REPORT

Government of Sikkim

IMPACT OF
LANDSLIDE AND EROSION CONTROL TREATMENT

UNDER
TECHNOLOGY DEVELOPMENT EXTENSION & TRAINNING PROJECT

WEST SIKKIM
2004-05 *to* 2008-09

ENVIS CENTRE SIKKIM
Forests Environment & Wildlife Management Department
Government of Sikkim

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Under

TECHNOLOGY DEVELOPMENT EXTENSION & TRAINNING (TDET) PROJECT

WEST SIKKIM
2004-05 *to* 2008-09

Sponsored by
Ministry of Rural Development
Department of Land Resource

Government of India

Conducted by

ENVIS CENTRE SIKKIM
On Status of Environment & its Related Issues

Under the Supervision of
C. Lachungpa, IFS
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Forests, Environment & Wildlife Management Department
Government of Sikkim

FOREWORD

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PCCF-cum-Secretary

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The report on Treatment of Landslide and Erosion Control in Sikkim is a pilot project to carry out research in combating and controlling landslide in the Himalayan region. This report is an initiative taken by the Ministry of Rural Development, Department of Land Resources to bring out research findings and further replicate it in the respective areas.

The Team of Land Use & Environment (LU & E) Circle and Environment Information System (ENVIS) has been working in close coordination since the establishment of ENVIS in the state, and is doing exceedingly well in environmental related issues. LU & E and ENVIS together has been successful in bringing out a number of publications and reports; namely, The State of Environment Report, Treatment of Landslide and Erosion in South Sikkim, quarterly Newsletters and several other awareness materials in the form of pamphlets and brochures. The publication of this report is yet another milestone.

As a result of performance in field of Project Implementation and its Publicity, Sikkim has achieved rewards in being one of the first states in the country to achieve 100% sanitation and also ranks first in conservation of natural resources and in performance of land use.

This report entails the treatment of landslide and erosion control in area of West Sikkim. The present study conducted by the team is highly appreciating. I fully acknowledge the efforts and wish them the very best in their future endeavor. I further encourage them to work on the same line with more technicalities and by method of community participation.

S. T. Lachungpa, IFS
PCCF-cum-Secretary

FOREWORD

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Road communication is a matter of great importance in the Himalayan landscape as the roads are the main lifeline through which trade, industry, commerce and security flourish. However, during the days of heavy rainfall, it is difficult to keep the road communication open and the traffic has to be diverted to long torturous routes which cost much more economical burden not only to the state but also to the individual poor people. There were occasions when even the alternative routes were closed on account of landslides and erosion, thereby bringing all the movements to a deadlock.

The damage on agricultural land caused by erosion or slides, in ordinary parlance, may not be considered to be serious economic loss as compared to road communication or other habitations, but for the poor farmers whose fields have been washed, it means the loss of livelihood for himself and his family. Besides the economic loss, there is unprecedented perturbation of environment due to constant landslide and soil erosion. For these reasons, the state has to face heavy demands from the afflicted farmers of different sectors/areas for soil conservation approach and protective remedies.

Considering the perpetual irksome impediments in day to day economy and social stress vis-a-vis environmental stress caused by landslide and erosion, the Forest Environment & Wildlife Management Department, Government of Sikkim had approached the Ministry of Rural Development Department, Department of Land resources, Government of India to extend financial and technological support for the control of landslide and erosion on selected watershed area. The Department has provided financial grant-in-aid under TDET programme to treat a few landslide areas in West District on Pilot Project basis, so that the findings and output of the project could be developed into a model for landslide and erosion control replicable to the Himalayan Landscape.

The report has been prepared on the basis of field experience for treating landslide and erosion of distinct dimension. The manifestation of the study indicates the impact of control on landslide and erosion; enhance biomass and resultant succession of vegetation through combined approach of bio-engineering technology. It suggest different parameters for contending landslides and supports sustainable economic vis-à-vis social understanding of the landslide through synergized efforts of sensitization, awareness and extension exercises carried out during the project implementation.

The advisory committee consists of Mines, Mineral & Geology Department, G.B.Pant Institute of Himalayan Environment and Development, Pangthang, ICAR Tadong, and other organizations who have provided guidance and technical inputs for implementation of the projects. Their technical inputs and suggestions gave sound footing for effective control of landslide and erosion. There are similar projects being implemented in South and North District also.

The report also provides recommendation on soil resources acceptable for certain species in degraded landslide and erosion stretch. It also measures the impact of dry paddy cultivation vis-à-vis wet cultivation and seeks social understanding of community on economic front with that of intangible impact on the eco-system. During the course of study, it was observed and noticed that the vegetation play a vital role for arresting landslide and erosion control which give long term stabilization.

Therefore, I quote a line from the speech of ***His Excellency the then 1st Governor of Sikkim, Late Shri B. B. Lall.***

"As far as man is concerned, I think he has to learn-perhaps through bitter experience- that forests and vegetation are his great friends and any denudation of them will cost him heavily in one form or the other".

C. Lachungpa, IFS
CCF-cum-Nodal Officer (FCA)
Land Use & Environment Circle

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Acknowledgement

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- *Dr. R. K. Awasthe (Principal Scientist), ICAR, Tadong and Dr. Varun Joshi (Scientist 'C'), G.B.Pant Institute of Himalayan Environmen & Developmentt, Panthang for their technical support and guidance during the implementation of the scheme and preparation of the report.*

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- *Also, Special mention to Mr. Pradeep Kumar, IFS, CF (WP) and Mr. Garap Dorjee Bhutia for necessary suggestions.*

The acknowledgement would remain incomplete and inauthentic if we fail to express our gratitude to the people of Salley, Pipalay, Pelling Naku Tadong and Rangsang for their warm hospitality and support during the field study in the respective watershed area.

- Team

CONTENTS

1 INTRODUCTION

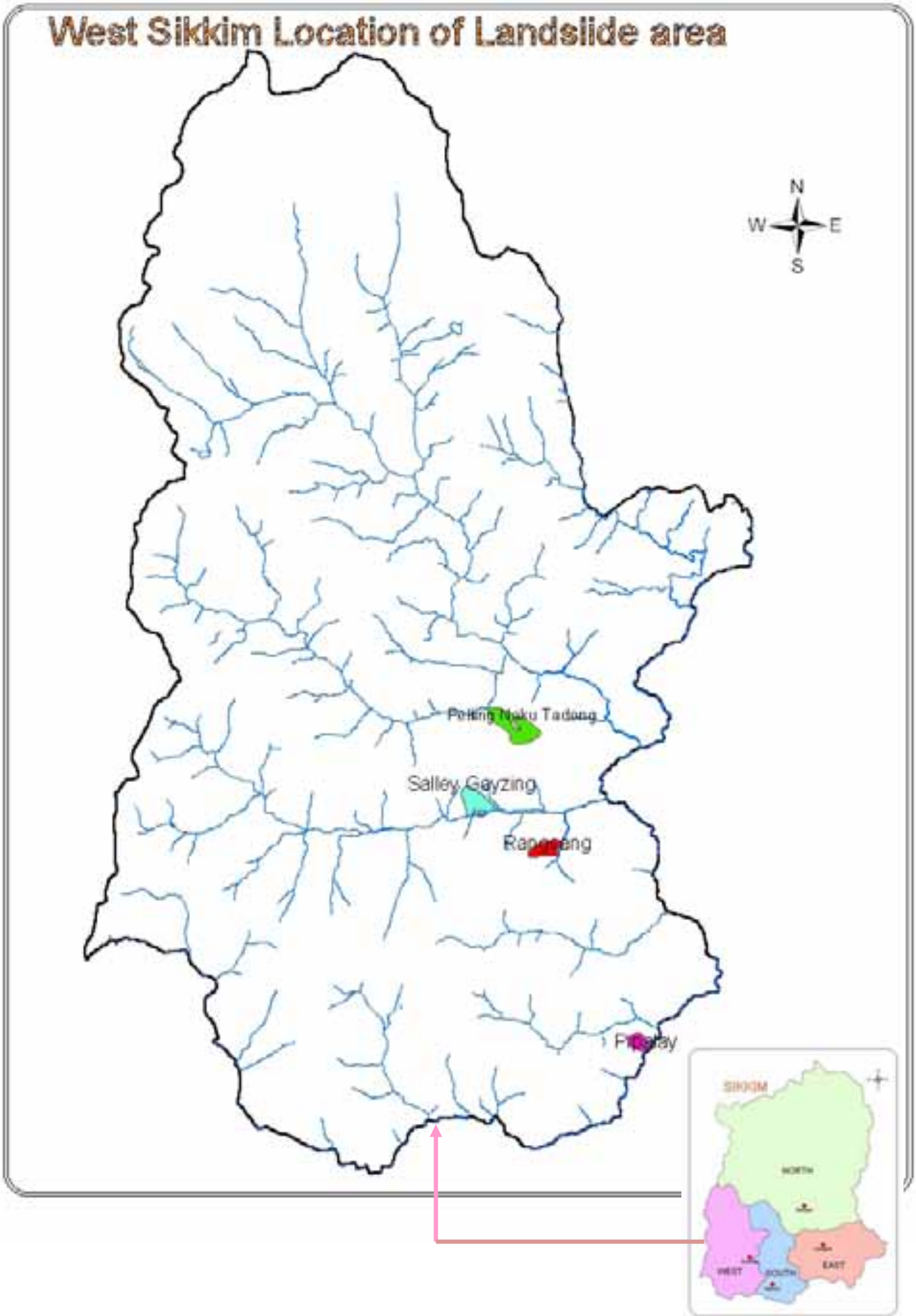
Sikkim, a small mountainous state in the eastern Himalayas covers an area of 7069 sq. km., extending approximately 114 km from north to south and 64 km east to west. It is also a hilly state consisting of tangled series of interlocking mountain chains rising range above range from the south to the foot of high peaks which marks the snow line in the north. The topography is such that it has earned itself a characteristic feature and the unavoidable natural disaster of all, the landslide. Landslide has thus been a part of this state since its formation.

Adding to it is the monsoon rains; Sikkim by virtue of being in the direct path of the monsoon is one of the wettest parts of the north eastern region, the climate varying from the sub-tropical to the wet temperate depending upon the altitude. The climate in this region is subtropical while in higher region it is wet temperate. The climate is temperate throughout, though considerable local changes are responsible for influencing the climatic condition from place to place. The rainy season usually starts by May and continues till November. The average annual rainfall in lower elevation is 2540 to 3810mm and at higher hills up to 2744m is 3810 to 5842mm. However the rainfall decreases beyond the altitudes of 3049m where the average rainfall is between 1270 to 1524mm. Sikkim is primarily a catchment area of the Teesta Drainage system.

The geographical location and the topography of this state make it vulnerable to landslides. Many efforts have been taken to cope up with this landslide that in unavoidable in the state.

The Project entitled **"Treatment of Landslide & Erosion Control work"** under **Technology Development and Extension & Training Programme", A Central Sector Scheme for Wasteland Development** is one amongst the effort to combat this natural disaster in the state. The proposed project was envisaged to check the erosion and landslides by way of engineering and biological measures. In addition, plantation has been proposed in the river beds and surrounding area for overall environmental improvement. It intends to arrest soil erosion & landslide on pilot project areas in West Sikkim and attempts to develop demonstration models for technology extension through awareness, education and extension program.

Landslide in this project includes wide range of ground movement such as rock falls, deep failure of slopes and shallow debris flow. Landslide occurrences have lead to the erosion of its rich biomass. The state Sikkim experiences the tribulations of landslides and other mass movements at various locations. Factors like the heavy monsoon rains, fragile young rock formations are the main reasons for triggering the landslides. The high intensity of rainfall causes extensive soil erosion and heavy losses of nutrients of soil by leaching. The unplanned developmental projects/ activities are the main cause of aggravation of soil erosion and landslide in the fragile hill landscape. The road itself is the biggest cause that can destroy the terrain and trigger landslides and generate sediments.


West Sikkim Location of Landslide area
N
W
E
S
Salley Gayzing
SIKKIM
WEST
EAST

Landslide being one of the prime geological hazards occurring in all the districts of Sikkim cause damage to property, affecting communication, transportation, and number of fatalities every year. Sikkim being a land locked State; disruption of road communication by landslides is an annual affair. In recent years Sikkim has been hit adversely by landslide creating chaos and disturbance in day to day activities. The common occurring landslides experienced in this region are slope failures of different type's i.e. rockslide, rock falls, rock toppling debris slide, debris slide, and rock cum debris slide. Although gravity acting in over-steeped slope is the primary reason for some landslide, earthquake's initiation towards landslide is a mere cause and effect relationship.

Despite several studies carried out at landslide prone areas, there is lack of in depth scientific study to mitigate this problem; this report is an attempt to bring forth the several scientific measures.

The proposed area is slightly steep with 40 degree slopes in upper reaches and 30 degree in lower reaches. But the whole terrain is landslip prone area.

1.1 Project Duration:- 2005-06 to 2007-2008.

1.2 Project Implementing Agency (PIA):-
Divisional Forest Officer (Land Use & Environment) West Sikkim.

1.3 Project Objectives: -

1. To immediately arrest soil erosion, stabilize failure sites, reduce potential for additional mass wastage, reduce stress on agricultural land, minimize sediment production and delivery to streams thereby reduce the risk of damage to fish habitat or domestic water supply. Initiate and accelerate natural regenerative process and also stabilize the landslide in river banks and gullies to reduce potential for channelized debris flow, reduce the volume of debris flow and debris floods.

2. To develop technologies, in association with other institutes for landslide treatment and set these areas as demonstration projects by using maximum locally available material and extension of this technology to affect rural communities.

3. Promote awareness, education and extension programs.

1.4 Project Area:-

- Pelling Naku Tadong
- Pipalay
- Salley, and
- Rangsang

The landslide area where work has been done has been spread out in all types of land including Private Land, Community Land and Reserve Forests.

