

## CHAPTER-8

### IMPACT OF LANDFORMS ON LAND USE

#### A STATISTICAL ANALYSIS

**8.1 INTRODUCTION :** The role of statistics in the social sciences has become an extremely useful means for building and refining theories of spatial organisation (Tukey 1962). For this purpose, the relevant Topo-Sheets (Scale 1 : 50,000) published by Survey of India have been intensively studied followed by frequent field checkings and the whole area of the Sali Basin has been divided into four geomorphological surfaces. Surface I (Gangajalghati Upland) has 45 grids, Surface II (Kora Upper Plain) has 310 grids, Surface III (Sonamukhi Rolling Plain) has 444 grids, and Surface IV (Bodai Low Flat Plain) has 115 grids altogether (Grid size being 1 km. x 1 km.). As discussed in the earlier chapters, eight parameters have been selected taking four from Landforms (1. Relative Relief, 2. Average Slope, 3. Drainage Density, and 4. Roughness Index) and four from Land use pattern (5. Area under forest, 6. Area under paddy, 7. Area under other crops, and 8. Area not available for cultivation). The parameters have been measured in each of the one Sq.km. grids superimposed on the individual Land Surface with a view to understand statistically the impact of landforms on land use pattern of the Basin. Discussions have been made on (i) Variation of the characters over the Surfaces (Table 8.1 and 8.2, Fig. 8.1), and (ii) Variation of the relationship between each and every pair of characters over the Surfaces (Table 8.3).

**8.2 SUMMARY MEASURES :** Summary measures are the indices that precisely measure various properties of a distribution. Measures like (i) Mean, (ii) Standard errors, (iii) Coefficient of variation, and (iv) Range have only been considered here and their uses in different forms are explained as follows :

**Mean :** Mean is the simple average of the different values of a variable. Precisely, it is a quotient obtained by dividing the total by the number of occurrences connected with it (Pal 1982). This can be

written as :

$$\bar{X} = \frac{\sum_{i=1}^N x_i}{N} \quad \text{where } N = \text{the total number of data Set (grids) of a surface.}$$

Table 8.1 depicts that the mean of relative relief in Surface I and II is more than 8 metres where as in the surface III and surface IV, it is below 5 metres. Average slope in conformity with the relative relief shows more or less same picture, but the drainage density is lower in surfaces II and III than that of the surfaces I and IV. Roughness index gradually falls from surface I to surface IV and the same trend is followed by the area under forest. Infact, in the surface IV, forest has become non existent.

**Standard Errors :** Standard Errors of differences of means have been calculated as the square root of the sum of the squares of their standard errors. Symbolically, this can be written as :

$$\sqrt{\frac{\sigma^2}{N}} = \frac{\sigma}{\sqrt{N}} = \text{S.E. of Mean} \quad \text{where } \sigma^2 = \frac{\sum_{i=1}^N (X_i - \bar{X})^2}{N}$$

In the Table 8.1 it reveals that standard error is highest (21.071) in the surface III and lowest (3.162) in the surface II for the characters like in relative relief, roughness index, area under forest and area under paddy. For the remaining characters, the lowest standard error is 6.708.

**Coefficient of Variation :** Coefficient of Variation (C.V.) provides a relative measure of variability by expressing the standard deviation as a ratio of the mean, or more usually, as a percentage of the mean (Clark and Hosking 1986). Formula of C.V. is as follows :

$$\text{C.V.} = \frac{\sigma}{\bar{X}} \quad \text{or} \quad \frac{\sigma}{\bar{X}} \cdot 100 \quad \text{where} \quad \begin{array}{l} \sigma = \text{Standard} \\ \text{deviation} \\ \bar{X} = \text{Mean} \end{array}$$

