a situation, the sense of ownership of land among the tribal farmers is lacking. There has been no forest settlement and forests are treated as un-classed forest. There is no Govt. Reserve Forest in the area. In earlier days, the forests were under the control of Maharajas who would give forestland to

the local tribal Chief for Jhum cultivation in recognition of sovereignty. Presumably this arrangement has continued. The Jhum cultivation (shifting cultivation) is done on steep to very steep slopes (50% to 80%). The Tribal people exercise unrestricted right to felling of trees not only for their domestic consumption but also for sale to neighboring areas and urban centers through commercial channel.

Physiography and Relief

Physiographically the entire catchment can be classified as follows-

Higher range with steep to very steep slope with temperate Alpine climate	>1,500 m
Medium hills with steep slopes, strongly sloping to very steep slopes	1,000-1,500 m
The foothills with rolling/ undulating topography & valley areas with sub-tropical climate	800-1,000 m

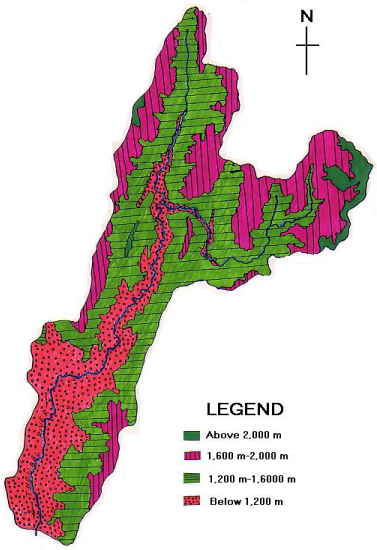

Fig. 4: *Physiography of Thoubal catchment*

Critical Areas of Degradation

The critically degraded areas of the catchment were demarcated and mapped on the basis of concentration of forest denudation and excessive Jhum cultivation. The areas at present may contain scrub or thin vegetation and in most of the places hard subsoil is exposed. There is concentration of critical areas in the lower and upper middle reaches of the catchment. Details of the areas are given below.

Table 2: *Details of critical areas in Thoubal catchment*

Block No.	Location	Area (Sq km)
1	Maphau – Lamlai Khuron – Mongbung	18.70
2	Lamlai Khullen	4.31
3	Bungpi – Sangkhai	5.03
4	Litan	3.95
5	Ringui	3.59
6	Lamlong Gate	4.31
7	Pharung – Simdang	2.88
8	Ukhrul – Simdang	3.59
9	Hungdung Upper and Lower	6.47
10	Tuinam – Phatang	2.17
	Total	**55.00**

Approach and Methodology

General

The constraints and problems of the catchment were analysed in detail for evolving a suitable model for the abandoned Jhum/scrub forest area and present Jhum land, which together contribute maximum erosion hazards in the catchment. Such areas constitute about 71% of the total geographical area. Project approach was adopted for preparation of an integrated development programme for the entire catchment.

Watershed Prioritisation and Treatment

Prioritization of different watersheds for implementing treatment measures was done on the basis of silt yield index and sediment yield rates using guidelines issued by All India Soil and Land Use Survey Organization, Dept. of Agriculture and Co-operation, Ministry of Agriculture, Govt. of India and Handbook on sediment prediction issued by the Govt. of India.

The priority Classes I and II were recommended to be taken up for integrated development and management of the eighteen (18) sub-watersheds demarcated within the catchment. Within sub-watersheds, erosion intensity mapping units were demarcated in land use map, which influences the extent and type of erosion. The planning of watershed management was done on the basis of land capability class established and management needs of the soils. The treatable area in each hilly watershed of the catchment has been estimated using soil survey technique. The treatment of watershed was planned on a project basis for a total period of five (5) years, whereas for pilot areas three (3) year project phasing was done.

Forestry and horticulture development programmes were recommended for ten (10) years. The high priority areas (I and II) were planned for treatment through vegetative measures like afforestation, silvi-culture, agro-forestry, horticulture and alley and ley farming systems. The Jhum land under cultivation that could be treated with alternative land use system was suggested. Suitable topo-sequences and strip and cover cropping alternated by silvi- pasture and silvi-horticulture has been recommended. Land shaping and terracing have been avoided as they are costly measures and could not be sustained.