1.5 Nature of problem identified:-

The reason why landslides occur in these areas in such high frequency is to be seen from the standpoint of evolution. The need for this recognition is that the mountain forming has resulted in increased erosion potential which is one of the most important factors in landslide evolution. Secondly, the geographical location of Sikkim produces abundance of precipitation which accelerates the down cutting of rivers and also

provides plentiful ground water supplies in the hill sides. As a result, landslides are important elements in the geo-morphological development in the mountain regions. Usually in this area, large scale landslides features are formed by aggregation of smaller landslides. Fissures and cracks also develop during landslide movement leading to infiltration of ground water.

Such condition cause localized instability and result in formation of smaller landslide within the large landslide. Most the current existing active landslides represent reactivated portions of larger landslide mass.

1.6 Justification:-

Landslides are major problem in hilly regions, in particular Sikkim. The multiplicities of factor like the young geological formations; soil structure, soil properties and heavy rainfall causes the erosion of the soil affecting the transport system, water supply and casualty of human lives. The fertile land adjoining the rivers gets washed away affecting the farmers and the environment on the whole. High intensity of rainfall and other natural disaster like the earthquakes trigger landslide to a major extent. These landslides cause extensive soil erosion and heavy losses of nutrients of land by leaching. The proposed project intends to establish the effectiveness of bioengineering measures in landslide stabilization in the watershed under study.

1.7 Approach and methodology used:-

The projects emphasizes on soils bioengineering method since it is an excellent tool for stabilizing soil erosion.

The soil bioengineering works included were:-

1. Hand packed stone wall inside sausage (gabion) in landslide area.
2. Jhora (stream) training works which include Hand packed stone wall inside sausage and G.I sausage wall with 1:2:4 PCC lining.

1.8 Other works include:-

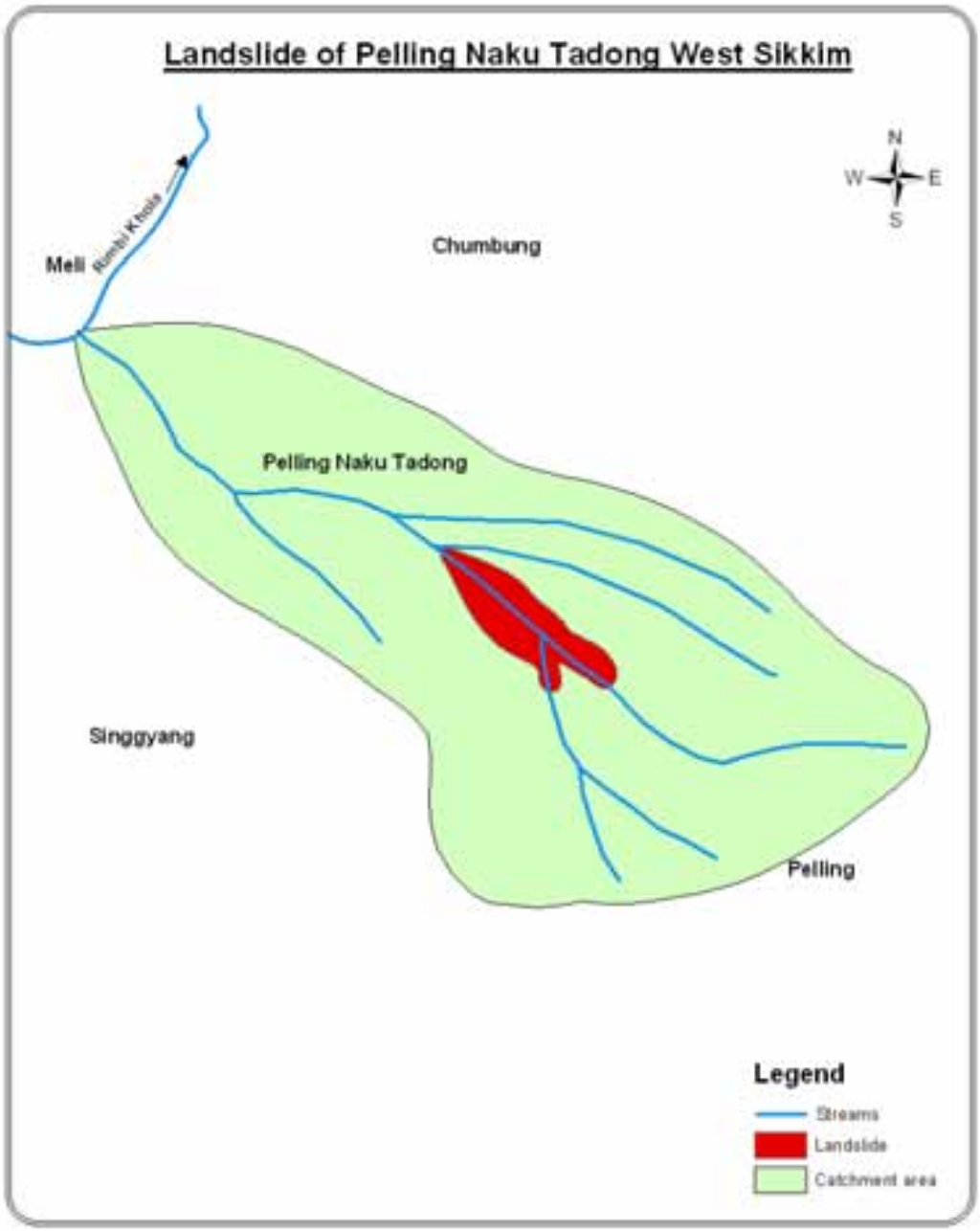
1. S.M.C Works
2. Afforestation.
3. Bamboo Plantation
4. Bally benching
5. Creation and maintenance of nursery
6. Application of Geosynthetic /Polymers
7. Regrading of slopes
8. Anchoring

The basic purpose of these bioengineering measures is to reduce slope angle; reduce surface tension; trap sediment; retard run-off; provide additional slope prevention for critical area above gullies. After the soil bioengineering works is done and the soil being thus retained paves way for another aspect that is enrichment of the nutrient in the soil. This is followed by afforestation, Plantation for soil binding, reducing water velocity, covering barren & exposed soil mass and overall improvement of environment.

1.9 Importance of this project and its replicability of results:-

The results obtained may or may not be directly applicable to all the hilly regions in the country but can certainly be replicated in similar geological regions with similar terrain, while other regions with a different topography can be replicated with slight modifications.

2 PELLING NAKU TADONG



GLOBAL POSITIONING SYSTEM

The landslide is conical in shape.

Top : N 27° 18' 33.6" EO 88°14'07.3" (accuracy 12 meters) elevation 1492 meters

Base : N 27° 18' 36.8" EO 88°14'01.8" (accuracy 8 meters) elevation 1396 meters

Side : N 27° 18' 36.7" EO 88°14'03.2" (accuracy 9 meters) elevation 1418 meters

Side : N 27° 18' 44.5" EO 88°13'57.8" (accuracy 11 meters)

This landslide area is quite a secluded area. To the north of the slide area lies the entire town of Lower Pelling which is one of the important tourist destinations of West Sikkim.

(Picture: Type of landslide in Pelling Naku Tadong)

2.1 Historical Account

1. The type of landslides in Pelling Naku Tadong were of slump and debris flow. The flow consisted of rapid mass movement in which loose soils, organic matter combine with entrained air and water to form slurry and then flows down slope. The flow mainly consisted of sandy soil mass of wet material that contains at least 50 percent sand-, silt-, and clay-sized particles, with viscous to fluid like motion of debris where the top soil had been completely washed away.

2. This erosion in this area dates backs to the year 1969. It was once a severe landslide prone area and also one of the most prominent sinking areas. During the entire period the land was totally barren. As informed by one of the supervisor in the area, the place was marshy and the whole area was inaccessible to walk. The area consists of sandy soil and the soil therefore being weak.

3. The area eroded was huge and above the eroded area is a crowded inhabitation (lower Pelling), however, this landslide area is at a safe distance from the eroded area. This landslide has proved to be a threat to the entire region of lower Pelling and could have hampered the entire region pulling areas from the upper region of the slide.

4. The area is marshy since a large number of seasonal water sources exist.

5. Seasonal springs are the characteristics of the Himalayan region. The springs continue to emerge seasonally especially during (June-July) rainy seasons, accompanied by the heavy rains which is one of the major disadvantage in the area.

6. Amongst many topographical pressures, there is an added anthropogenic pressure being invaded during the winter season to avail grass for fodder and fuel.

2.2 Water Sources:- Streams

(Pictures: Perennial streams in the area)

There is a presence of three perennial streams which merges to Rimbi khola. Water velocity of the streams are 0.377; 0.377; 0.2857 m/sec respectively with as average of 0.36 m/sec. One of the streams was mainly responsible for increasing the pace of the landslide, but this stream has been guarded by hand packed walls inside sausage guide walls on both sides of the stream, which has altogether helped in retaining the further slip of the area.

Addition to the perennial springs is the seasonal water sources which is numerous in number making the area damp and marshy. The other two streams run parallel to one another flowing longitudinally downward. The reason for the area being swampy is that the whole area is interspersed with seasonal water springs. The soil being sandy in nature it does not retain enough water in it, therefore the water runs along the surface of the slope.

2.3 Engineering work: - Area worked is 3 ha

Before

After

1. Hands packed walls inside sausage guide walls have been made extensively all over the area to a large extent from the top of the slide to the base at regular interval along steep slopes. This has also been done along the perennial springs to prevent it from expanding.

2. Due to the construction of Hands packed walls inside sausage guide walls a large number of tree species have regenerated in large amount. Herbs shrubs have invaded the area to a large extent. Thus, these stone packed walls have shown that this is an effective way in stabilizing the slope.
3. Numerous species have grown in that area and the Hands packed walls along the stream have proven to be the backbone in bringing stability to that area. Since the area has not only stabilized but also regenerated in terms of its flora.
4. The area is dominated by sandy soil which doesn't have much water holding capacity. Followed by the area is swampy, therefore a drain has also been built on the slope for proper channeling of water, which prevents excess sewage of water in the land.

2.4 Soil & Moisture Conservation Works

Cutting of species like *Macaranga denticulate, Rhus succedanea, Caruga pinnata, Schima wallichi, Shorea robusta, Terminalia myriocarpa, Tectona grandis* were planted.

2.5 Present Status

The area previously was in a very bad shape, with irregular terrain and difficult topography.

The condition of slope at present has regenerated to a large extent. Complete forestation has taken place and is satisfying. Although the soil present here is micaceous and since no seepage of water takes place The seasonal springs continue to emerge and run haphazardly, but due to the hand packed walls inside GI sausage that is built, prevents the erosion the soil and does not allow erosion of the soil randomly.

(Picture Above: Regenerated flora)
(Picture Below: Regenerated area from a distance)

There is an exuberant growth of *Alnus spp* in the entire region growing from the beginning of the slope till its base. However *Alnus spp* has helped in retaining the soil and given spaces for the smaller herbs and shrubs to grow adding to the expansion of flora in the region.

Herb species like *Eupatorium adenophorum* is also found equally distributed all over. The weed has the ability grow luxuriantly in diverse habitats, most of which being harsh and nutrient-deficient. It is therefore speculated that the vigorous growth may be due to the association of species with native symbiotic mycorrhizal fungi thus immobile nutrients *viz*, P, K, Ca, N, Zn and water to the host (Read *et al*. 1976, Cooper and Tinker 1978, Rhodes and Gerdemann 1978, Allen 1982, and Kothari *et al*. 1991).

2.6 RECOMMENDATIONS

- Since the drainage system is weak in terms of the soil present in the region, subsurface drainage pipes, perforated pipes, hume can be further laid down for further improvement of the area.

- Plant spp with high evapo-transpiration can be further used for transpiring excess water in the soil.

2.7 SOIL TEST REPORT PELLING

SEIVE ANALYSIS			
Location of Sample	**Pelling(shoulder area) Ao, Sandy**		
Date of Test	**19/02/2009**		
			IS=1498-1970
IS sieve sizes(mm)	**wt. of retained sample (gms)**	**Sample retained (%)**	**Sample passing (%)**
4.75	18.81	18.81	80.90
2.36	17.88	17.88	63.02
1.18	22.95	22.95	40.07
0.600	13.87	13.87	26.20
0.425	4.79	4.79	21.41
0.300	5.14	5.14	16.27
0.150	8.59	8.59	76.80
0.075	4.67	4.67	3.01
Pan	3.01	3.01	0.00
Gravel (%)=36.69	**Sand (%)=55.34**	**Silt (%)=4.67**	**Soil (%)=3.01**
Moisture content=8.55%			

SEIVE ANALYSIS			
Location of Sample	**Pelling Top soil (shoulder area) Ao_1, Sandy upto 2ft**		
Date of Test	**19/02/2009**		
			IS=1498-1970
IS sieve sizes(gm)	**wt. of retained sa mple(gms)**	**Sample retained (%)**	**Sample passing (%)**
4.75	30.62	30.62	69.08
2.36	17.89	17.89	51.19
1.18	15.99	15.99	35.20
0.600	13.59	13.59	21.61
0.425	5.43	5.43	16.18
0.300	6.14	6.14	10.04
0.150	6.98	6.98	3.06
0.075	2.21	2.21	0.85
Pan	0.85	0.85	0.00
Gravel (%)=48.51	**Sand (%)=48.13**	**Silt (%)=2.21**	**Soil (%)=0.85**
Moisture content=8.44%			

SEIVE ANALYSIS			
Location of Sample	**Pelling (shoulder area) base Sandy soil 2ft to 3½**		
Date of Test	**19/02/2009**		
			IS=1498-1970
IS sieve sizes(gm)	**wt. of retained sample(gms)**	**Sample retained (%)**	**Sample passing (%)**
4.75	36.18	36.18	63.66
2.36	16.01	16.01	47.69
1.18	15.46	15.46	32.19
0.600	14.88	14.88	17.31
0.425	5.08	5.08	12.23
0.300	4.35	4.35	7.88
0.150	5.42	5.42	2.48
0.075	1.69	1.69	0.77
Pan	0.77	0.77	0.00
Gravel (%)=52.19	**Sand (%)=45.19**	**Silt (%)=1.69**	**Soil (%)=0.77**
Moisture content=9.76%			

