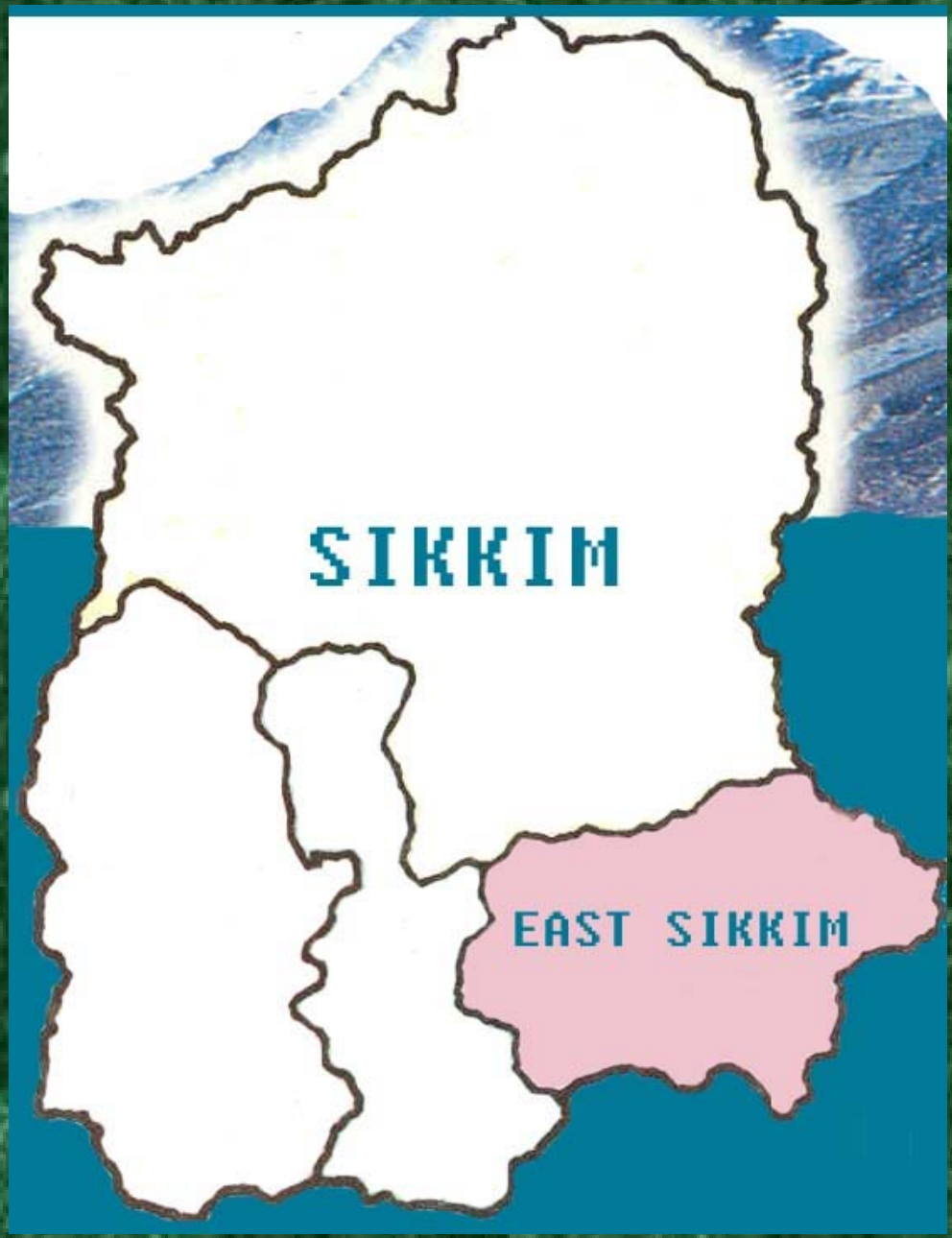
S I K K I M



AREA: 7,096 sq. km
DENSITY : 76,17/sq.km
POPULATION: 540,493
DISTRICT: 4
NORTH : 4,226 sq. km
EAST : 954 sq. km
SOUTH : 750 sq. km
WEST : 1,166 sq. km

ABSTRACT

In the present study, surface and sub-surface soil samples of two active and presently passive landslide prone area in Sikkim and vegetation buffer at varying slopes were analyzed. On the basis of four physiographic units of soil, erodibility factor 'K' was determined to asses the soil detachment pattern. The results showed that soil under escarpments and dip slope has the highest K value, where as the lowest 'K' value was found in soils of hill to ridge and summit physiographic positions. Soils with higher content of the fine to coarse particle fractions, low organic matter percent are more erodible. It was also showed that low mineral content with less vegetation are active site of landslide. Based on the erodibility indices are quadrant of vegetation, the majority of soils were under moderate erodible class applied for both surface and Sub-surface soil. Interestingly, areas dominated by *Alnus* spp. were more active Sites for landslide.

Soil erodibility, its relationship with some physico-chemical parameters of soil and Vegetation buffers of landslide prone area in Sikkim

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What is Soil Erodibility Factor 'K'?

1. The erodibility of a soil is an expression of its inherent resistance to particles
   detachment and transport by rainfall.

2. It is a cohesive force between the soil particles and may vary either in presence
   or absence of plant cover.

3. For a particular soil, 'K' factor is the rate of erosion per unit erosion index.

4. Soil texture, Structure, organic matter, permeability, are the principle factor
   effecting 'K' factors.

6. The 'K' factor reflects the facts that different soil erode at different rates while
   the other factors that effect erosion are total water capacity, Rain splash, abrasion,
   infiltration rate and dispersion.

7. According to Goldman *et al.* (1986) and Mitchell & Bubenger (1980) the soil erodibility factor 'K' ranges in between 0.02 – 0.69.