Care was taken in evolving alternative land farming system for jhum land and hill slope cultivated areas. In this system, it is proposed to incorporate suitable leguminous cover crops in the traditional mixed cropping, which provides food crops, vegetables and cash crops preferred by the local tribes with minimum change. The alternative land use system suggested can easily be adopted by the farmers without involving much expenditure. The cost effective cheap technology suggested would go a long way in transforming the entire economy of the catchment within a period of 8 to 10 years.

For fertility management of jhum lands and steep slope lands, organic farming system has been given due weightage. This is expected to improve soil productivity and moisture regime of the watershed, which in turn, will provide favorable condition for establishment of vegetation in the long run.

The treatment measures suggested are basically through vegetative resources regeneration. Such measures will improve capability of land resources and promote ancillary farm activities through silvi-horticulture plantation, forestry etc. Irrigation tanks suggested will reduce the farmers' dependence on community land. All these measures will help in gradually

switching over from shifting to settled cultivation.

Strategy

The strategy of the project, comprises the following-

- Adoption of project approach;
- Integration of sectoral measures for watershed development and its maintenance;
- Conservation / treatment measures through prioritization approach;
- Emphasis on sustainability of treatment measures;
- Vegetative thrust for conservation measures;
- Improvement of environment for population dependent on watershed;
- Measures for sustaining benefit of treatment through institutional and operational mechanism;
- Promotion of skills of farmers and field functionaries;
- Administrative arrangement for direction, control and recommendation of programme

Watershed Prioritisation in the Catchment

Based on soil survey and satellite imagery, land use map was prepared. Demarcation of sub-watersheds (18 nos.) was done with drainage map superimposed on it. The priorities are fixed on the basis of silt yield index worked out for each erosion intensity-mapping units demarcated within the watersheds. The technique of prioritization as suggested by the Department of Agriculture and Co-operation, GoI has been adopted. The sediment yield index has been estimated using the following formula.

$SI = (EI \times A_{ie} \times D)/ (A_W \times 100)$ Where,

SI = Sediment yield index

EI = Weighted value of erosion intensity unit

A_{ie} = Area of the erosion intensity unit in a sub-watershed

D = Delivery ratio

A_w = Total area of sub-watershed

Details of erosion index mapping unit demarcated on the map in the scale of 1:25,000 are shown below.

Table 3: Characteristics of erosion intensity mapping unit of Thoubal catchment

Physio-graphic Unit	Erosion Intensity Mapping Unit	Slope (%)	Land Use	Soil Texture	Protective Measure	Erosion Status	Weighted Delivery Ratio
Hilly area (valleys undulating)	H	1-10	Mostly cultivated	Silty clay loam	Unprotected	Slightly to moderately eroded	13/95
Mountain side slope	J_1	15-50	Jhum land	Silty clay loam-skeletal	Unprotected	Considerable erosion	16/95
Mountain side slope	J	10-35	Jhum land	Silty clay loam	Unprotected	Severe sheet, moderate rill erosion and occasional landslides	15/90
Mountain side slope	J_2	15-50	Abandoned shifting cultivation areas,	Silty clay loam-	Unprotected sparse vegetative	Moderate sheet and rill erosion	13/90

			scrub forest	gravely skeletal	cover of grass		
Mountain side slope	J_3	35-70	Scrub forest/abandoned Jhum areas	Silty clay	Unprotected with human interference	Severe to moderate sheet and rill erosion	14/90
Hill side and foot hills river terraces	K	5-20	Wetland paddy terraces	Silty clay	Well-terraced	Slight sheet erosion	11/95
Mountain side slope	F_2	15-50	Moderately dense forest and natural pastures	Silty clay loam	Protected erosion	Slight sheet erosion	11/85

The erosion intensity map implies a set of relevant parameters of soil erosion that exert combined influence on soil detachment. The factors considered include physiography and land slope that control the amount and velocity of runoff, soil characteristic that decides potentiality for erosion, vegetative cover condition that offers protection to the soil, land use and interference by human and biotic factors which modify or influence other factors.

The parameters of erosion intensity unit where determined by remote sensing technique, as there is no land use data available from the area. The drainage map prepared in the scale of 1:25,000 was superimposed on the land use map to assess and determine the influence of different factors and delivery ratio for individual erosion intensity mapping units.