SEIVE ANALYSIS			
Location of Sample	**Pelling back slope, Top Layer 1½$f_{t)}$**		
Date of Test	**19/02/2009**		
			IS=1498-1970
IS sieve sizes(mm)	**wt. of retained sample (gms)**	**Sample retained (%)**	**Sample passing (%)**
4.75	37.80	37.80	62.16
2.36	12.77	12.77	49.39
1.18	11.71	11.71	37.68
0.600	6.61	6.61	31.07
0.425	2.55	2.55	28.52
0.300	3.66	3.66	24.86
0.150	12.26	12.26	12.60
0.075	8.50	8.50	4.10
Pan	4.10	4.10	0.00
Gravel (%)=50.57	**Sand (%)=36.79**	**Silt (%)=8.50**	**Soil (%)=4.10**
Moisture content=13.32%			

SEIVE ANALYSIS			
Location of Sample	**Pelling back slope**	**Middle Layer**	**1½ft to 3ft)**
Date of Test	**19/02/2009**		
			IS=1498-1970
IS sieve sizes(gm)	**wt. of retained sa mple(gms)**	**Sample retained (%)**	**Sample passing (%)**
4.75	29.64	29.64	70.08
2.36	12.66	12.66	57.42
1.18	11.44	11.44	45.98
0.600	6.71	6.71	39.27
0.425	2.81	2.81	36.46
0.300	5.47	5.47	30.99
0.150	17.72	17.72	13.27
0.075	9.15	9.15	4.12
Pan	4.12	4.12	0.00
Gravel (%)=42.30	**Sand (%)=44.15**	**Silt (%)=9.15**	**Soil (%)=4.12**
Moisture content=14.53%			

SEIVE ANALYSIS			
Location of Sample	**Pelling back slope**	**Base layer**	**3ft**
Date of Test	**19/02/2009**		
			IS=1498-1970
IS sieve sizes(gm)	**wt. of retained sample(gms)**	**Sample retained (%)**	**Sample passing (%)**
4.75	30.30	30.30	69.25
2.36	15.68	15.68	53.57
1.18	11.60	11.60	41.97
0.600	6.36	6.36	35.61
0.425	2.35	2.35	33.26
0.300	4.59	4.59	28.67
0.150	15.87	15.87	12.80
0.075	8.56	8.56	4.24
Pan	4.24	4.24	0.00
Gravel (%)=45.98	**Sand (%)=40.77**	**Silt (%)=8.56**	**Soil (%)=4.24**
Moisture content=11.39%			

SEIVE ANALYSIS			
Location of Sample	**Pelling(toe slope) 1½ft**		
Date of Test	**19/02/2009**		
			IS=1498-1970
IS sieve sizes(mm)	**wt. of retained sample(gms)**	**Sample retained (%)**	**Sample passing (%)**
4.75	31.42	31.42	68.35
2.36	20.96	20.96	4.73
1.18	17.96	17.96	29.43
0.600	8.36	8.36	21.07
0.425	2.69	2.69	18.38
0.300	2.79	2.79	15.59
0.150	7.81	7.81	7.78
0.075	4.81	4.81	2.97
Pan	2.97	2.97	0.00
Gravel (%)=52.38	**Sand (%)=39.61**	**Silt (%)=4.81**	**Soil (%)=2.97**
Moisture content=5.48%			

SEIVE ANALYSIS			
Location of Sample	**Pelling(toe slope)**		**1½ft to 2½ft)**
Date of Test	**19/02/2009**		
			IS=1498-1970
IS sieve sizes(mm)	**wt. of retained sample (gms)**	**Sample retained (%)**	**Sample passing (%)**
4.75	28.10	28.10	71.69
2.36	21.77	21.77	49.92
1.18	19.97	19.97	29.95
0.600	9.19	9.19	20.76
0.425	2.73	2.73	18.03
0.300	2.97	2.97	15.06
0.150	6.83	6.83	8.23
0.075	4.55	4.55	3.68
Pan	3.68	3.68	0.00
Gravel (%)=49.87	**Sand (%)=41.69**	**Silt (%)=4.55**	**Soil (%)=3.68**
Moisture content=5.42%			

SEIVE ANALYSIS			
Location of Sample	**Pelling(toe slope)**		**2½ft & below)**
Date of Test	**19/02/2009**		
			IS=1498-1970
IS sieve sizes(mm)	**wt. of retained sample (gms)**	**Sample retained (%)**	**Sample passing (%)**
4.75	27.64	27.64	72.01
2.36	22.72	22.72	49.29
1.18	18.07	18.07	31.22
0.600	8.37	8.37	22.85
0.425	2.65	2.65	20.20
0.300	3.45	3.45	16.75
0.150	7.61	7.61	9.14
0.075	5.11	5.11	4.03
Pan	4.03	4.03	0.00
Gravel (%)= 50.36	**Sand (%)=40.15**	**Silt (%)=5.11**	**Soil (%)=4.03**
Moisture content=9.27%			

SEIVE ANALYSIS			
Location of Sample	**Pelling(Toe slope) sandy soil**		**3ft**
Date of Test	**19/02/2009**		
			IS=1498-1970
IS sieve sizes(mm)	**wt. of retained sample(gms)**	**Sample retained (%)**	**Sample passing (%)**
4.75	29.64	29.64	70.28
2.36	19.47	19.47	50.81
1.18	18.51	18.51	32.30
0.600	10.61	10.61	21.69
0.425	3.71	3.71	17.98
0.300	3.97	3.97	14.01
0.150	7.22	7.22	6.79
0.075	4.15	4.15	2.64
Pan	2.64	2.64	0.00
Gravel (%)=49.11	**Sand (%)=44.02**	**Silt (%)=4.15**	**Soil (%)=2.64**
Moisture content=7.44%			

Table 1: Record of herbs species in Pelling Naku Tadong (sample plotting 10m x 10m)

Scientific name	No of individual in quadrant number	Total number of individual	Total no of quadrants of occurrence	Total no of quadrants studied	Abundance	Density
Artemisisia vulgaris	5+6+4+3	18	4	10	4.5	0.4
Elastostema obtusum	18+21+29+32	100	4	10	25	0.4
Eupatorium adenophorum	39+31	70	2	10	35	0.2
Polygonum molle	10+2+5+3	20	4	10	5	0.4
Cynodon dactylon	abundance					
Drymaria diandra Blume	abundance					
Eupatorium odoratum	abundance					

Table 2: Record of shrubs species in Pelling Naku Tadong (sample plotting 10m x 10m)

Scientific name	No of individual in quadrant number	Total number of individual	Total no of quadrants of occurrence	Total no of quadrants studied	Abundance	Density
Rubus ellipticus	5+10+3+6	24	3	10	8	0.3
Edgeworthia gardneri	7+5+10	22	3	10	7.3	0.3
Lantana camara	8+6+4	18	2	10	9	0.2
Osbeckia crinita	12+25+18+5+10	70	5	10	14	0.5
Boehmeria macrophylla	1+2	3	2	10	1.5	0.2
Dichroa febrifuga	3	3	1	10	3	0.1
Girardiana palmate	5+6+9+8	28	4	10	7	0.4
Sellaginella	Abundance					
Lycopodium	Abundance					

Note: Abundance is described as the number of individuals per quadrate of occurrence.
Density is the number of individual per quadrate.

Table 3: Record of tree species in Pelling Naku Tadong (sample plotting 10m x 10m)

Checklist of plant species Scientific name	No of individual in quadrant number	Total number of individual	Total no of quadrants of occurence	Total no of quadrants studied	Abundance	Density
Pieris ovalifolia	1+1	2	2	10	1	0.1
Ostodes paniculatus	1	1	1	10	1	0.2
Ficus roxburghii	1+1	2	2	10	1	0.2
Cinnamomum glanduliferum	1	1	1	10	1	0.1
Phyllanthhus emblica	1+3+1	5	3	10	1.66	0.3
Castanopsis tribuloides	1+ 1	2	2	10	1	0.2
Maesa chisia	1	1	1	10	1	0.1
Viburnum cordifolium	1+1	2	2	10	1	0.2
Schima wallichi	1+1	2	2	10	1	0.2
Mallotus nepalensis	3+ 9+ 5+ 3	20	4	10	5	0..4
Alnus nepalensis	70+ 71+ 14 + 52 + 20 + 10 + 53	290	7	10	41.428	0.7
Ficus bengalensis	1	1	1	10	1	0.1
Litsea polyantha	1+1	2	2	10	1	0.2
Engelhardtia spiciata	2+5+12	19	3	10	6.33	0.3

Note: *Alnus nepalensis* were found to be in abundance, since the plant has regenerated to a large extent. However, the species of *Alnus* grown had variations in height ranging from 3ft onwards to 3ft and girth ranging from I' to 10"

Note: Abundance is described as the number of individuals per quadrate of occurrence.
Density is the number of individual per quadrate.

2.8 PHOTO GALLERY

Photo Gallery of Pelling Naku Tadong Landslide

INITIALLY

Rock-cum-debris flow

Status of the area in the beginning

WORK IN PROGRESS

Hand packed stone wall inside sausage being built

Drainage wall for the channeling of water

Plantation of saplings in eroded area

Photo Gallery of Pelling Naku Tadong Landslide

Regeneration process

Augment growth of the flora

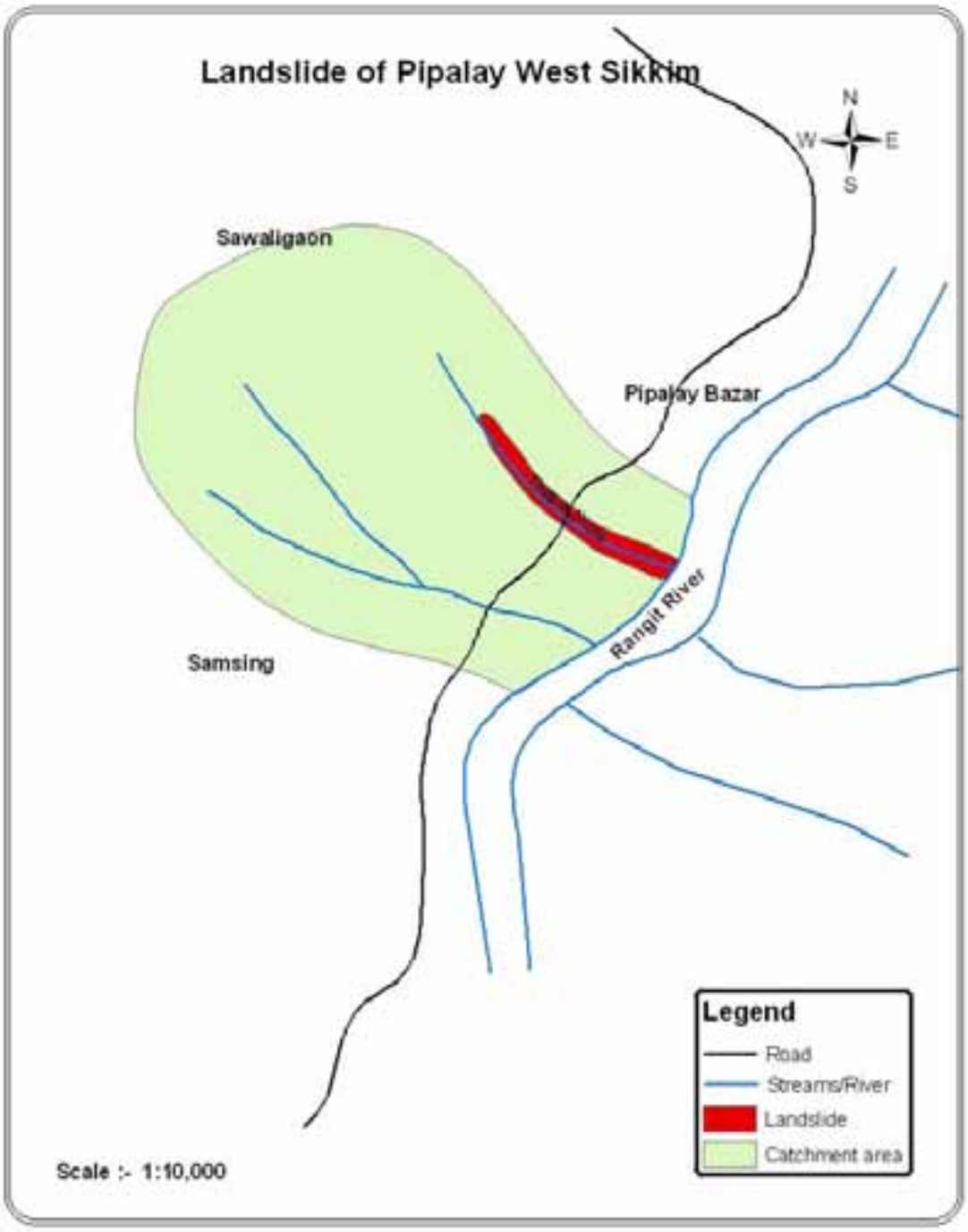
PRESENT STATUS

Regenerated area

Growth of Alnus nepalensis around the Hand Packed wall

Abundant growth of Alnus spp

3 PIPALAY



GLOBAL POSITIONING SYSTEM

Shoulder side : N 27° 09’ 44.9” EO 88° 17’26.0” (accuracy 12 meters) Elevation 508 mtrs

Shoulder side : N 27° 09’ 43.9” EO 88° 17’28.6” (accuracy 13 meters) Elevation 488 mtrs

Shoulder side : N 27° 09’ 44.1” EO 88° 17’31.4” (accuracy 14 meters) Elevation 428 mtrs

Side : N 27°09’44.1” ” EO 88° 17’31.4” (accuracy 14 meters)

Base : N 27°09’42.2” ” EO 88° 17’36.3” (accuracy 8 meters)

The area affected is Thapa Jhora which is surrounded by Sawaligaon on the north, Thapa Jhora busty to the west and Pipalay bazaar to the east and river Rangit to south. This Jhora drains down to the river Rangit intersected by road that connects west district of Sikkim to the other districts. Erosion in these roadside areas creates a major problem in the transport system of the district as well as the state itself; cutting west Sikkim from the rest of the state.