Mathematical equation of Soil erodibility factor 'K' has been represented by
Goldman *et al.* (1986) and Wisehmeier *et al.* (1971)

$$K_{fac} = 1.292\ [2.1 \times 10^{-6} f_p - 1.14 \times (12 - P_{om}) + 0.0325(S_{str} - 2) + 0.025\ (f_{per} - 3))$$

In which,

$f_p = (P_{silt} \times 100 - P_{clay})$

Where f_p is the particle size parameter,

P_{om} is the percent of organic matter,

S_{str} is the soil structure index,

f_{per} is the profile permeability class factor,

P_{silt} is the percent of silt, and

P_{clay} is the percent of clay.

The factor 1.292 is needed to convert from the English unit to the metric units.

Erodibility classification of landslide was done according to the technique adopted by Presant and Acton (1984).

K factor	Erodibility class
<0.020	Negligible
0.020 – 0.039	Low
0.039 – 0.053	Moderate
0.053 – 0.066	High
> 0.066	Very high

How we have classified the Soil texture classes of four landslide prone areas?

Magnitude of 'K' factor is a function of organic matter content and soil textural classes.
[After Stewart et al. (1975)]

Site	Textural class	P_{om} %	'K' value	Erodible class
1. Amdogolai	Sandy clay	3.27	0.08479429^{D}	Very High
2. Beto	Sandy clay	1.724	0.13113672^{C}	Very High
3. Ganeshtok	Sandy clay	0.05	0.14765681^{B}	Very High
4. Namli	Sandy clay	0.48	0.17922921^{A}	Very High

Landslide

Landslide is the Sudden onset hazard, it is also define as a phenomenon of down slop transport of soil and rock resulting from naturally occurring vibration, changes in direct water content, removal of lateral support, loading with weight and weathering or human manipulation of water courses, heavy precipitation soil factors and slope composition.

Studied area of Landslide

1. **Amdogolai** (Located 1 Km down away from capital Gangtok)
2. **Beto (Located 15 Km away from Gangtok)**
3. **Ganesh Tok (Located 3 Km away from Gangtok, above densely populated Chandmari, Nathula Highway, Tourism spot)**
4. **Namli, 9th Mile (Located 18 Km away from Gangtok, National Highway 31 A)**

Beto landslide

Ganeshtok landslide

Amdogolai landslide

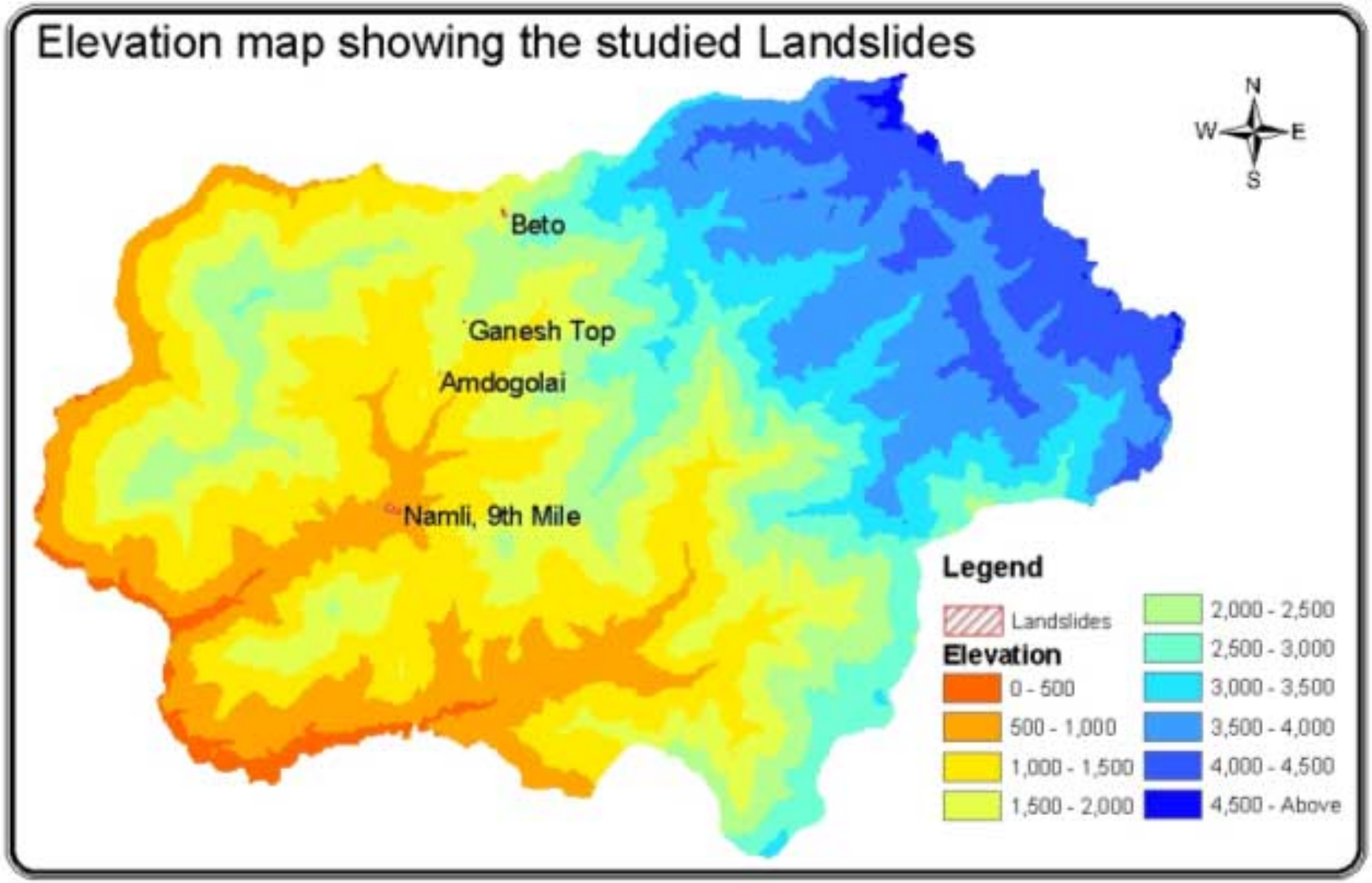
Namli landslide


Amdogolai landslide,
a great concern to
citizen!