The delivery ratio was adjusted for each of the mapping units falling in different sub-watersheds. The delivery ratio suggests the percentage of eroded material that finds entry into the drainage system, reservoir and floodplains. The shape and size of sub-watershed relief, physiography, flow, soil characteristic, distance from active streams, reservoir etc. were considered for adjusting delivery ratio.

Priority Classes

The ultimate aim of this survey was to demarcate priority sub-watersheds for soil conservation planning. The rating of sediment yield index of each sub-watershed was done. Higher value of sediment yield index suggests higher priority and vice-versa. Fixation of priorities was done based on silt yield index value in the following categories.

Vary high priority - >1,300
High priority - 1,200 to 1,299
Medium priority - 1,100 to 1,199
Low priority - 1,000 to 1,099

The sub-watershed-wise areas under priority classes and relative priorities are given below.

Table 4: *Area under different priority classes and sediment yield from the watersheds*

Watershed No.	**Abandoned Jhum/Scrub Forest/Jhum Land (ha)**		**Average for Watershed**		**Relative Priority**
	High priority	**Very high priority**	**Sediment Yield /100 km^2/year**	**Priority Class**	
1	-	750	6.65	High	15
2	-	1152	10.57	High	5
3	745	-	7.93	High	13
4	1436	-	9.20	High	8
5	336	-	3.64	Low	18
6	1667	-	4.68	Low	17

7	980	-	7.15	High	14
8	-	1451	9.17	High	6
9	938	-	5.61	High	16
10	-	1069	11.12	High	3
11	-	1199	9.03	High	9
12	-	1016	8.20	High	12
13	-	1452	9.55	High	7
14	-	1093	10.57	High	4
15	-	1307	8.587	High	10
16	1573	-	8.20	High	11
17	-	2078	11.40	High	1
18	-	3197	11.33	High	2
Total	**7675**	**15764**			

- Treatable Areas = (7675 + 15764) ha= 23439 ha
- Average sediment yield for the catchment = 8.48 ha m/100 km^2/year

Table 5: *Priority classifications of sub-watersheds of the catchment*

Priority Category	**Watershed No.**	**No. of Watersheds**	**Area (ha)**	**Percentage Area**
Very high (>1300)	Nil	-	-	-
High (1200-1299)	17,18,11,3	4	14,697	27.90
Medium (1100-1199)	1,2,3,4,5,6,7,8,9,10,12,13,14,16	13	33,192	63.00
Low (1000-1099)	6	1	4,811	9.10
Total		**18**	**52,700**	**100.00**

Area under each Erosion Intensity Mapping Unit (EIMU) was worked out to estimate the treatable area. Except mapping unit 1-2 (mix moderately dense forest) and EIMU (K) (terraced land), which together works out to 26.50% of the catchment, the other EIMUs represent treatable area. It has been estimated through remotes sensing technique and also on the basis of ground verification that only 60% of the area within abandoned Jhum/scrub forest (J2 and J3) needed treatment. The total treatable area works out to be about 54% of the catchment. EIMU-wise percentage of area and treatment needs are shown below.

Table 6: *Treatable area and treatment needs of different erosion intensity mapping unit*

EIMU Symbol	**Area (ha)**	**% of Area**	**Treatment Needed**
K	3,488	6.6	Maintenance of wetland paddy terraces and water management.
H	710	1.3	Alternative silvi-pasture, silvi-horticulture and strip cover cropping system, grassed waterways and soil water management.
J	1,086	1.8	Alternative silvi-pasture, silvi-horticulture and strip cover cropping system, grassed waterways and soil water management.
J1	1,114	2.1	Alternative silvi-pasture, silvi-horticulture and strip cover cropping system, grassed waterways and soil water management.
J2	17,315	32.8	Protection and management of soil and plant resource ley and alley farming system Rainfall Water Harvesting and recycling terraces improvement and grassy waterways. Enrichment plantation and silvi-culture.
J3	18,468	35.0	Protection and management of soil and plant resource ley and alley farming system Rainfall Water Harvesting and recycling terraces improvement and grassy waterways. Enrichment plantation and silvi-culturte.
F2	10,518	19.9	Enrichment plantation, protection and conservation forestry.
Total	**52,700**	**100**	