(Picture: Landslide area treated with base structure)

The landslide area is conical in shape; the width of the slope was approximately 57 meters. There is an inhabitation site alongside the slopes although unaffected by the landslide. Initially the area was barren and the main reason for the causation of this landslide is deforestation.

3.1 Historical account

(Pictures below: Landslide area showing rolling stones along the slope and held by sausage wall)

1. The type of landslides in Pipalay were of topple type consisting of falling boulders rocks along with the soil, down the slope The eroded material mainly consisted of rocks and boulders. The soil manly consists of eroding stones making it infertile for plantation. But alongside the Thapa jhora are numerous plants that have grown after the soil has been retained by the construction of Hand packed walls inside G.I sausage.

2. The area was once a heavy eroding landslide. The erosion of the area dates back to 1994-95.The area is a forest land (Khasmal), but on either side of the eroded area are habitation site, undisturbed by the landslide. The landslide however did not affect the habitation zone, being at a considerable distance from it. Although the occurrence of landslide was serious loss to the local inhabitants as it had completely washed down the vegetation site in the area. The habitation at present is thick and not much affected by the landslide.

3.2 Water Sources

The area is dry and arid. There is an absence of streams in this site in Pipalay (Thapa Jhora). Although, seasonal springs do exist, and velocity of the streams is negligible since all the water sources are channelized to different other places for irrigational purpose. Rateypani was the sources of water to this area but now it has been diverted to other area for irrigational purpose. All Surrounding area is a habitation zone. The streams usually remain dry during most parts of the year except during the month of June to August when there is heavy rainfall in the entire region.

3.3 Engineering Work

1. Hand packed walls inside G.I sausage have been built at regular intervals from the top of the slope continuously to the base of the slope. The spacing between the hands packed walls inside G.I sausage in the area is about approximately 3-5 meters.
2. This was mainly done in order to minimize the flow of the landslide from the top to the base, since the slope was steep and couldn't retain any soil.

(Picture: Site brought under control with gabion structures)

3. Slope grading is carried out frequently in the eroded area to prevent further erosion of the already eroded area.
4. Plum Cement Concrete 1:2:4 has also been done in certain places for stronger grip of the area. C.C.M walls have been built across the landslide in some of the areas.

The area is rocky and the flow of the landslide mainly consists of rocks and boulders. Since extensive hand packed walls inside G.I sausage have been built at regular intervals from the base of the slope to the top of the slope continuously, this has helped in the making the land stable, further regenerated the area as a whole. The presence of this hand packed walls inside G.I sausage prevents the mass movement of rocks and boulders, and prohibits its downward flow.

(Picture: Series of sausage walls)

3.4 Other Works Done

Coir matt was laid down in some places; this acts as an alternative to mulching process. Additionally this coir matt gradually decays in the soil thus forming the soil constituents. The Laying down of coir matt is however advantageous since it helps in soil binding plus helps in the growth of herbs and shrubs.

3.5 Soil & Moisture Conservation Works

Plantation like *Tectona grandis* (Teak), *Terminalia myriocarpa* (Pani Sanj), Bamboo, *Melia azadarach* (bakaino), *Duabanga sonneratioides* (lampate), Neem patti, *Tetrameles nudiflora* (Mainakath), Thysanolaena maxima (Amliso); have been done. This has however regenerated thus maintaining the floral species in this area.

3.6 Present Status of Pipalay Landslide at Thapa Jhora

(Picture: Engineering structures are supplemented with regeneration process)

1. The area on the whole is hot dry & humid. At present the landslide seemed to have stabilized and regenerated. Area which was barren previously is now much greener. The area has dense canopy of trees. Flora has grown extensively with an exuberant growth of teak.

2. At upper reaches the landslide has almost stabilized. The soil consists of black laterite soil accompanied by rocks and boulders.

3. During the winter season the streams almost get dried up. The streams are small and the water velocity is negligible.

3.7 Regeneration of the Flora

There is a dense canopy of trees. *Tectona grandis* (Teak) has grown exuberantly in the area. *Mikania cordata* which grows in abundance in this area can be profitable in the long run as it helps in retaining the texture of the soil.

Physiography of the slope: The degree of the slope at upper reaches 50° and 35-45° at lower reaches.

3.8 Recommendations

Alternatives to this area would generally be Afforestation to a large extent. Since Sal *Shorea robusta* is very suitable to this an area like this. The future prospect would be plantation of trees like *Shorea robusta* and *Terminalia myriocarpa.*

3.9 SOIL TEST REPORT PIPALAY THAPA JHORA

Sieve analysis			
Location of Sample	**Pipalay Thapa Jhora(Ao foot slope)**		
Date of Test	**19/02/2009**		
			IS=1498-1970
IS sieve sizes(mm)	**wt. of retained sample(gms)**	**Sample retained (%)**	**Sample passing (%)**
4.75	18.62	18.62	80.98
2.36	15.51	15.51	65.47
1.18	18.27	18.27	47.20
0.600	12.59	12.59	34.61
0.425	9.1	9.1	25.51
0.300	7.01	7.01	18.50
0.150	9.83	9.83	8.67
0.075	4.51	4.51	4.16
Pan	4.16	4.16	0.00
Gravel (%)= 34.13	**Sand (%)=56.80**	**Silt (%)=4.51**	**Soil (%)=4.16**
Moisture content=7.99%			

SEIVE ANALYSIS			
Location of Sample	**Pipalay Thapa Jhora Cr**	**(foot slope)**	
Date of Test	**19/02/2009**		
			IS=1498-1970
IS sieve sizes(mm)	**wt. of retained sample(gms)**	**Sample retained (%)**	**Sample passing (%)**
4.75	24.96	24.96	75.03
2.36	17.64	17.64	57.39
1.18	14.86	14.86	42.53
0.600	14.23	14.23	28.30
0.425	6.05	6.05	22.25
0.300	5.47	5.47	16.78
0.150	7.8	7.8	8.98
0.075	4.37	4.37	4.61
Pan	4.61	4.61	0.00
Gravel (%)=42.60	**Sand (%)=48.41**	**Silt (%)=4.37**	**Soil (%)=4.61**
Moisture content=6.52%			

SEIVE ANALYSIS

Location of Sample	**Pipalay(summit area)15m)**		
Date of Test	**19/02/2009**		
			IS=1498-1970
IS sieve sizes(mm)	**wt. of retained sample(gms)**	**Sample retained (%)**	**Sample passing (%)**
4.75	34.20	34.20	65.78
2.36	12.01	12.01	53.77
1.18	12.30	12.30	41.47
0.600	7.58	7.58	33.89
0.425	3.03	3.03	30.86
0.300	3.89	3.89	26.97
0.150	11.22	11.22	15.75
0.075	10.53	10.53	5.22
Pan	5.22	5.22	0.00
Gravel (%)= 46.21	**Sand (%)=38.02**	**Silt (%)=10.53**	**Soil (%)=5.22**
Moisture content=17.86%			

SEIVE ANALYSIS			
Location of Sample	**Pipalay (summit area)**	Below 15m	
Date of Test	**19/02/2009**		
			IS=1498-1970
IS seive sizes(gm)	**wt. of retained sa mple(gms)**	**Sample retained(%)**	**Sample passing(%)**
4.75	33.98	33.98	65.69
2.36	17.11	17.11	48.58
1.18	15.01	15.01	33.57
0.600	5.95	5.95	27.62
0.425	2.01	2.01	25.61
0.300	2.36	2.36	23.25
0.150	7.57	7.57	15.68
0.075	8.75	8.75	6.93
Pan	6.93	6.93	0.00
Gravel (%)=51.09	**Sand (%)=32.90**	**Silt (%)=8.75**	**Soil(%)=6.93**
Moisture content=13.28%			

SEIVE ANALYSIS			
Location of Sample	**Pipalay(summit area)**	**Cr layer**	
Date of Test	**19/02/2009**		
			IS=1498-1970
IS seive sizes(gm)	**wt. of retained sa mple(gms)**	**Sample retained(%)**	**Sample passing(%)**
4.75	8.58	8.58	90.74
2.36	6.59	6.59	84.15
1.18	7.94	7.94	76.21
0.600	8.54	8.54	67.67
0.425	4.36	4.36	63.31
0.300	5.28	5.28	58.03
0.150	17.08	17.08	40.95
0.075	21.41	21.41	19.54
Pan	19.54	19.54	0.00
Gravel (%)= 15.17	**Sand (%)=43.20**	**Silt (%)=21.41**	**Soil (%)=19.54**
Moisture content=23.38%			

Table 4: Record of Tree Species in Pipalay (sample plotting 10m x 10m)

Scientific name	No of individual in quadrant number 1,2,3……..10	Total number of individual	Total no of quadrants of occurance	Total no of quadrants studied	Abundance	Density
Anthocephalous cadamba	8+3	11	2	10	5.5	0.2
Macaranga denticulate	3	3	1	10	3	0.1
Bambusa spp	abundance			10		
Musa spp	1+2+3	6	3	10	2	0.3
Heynea trijuga	1+1	2	2	10	1	0.2
Sapium baccatum	2	2	1	10	2	0.1
Terminalia myriocarpa	3+1+3	7	3	10	2.33	0.3
Tectona grandis	2+1+1+1+5+4	14	6	10	2.33	0.6
Mallotus philippinensis	1+1+2	4	3	10	1.333	0.3
Ficus roxburghii F moraceae	3+1+2+1	7	4	10	1.75	0.4
Buddleia asiatica Butterfly bush	7+1	8	2	10	4	0.2
Symplosos phyllocalyx Symplocaceae	1+1	2	2	10	1	0.1
Tetrameles nudiflora datiscaceae	4	4	1	10	4	0.1
Litsea polyantha Juss	1+1+1	3	3	10	1	0.3
Bauhinia purpurea	1+1	2	2	10	1	0.2
Melia azadirachta	1	1	1	10	1	0.1
Melia azadarach	1+1	2	2	10	1	
Duabanga sonneratioides Ham sonneratiaceae	1	1	1	10	1	0.1
Mallotus nepalensis	1+2	3	2	10	1.5	0.2

Note: Abundance is described as the number of individuals per quadrate of occurrence.

Density is the number of individual per quadrate.

Table 5: Record of Herbs Species in Pipalay (sample plotting 10m x 10m)

Scientific name	**No of individual in quadrant number**	**Total number of individual**	**Total no of quadrants of occurance**	**Total no of quadrants studied**	**Abundance**	**Density**
Eupatorium adenophorum	**10+11+13**	**34**	**3**	**10**	**11.333**	**0.3**
Pilea anisophylla urticaceae	**9+7+12**	**28**	**3**	**10**	**9.33**	**0.3**
Benincasa hispida Climber F cucurbitabceae	3	1	10	3	0.1	
Calamus acanthospathus Areaceae	1	1	1	10	1	0.1
Ichinocarpus fructescens F: apocynaceae	1	1	1	10	1	0.1
Cucurbita moschata Poir			10			
Cynodon dactylon	15+20+25+14	74	4	10	18.5	0.4

Table 6: Record of Shrubs Species in Pipalay (sample plotting 10m x 10m)

Scientific name	**No of individual in quadrant number**	**Total number of individual**	**Total no of quadrants of occurrence**	**Total no of quadrants studied**	**Abundance**	**Density**
Thysanolaena maxima; poaceae	**10+11+16**	**37**	**3**	**10**	**12.3**	**0.3**
Morus alba	**9**	**9**	**1**	**10**	**9**	**0.1**
Lantana camara	**15**	**15**	**1**	**10**	**15**	**0.1**

Note: Abundance is described as the number of individuals per quadrate of occurrence.

Density is the number of individual per quadrate.