Beto Landslide
Too narrow to pass!


Ganesh Tok landslide
Nearly you got me!

Namli, 9th mile landslide
A horror to vehicle pass!


Elevation map showing the studied Landslides
N
W
E
S
Beto
Ganesh Top
Amdogolai
Namli, 9th Mile
Legend
Landslides
Elevation
0 - 500
500 - 1,000
1,000 - 1,500
1,500 - 2,000
2,000 - 2,500
2,500 - 3,000
3,000 - 3,500
3,500 - 4,000
4,000 - 4,500
4,500 - Above

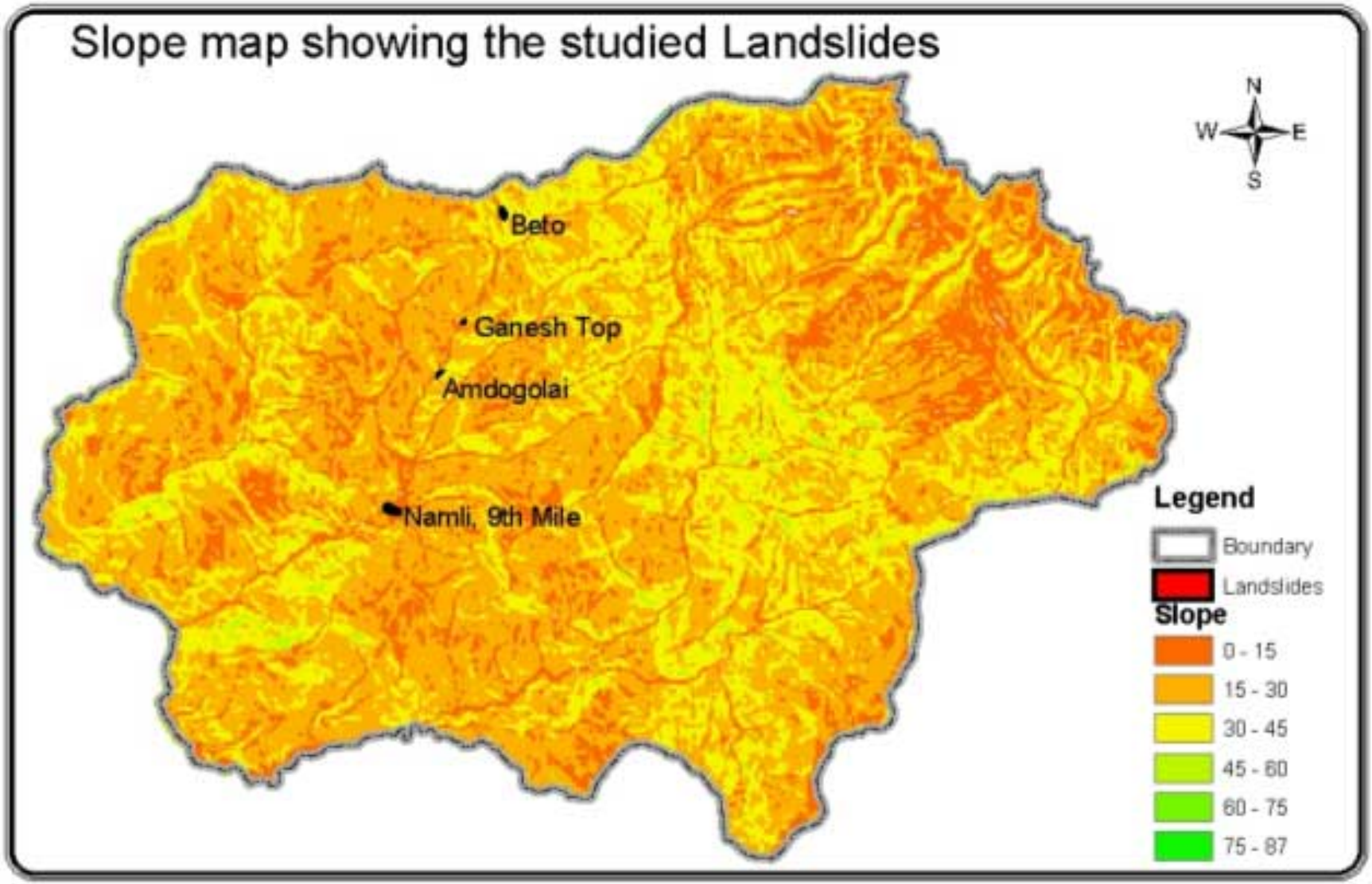

Slope map showing the studied Landslides
N
W
E
S
Beto
Ganesh Top
Amdogolai
Namli, 9th Mile
Legend
Boundary
Landslides
Slope
0 - 15
15 - 30
30 - 45
45 - 60
60 - 75
75 - 87

Table 1. Salient features of Soil at four different Landslide prone places.