Sediment Yield

Sediment yield from humid sub-tropical hill and temperature sub-alpine zone of river Thoubal catchment was estimated using the equation suggested in Hand Book of Sedimentation. The evenly distributed high rainfall with lower intensity has provided favourable condition to good vegetative stand of various grass spices like *Imperata cylindrical, Sacharum spontaneum, Sacharum officinarum,Pharagmites karka, Andropogon* species, and host scrub and tress of moderate forests. Soil moisture regime is depleting in about 50% of the catchment area meaning that runoff percentage is increasing resulting in accelerated soil erosion. Creation of open areas due to denudation of land surface further intensifies the problem. However, grasses and plants thrive well in the wet climate. Soils are deep and productive with medium to high content of organic carbon and high water holding capacity.

Erodibilty Index and P/T Ratio Adjustment Factor

In mildly acidic to strongly acidic silty-loam to silty-clay soils, the influence of soil particles smaller than 2 micron with negative value causes distortion in prediction of yield rate as the upper 5 cm soil contains less percentage of finer particles due to high rate and velocity of runoff water in the area. The comparison with experimental results of ICAR at Barapani (in similar agro-climatic zone) reveals that the silt load predicted is more akin to experimental values. Man-made effects of slashing, cutting and burning process in about 50% of the area in contributing maximum to the erosion and sediment. Further, the P/T ratio has been adjusted in accordance with the vegetative cover. The P/T ratio of 0.923 has been adjusted at 75% of P/T value as biotic interference in cutting, feeling, burning system affects density of plant population and canopy cover. The formula has been found to be in conformity with the experimental and soil survey results.

Sediment Yield Estimation and Priority Classification

Sediment yield estimation was done taking into consideration, vegetal cover (Cover Factor), rainfall, temperature, conservation practices, slope, soil factor and erodibility-index. The equation applied is as under.

$$Log(100+Y)=6.63792-Log(100+X_1)^{2.40504}+Log(1000+X_2)^{0.06567}-Log(100+X_3)^{0.01820}+Log(100+X_4)^{0.04019}$$

Y= Sediment yield in acre feet/sq. mile/year

X_1= P/T Ratio-indirect expression of natural response of vegetation to climate. (P/T ratio has been adjusted to 75% due to biotic interference)

X_2=Average slope %

X_3= Influence of coarse particle

X_4= Erodibility index. Since, soil is acidic. Negative value has been assumed.

Priority Classification: On the basis of erosion intensity range, the sub-watersheds have been classified as

(ha m/100 km^2)	(Erosion Intensity)
0-0.5	Insignificant erosion
0.5-5	Slight erosion (low priority)
5-15	Moderate erosion (High priority)
15-50	severe erosion (Very high priority)

Sediment Yield Prediction and Estimation of Treatable Area

Silt yield prediction of all the 18 sub-watersheds demarcated was made. The silt yield prediction for areas with insignificant vegetal cover and that are prone to erosion are classed as Area-A. The treatable area assessed in this class comprises about 89% of the total treatable area including 60% of abandoned Jhum land/scrub degraded forest and 100% of the present Jhum land area. Only 11% of the total treatable assessed, falls in the second category (classed as Area-B), which include mixed moderate dense forest (including 40% of abandoned Jhum Land/scrub forest) and terraced paddy land.

Soil and Water Conservation Measures

Mechanical measures were suggested for treatment of excessively eroded areas that have lost about 3/4th of the soil depth and vegetal cover. As mechanical structures involving high cost but shorter life span cannot be sustained in the area, they have been envisaged to be supportive to vegetative measures and production technology suggested. Low-cost, sustainable production technology of model Jhum control programme through Alley and Ley farming system with silvi-culture and pasture development needs to be supplemented with conservation and recycling of rainwater. Soil and water conservation measures for agricultural/non-agricultural lands were planned in an integrated manner following project approach.