3.10 PIPALAY PHOTO GALLERY

Photo Gallery of Pipalay Landslide

Steep slope aggravates rolling stones

The same site brought under control with gabion structures strengthening site cuttings thereby improving natural regeneration

Series of sausage wall protected agricultural land and improved regeneration process

The same site fully stabilized now

Photo Gallery of Pipalay Landslide

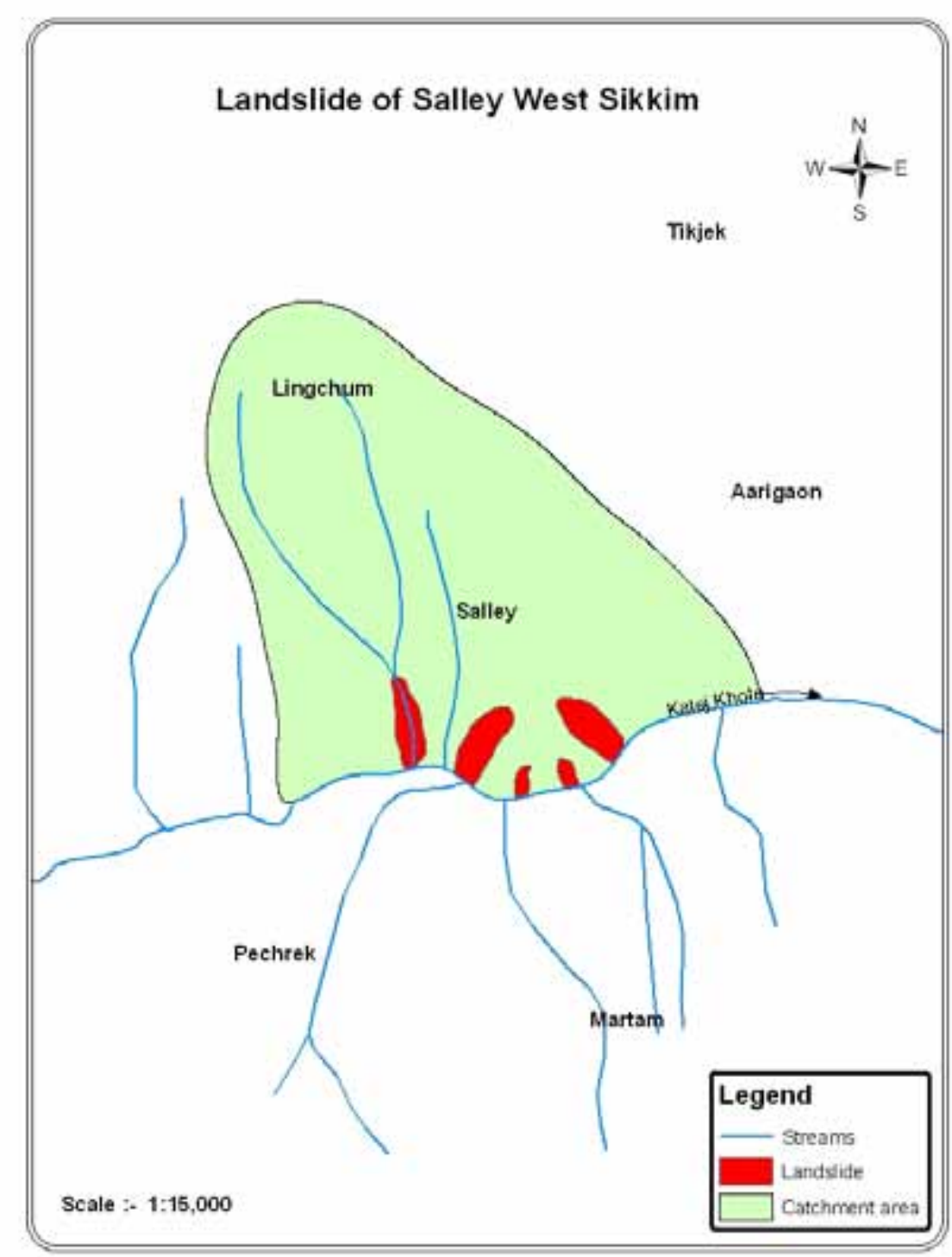
Mass movement of slush and debris checked by protective walls reduced silt flow and improved biomass production

The same area under complete vegetation

Faulty agricultural practice induced landslide and erosion; the sausage wall with Bio-engineering measures protected the agricultural land

Barren land treated with bio-engineering works & planted palatable fodder biomass,

4


Landslide of Salley West Sikkim
N
W
E
S
Tikjek
Lingchum
Aarigaon
Salley
Pechrek
Martam
Legend
Streams
Landslide
Catchment area
Scale :- 1:15,000

Salley is an agricultural land. On the upper site of Salley a new road is being constructed connecting the village Arigaon to lower Lunggchik. To the north Salley is Lingchom; to the right lies Parbok and to the left is Arigaon from where the road is being dug. To the south is Kalej River.

(The terrace lands frequently affected by fracture of land and cutting by Kalej Khola)

The topography of the region is such that there is an agricultural land extending from the summit of the slope towards the river base called Kalej khola. Since erosion and slip of the land is at the base of the slope, this has proved to be a great threat to the villages. This area at present is weak and fragile due to erosion at the base. The landslides are recent in origin (2005-06) as compared to the other area proposed in West Sikkim. The landslide is due to already existing landslide in the area. The previous landslides started from 1995 onwards. Existence of natural springs as well as seasonal springs occur widely and irregularly all over the area. These springs do not have a channelize flow as it flows downstream and flows irregularly on the surface layer leading to formation of gully; along with it carrying the rich soil nutrients. The surface runoff is percolated through the fissured and fragmented slopes aggravating the process of soil erosion and landslides.

4.1 Historical Background:-

The area affected by landslide extends to a vast stretch. The area thus proposed for treatment is large, the landslide is however not continuous but interspersed by a stable land in between. There is the presence of small landslide is in an array (many small landslides is seen to occur here and there).

(The type of Landslide in the area and the same area under control)

The type of Landslide in Salley were of the creep type, loose soil, in an around tree and bamboo grooves. The process of erosion is slow and gradual and the area eroded belongs to the forest land as well as private land. In the agricultural region above is also an inhabitation site. The erosion of land at the base is pulling the upper regions leading to formation of cracks in the slope. These cracks are quite big in size and during the rainy season, water penetrates into these cracks leading to excess sewage of water into the soil making it difficult to hold the added pressure of water and further weakening the soil.

Additionally, anthropogenic pressures from the agricultural land i.e. the paddy fields above adds to the misery of the already pitiable condition of the soil since water seepage takes place at a faster rate to meet paddy utilization. The reason stated by the local inhabitants for the cause of erosion is due to the paddy field above the eroded area. This perhaps remains in a debatable position as the advantage of terrace cultivation is that it holds water in the fields and prevents water logging. The constant toe cutting action and changes in the course of Kalej River is also responsible for the slope failure. People in this village fear of their area being washed away gradually.

4.2 Streams

There area the presence of a large number of seasonal springs running in a haphazard manner.

4.3 Engineering Works

Engineering works done in this area have benefited the area as a whole.

Hand packed walls inside G.I. Sausage is done in Forest land and Goucharan as well. These walls have been laid down to reduce slope angle, surface erosion, retard runoff and thus provide additional slope protection for area above gullies. The walls have been constructed at a certain interval where the surface runoff is high and in areas of gully formation. In between the walls are supplemented with vegetation to support stabilization.

(Picture: The landslide under control)

Jhora training works i.e. hand packed stone wall inside sausage have been built along the river beds to prevent the excess pressure on the banks of the river, further preventing the gush of water from eroding the soil mass and causing landslide. The works have enhanced the process of regeneration, soil binding thus reducing species stress and loose soil formation.

(River bank treatment reduces scouring action of river and strengthens bank)

(Control of toe erosion by engineering works Supplemented with vegetation)

4.4 Soil and Moisture Conservation Works

1. Cutting of soil binder species like kadam, dhokray, faledo, *Agape americana.* Plantation of Amliso (Broom Grass) is done.
2. The survival rate of plants is about 70%. The area where the Hand packed walls inside G.I Sausage is done has improved to a certain extent and afforestation of the area has survived. However, there have recently been landslides at certain interval in an irregular manner. This in return has proved to be a great threat to the villagers living in upper inhabitation zone.
3. Presence of climber *Mikania cordata* has disturbed the entire region as it does not allow planted saplings and other shoots to grow. This climber extends up to tall trees as well. The climber does not have strong roots, which would have helped in the soil binding process.
4. Small terraced contour works rendered effective moisture conservation and promotes growth of vegetation.
5. The extreme exposed sites are treated with bally benching activity to create relevant niche to allow vegetation succession.

(Pictures above: The growth of vegetation indicates positive impact of landslide treatment)

4.5 Other works done in the area:-

1. Dry cultivation was also done in this area by land use & Environment Department hoping this would be an alternative to the wet cultivation thus preventing further erosion, but the yield obtained by this dry cultivation method amounted to half the yield obtained through wet cultivation; Reasons for not gaining the optimum yield could be that the Indian Council for Agricultural Research had recommended Panti dhan to be used, but due to non availability of this type, locally available seeds Attey was used. Therefore this could be one of the probable reasons for the yield not being fruitful.
2. Coir mats made up off jute was laid down during rainy season to prevent erosion, in mulching process, soil binding process, further helping in the growth of certain herbs and shrubs. Mulch conserves moisture in soil, acts as an insulator. ***(Picture: Gentle slope with flying ash and moving soil checked with geo-textile technology supplemented with vegetation)***

3. Afforestation works: **-** Kaijal, Pani sans, Khanakpa, Okhar, Lopsi, Nimpatti, Chekrasi, Bakai, Bamboo were planted.

NOTE:-

- *Alnus spp* have grown extensively and overcrowded to a large extent. There is no spacing of the sapling *Alnus spp* which in turn affects the growth of the entire flora of the area. The exuberant growth of this Himalayan Alder has put a lot pressure on soil. A sample study of Pallard experiment to reduce the canopy and allow regeneration may be necessary.

4.6 Recommendations:-

1. The area requires an extensive drainage channel for a proper channelized flow of water so that there is no over pouring of water in the field and land. This will ultimately help in the prevention and expansion of gullies.
2. A Channelize flow of water is needed when fields are over flooded during monsoon and the sowing seasons.
3. The engineering structures should be supplemented by adequate and relevant species.
4. Neutralization of soil to enrich fertility may be necessary.
5. Bio-engineering measures should be given top priority.
6. Mass education, awareness and sensitization of local community on impact of landslides through institutionalization may be necessary.
7. High yielding paddy seed species selection for dry cultivation is necessary.
8. the practice of SLIP RESERVE should be revocated.

4.7 Further attention regarding the area in Salley:-

Salley is a fragile area and further works need to be done in this region to stabilize it. The whole terrain is covered by agricultural land and the dry cultivation method have not proved to be efficient enough since the yield obtained is only half of what is gained by wet cultivation. Therefore, wet cultivation continues in this area. The upper area is completely under agriculture and the lower region is barren as the people have stopped irrigating the fields due to the fear of land being eroded by the monsoon rains. However, the water from the agricultural fields run down the slope creating an unchannelize flow of water making the area vulnerable to erosion.

4.8 SOIL REPORT OF SALLEY

SEIVE ANALYSIS			
Location of Sample	**Salley**	**Back slope layer Ao**	**½ ft**
Date of Test	**13/03/2009**		
			IS=1498-1970
IS sieve sizes(mm)	**wt. of retained sample (gms)**	**Sample retained (%)**	**Sample passing (%)**
4.75	17.31	17.31	82.34
2.36	15.49	15.49	66.85
1.18	18.5	18.5	48.35
0.600	13.55	13.55	34.80
0.425	5.53	5.53	29.27
0.300	7.39	7.39	21.88
0.150	11.91	11.91	9.97
0.075	6.17	6.17	3.80
Pan	3.80	3.80	0.00
Gravel (%)=32.80	**Sand (%)=56.88**	**Silt (%)=6.17**	**Soil &Clay (%)=3.80**
Moisture content=2.54%	**Soil color:- Brown**	**Stone - 40%;**	**Twigs - 20%**

SEIVE ANALYSIS			
Location of Sample	**Salley**	**Back slope Ao layer**	**½ft to 1½ft**
Date of Test	**13/03/2009**		
			IS=1498-1970
IS sieve sizes(mm)	**wt. of retained sample (gms)**	**Sample retained (%)**	**Sample passing (%)**
4.75	12.92	12.92	87.01
2.36	18.54	18.54	68.47
1.18	21.61	21.61	46.86
0.600	16.12	16.12	30.74
0.425	5.60	5.60	25.14
0.300	7.62	7.62	17.52
0.150	12.8	12.8	4.72
0.075	3.88	3.88	0.84
Pan	0.84	0.84	0.00
Gravel (%)=31.46	**Sand (%)=63.75**	**Silt (%)=3.88**	**Soil &Clay (%)=0.84**
Moisture content=12.82%	**Soil color :- Brown**	**Stone – 40-45%;**	**Twigs – 10%**

SEIVE ANALYSIS			
Location of Sample	**Salley**	**back slope B layer**	**1½ft to 3½ft**
Date of Test	**13/03/2009**		
			IS=1498-1970
IS sieve sizes(mm)	**wt. of retained sample (gms)**	**Sample retained (%)**	**Sample passing (%)**
4.75	21.06	21.06	78.91
2.36	19.71	19.71	59.20
1.18	17.96	17.96	41.24
0.600	13.52	13.52	27.72
0.425	5.08	5.08	22.64
0.300	8.13	8.13	14.51
0.150	11.69	11.69	2.82
0.075	2.32	2.32	0.50
Pan	0.50	0.50	0.00
Gravel (%)=40.77	**Sand (%)=56.38**	**Silt (%)=2.32**	**Soil &Clay (%)=0.50**
Moisture content=7.30%	**Soil color :- Brown**	**Stone – 25-30 %; Twigs – absent %**	

SEIVE ANALYSIS			
Location of Sample	**Salley,**	**Cr back slope**	**3½ft below**
Date of Test	**13/03/2009**		
			IS=1498-1970
IS sieve sizes(mm)	**wt. of retained sample (gms)**	**Sample retained (%)**	**Sample passing (%)**
4.75	21.53	21.53	78.39
2.36	18.42	18.42	59.97
1.18	18.52	18.52	41.45
0.600	15.46	15.46	25.99
0.425	6.2	6.2	19.79
0.300	8.09	8.09	11.70
0.150	9.78	9.78	1.92
0.075	1.60	1.60	0.32
Pan	0.32	0.32	0.00
Gravel (%)=39.95	**Sand (%)=58.05**	**Silt (%)=1.60**	**Soil &Clay (%)=0.32**
Moisture content=10.28%			
Soil color :- Dark Brown			
Stone – 15-20 %; Twigs – absent %			

SEIVE ANALYSIS			
Location of Sample	**Salley**	**Summit layer**	**½ ft**
Date of Test	**13/03/2009**		
			IS=1498-1970
IS sieve sizes(mm)	**wt. of retained sample (gms)**	**Sample retained (%)**	**Sample passing (%)**
4.75	16.32	16.32	83.62
2.36	17.31	17.31	66.31
1.18	19.75	19.75	46.56
0.600	13.85	13.85	32.71
0.425	5.25	5.25	27.46
0.300	7.27	7.27	20.19
0.150	12.19	12.19	8.00
0.075	5.35	5.35	2.65
Pan	2.65	2.65	0.00
Gravel (%)=33.63	**Sand (%)=58.31**	**Silt (%)=5.35**	**Soil &Clay(%)=2.65**
Moisture content=7.17%			
Soil color :- black			
Stone – 15-20 %; Twigs – absent %			