Site	Slope %	Colour	Drainage	Textural group	Erosion	Land use
Amdogolai	25.88 – 50.00	Brown	Absent	Sandy clay	Positive	Natural vegetation, man made constructions
Beto	50.00 – 70.71	Light brown	Absent	Sandy clay	Positive	Natural vegetation
Ganesh tok	25.88 – 50.00	Light brown	Absent	Sandy clay	Positive	Natural vegetation, man made constructions
Namli	8.72 – 50.00	Brown	Absent	Sandy clay	Positive	Natural vegetation

Table 2. Physico-chemical properties of Soil at different location of landslide prone area

Site	Depth (cm)	pH	E.C. m.mho /cm	Organic Carbon %	Organic Matter %	Chloride %	Sand %	Very fine sand %	Silt %	Clay %
Amdogolai	0.00 – 100	5.92	0.06	1.90	3.27	0.100	42	18	6	34
Beto	0.00 – 100	5.83	0.02	1.00	1.724	0.162	51	11	6	32
Ganeshtok	0.00 – 100	5.86	0.03	0.03	0.05	0.165	62	4	2	32
Namli	0.00 – 100	6.12	0.03	0.28	0.48	0.110	43	5	18	34

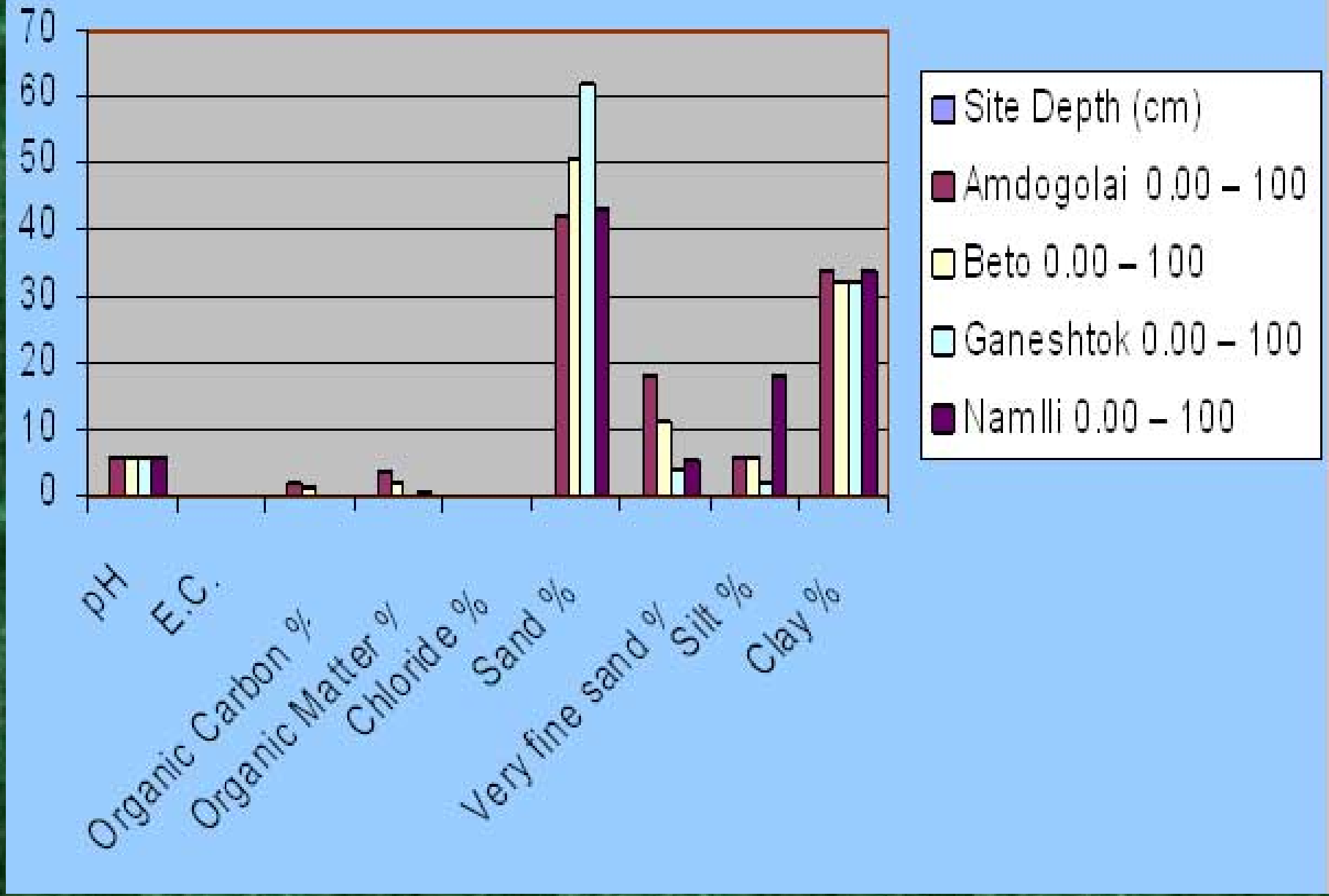
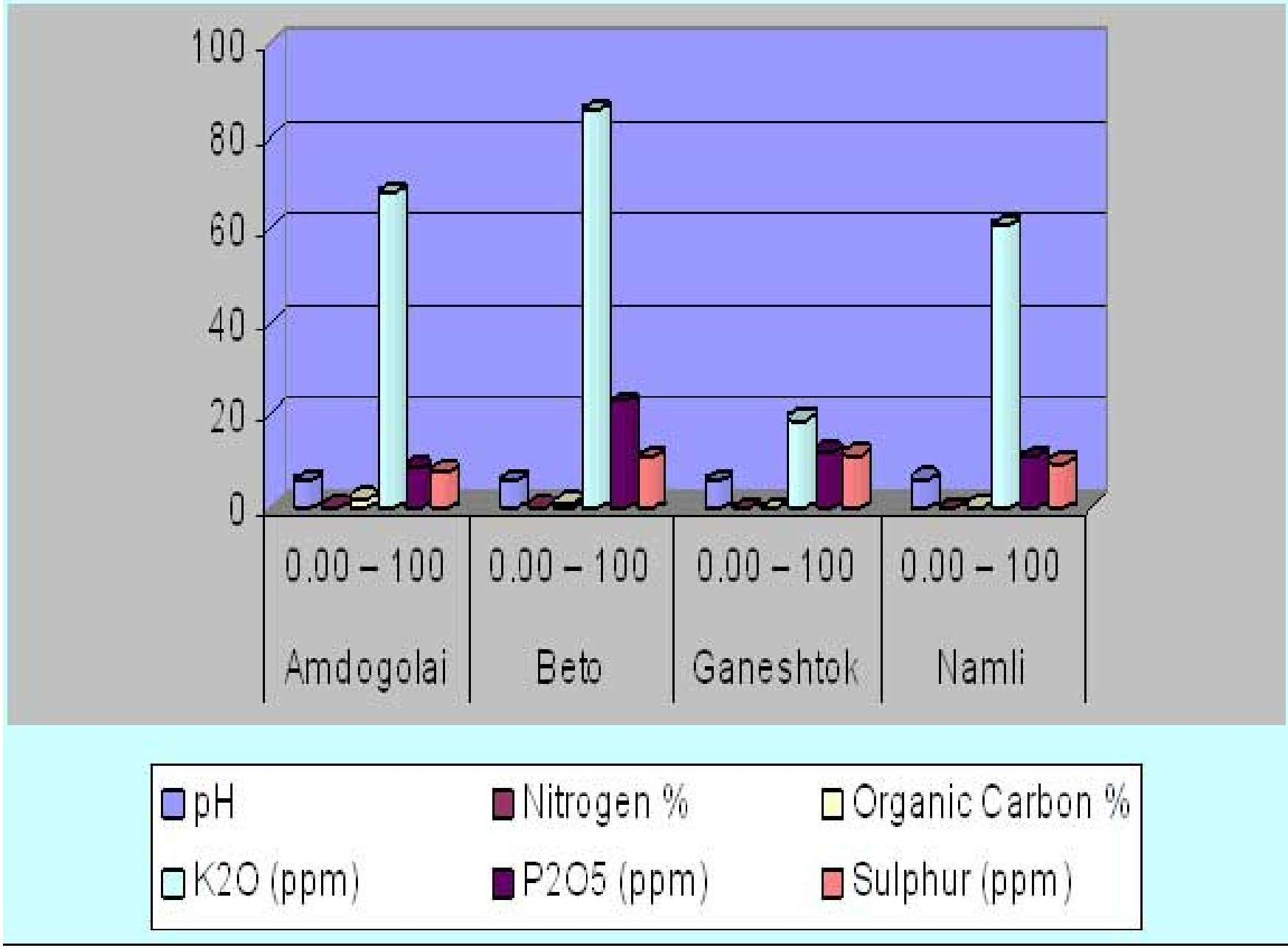