**Table 8.1.** Summary measures of different characters  
for each land surface in the Sali Basin

Surface	Data set	Mean	S.E.	C.V.	Range
<b>1. Character : Relative relief</b>					
I	45	8.600	6.709	296.65	8.00-20.00
II	310	8.209	3.162	286.53	5.00-10.00
III	444	5.718	21.071	239.12	5.00-26.00
IV	115	3.323	10.724	183.92	1.00- 9.00
<b>2. Character : Average slope</b>					
I	45	28.556	6.709	524.37	10.00-80.00
II	310	30.610	17.607	553.27	10.00-80.00
III	444	21.563	21.071	464.36	10.00-67.00
IV	115	16.644	10.724	407.96	8.00-54.00
<b>3. Character : Drainage density</b>					
I	45	0.663	6.708	81.41	0.01-2.50
II	310	0.528	17.607	76.03	0.01-2.50
III	444	0.513	21.071	71.60	0.01-2.00
IV	115	0.586	10.724	76.57	0.01-2.00
<b>4. Character : Roughness index</b>					
I	45	1.356	6.708	116.43	0.50-3.75
II	310	1.459	3.162	120.77	0.50-3.75
III	444	1.015	21.071	100.77	0.45-3.75
IV	115	0.803	10.724	89.59	0.45-2.50
<b>5. Character : Area under forests</b>					
I	45	0.4604	6.708	116.43	0.50-3.75
II	310	0.4939	3.162	120.77	0.50-3.75
III	444	0.5863	21.071	100.77	0.45-3.75
IV	115	0.0100	10.724	89.59	0.45-2.50
<b>6. Character : Area under paddy</b>					
I	45	0.4604	6.708	67.85	0.10-0.89
II	310	0.1843	3.162	70.28	0.11-0.90
III	444	0.4339	21.071	28.51	0.01-0.52
IV	115	0.5224	10.724	10.00	0.01-0.02
<b>7. Character : Area under other crops</b>					
I	45	0.0776	6.708	88.20	0.02-0.19
II	310	0.0746	17.609	86.37	0.01-0.21
III	444	0.1817	21.071	42.63	0.10-0.58
IV	115	0.1686	10.724	12.98	0.10-0.21
<b>8. Character : Area not available for cultivation</b>					
I	45	0.297	6.708	54.51	0.13-0.54
II	310	0.253	17.607	50.33	0.03-0.69
III	444	0.306	21.107	55.30	0.10-0.81
IV	115	0.302	10.724	54.96	0.14-0.61

Coefficient of variation is lowest in the surface IV for relative relief. For average slope, it is higher in the surfaces I and II than in the surfaces III and IV, and for drainage density it is lowest in the surface I. C.V. of roughness index is lowest in the surface IV and of forest land, highest in the surface II. For under paddy, C.V. is lowest in the surface II and for area under other crops it is lowest in the surfaces I and II. Area not available for cultivation has no such significant variation.

**Range :** Range is the simplest measure of dispersion which is nothing but the difference between the maximum value and the minimum value of a distribution (Singh and Mishra 1982). Maximum range of relative relief, area under other crops and area not available for cultivation are marked in the surface III while the maximum range of average slope, drainage density and area under paddy are in the surface II and III (Table 8.1). Roughness index and area under forest have low range only in the surface IV.

**8.3 Z-STATISTIC OF PAIRS OF SURFACES :** Standard Errors of differences of means have been calculated which shows how much on an average a given  $(\bar{X}_1 - \bar{X}_2)$  is likely to differ from the central point of distribution of differences. For enumerated and metric variables, the relative position of an individual score can be assessed by expressing the score as a ratio of some other selected score or value. As the sample sizes of each surface is very large, Z-statistic is assumed to follow standard normal distribution. Therefore, Z-statistic have been calculated (Table 8.2) in pairs of Land surfaces of each character. As the population variances are unknown here, they are replaced by the sample variances already mentioned.

$$Z = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{\sigma_1^2}{N_1} + \frac{\sigma_2^2}{N_2}}}$$

Where

- $\bar{X}_i$  = Mean of the character of i-th land surface
- $\sigma_i^2$  = Variance corresponding to the i-th land surface
- i = 1, 2
- $N_i$  = Total number of grids in the i-th surface

Table 8.2 The values of Z-scores in pairs of the Surfaces in the SaliBasin, Bankura.

Pairs of surfaces	Relative relief	Average slope	Drainage density	Roughness index	Area under forests	Area under paddy	Area under other crops	Area not available for cultivations
I & II	1.032	0.659	1.165	0.686	0.952	16.953*	0.246	2.096*
I & III	14.413*	2.302*	1.320	2.339*	11.741*	0.871*	8.675*	0.431
I & IV	15.251*	3.850*	0.618	8.920*	14.082*	2.582*	0.128	0.215
II & III	10.806*	7.303*	0.224	7.998*	26.283*	34.293*	22.311*	5.585*
II & IV	18.250*	10.191*	0.255	10.153*	32.271*	31.441*	14.711*	3.275*
III & IV	14.741*	4.215*	1.194	3.863*	14.851*	5.332*	2.221*	0.268

\*Significant at 5 per cent level of significance

**Relative Relief :** Statistically the relative relief of surface I does not differ from surface II. In the remaining pairs of surfaces it differs significantly. Mean values of surface I and II are in order of 8 metres whereas in surface III and IV, it is much lower. The range of relative relief in the surface IV is also low, between 1 and 9 metres and it is highest in the surface I (8-20 m.). Standard error of mean in the surface I and II is much lower than that of the surface III and IV. The Z-value is 1.03 in the pair of surface I and II which is very low in compared to that with the other pairs of surfaces. C.V. is highest in surface I and lowest in surface IV, which means the gradual fall of relative relief from the Gangajalghati Upland to Bodai Low Flat Plain of the Basin.