SEIVE ANALYSIS			
Location of Sample	**Salley** **Summit layer B_1**		**1½ ft**
Date of Test	**13/03/2009**		
			IS=1498-1970
IS sieve sizes(mm)	**wt. of retained sample (gms)**	**Sample retained (%)**	**Sample passing (%)**
4.75	24.62	24.62	75.19
2.36	17.43	17.43	57.76
1.18	19.26	19.26	38.50
0.600	13.14	13.14	25.36
0.425	4.79	4.79	20.57
0.300	5.69	5.69	14.88
0.150	8.86	8.86	6.02
0.075	3.97	3.97	2.05
Pan	2.05	2.05	0.00
Gravel (%)=42.05	**Sand (%)=51.74**	**Silt (%)=3.97**	**Soil &Clay (%)=2.05**
Moisture content=7.60%			
Soil color :- Brown			
Stone – 20-25 %; Twigs – absent %			

SEIVE ANALYSIS			
Location of Sample	**Salley Black soil**	**Summit Ao_1**	**I½ft to 2ft**
Date of Test	**13/03/2009**		
			IS=1498-1970
IS seive sizes(mm)	**wt. of retained sample (gms)**	**Sample retained (%)**	**Sample passing (%)**
4.75	8.69	8.69	90.88
2.36	12.02	12.02	78.86
1.18	18.5	18.5	60.36
0.600	16.19	16.19	44.17
0.425	6.67	6.67	37.50
0.300	8.54	8.54	28.96
0.150	14.57	14.57	14.39
0.075	7.62	7.62	6.77
Pan	6.77	6.77	0.00
Gravel (%)=20.17	**Sand (%)=64.47**	**Silt (%)=7.62**	**Soil &Clay(%)=6.77**
Moisture content= 14.27%			
Soil color :- Brown			
Stone – 15-20 %; Twigs – absent %			

SEIVE ANALYSIS			
Location of Sample	**Salley**	**Summit**	**(Cr layer)**
Date of Test	**13/03/2009**		
			IS=1498-1970
IS sieve sizes(mm)	**wt. of retained sample (gms)**	**Sample retained (%)**	**Sample passing (%)**
4.75	40.95	40.95	58.89
2.36	17.6	17.6	41.29
1.18	14.15	14.15	27.14
0.600	9.54	9.54	17.60
0.425	3.29	3.29	14.31
0.300	4.51	4.51	9.80
0.150	6.74	6.74	3.06
0.075	2.24	2.24	0.82
Pan	0.82	0.82	0.00
Gravel (%)=58.55	**Sand (%)=38.23**	**Silt (%)=2.24**	**Soil &Clay(%)=0.82**
Moisture content=9.72%			
Soil color :- Shiny brown			
Stone – 25-35%; Twigs – absent %			

Table 7: Record of tree species in Salley (sample plotting 10m x 10m)

Scientific name	No of individual in quadrant number	Total number of individual	Total no of quadrants of occurrence	Total no of quadrants studied	Abundance	Density
Alnus nepalensis	4+1+3+20+19	47	5	10	9.4	0.5
Evodia fraxinifolia	5	5	1	10	5	1.1
Melia azedarach	1+2	3	2	10	1.5	0.2
Melia azairachta	1+2	3	2	10	1.5	0.2
Terminalia myriocarpa	3+4	7	2	10	3.5	0.2
Buddleia asiatica	1+1	2	2	10	1	0.2
Duabanga sonnertoides	2	2	1	10	2	0.1
Mallotus nepalensis	1+1	2	2	10	1	0.2
Bambusa spp	2+13+16+3+7+14	55	6	10	9.16	0.6
Linustrum confusum	1	1	1	10	1	0.1
Albizza procera	1+3+	4	2	10	2	0.2
Ficus clavata	2+3+4+1	10	4	10	2.5	0.4
Pilea spp	1+	1	1	10	1	0.1
Faledo	2	2	1	c	2	0.1
Dhokray	6+30	36	2	10	18	0.2
Hattibar	5+4+6	15	3	10	5	0.3
Gungring	3+3+4+5+6+3+3+3	30	8	10	3.75	0.8
Nango rukh	1+1+3	5	3	10	1.66	0.3
Amara	1	1	1	10	1	0.1
Musa spp	1+13+11	25	3	10	8.33	0.3

Note: Abundance is described as the number of individuals per quadrate of occurrence.

Density is the number of individual per quadrate.

Table 8: Record of shrub species in Salley (sample plotting 10m x 10m)

Scientific name	No of individual in quadrant number	Total number of individual	Total no of quadrants of occurrence	Total no of quadrants studied	Abundance	Density
Boehmeria macropylla	6+9	15	1	10	15	0.1
Morus laevigata Wall	20+13+15+20	68	4	10	17	0.4
Thysanolaena maxima	3+12+11+16+13	55	5	10	11	0.5
Lantana camara	2+2+2+5	11	4	10	2.75	0.4
Datura metel	2	2	1	10	2	0.1
Agape Americana	5+4+2+1	12	4	10	3	0.4

Table 9: Record of herb species in Salley (sample plotting 10m x 10m)

Scientific name	No of individual in quadrant number	Total number of individual	Total no of quadrants of occurance	Total no of quadrants studied	Abundance	Density
Heliotropium indicum				10		0.
Drmaria dyandra Blume1	abundance			10		0.
Nicotiana tabacum	1+5	6	2	10	3	0.2
Cynodon dactylon	10+15	25	2	10	12.5	0.2
Eupatorium adenophorum	15+12+11+13+16	67	5	10	13.4	0.5

Note: Abundance is described as the number of individuals per quadrate of occurrence.

Density is the number of individual per quadrate.

4.9 PHOTO GALLERY

Photo Gallery of Salley Landslide

Landslide study team in Salley watershed

Total landscape of Salley at a distance

Wet cultivation is one of landslide aggravation;
Treatment of the site cutting with sausage wall rendered protection
.

Degraded land brought under cultivation with contour bounds

Kalej khola at the base of the slope, a major problem creater.

Movement of slush, boulders and soil checked with local dry stone wall

Part of Agricultural land damage due to landslide and erosion- A common feature.

Part of Agricultural land damage and the formation of gullies

Landslide interspersed in between stable area

Area required landslide treatment

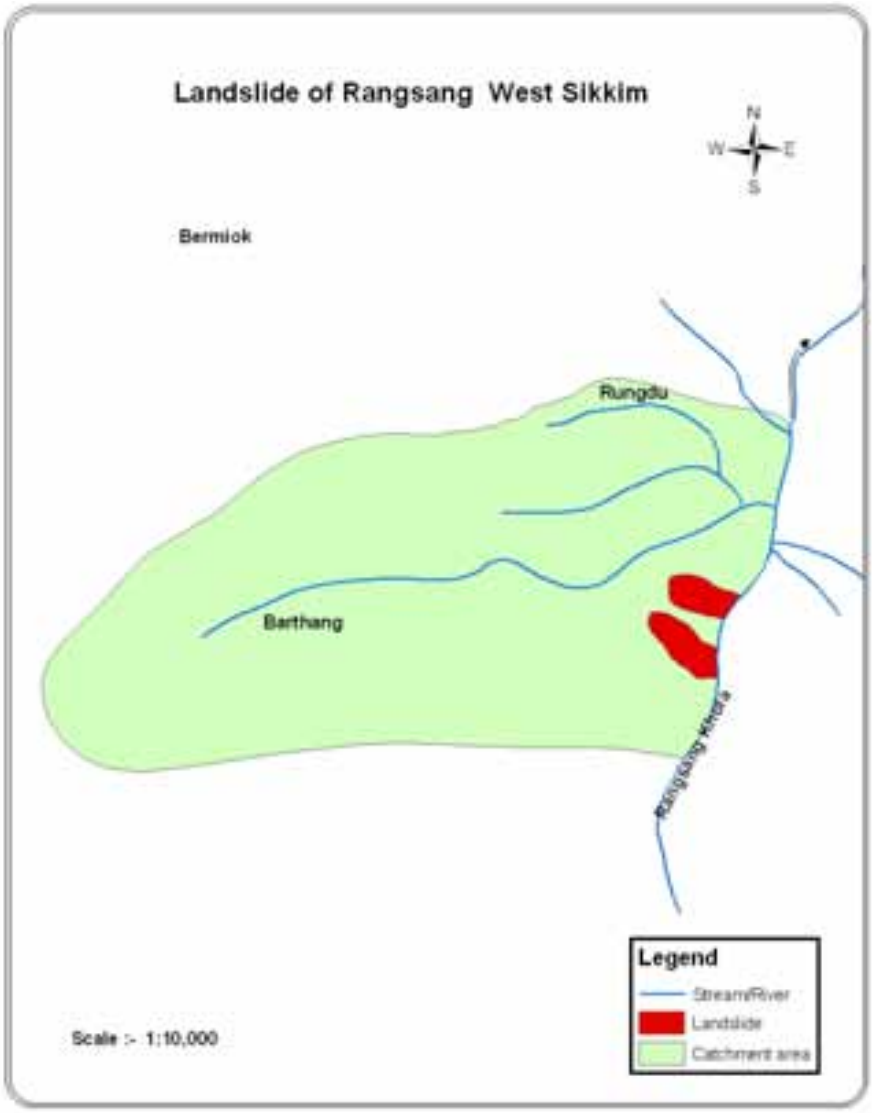
Area required landslide treatment

Drainage channel

Improvement of tree, shrub and grasses in the watershed area

Impact of 1st treatment of landslide with profuse growth of local species.

Agape spp strengthens landslide area and helps in regeneration of the area



The area is similar to that of Salley but the land in this area has stabilized to a large extent. In Comparison to Salley this area seems to have regenerated wholly.

GLOBAL POSITIONING SYSTEM

The landslide is stretched out to a vast area,

Top: - N 27° 15' 08.1" EO 88° 15' 06.0" (Accuracy 10 Meters) Elevation 1006 metres.

Side: - N 27° 15' 02.8" EO 88° 15' 14.5" (Accuracy 12 Meters) Elevation 1006 metres.

5.1 Historical background:-

The type of Landslide in Rangsang is of the creep type with slow and steady movement of soil or rock, often indicated by curved tree trunks. The landslide area is watershed area and situated at the base of the entire region towards the Rangsang river. The landslide in this area is very old and the year that took place is approximately 1990. As per the version of the villagers, the area was totally washed away by heavy and incessant rain during 1990. Loss of life, extensive damage of property and agricultural land by heavy landslide has been reported. The scares of the horrifying incidents are visible even today. Mental stress of villagers is still fresh in their mind. However, at present the landslide has productively stabilized and secondary succession to a large extent is noticeable. The works in this landslide started only in the year 2004. Thereafter the area has rapidly regenerated in terms of its vegetation.

The landslide seemed conical in shape; since the area is huge it was difficult to demarcate the eroded area. Although some land have been eroded at certain interval the intensity is small and do not impose a serious threat in future. Here also there is an array of landslide interspersed by a stable land in between them.

(Picture: Treated landslide with fast regeneration of vegetation)

Trees like *Schima wallichi* have been uprooted during its course of erosion, but due to their length they have not been able to carry it at a considerable distance from its uprooted area. These uprooted trees in turn have helped in retaining the soil and then growth of certain grasses, herbs and shrubs. A little intervention of sal reveals visible growth of vegetation.

Impact of landslide indicated growth of vegetation

5.2 Streams:-

Seasonal springs which is characteristic of the Himalayan region exists in this region also, but the scene here were particularly different since the flow of the spring waters ran through the Hand packed walls inside GI sausage. Therefore the irregular flow of water randomly in the region has reduced.
Presence of perennial springs draining into Ransang river and finally merging to the Kalej river.

(Picture: Impact of Bio-engineering treatment of heavy landslide zone. A fully stabilized site)

5.3 Engineering works done:-

The total area where works done accounted for is 22 ha.Hand packed walls inside GI sausage has been built at areas which were heavily eroded and at regular interval where gullies are present. The former lead to stabilization of land and latter prevented the gullies from expanding.

(Pictures above: Protection of landslide with sausage wall rendered protection of agricultural forest land)

Certain areas where the trees have been uprooted by the landslide have alternatively helped in detaining the eroded soil. River training work was done along the Rangsang river at the base to prevent further erosion of the land near the river area.

Protection of cardamom field with toe walls

5.4 Soil & moisture conservation works:-

Plantation of species like *Bischofia japonica*, *Thysanolaena maxima,* Bamboo, faledo. *Lantana camara* were done throughout the area. This species have done extremely well with its characteristic property of binding the soil and water holding capacity. Another added advantage is that of the pteridophytic species that is *Dicranopteris linearis* were found to be in abundance all over the area. *Dicranopteris linearis* can grow on poor soils and scramble over steep slopes, quickly taking over bare soil after a land slide, or soil affected by erosion and other wastelands. The quick growing fern helps to bind the soil and return nutrients to the soil. The slender, spreading rhizomes and the mat of old leaves protect the soil from further erosion while the young leaves trap debris. It also controls air pollution and improves water regime.

Fern spp. regulate dust pollution and maintain water regime.

Broom sticks grass control and stabilize erosion. It provides fodder, fuel wood and broom improving local economy

Fully stabilized watershed

Table 10: Record of tree species in Rangsang (sample plotting 10m x 10m)

Checklist of plant species Scientific name	No of individual in quadrant number	Total number of individual	Total no of quadrants of occurrence	Total no of quadrants studied	Abundance	Density
Alnus nepalensis	40+15+3+14	72	4	10	32	0.4
Mallotus nepalensis	9+8+3	20	3	10	6.66	0.3
Buddleia asiatica	3	3	1	10	3	0.1
Psidium guayava	2	2	1	10	2	0.1
Ficua clavata	1+1+1	3	3	10	1	0.3
Bambusa natans	2+3	5	2	10	2.5	0.2
Ostodes paniculatus	2+3	5	2	10	2.5	0.2
Chekrasi	1	1	1	10	1	0.1
Jhusulpate	9+8+1	18	3	10	6	0.3
Oroxylum indicum	1+1	2	2	10	1	0.2
Litsea polyantha	1	1	1	10	1	0.1
Ficus roxburghii	1+1	2	2	10	1	0.2

Note: Abundance is described as the number of individuals per quadrate of occurrence.