70
60
50
40
30
20
10
0
pH
E.C.
Organic Carbon %
Organic Matter %
Chloride %
Sand %
Very fine sand %
Silt %
Clay %
Site Depth (cm)
Amdogolai 0.00 – 100
Beto 0.00 – 100
Ganeshtok 0.00 – 100
Namlli 0.00 – 100

Table 3. Physico-chemical properties and soil erodibility factor 'K'

Site	Depth	Slope %	Sand % (0.1 – 2.0 mm)	Silt + very fine sand %	Textural group	Organic matter %	Struct-ural code	Perm-eability code	'K' value	Erodible class
Amdogolai	0.00 – 100	25.88 – 50.00	42	24	Sandy clay	3.27	2	5	0.0847	Very high
Beto	0.00 – 100	50.00 – 70.71	51	17	Sandy clay	1.724	3	5	0.1311	Very high
Ganeshtok	0.00 – 100	25.88 – 50.00	62	8	Sandy clay	0.05	3	6	0.1476	Very high
Namli	0.00 – 100	8.72 – 50.00	43	22	Sandy clay	0.48	2	5	0.1792	Very high

Table 4. Mineral nutritional status of soil

Site	Depth (cm)	pH	Nitrogen %	Organic Carbon %	K_2O (ppm)	P_2O_5 (ppm)	Sulphur (ppm)
1. Amdogolai	0.00 – 100	5.92	0.16	1.90	67.80	8.71	7.86
2. Beto	0.00 – 100	5.83	0.09	1.00	85.80	22.85	10.80
3. Ganeshtok	0.00 – 100	5.86	0.02	0.03	19.20	11.97	11.50
4. Namli	0.00 – 100	6.12	0.02	0.28	61.20	10.88	9.82


100
80
60
40
20
0
0.00 – 100
0.00 – 100
0.00 – 100
0.00 – 100
Amdogolai
Beto
Ganeshtok
Namli
pH
Nitrogen %
Organic Carbon %
K2O (ppm)
P2O5 (ppm)
Sulphur (ppm)

On the basis of table 4.

Nutritional factors plays a significant role in covering the slided area

pH : i). Influence microbial population
ii). Bio-availability of nutrients for plant growth
iii). Influence chemical weathering of soil

Acidic Range	Acidic class
>4.5	Very acidic
4.5 – 6.00	Medium acidic
6.00 – 6.99	Acidic
7.5 – 8.5	Alkaline
8.5 – 10.5	Stalinized
>10.5	Very strong or highly Stalinized

Nitrogen (N %), require >0.06% to promotes the healthy growth and population of plant sp.
K_2O (ppm), require >100 below that hamper cell osmoticum.
P2O5 (ppm) >20.00 (requirement), very essential for ATP synthesis
S (ppm) >40.00 (requirement), regulates the growth of plant.