Bench terracing

Bench terracing in the pilot area has been proposed for 10 ha and in others parts of the catchment it is for 240 ha. These terraces are proposed mainly for hill slope cultivation areas with not more than 15-20% slope. Bench terraces of 0.25 ha (for farmers), included under Jhum control programme will be constructed to provide additional source of production for their food requirement. It is estimated that about 17% of the area (42.5 ha) will be lost in terracing due to bund formation. To utilize surface area of the terrace riser (about 2 times the area lost), it is suggested that perennial grasses and legumes like *Setaria sphocelata, thin Napier, Gunea Shanata, Centrocena, Pubescence, Macroptilium, Atropurpureun and Stylosanthes guyanensis* may be grown. This has potential to maintain 1.8 cattle unit/ha as per study of ICAR Centre, Barapani. Green forage will be available for about 10 months/

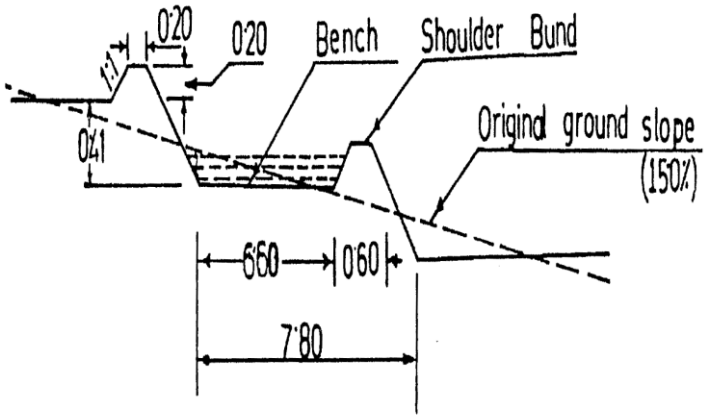

Fig. 5: *Design details of bench terrace*

Terraces are to be constructed with 1.17 m Vertical Interval (VI) and 6.66 m Horizontal Interval (HI). About 4% grade has been provided for inward inclination and 0.4% grade will be allowed in drainage channel formed for carrying excess runoff at calculated safe velocity of 0.51 m/sec through grassed waterways. Peak rate of runoff was calculated at rainfall intensity equal to time of concentration for rainfall duration of 1-hour.

year with expected yield of 40-50 MT/ha.	

Water harvesting structure for irrigation and pisciculture

Water harvesting structures have been planned for storage and recycling of excess runoff. Runoff water impregnated with sediment load will get deposited within the storage structure and nutrient contained in the runoff water also will be recycled for growing crops in terraced fields resulting in 15-20% increase in yield. For pisciculture, a group of farmers may be allowed to carry out fish farming as to be decided by village chief/village community/watershed management committee. Income raised over the margin of profit will be invested for other economic activities like silvi-pasture development, afforestationetc in the catchment.

The structure will have a water area of 1.12 ha (125 m × 90m) with 1.8 m average depth and has capacity of 2.0 ha m plus 0.567 ha m storage due to excavation. Assuming 0.45 m loss in water column due to evaporation and seepage the available water for irrigation will be 2 ha m at 70% irrigation efficiency and 0.22 ha m dead storage that will be available (1.25 ha m), it can provide 3 lifesaving irrigations to 4-5 ha area. In the pilot area two such structures have been planned in addition to water harvesting cum silt retention structures. In other areas of the catchment 40 structures have been planned.

Water harvesting cum silt retention structure

Small water harvesting structures are planned for an assumed catchment of 8 ha as per soil and physiographic conditions of the area. These structures may be constructed in community land as well as in individuals' land. In total eighty (80) structures were planned, including two (2) structures in the pilot area. In the pilot area one site has perennial source of spring water too.