Density is the number of individual per quadrate.

Table 11: Record of shrub species in Rangsang (sample plotting 10m x 10m)

Checklist of plant species Scientific name	No of individual in quadrant number	Total number of individual	Total no of quadrants of occurrence	Total no of quadrants studied	Abundance	Density
Thysanolaena maxima,	8+10+9+11+6	44	5	10	8.8	0.5
Vaccinium retusum	2	2	1	10	2	0.1
Osbeckia crinata	3+4+2+1	10	4	10	2.5	0.4
Bauhinia variegate	Abundance			10		

Table 12: Record of herb species in Rangsang (sample plotting 10m x 10m)

Checklist of plant species Scientific name	No of individual in quadrant number	Total number of individual	Total no of quadrants of occurrence	Total no of quadrants studied	Abundance	Density
Eupatorium odoratum	9+5+6	20	3	10	6.66	0.3
Eupatorium adenophorum	6+7+5	18	3	10	6	0.3
Cynodon dactylon	11+12+13	36	3	10	12	0.3

Note: Abundance is described as the number of individuals per quadrate of occurrence.

Density is the number of individual per quadrate.

5.5 PHOTOGALLERY

Photo Gallery of Rangsang Landslide Area

Type of debris flow

Patches of landslides in the area

Uprooting of tress by erosion and the retention of soil by the blockage by the tree trunks.

Regeneration of flora

Abundant growth of Thysanolaena maxima

Engineering works supplemented with vegetation

Retention of the soil by hand packed stone wall
Inside G.I sausage, therefore profuse vegetation growth

Retention of the soil by hand packed stone wall
Inside G.I sausage, therefore profuse vegetation growth

6 SOIL TEST REPORT

Soil is a layer of natural materials on the earth's surface containing both organic and inorganic materials capable of supporting plant life, the material that covers the earth's surface in a thin layer. It may be covered by water, or it may be exposed to the atmosphere. Ideal soil should contain about 50% solid material and 50% pore space. Soil contains four main components: inorganic material, organic matter, water, and air. About half of the pore space should contain water and half of the space should contain air. Soil organic matter consists of decaying plant and animals. There are two types of organic matter. Original tissue is that portion of the organic matter that can still be recognized. Twigs and leaves covering a forest floor are good examples. Humus is organic matter that is decomposed to the point where it is unrecognizable. Purposes of organic matter: affects the soil structure by serving as a cementing agent, returns plant nutrients to soil, helps store soil moisture, makes soil more tillable for farming, and provides food (energy) for soil microorganisms, which makes the soil capable of plant production.

A soil test can be an important management tool in developing an efficient soil fertility program, as well as monitoring a field for potential soil and water management problems. A soil test provides basic information on the nutrient supplying capacity of the soil.

The parameters for checking the fertility of the soil lie in testing the chemical properties of soil Chemical Properties of Soil that is:-

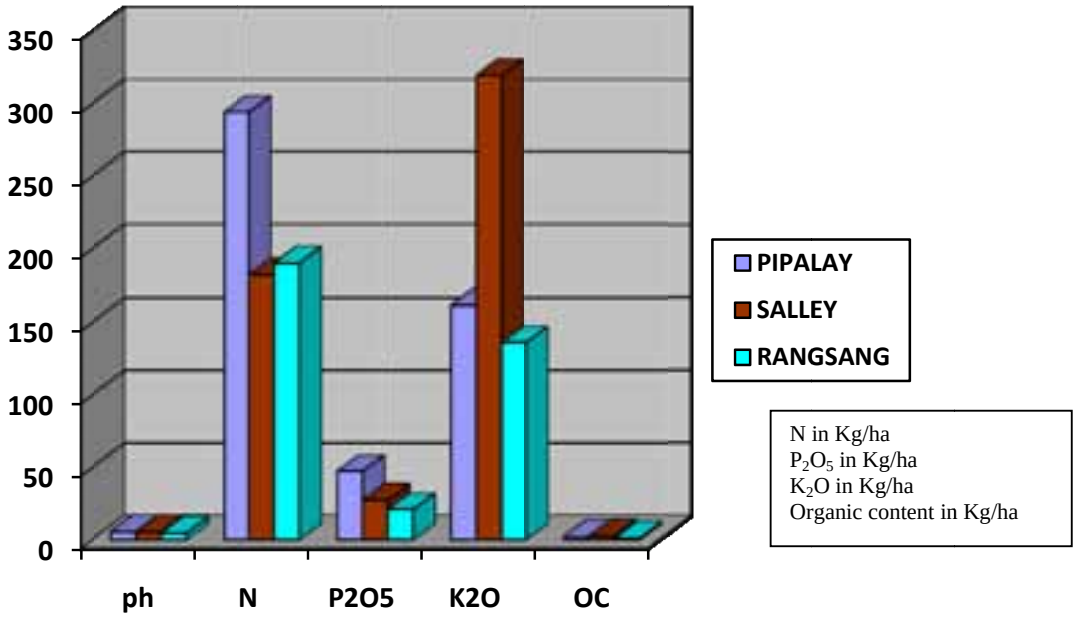
- Cation Exchange Capacity (CEC)
- pH
- Salinity

All living organisms are sensitive to pH. The plant roots will not function optimally in soils outside a specific pH range unique to that organism. If the pH of the soil is extreme either alkaline or acid, the plant will die. Soil microorganisms, insects, and other animals present in the rhizosphere are equally sensitive to pH. Alkaline soils have pH 7.5 - 8.5.Acidic soils have pH 4 - 6.5.Soils with pH values outside these ranges is usually toxic to most plants.

pH of the soil in the regions of West Sikkim consists of high pH but the soil testing analysis reports show that the soil is slightly acidic in nature and within the permissible range. It is therefore evident that the vegetation in these areas has decreased the acidic condition of the soil making it suitable for the succession of the plants.

6.1 Fertility index

Chemical Evaluation	Name of Erosion Site		
	Pipalay	**Salley**	**Rangsang**
pH	**5.6**	**5.8**	**4.8**
N	**294.00kg/ha (medium)**	**182.0 kg/ha (medium)**	**190.0kg/ha (medium)**
P_2O_5	**47.50 kg/ha (high)**	**27.50 kg/ha (medium)**	**21.00 kg/ha (medium)**
K_2O	**162.00 kg/ha (medium)**	**319.50 kg/ha (high)**	**136.00 kg/ha (medium)**
Organic content	**2.36 kg/ha (high)**	**2.75 kg/ha (high)**	**1.23 kg/ha(medium)**



Watershed area	Location of the Sample	Gravel %	Sand %	Silt %	Soil %	Moisture content %
Pelling Naku Tadong	Shoulder side, top	36.69	55.34	4.67	3.01	8.55
	Shoulder side, middle	48.51	48.13	2.21	0.85	8.44
	Shoulder side, base	52.19	45.19	1.69	0.77	9.76
	Back slope, top	50.57	36.79	8.50	4.10	13.32
	Back slope, middle	42.30	44.15	9.15	4.12	14.53
	Back slope, base	45.98	40.77	8.56	4.24	11.39
	Toe, top	52.38	39.61	4.81	2.97	5.48
	Toe, middle	49.87	41.69	4.55	3.68	5.42
	Toe base	50.36	40.15	5.11	4.03	9.27
Pipalay	Footslope Ao	34.13	56.80	4.51	4.16	7.99
	Footslope Cr	42.60	48.41	4.37	4.61	6.52
	Summit area Ao	46.21	38.02	10.53	5.22	17.86
	Summit area Ao_1	51.09	32.90	8.75	6.93	13.28
	Summit area Cr	15.17	43.20	21.41	19.54	23.38
Salley	Bask slope Ao	32.80	56.88	6.17	3.80	2.54
	Bask slope Ao_1	31.46	63.75	3.88	0.84	12.82
	Bask slope B	40.77	56.38	2.32	0.50	7.30
	Bask slope Cr	39.95	58.05	1.60	0.32	10.28
	Summit Ao	33.63	58.31	5.35	2.65	7.17
	Summit Ao_1	42.05	51.74	3.97	2.05	7.60
	Summit B	20.17	64.47	7.62	6.77	14.27
	Summit Cr	58.55	38.23	2.24	0.82	9.72

After fertility test and soil profile analysis, it was found that "Gravelly Loamy" sand is predominant through the catchment area of erosion sites in West Sikkim. Due to the high percentage of gravel, sand and silt, water holding capacity of soil is very negligible. As a result, flush of rain may erode huge mass of gravel with sand. Hence, sausage walls have been built to reduce slope angle, retard run off and trap sediments etc. This reduction of slope angle retains the debris and therefore new succession of plan is availed.

7 COMMUNITY PARTICIPATION

The Government of India approved and sanctioned a project under TDET scheme for treatment of landslide and erosion control work in West Sikkim since 2004-2005. In the guidelines, awareness and training were emphasized for community participation in the proposed watershed areas. Community participation with regard to training of farmers forms an integral part of the project.

Successful implementation of the work largely depends on the involvement of the people living in and around the targeted area. Therefore, when a work is being carried out in a proposed area, it is important for the localities of the targeted area to be well informed about the project. Often there is a lack of communication between the Project Implementing Agency and the people living at the grass root level. Therefore there is a need for unison in the successful implementation of the project in an area. This can only be met in the form of community participation.

Community participation is one amongst the most important weapon in the successful completion of the project and combating the natural disaster. Community participation can only be brought about in the form of awareness activities; likewise, awareness activities were carried out by the Project Implementing Agency (PIA) the DFO (LU &E) West district in the watershed areas namely, Pipalay, Salley, Rangsang and Pelling Naku Tadong. The awareness activities in the watershed area were conducted before initiation of the work. Suggestions were taken from the people living in and around the area of the landslide. The people gathered were gravely concerned about the landslides. The basic agenda for awareness were fertility improvement, moisture improvement, and landslide treatment and erosion control. The participants included were the farmers and local habitants.

An awareness programme on implementation of dry cultivation methods under TDET scheme by Indian Council of Agricultural Research (ICAR) for purpose of experiment was carried out. The awareness programme was mainly initiated in order to convince the villagers regarding the new technology development and training programme to control landslide and erosion. Dry cultivation was thought to be an alternative to wet cultivation since both the sites in Salley and Mangthang are hilly slopes where generation of water in rainy season is high. However, this did not turn out successful since the turnover of rice production was found to be almost half of what is obtained when wet cultivation process is followed. Nevertheless, dry cultivation will certainly reflect positively in future prospect since percolation of water gets reduced. The people in rural areas hence need to be educated in terms of dry cultivation methods and its extension programmes.

Adding to the awareness factor is the participation of the people. While bio-engineering works were being carried out in the area, the labor employed were the local unemployed youth; on doing this the people have an additional source of income and gain experience in the long run. This would not

only ensure proper work in their area but also make them self reliant in conducting minor works to sustain the eroded area in case of any threat in the future.

Since a good rapport was maintained by the officials and field staff with the local people during the course of work; helpful suggestions were taken from the people. The people in the process were educated in terms of fertility improvement, moisture improvement, treatment of eroded area etc. Further discussions about the biological, engineering measures on landslide were made.

Apart from educating the inhabitants of the landslide area, the awareness activities were initiated during the most celebrated days of the department i.e. World Earth Day, Wetland day, and World Environment day and so on. These programmes were carried out with the help of teachers, students, panchayat members and the unemployed youth to convey message on environment related issues. During these events, people were educated in the Global warming issues, and measures to help reduce the problem by being conscious and aware. World Wetland Days were celebrated keeping in mind the motive of Preservation & Conservation. Culturally, wetland areas like lakes are considered sacred. Its manifest function is traditionally accepted to be divine and the latent function to preserve and conserve. As far as preservation and conservation is concerned, State Green Mission which focuses on sustainable development was highlighted to the people for wider information.

Co-ordination meetings were conducted with Indian Council of Agricultural Research (ICAR) for dry cultivation methods in Salley, experimenting on whether the dry cultivation would be preferable in hilly area; Mines, Minerals and Geology Department, (Government of Sikkim) for soil testing Analysis and anchoring of rocks in fragile areas, G. B. Panth Institute (Pangthang) for monitoring and evaluation process; regarding the TDET project.

Extension

This project aims in extension works by raising rich biomass; plantation and conservation of locally available plant species to be the basic onward activities. An example, *Thysanolaena maxima* (broom grass) has a commercial importance for supply of this broom grass to nearby factories. So this plant species have soil binding properties as a result of which it serves two purposes, beneficial to the people for economy and for the sustainability of land. The people on their own can plant species like this which is profitable in both ways. Another factor is Bamboo which prevents erosion and is needed mostly in the villages in many occasions also for bally benching purposes where landslide is mild.

Since in certain area *Alnus spp* grows exuberantly, an effort by the people to sincerely protect and prevent felling activity would help in regeneration of the area. Further, anthropogenic pressure for availing fodder for fuel wood in the eroding area needs to be minimized. Controlled grazing or rotational grazing to be carried out which will prove to be helpful in checking soil erosion to some extent. The trees and shrub species can be grown on the fringes of the landslide area to prevent invasion of landslide area by humans and animals leaving the area for its regeneration.

8 CRITICAL ANALYSIS

The landslides in all the areas studied have shown colossal growth in terms of its flora. The bio-engineering works and soil moisture conservation works have blended very well to stabilize the area. The topography of all the studied area is different. The type of erosion varied from place to place with debris flow, rock cum debris flow to falling boulders. As a result of which, each area have shown variation in terms of the flora adapted to the region.

Positive impact of landslide treatment

Among all the landslide areas studied, the most common tree species found were the common Himalayan alder, *Alnus nepalensis*. This tree species were found in abundance in almost all the landslide regenerated areas.