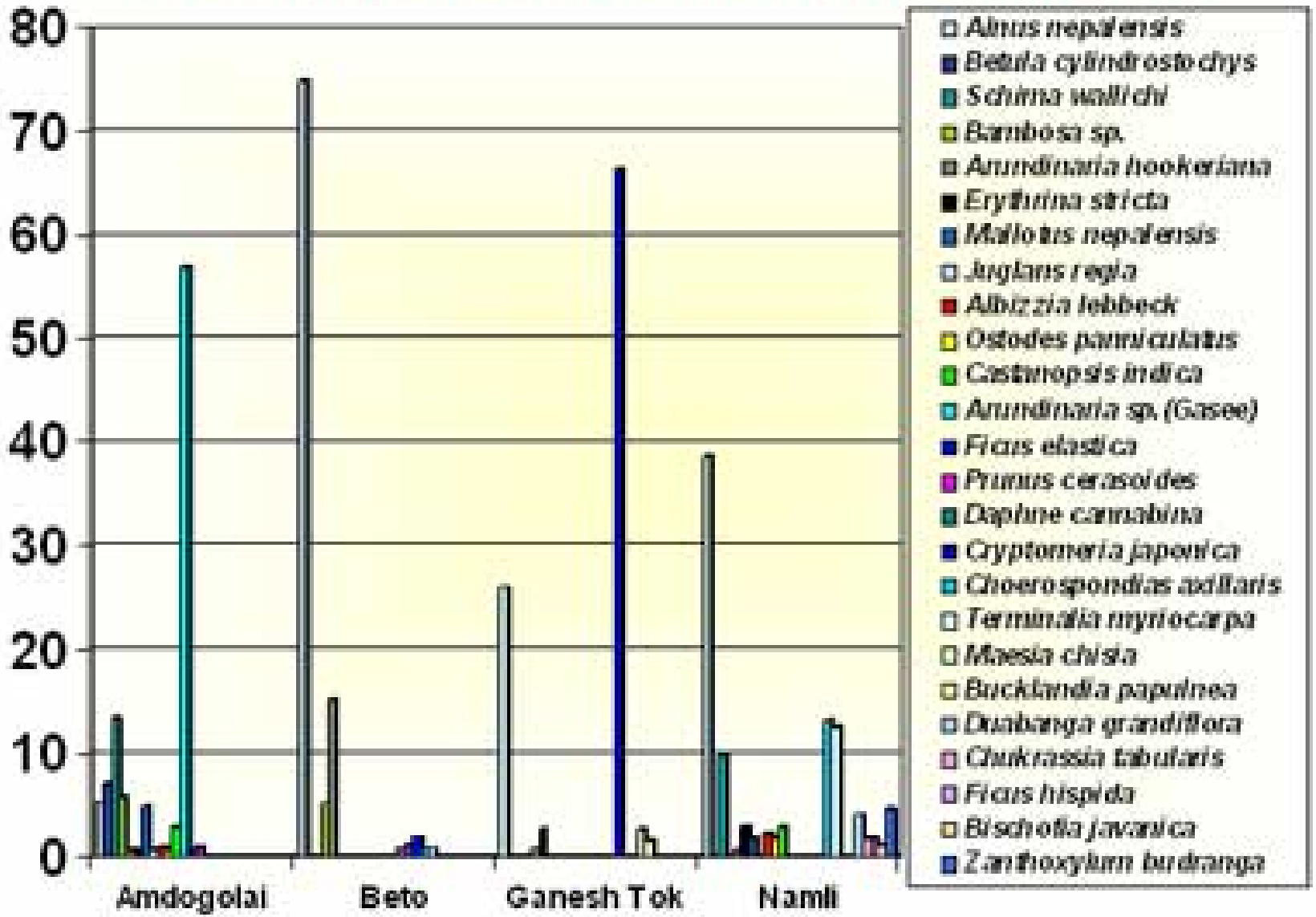
The ranges of nutrient parameter vary from plant to plant.
(Data source :- TRA, Department of Agriculture, Govt. of W.B.)