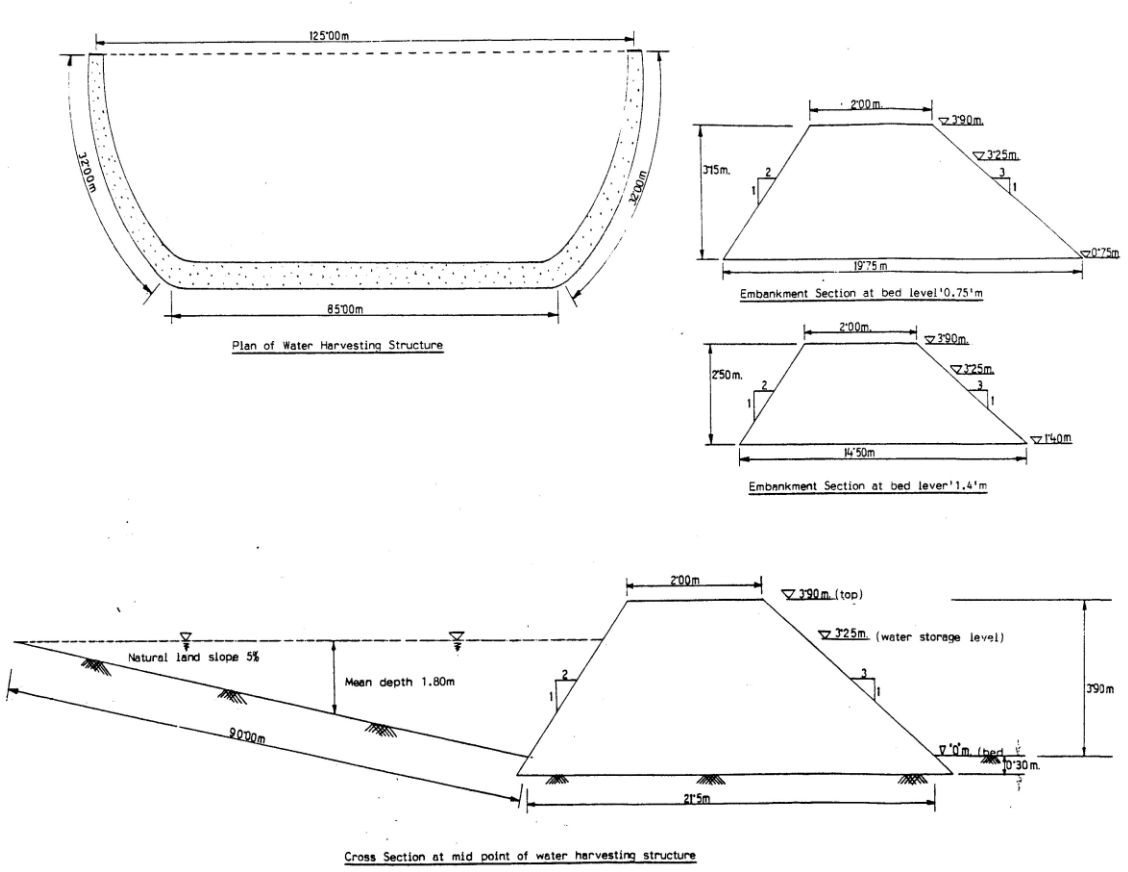

Fig. 6: *Design details of water harvesting structure*

Staggered Trenches

Staggered trenches are planned for silvi-horticulture in abandoned Jhum/degraded areas (20-40% slope). These have capacity to arrest the runoff to the extent of 297 m^3/ha. Staggered contour trenches for 409 ha of horticulture plantation in strips of Jhum area model proposed will store runoff of 12.15 ha m. Trenches will be spaced 5 m horizontally and within rows at 3 m as shown. One continuous trench will be provided after every 5 rows of trenches across the slope to arrest escaped runoff.

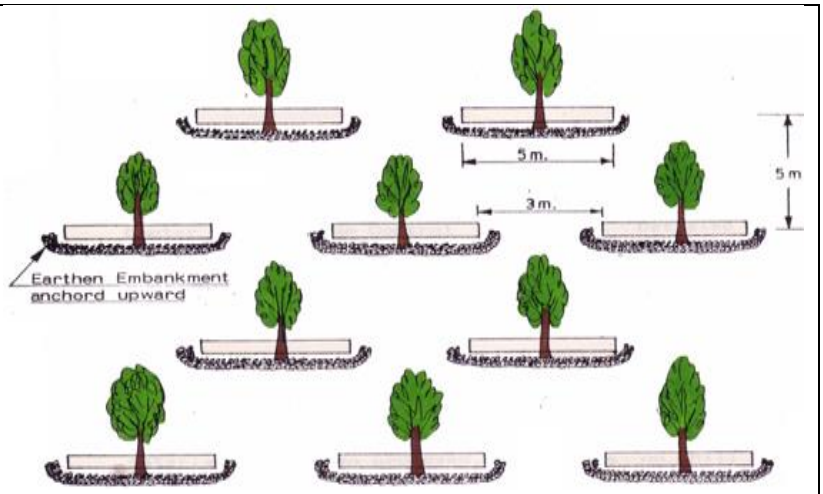

Fig. 7: *Staggered trenches for silvi-horticulture*

Minor soil and water conservation works

Minor soil and water conservation measures such as brush wood dam with locally available material were proposed. The areas on hill slopes where rill formation takes place could be effectively treated with these measures.