**Average Slope :** Only surface I does not differ from surface II in average slope. Value of mean in this pair is in order of 28-30 and the Z-value is 0.66. Standard error of mean in the surface I is much low. Range of average slope in surface I and II is higher than that in the surface III and IV. Z-values of average slope in all the pairs of surfaces except the pair of surface I and II are statistically significant. Surface-wise variability of average slope is better than that of the relative relief. C.V. is in order of more than 5 in surface I and II, and below 5 in surface III and IV.

**Drainage Density :** The Sali Basin is characterized by moderate rainfall, coarse textured soil and more or less gentle slope. Accordingly, the drainage density of the Basin does not differ significantly from Surface to Surface. Mean values of drainage density in all the Surfaces are in order of .5 and .7 and the range is in between 0.01 and 2.50 and C.V. is also between 76 and 81. The Z-value has also not attained the level of significance in the pairs of Surfaces.

**Roughness Index :** Roughness index is the most important landform parameter in the Sali Basin. Surface-wise variability of roughness index and the influence on other parameters are significantly marked. Mean value of roughness index is in order of below 1 in surface IV and above 1 in surfaces I, II and III. Standard error of means are lower in surface I and II and very high in surface III which is (above 20) and moderate in surface IV (above 100). C.V. is lowest in surface IV (below 100) and in all other surfaces, it is above 100. Z-values highly differ from surface II and IV and also from I to IV. Z-values have attained statistical significant level in all the pairs of surfaces except in surface I and II.

**Area Under Forests :** Area under forests including cultured forests does not vary from surface I to II. Mean values are low in all the surfaces and in the surface III, it is very low. Standard error of mean in surface III is very high, and range in all the Surfaces also does not vary much. Z-value is highest in the pairs of II and IV, and II and III, moderate in pairs of III and IV, I and IV Surfaces.

**Area Under Paddy :** Paddy is the most important crop since it has not only covered more than 90 per cent of the total cropped area in the Basin, but also it is the staple food as well as its cultivation has practically become the only source of employment in the area. Z-values significantly vary from the pairs of surfaces, but highest Z-value is observed in the pair of surface II and III. Values of mean of the area under paddy is in order of 0.18 in surface II and in other surfaces, between 0.43 and 0.52. Standard error of mean is highest in surface III. C.V. is highest in surface II and lowest in surface III.

**Area Under other Crops :** Surface pairs of II and III, II and IV, III and IV have significant variability of Z-values in the case of area under other crops. This is due to the fact that surface III, IV and parts of II have development of irrigation (canal and tube-well) in recent years and as a result, diversity of cropping has started from the age old traditional mono-crop (paddy) cultivation. Values of mean in surface I and II are in order of 0.07 and surface III and IV, 0.18 within the range of 0.01 and 0.58.

**Area Not Available for Cultivation :** Surface I does not differ from surface II, III and IV in the mean values of area not available for cultivation. Standard error of mean is lowest in surface I and highest in surface III. The range of all surfaces is within 0.10 and 0.81. Z-values are not significant in the pairs of surfaces I and III, I and IV, and III and IV. More or less the area not available for cultivation is evenly distributed and not much dependent on other parameters. This is because of the fact that the infrastructure for human habitation in the entire Basin is poorly but evenly developed (Fig. 8.1).