Table 5. Vegetation pattern

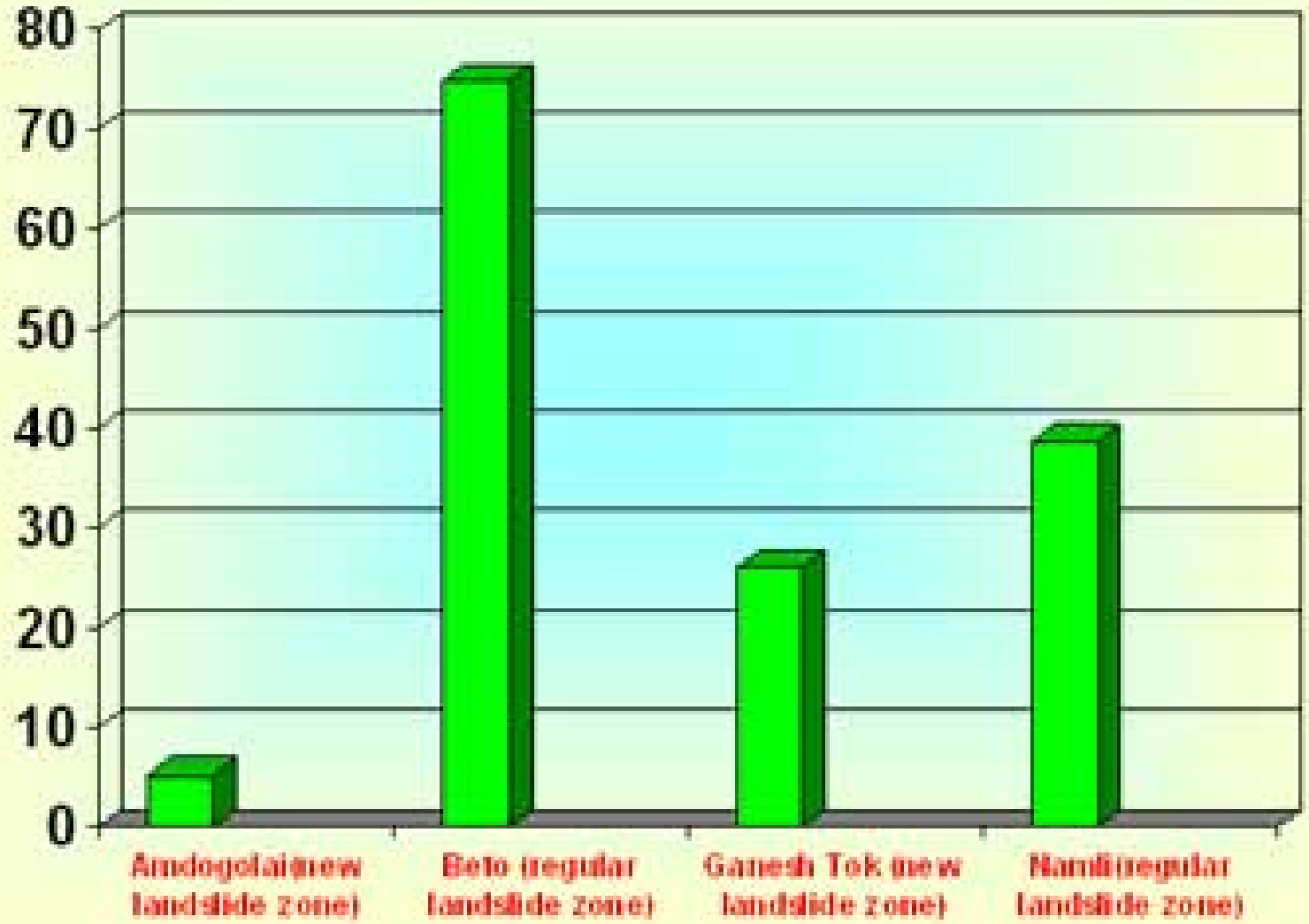
Site	Slope %	Type of plant (20/20 m for tree) (5/5 m for shrub) and (1/1 m for herb)	Frequency
Amdogolai	25.88 – 50.00	Tree	91
		Shrub	34
		Herb	94
Beto	50.00 – 70.71	Tree	128
		Shrub	39
		Herb	115
Ganeshtok	25.88 – 50.00	Tree	177
		Shrub	40
		Herb	110
Namli	8.72 – 50.00	Tree	174
		Shrub	17
		Herb	118

The vegetation pattern can play vital role in subsidizing the soil erosion;

- Enhance the root reinforcement, plugging the soil aggregate;
- Plant litter increase of soil organic matter.
- Reduce raindrop splash force, relying to its canopy types


Relative Density of different species at four landslide zones
80
70
60
50
40
30
20
10
0
Amdogolai
Beto
Ganesh Tok
Namli
Alnus nepalensis
Betula cylindrostachys
Schima wallichi
Bambosa sp.
Arundinaria hookeriana
Erythrina stricta
Mallotus nepalensis
Juglans regia
Albizzia lebbeck
Ostodes paniculatus
Castanopsis indica
Arundinaria sp. (Gasee)
Ficus elastica
Prunus cerasoides
Daphne cannabina
Cryptomeria japonica
Choerospondias axillaris
Terminalia myriocarpa
Maesia chisia
Bucklandia populnea
Duabanga grandiflora
Chukrassia tabularis
Ficus hispida
Bischofia javanica
Zanthoxylum budranga