Accordingly, planting of contour hedge, soding of embankment of water harvesting structure, gully slips etc. are envisaged under this programme.

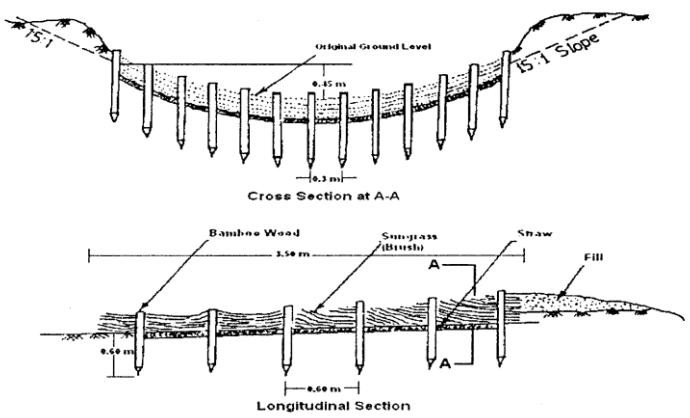

Fig. 8: Design details of brush wood dam

Vegetative contour hedge

Vegetative hedge of vetiver grass was planned instead of mechanical interception bund in the mixed and cover crop strips under Jhum control model. The total length of hedge in unit of 2.2 ha land is 500 m.

Jhum control programme

About 1,500 ha of area under Jhum cultivation has been proposed to be covered under alternative system of farming phased over 5 years. Staggered trenches for silvi-horticulture and vegetative contour hedge for cover and mixed crop strips were planned. The vetiver hedge has been found to be very effective in controlling soil and water losses from soil erosion prone area.

Compensatory Afforestation

The management plan of Thoubal catchment (forestry sector), lays maximum emphasis on afforestation/ reforestation programme in all critically degraded areas and retention of forests (natural or manmade) excluding in 40% slope and providing alternative employment and economic opportunities to people living in the catchment area. This is expected to reduce their dependence on the valuable natural assets. Based on the field visits and interpretation of relevant maps the areas under forest and the areas to be afforested are shown.