**8.4 CORRELATION COEFFICIENT :** Spatial Correlation Coefficient has been computed for different pairs of characters on the basis of the following formula of the Spearson's product moment coefficient of correlation, (Norcliffe 1977) :

$$r = \frac{N \sum_i X_i Y_i - \left( \sum_i X_i \right) \left( \sum_i Y_i \right)}{\sqrt{\left[ N \sum_i X_i^2 - \left( \sum_i X_i \right)^2 \right] \left[ N \sum_i Y_i^2 - \left( \sum_i Y_i \right)^2 \right]}}$$

Where  $i = 1, \dots, N$

$X_i$  = Value of character X corresponding to  $i$ -th grid

$Y_i$  = Value of character Y corresponding to  $i$ -th grid

$N$  = Number of grids

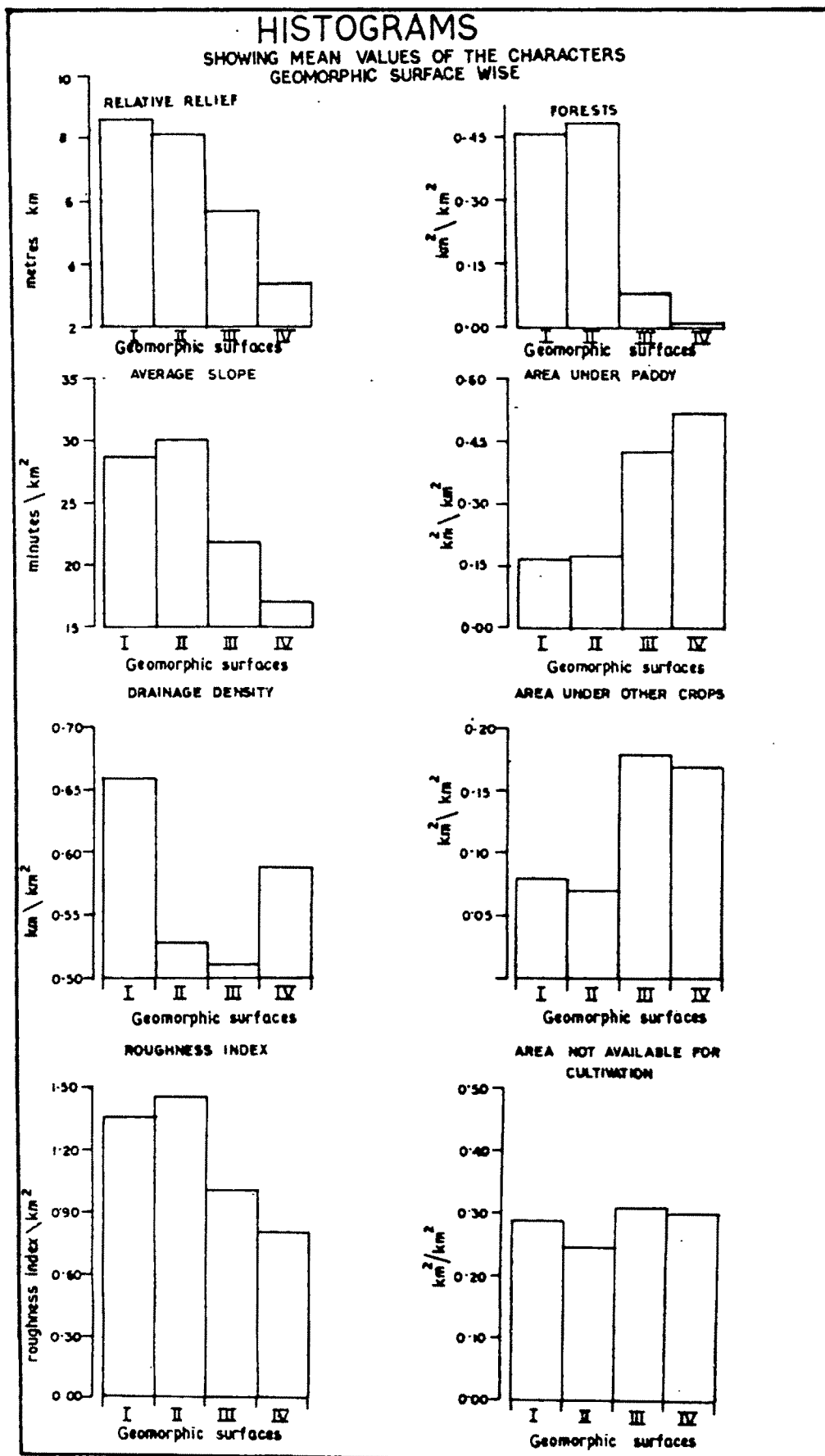


Fig. 8-1



(The equation involves the summations of  $X_s$ ,  $Y_s$ ,  $x_s$  squared and the sum of the product of  $x$  and  $y$ )