Relative Density of *Alnus nepalensis*



Density of *Alnus nepalensis* is correlated with the occurrence of landslide

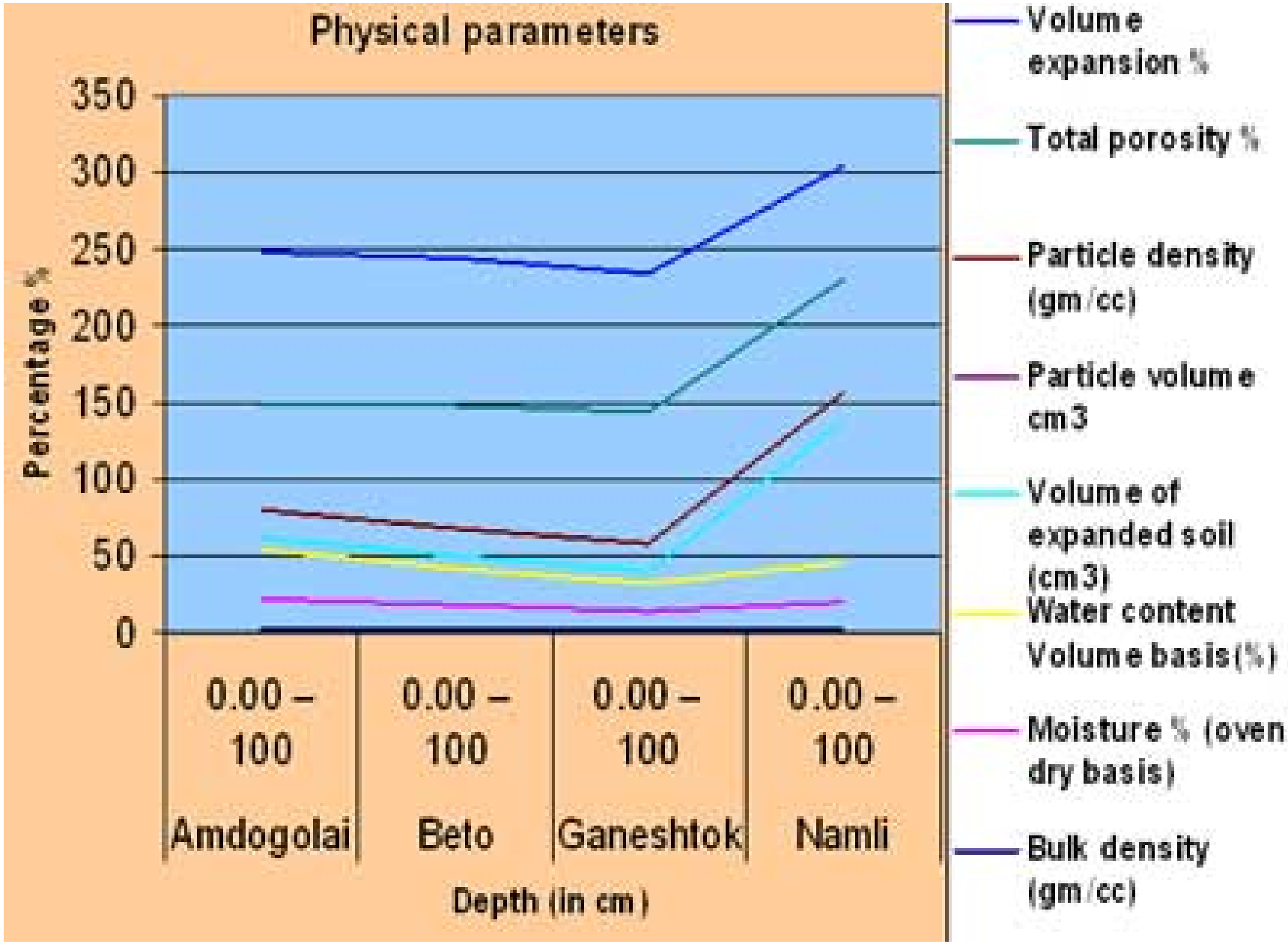
It may be predicted that succession and adaptation of *Alnus* sp. is higher than any other species present in landslide zone.

Quicker invasion of *Alnus* sp. in landslide zone may be due to its high root reinforcement strength.

Alnus species can be successfully bioengineered for preventing soil erosion as well as for the enrichment of soil fertility.

Table 6. Other physical parameters

Site	Depth cm	Bulk density (gm/cc)	Moisture % (oven dry basis)	Water content Volume basis(%)	Volume of expanded soil (cm^3)	Particle volume cm^3	Particle density (gm/cc)	Total porosity %	Volume expansion %
Amdogolai	0.00 – 100	1.53	20.6	31.53	9.04	16.59	0.908	68.5	100
Beto	0.00 – 100	1.33	17.1	22.86	8.84	17.71	0.740	79.7	95.35
Ganeshtok	0.00 – 100	1.51	12.3	18.62	7.47	18.13	0.818	84.6	89.72
Namli	0.00 – 100	1.57	17.5	27.51	9.18	16.99	0.909	72.7	75.83


Physical parameters
350
300
250
200
150
100
50
0
Percentage %
0.00 – 100
0.00 – 100
0.00 – 100
0.00 – 100
Amdogolai
Beto
Ganeshtok
Namli
Depth (in cm)
Volume expansion %
Total porosity %
Particle density (gm/cc)
Particle volume cm3
Volume of expanded soil (cm3)
Water content Volume basis (%)
Moisture % (oven dry basis)
Bulk density (gm/cc)

- Compactness (bulk density) of soil generally range from 1.60 – 1.75

- Less moisture indicates higher infiltration rate, greater permeability, high porosity.

- Organic matter and fine soil particles act as a binder between two or more soil particles.

Table 7. Monthly average rainfall status during 2006-2007

Year	Month	Average rainfall (mm)/day	Rainfall status
2006	January	0.07	
	February	0.81	
	March	2.23	
	April	6.53	
	May	17.71	High rainfall
	June	15.80	High rainfall
	July	17.59	High rainfall
	August	20.16	High rainfall
	September	14.94	
	October	2.37	
	November	0.29	
	December	0.48	
2007			
	January	0.24	
	February	5.82	
	March	2.38	
	April	9.91	
	May	14.85	
	June	19.29	High rainfall
	July	21.36	High rainfall

	August	16.09	
	September	16.39	
	October	4.35	
	November	2.23	
	December	0.17	

Source : Meteorological Centre, Government of India, Baluwakhani, Gangtok

Rain water and gravitational force act downwards and cause the breaking down of bonded soil particles.

Higher rainfall decreases the nutritional status of soil due to higher infiltration.

MITIGATION MEASURES

The most basic requirements:

- To prevent water from concentrating and moving down the slope in a narrow path
- To slow down the moving water
- To grow the strips of stubble or other vegetation cover which might catch and hold the moving particle of soil. Mitigation may be possible through grass bioengineering.

Suitable methods to prevent soil erosion or to control the huge disasters from Landslide.

1. **Biological methods :**
   - **(a) Agronomic practices**
     - **Contour farming**
     - **Mulching**
     - **Strip cropping**

3. **Agrostological methods**
   - **(a) Lay farming**
   - **(b) Retiring to grass**

4. **Supplement to Biological methods**
   Mechanical method/engineering application
   (a). Basin listing
   (b). Contour terracing
   - **Channel terrace**
   - **Broad based ridge terrace**
   - **Bench terrace**

5. **Other methods**
   (i) Gully water flow control through drainage system
   (ii) Stream bank protection
   (iii) Afforestation

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