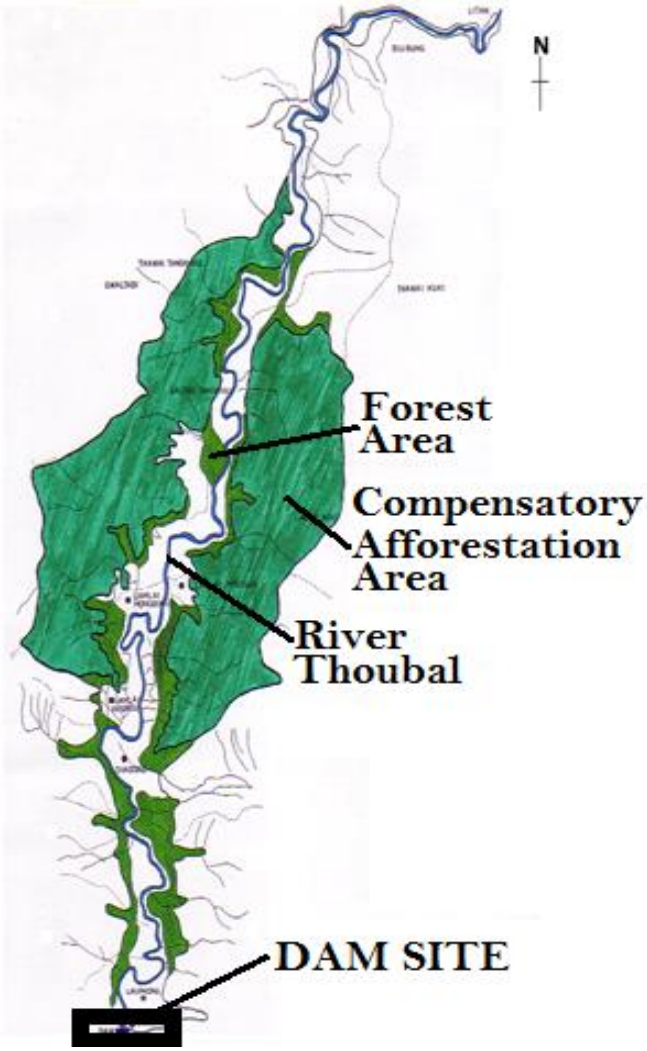

Fig. 9: *Forest area and area for compensatory afforestation*

Total Area to be Treated

Out of total treatable area of 23,439 ha assessed, about 3,275 ha will be treated with Jhum control programme and other soil and water conservation measures. The forestry, social forestry and silvi-pasture will provide vegetative cover in 7,309 ha. Thus, total area to be treated is 10,584 ha. The remaining area of 12,855 will be allowed to regenerate as such lands have capability to rejuvenate in a natural process. In addition, the net irrigation potential of water harvesting structures and spring sources works out to be 538 ha.

Table 7: *Details of area (in ha) to be treated/ benefited with the soil conservation measures*

Treatment (Forestry)	**Year of Plan**										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**
Afforestation	300 *10	300 10	300 10	300 10	300 10	300 -	300 -	300 -	300 -	300 -	3,000 50
Compensatory Afforestation	390	400	400	-	-	-	-	-	-	-	1,190
Social forestry	100 *1	100 1	100 1	100 1	100 1	100 -	100 -	100 -	100 -	100 -	1,000 5
Silvi-pasture	100	100	100	100	100	100	100	100	100	100	1,000

Enrichment Planting	100 *10	100 *10	100 *10	100 *10	100 *10	100	100	100	100	100	1,000 50
Forestry belt (reservoir periphery)	2	3	3	3	3	-	-	-	-	-	14

*Pilot area

Treatment (Forestry)	Year of Plan					
	1	2	3	4	5	Total
Jhum control programme	300	300	300	300	300	1,500*
Horticulture	30	35	35	30	30	160
Bench Terracing	50	50	50	50	50	250
Minor soil and water conservation	40	40	40	40	40	200
Water harvesting structure for irrigation & pisciculture Area treated Area irrigated	 100 32	 100 32	 113 36	 112 36	 100 32	 525 138
Water harvesting structure (irrigation & silt retention) Area treated Area irrigated	 128 24	 128 24	 128 24	 128 24	 128 24	 640 120
Spring water irrigation (Area irrigated)	50	50	50	50	50	250
Total **Area treated** **Area irrigated**	 **1661** **106**	 **1667** **106**	 **1690** **110**	 **1284** **110**	 **1272** **106**	 **10584** **538**

** Includes silvi-horticulture/staggered trenches, contour hedge, silvi-pasture and cover/ mixed cropping*

Financial Outlay

The Catchment Area Treatment Plan envisages a total financial outlay (2005-06 Price Index) of Rs. 2289.243 lakh phased over a period of 10 years, of which about Rs. 2112.781 lakh (92.29%) will have to be invested by the Government in the form of grant or subsidy, Rs. 144.589 (6.32%) has been proposed as loan from financial institutions and the balance of about Rs. 31.873 lakh (1.39%) has to flow as Beneficiaries' Contribution. Normal pattern of subsidy as available to small and marginal farmers is recommended. The fund is to be channelized through the PIA to various line departments, to implement the respective sectoral programmes.

Conclusion and Justification of Investment on Catchment Treatment

It is well known that degradation of catchment causes-

- Rapid siltation of the reservoir
- Excessive run-off during rainy season
- Less or no flow during dry periods
- Reduction not only in the life of the project, but a threat to dam safety itself
- Flood hazards and land degradation control in downstream catchment
- Severe hazard to local flora and fauna, including plants and animals threatened with extinction and to the environment as a whole.

Thus, it can be concluded that investment in Catchment Area Treatment Plan related to any reservoir project is worth it, whether it is under public or private sectors.

Recommendations

Salient recommendations for smooth implementation of the CAT Plan are given below:

- Selection of species as per the **approved list**
- Sub-contracting of afforestation through local people/agencies should be encouraged
- Project authorities should ensure frequent meetings with the forest

department and executing teams to enable smooth implementation of the plan and ensure financial flow

- Forest department should help involvement of the project-affected families and local population in such an activity to generate employment. This mode called the Participatory Mode would inculcate among the catchment dwellers a sense of belongingness and ownership of the catchment areas itself.

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