Correlation Coefficient is a mathematical measure of the degree of association between two paired variables (Mc Cullagh 1974) or more, but it is important to emphasise that a correlation co-efficient shown to be statistically significant does not necessarily imply that there is a causal relationship between two variables. In the present study area, attempts have been made to study the mutual correlation (Table 8.3) separately among physical parameters and land use parameters and also combinely the physical and the land use parameters. This knowledge can help in suggesting theoretical hypothesis regarding the cause and effect. Pearson's 'r' is a standard measure of linear covariance. The value of  $r$  varies between -1 and +1. The value +1 or -1 indicates a perfect positive or negative correlation (Mahmood and Raza 1977). It should be noted that the correlation measure is a linear correlation between the two variables, and a value of  $r$  near zero indicates that there is no linear correlation between the two variables. That does not mean that they are unrelated, for there may be a high non linear correlation between them (Clark and Hosking 1986).

**Mutual Correlation Among the Physical Parameters :** There is more or less a significant positive correlation among physical parameters (Table 8.3) in all the geomorphic surfaces(s). Relative relief has significant positive relation with average slope at S-I and highly significant positive relation with average slope at S-IV. Relation between relative relief and roughness index is highly positive at S-IV. Average slope has highly significant positive correlation with Drainage density at S-I and highly significant negative correlation at S-IV. This is because of the perfectly plain land at the confluence part of the river Sali. Highly significant positive correlation exists between average slope and roughness index at all the surfaces (i.e. from S-I to S-IV) whereas, drainage density has highly significant positive correlation with roughness index only at S-I which represents undulating terrain of the plateau fringe. Of all the physical parameters, the roughness character is most important since it is significantly correlated with drainage

Table 8.3. Correlation Matrix of Geomorphic Surfaces

	Average slope	Drainage density	Roughness index	Area under forest	Area under paddy	Area under other crops	Area not available for cultivation
<b>Surface I (45 data set)</b>							
Relative relief	0.303*	0.132	0.000	0.000	-0.100	-0.142	0.110
Average slope		0.390**	0.965**	0.059	-0.177	-0.022	0.100
Drainage density			0.418**	0.004	-0.010	0.100	0.000
Roughness index				0.049	-0.100	0.000	0.100
Forest area					-0.746**	-0.255	-0.598**
Paddy area						0.200	-0.000
Other crops' area							-0.084
<b>Surface I (310 data set)</b>							
Relative relief	0.101	0.126	0.083	-0.218*	0.281**	0.110	0.089
Average slope		0.094	0.858**	-0.204*	0.181	0.060	0.159
Drainage density			0.125	-0.328**	0.289**	0.117	0.298**
Roughness index				-0.209*	0.171	-0.010	0.212*
Forest area					-0.804**	-0.584**	-0.830**
Paddy area						0.442**	0.403**
Other crops' area							0.382**
<b>Surface III (444 data set)</b>							
Relative Relief	0.127	0.163	0.137	0.210	-0.072	0.007	-0.069
Average slope		0.133	0.960**	0.049	-0.036	0.024	0.001
Drainage density			0.128	0.042	0.075	0.018	-0.127
Roughness index				0.004	-0.023	-0.049	0.005
Forest area					-0.560**	0.101	-0.107
Paddy area						-0.139	-0.670**
Other crops' area							-0.870*
<b>Surface IV (115 data set)</b>							
Relative relief	0.403**	-0.031	0.381**	-0.000	-0.180	0.061	0.141
Average slope		-0.487**	0.964**	-0.000	-0.062*	0.055	0.034
Drainage density			-0.037	0.000	0.142	0.090	-0.179*
Roughness index				-0.000	0.061	0.039	0.040
Forest area					0.000	0.000	0.000
Paddy area						-0.219*	-0.911**
Other crops' area							0.186*

\* = Significant at 0.05 per cent level of significance

\*\* = Significance at 0.01 per cent level of significance

density, average slope as well as relative relief in most of the areas of the Basin. Therefore, the local erosional nature of the Basin is to be considered seriously for better micro-level land use planning.

**Mutual Correlation Among the Land Use Parameters :** The same table 8.3 broadly depicts that unlike the positive correlation among the physical parameters there is a significant negative correlation among the land use parameters. Area under forest has highly significant negative correlation with the area under paddy cultivation at S-I, S-II and S-III whereas, at S-IV because of the practically non-existence of forest, the relation between forest and other land use parameters has been zero. Forest has highly non-significant correlation with area not available for cultivation (S-I and S-II) and with area under other crops (S-II). Area under paddy cultivation has highly significant positive correlation with area under other crops and area not available for cultivation at S-II but negative at S-IV and also negative significant relation with area not available for cultivation at S-III. Area under other crops has significant positive correlation with area not available for cultivation at S-II and S-IV but negative relation at S-III. On the one hand, area under forest gradually decreases from upper part of the Basin to the lower part while on the other hand, due to the presence of better ecological conditions particularly the increasing irrigation facilities, the area under different crops and the area not available for cultivation i.e. mainly the settlements and village ponds increase remarkably.