There is an overcrowding of Utis and the quadrant studies witnessed about 100-120 number of *Alnus* trees in the quadrant of 10m X 10m. However, there is an interspecies struggle of this *Alnus spp,* as a result of which they compete for space and existence, hence, all species that regenerate do not attain maturity. At present the available height of the tree species range from 3ft and above. But those that attain maturity can be successful in preventing soil erosion. Since this *Alnus spp* grow well on soils with high water content, it does not require high soil fertility, but indeed it improves the soil and enhances its nutrient level.

Alnus spp being a pioneer species grow well in full light and preferably permeable soils. It forms a symbiosis with N-fixing actinomycetes of the genus *Frankia*. Although the biochemistry and physiology of the 'alder-type' symbiosis with *Frankia* are not fully understood, cell-free preparations of nitrogenase have been obtained from, *Alnus* nodules (Postgate 1979). Studies in West Bengal indicated that nitrogenase activity was highest in young nodules irrespective of tree age and concluded that; *A. nepalensis* is capable of fixing significant amounts of nitrogen (Sharma and Ambast 1984). Sharma et al. (1985) investigating soil properties under five stands in the Eastern Himalaya found that total soil N increased with increasing stand age.

(Positive impact of landslide treatment)

In area like Rangsang, lot of *Agave Americana spp* was found. This is an evergreen and a perennial shrub introduced in landslide area of Salley. This shrub acts as a soil binding species and prevents soil erosion in the slip area. This shrub species is also favored in the region of Salley which is a hot and a humid area.

Ageratum conzzoides a climber species found in many areas of Pipalay is found to be distributed throughout the area. An advantage of this climber is that it acts as a mulching agent in the soil and does not enable direct penetration of water to the soil.

Another climber species that is *Mikania cordata* was distributed throughout the area in Salley. It is a rapidly-growing, creeping perennial vine up to 10 m long, and grows to such extent and height that it twines around young trees, smothering them and form dense, tangled mass. *M. cordata* contains a substance that inhibits growth of other plants. The presence of such species is a necessary evil, since it acts as a mulching agent, and at the same time invades the other trees and shrub species hindering then in their growth.

(Presence of root nodules and improvement of Mycorrhiza)

Presence of Pteridophytic species like *Dicranopteris linearis* (bhui amala) was found to be in abundance. Being among the few plants that can grow on poor soils and scramble over steep slopes, this species quickly takes over bare soil after a land slide, or soil affected by erosion and other wastelands. The quick growing fern helps to bind the soil and return nutrients to the soil. The slender, spreading rhizomes

and the mat of old leaves protect the soil from further erosion, while the young leaves trap debris. As these decay, nutrients are returned to the soil. However, few plants can grow where *Dicranopteris linearis* thicket dominates. But, the thick mat of dead leaves is highly flammable and the thicket can be quickly destroyed by fire during the dry season. New plants can then grow in the area, and as they cannot survive under shade, there is a chance for other plants to continue the succession.

Thysanolaena maxima which have an extensive deep and wide spreading root system, dense fibrous root system and strong roots for enhanced soil shear strength helps in armoring the slope against the surface erosion from both run off and rain splash. This species has multifunctional purposes; it binds soil, provides fodder throughout the year, its inflorescence is used as broom and its struts contain high calorie for fuel wood. It is harder species suitable to rehabilitate degraded land.

(Various levels of vegetation growth treated under the landslide)

Since tree species like *Alnus nepalensis* is directly proportional in its growth in landslide prone area, this is an added advantage to the erosion area. Secondly, *Agape americana* have proved to be a promising shrub in retaining slip area. Although climber species like *Mikania cordata* is very futile in the regeneration process, we have an option of *Ageratum conzzoides* and *Spilanthus acmella* that is grown wild and in abundance to help mulching process during the rainy season. Pteridophytic species like *Dicranopteris linearis* (bhui amala) further helps in binding of the soil and in regenerating the area. *Erythema spp.* is one of the important fast growing species mending soil profile and controlling landslides in the lower and middle zones. *Viburnum spp*. also helps to control soil erosion by placing cutting which spreads and binds soil.

It is evident from the soil tested that the acidity of the soil has decreased neutralizing the acidic nature of the soil thereby making the area suitable for succession of various climax species.

Owing to high content of gravel and sand, it is evident that the soil has almost negligible water holding capacity. Hence to counter the problem, sausage walls with supplemented growth of vegetation has been rendered to serve the following advantageous effects:

- Reduction in slope angle, thereby providing greater support and retention.
- Retardation of surface run-off.
- Increase in the water holding capacity of the soil.
- Regeneration of plants.

9 CONCLUSION & RECOMMENDATION

If air is considered essential for life, land is the platform for the same. Land provides base to all flora and fauna and even under water, it is the land where flora roots to regulate the life cycle of the fauna. Land is therefore an essential resource for one's existence and livelihood. Land is also an immobile factor of production and is limited in its amount so it is essential to preserve what is there and act responsively towards it.

Sikkim till date has witnessed consecutive landslide in all its four districts every year creating a menace in day to day life of the people. The topography, terrain and climate of Sikkim are diverse. Hence, it is difficult to apply the same nature of work in all the areas. However, the work has been carried out keeping in mind the nature of the slide and the topography of the area. Therefore, it is obvious to say that the works proposed and the works done in the area have complimented very well.

The main focus in stabilizing the slip area are taken, keeping in mind, the topography of the area, causes for the erosion, type of landslide that occur ranging from rockslide, rock falls, rock toppling debris slide, debris slide, and rock cum debris slide. During the investigation of landslide area, it has been found that the areas were huge and no proper demarcation of the slide could be drawn. As a matter of fact, some area have regenerated immensely, while in some, further works need to be done for complete stabilization.

The areas proposed in West Sikkim were Pelling Naku Tadong, Pipalay, Salley, and Rangsang; of these areas, works in Pelling Naku Tadong, Pipalay, Salley have been carried out extensively and meticulously.

Pelling Naku Tadong slide was huge in area and the whole area could not be investigated, since the area at present has regenerated immensely. This slide consisted of debris flow consisting of sandy soil mass of wet material. The flow consisted of viscous to fluid like motion of debris where the top soil had been completely washed away. The soil gets washed away every year by the monsoon rains and the process of leaching occurs in the area. The engineering works done in the area include hand packed walls inside sausage guide walls, construction of drains on the slope for proper channelization of water which prevents excess sewage of water in the land.

In area consisting of falling boulders as found in the site of Pipalay, they were checked by a regular interval of hand packed walls inside sausage guide walls to reduce slope angle and check further flow. This is doing persistently well in the area. However these works have been done looking at the prospect of the area.

In Salley, the typology of landslide varied from rock cum debris flow to rock falls and creep type pulling up of tress and bamboo grooves along the with the soil. The topography of the land is such that the anterior region is under agriculture where terrace farming is carried out, followed by a barren land in between and the slip area at the base which drains down to the Kalej River. Since, terrace farming is practiced in the anterior region of the slope, during sowing season when there is excess water in the fields, water flows downward by the gravitational pull as a result of which the barren land in the base gets easily washed away and the slope becomes much steeper further inviting the erosion of the areas. Frequent landslide in this area have hindered the people to carry out farming in the lower areas as there is a threat of land being washed away by the incessant rain. For prevention of such mishaps there is a need of an exhaustive drainage channel all over the place for which a lot of funds is required and cannot be done in limited fund.

River training works along the banks of the river

The engineering works have proved to be successful in these areas i.e. Hand packed stone wall inside sausage (gabion) in landslide area. Jhora (stream) training works which include Hand packed stone wall inside sausage and G.I sausage wall with 1:2:4 PCC lining.

Since the river beds which is continually under the pressure of the gushing water in the rivers, the river training works and the laying down of hand packed stone wall inside sausage has prevented the gush of water from eroding the soil mass.

After the engineering works were done, soil and moisture conservation works were carried out. Thus the sequential process of engineering works followed by plantation worked exceptionally well. The main motive was to prevent leaching and retain the soil to support plantation works. The area showed an immense growth of *Alnus spp,* owing to its affinity for growing in the slip area.

Besides engineering works, other works include S.M.C Works; Afforestation; Bamboo plantation; Bally benching; Creation and maintenance of nursery; Application of Geosynthetic polymers; Regrading of slopes and anchoring. A combination of Soil Moisture Conservation works and Engineering works have proved to be worthwhile in stabilizing the area.

Pallarding of Alnus may be the solution to reduce pressure of erosion and landslide and to provide adequate increment of daily requirement of fuel wood, timber and fodder to great extent.

RECOMMENDATIONS

Studies in landslide treatment have been done from time to time. For prevention of further erosion and loss of soil by leaching, an extensive study is required. The topography, climatic condition, amount of rainfall, type of soil, type of rock composition needs to be investigated in detail. For this, there is a dire need for an inter-departmental and intra-departmental approach for a concrete solution.

This project has made an effort to reach out to the concerned department in finding solution in terms of geology and soil type in the area concerned. Timely monitoring has been done by the G. B. Pant Institute of Himalayan Environment & Development, Pangthang Gangtok, Sikkim.

To ensure complete stabilization of eroded areas, the following initiative needs to be ensured:

- Extensive drainage system, sub surface drainage pipes, perforated pipes is needed which requires more funds; during monsoon season there arises seasonal springs that flows unsystematically in the hilly terrain carrying with it rich soil nutrients, further decreasing the capacity of the soil to retain excess water. Plant species with high evapo-transpiration can be further used for transpiring excess water from the soil.

- Afforestation;
  In certain areas, dense tree canopy can a sole alternative. Species like *Tectona grandis, Terminalis myriocarpa, Shorea robusta* which is suited to hot and humid climatic condition can be grown extensively. In cold and temperate regions *Alnus spp, Viburnum spp., Erythema spp.,* can be initiated and grown profusely.
  Plant species like *Agave Americana spp, Ageratum conzzoides, Dicranopteris linearis* (bhui amala), *Thysanolaena maxima, Bambusa natans* have been found to be efficient in soil binding process which can grow in soil which is nutrient deficient.

- Terrace farming to be practiced uniformly in the entire slope leaving no barren stretches of land in between:
  In most area farming is done in upper region whereas in lower region it is not. As a result of which, the excess water from the upper region flows erratically to the region below. This will facilitate erosion in the lower region where landslides gain momentum. In the process the above area gets gradually pulled.

- Selection of suitable fodder;
  Selection of evergreen fodder species like *Ficus spp, Thysanaolaena maxima* can be grown on the fringes of the landslide area. As a result of which, the landslide areas remain un-invaded by humans and animals, leaving it for regeneration.

- Bio-engineering works like hand packed walls inside G.I. sausage have proved to be very effective in stabilizing the slope area; it reduces slope angle, retard run off, trap sediment capture and utilize both surface and sub-surface water.

- Suitable Soil Moisture Conservation works need to be adopted to extend and promote natural regeneration.

- Dry cultivation should be preferred to wet cultivation in steep terrain;
  Practice of dry cultivation methods may be encouraged in steep slope owing to it high sustainability of soil and lower risk of erosion compared to wet cultivation practices. The low yield from the dry cultivation may hence be considered trifling as against the prolonged usage of the terrain for agricultural purposes.

- Exploring innovative approaches from the locally available malent or inspirations may also be considered as an effective measure to better understand the nature of the work.

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ANNEXURE

WORK PROGRAMME

SL. No.	Activity	Rate in Rs.	Year wise Physical and Financial (Rs. In lakhs) target									
			2004-2005		2005-2006		2006-2007		2007-2008		Total	
			Phy	Fin	Phy	Fin	Phy	Fin	Phy	Fin	Phy	Fin
1	Protective works											
	a. H.P. stone wall inside sausage in landslide area in rmts.	4,400.0	1099.98	48.4	980	43.1	520	22.9	0	0.0	2600	114.4
	b. stream training works											
	I. H.P. stone wall inside sausage for river training (in r mts)	4,400.0	780	34.3	720	31.7	0	0.0	0	0.0	1500	66.0
	II. G.I. sausage wall with 1:2:4 PCC lining (in r mts)	6,400.0	0	0.0	0	0.0	40	2.6	160	10.2	200	12.8
2	S.M.C Works (in ha)	33,000.0	0	0.0	20	6.6	30	9.9	50	16.5	100	33.0
3	Afforestation (in Ha)	20,340.0	0	0.0	15	3.1	60	12.2	75	15.3	150	30.5
	1st year maintenance (in ha)	3,700.0	0	0.0	0	0.0	15	0.6	60	2.2	75	2.8
4	Bamboo Plantation with brdesting of seed (in ha)	25,700.0	0	0.0	30	7.7	75	19.3	45	11.6	150	38.6
5	Bally benching (in ha)	24,850.0	0	0.0	20	5.0	20	5.0	10	2.5	50	12.4
8	Application of Geosynthetics/polymers (in sft)	185.0	0	0.0	0	0.0	5000	9.3	5000	9.3	10000	18.5
9	Regarding of slope (in cum)	55.0	0	0.0	0	0.0	7500	4.1	7500	4.1	15000	8.3
10	Anchoring/ Shotcreting 9in m)	6,500.0	0	0.0	0	0.0	20	1.3	80	5.2	100	6.5
13	Supervisors (per person)	72,000.0	1	0.7	1	0.7	1	0.7	1	0.7	4	2.9
14	Adm. Overheads LS	100,000.0	14	14.0	10.5	10.5	7	7.0	3.5	3.5	35	35.0
15	**Total**			**97.4**		**108.4**		**94.7**		**81.1**		**381.6**

Note: All the sites are not at the exactly same distances as have been worked out in rate analysis of Hand Packed walls. The distances involved in transportation are the average distance. The actual lengths of the wall will depend on their distances form quarry sites and stores. However, in no case they will be less than lengths projected in the work programme.

Year-wise and share wise financial outlay

S.No	Share bearer	2004-2005	2005-2006	2006-2007	2007-2008	Total
1	Beneficiary share	3.2	3.2	3.2	3.2	12.8

2	State Govt. share	0.0	6.4	14.0	15.6	35.9
3	DoLR Share	94.2	98.8	77.6	62.3	332.9
4	Total	97.4	08.4	94.7	81.1	381.6