**Mutual Correlation Among Physical and Land Use Parameters :** Relative relief has significant positive correlation with average slope (S-I and S-IV), roughness index (S-IV), area under forest (S-III), area under paddy (S-II) and negative correlation with area under forest (S-II). Average slope has positive correlation with drainage density (S-I), roughness index (S-I, S-II and S-IV) and negative correlation with drainage density (S-IV). Drainage density has positive correlation with roughness index (S-I), area under paddy (S-II), area not available for cultivation (S-II) and negative correlation with area under forest (S-II).

Area under forest has negative correlation with area under paddy (S-I and S-II), area not available for cultivation (S-I and S-II) and area under other crops (S-II). Area under paddy has positive correlation with area not available for cultivation (S-II) and negative correlation with area under other crops (S-IV) and area not available for cultivation (S-III and S-IV). Thus it is found that the area under forests have fully non-significant correlation with all other parameters at S-I and S-IV. Similarly, area under paddy has non-significant correlation at S-IV and area under other crops have also non-significant correlation at S-I and S-IV. Forest lands sharply fall at the S-III and S-IV in compared to those at S-I and S-II mainly because of better irrigational facilities. It is well noted that all the selected physical parameters have negative correlation only at S-IV where land use parameters are highly significant.

**Surface-wise Correlation among the Parameters :** The Table 8.3 presents the values of the correlation co-efficients between each and every pair of the characters under study for each of the geomorphic surfaces :

**Surface I :** Average slope bears a significant positive relationships with other physical parameters. The relationship with roughness index is maximum. Area under forests bears a strong negative relationship with area under paddy and area not available for cultivation. It has been observed that there is little relationship between physical and land use characters.

**Surface II :** Area under forest bears a significantly negative relationship with all the physical character under study. Average slope bears a positive highest relation with roughness index. Among the land use parameters area under paddy bears a positive relationship with relative relief and drainage density. Further, area under forest bears a negative relation with all the land use parameters. Area not available for cultivation bears a positive relation with all the parameters except relative relief, average slope and area under forest.

**Surface III :** Among the physical parameters, average slope bears a highly positive relation with roughness index and among the land use parameters, there are negative relations for the area under forest and area not available for cultivation versus area under paddy, area not available for cultivation versus area under other crops. There is no relationship among other character pairs in the land use sector.

**Surface IV :** Area not available for cultivation bears a highly negative relation with area under paddy whereas less negative relationship has observed with area under paddy versus area under other crops and area not available for cultivation versus drainage density. Other characters of land use parameters are unrelated.

Among the physical characters except drainage density versus relatively relief or roughness index, significant relationship are observed for each pair. Drainage density bears a strongly positive relation with average slope.

**8.5 CONCLUDING REMARKS :** Variations of all the eight characters, as stated earlier, over the geomorphologically divided (micro-level) four Surfaces of the Sali Basin (Table 8.1) reveal that relative relief, average slope and area under forests on Gangajalghati Upland (Surface I) and Kora Upper Plain (Surface II) have practically no variation. However, some variations are marked on Sonamukhi Rolling Plain (Surface III) and Bodai Low Flat Plain (Surface IV) in these characters. Drainage density and area not available for cultivation characters are on an average insignificant. Area under paddy and area under other crops in surface III and IV are much more variable when compared those to surface II and I. Surface-wise variability of roughness index and its influence on other parameters is significantly marked in the Basin.

Variation of the relationship between every pair of characters over the Surfaces (Table 8.2) is marked significant except in the case of the character drainage density. Variation between surface II and IV, and II and III is statistically significant in the case of all the characters except drainage density. Variation of the relationship among

different characters between the pairs of Surfaces I and II reveals that the Surface II having better terrain condition and water availability in compared to Surface I, possesses the area under paddy much higher.

Correlation matrix among the characters (Table 8.3) reveals that there is more or less significant positive correlation among the physical parameters in all the land surfaces. Highest significant positive correlation exists between average slope and roughness index in the whole area of the Basin.

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