Characterization and Utilization of Natural Resources for Planning at Microlevel for Sustained Productivity in Rainfed Agro-Eco System

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It is realized that the land, water and plant resources need to be characterized, developed, used and managed efficiently in an integrated and comprehensive manner for sustained crop productivity in general for other areas and for rainfed agro-eco systems in particular.

For characterization of soil resources, the synoptic coverage and high resolution of remotely sensed satellite image (Standard FCC imagery of IRS-ID, LISS-III) and topographic data analysis procedures are required. If this procedure is not available, alternatively, the available soft copy of the soil map and drainage map at micro watershed level of the state may be used for preparing the thematic map on soil resource, which will be of broader category. For accurate delineation of different soil units contained in the soil map, detailed soil survey is essentially required. It is expected that, the above cited evaluation will be highly helpful for better land use planning and management at basin/watershed level, and this will also help in the areas of ground water exploration, soil and water conservation and watershed management.

For characterization of rain water resources, and its consequent use at micro level requires strengthening of the net work of rainguages by installing automatic weather stations at each of the panchayat level for accurate assessment of rain water supply status. Further, it is also required to have combination of normalized differential vegetation index (NDVI) and surface skin temperature (TS) temperature – vegetation dryness index (TVDI) and Apparent thermal inertia (ATI).

Table 1. Morphometric parameters at sub-basin level.

Sub Basin	Area (Sq. km)	Perimeter (km)	Basin Length (km)	Drainage Order (in No.)					Total Number	Cumulative Length (km)	Log Cumul. Length	Stream Frequency (No./sq km)	Bifurcation Ratio	Drainage Density (km/sq.km)	Texture Ratio	Form Factor	Circulatory Ratio	Elongation Ratio
	(A)	(P)	(Lb)	N1	N2	N3	N4	N5		(L)		(Fu)	(Rb)	(Dd)	(T)	(Rf)	(Rc)	(Re)
1	25.22	37.07	14.79	106	28	6	1		141	84.89	1.93	5.56	3.78	3.36	2.85	0.12	0.23	0.38
2	34.68	35.48	14.02	114	22	4	2	1	143	99.82	1.99	4.12	5.18	2.88	3.21	0.17	0.34	0.47
3	23.39	20.05	7.34	36	7	3	1		47	45.84	1.66	2.01	5.14	1.96	1.79	0.43	0.73	0.74
4	30.98	26.55	10.69	64	16	4	1		85	75.48	1.87	2.74	4.00	2.43	2.41	0.27	0.55	0.58
5	51.31	32.49	11.33	95	22	4	3	1	125	108.91	2.04	2.43	4.32	2.12	2.92	0.39	0.61	0.71
6	32.58	26.54	8.87	43	13	3	1		60	63.73	1.80	1.84	3.31	1.95	1.62	0.41	0.58	0.73
7	21.62	20.67	7.85	18	3	1			22	37.65	1.57	1.02	6.00	1.74	0.87	0.35	0.63	0.66
8	56.36	37.28	14.82	92	19	3	1		115	130.25	2.11	2.04	4.84	2.31	2.46	0.25	0.51	0.57
9	31.55	22.20	8.24	34	6	2	1		43	51.12	1.71	1.36	5.66	1.62	1.53	0.46	0.80	0.77
10	12.76	15.78	6.39	21	6	1			28	25.30	1.40	2.19	3.50	1.98	1.33	0.31	0.64	0.63
11	28.63	21.09	7.07	52	9	2	1		64	52.94	1.72	2.23	5.77	1.85	2.46	0.57	0.81	0.85
12	27.94	23.87	9.1	33	9	3	1		46	53.43	1.73	1.64	3.66	1.91	1.36	0.34	0.61	0.65
13	63.54	39.47	14.92	72	19	5	1		97	113.39	2.05	1.53	3.79	1.78	1.82	0.28	0.51	0.60
14	33.67	26.44	10.48	48	12	3	1		64	66.99	1.82	1.90	4.00	1.99	1.81	0.31	0.60	0.62
15	131.27	55.80	17.77	196	52	13	3	1	265	250.37	2.39	2.02	3.77	1.91	3.51	0.41	0.53	0.72
16	127.26	45.77	17.17	235	56	16	4	1	312	273.06	2.44	2.45	4.19	2.14	5.13	0.43	0.76	0.74
17	15.65	21.44	8.65	42	9	2	1		54	40.90	1.61	3.45	4.66	2.61	1.96	0.21	0.43	0.52
18	33.82	26.03	9.63	74	18	6	2		100	70.36	1.85	2.95	4.11	2.08	2.84	0.36	0.63	0.68
19	51.08	33.56	12.05	52	11	1			64	79.17	1.89	1.25	4.73	1.55	1.55	0.35	0.57	0.67

Soil Resource:

Remote sensing and GIS techniques are effective tools for conducting morphometric analysis. It is considered to be the most satisfactory method as it enables us to understand the relationships among the different aspects of drainage pattern of the basin/watershed. The morphometric analysis with the satellite data in conjunction with the lithological, geomorphological and land use/land cover properties improve the delineation capabilities it will also help in upgradation of some of the drainage channels, which are altered by the natural forces or human induced activities.

The basin/watershed area will be divided into sub basins/micro-watersheds based on the water divide concept to derive various morphometric parameters.

In the present study the area has been divided into 19 sub basins. The drainage pattern of these basins ranged from dentric to sub-dentric and parallel to sub parallel with first order at higher elevations to fifth order in the lower elevations.

The area of sub-basins ranges from 12.76 Km^2 (10th sub-basin) to 131.76 Km^2. the shape of the sub-basins ranges for elongated to circular in nature.

Analysis of the topography and satellite imagery enable to recognize different broad physiographic units.

The analysis of the present study area indicated the following properties.

- The area is basically of basaltic origin and is influenced by the various fluvio-morphological processes.
- Physiographically, dissected hills of the Deccan lava flow are observed in the northern and western and south eastern parts with an elevation ranging from 400 to 520 m above msl.
- The plateau occupying the lower parts of dissected hills and their elevation ranges from 300-400 m msl.
- The plains extending from north to south are depositional in nature and their elevation ranges from 240 to 300m msl.
- The isolated mounds are also observed as relict land forms due to various denudational processes.

  The various morphometric parameters (as listed in Table-1) at sub-basin level will have to be collected for further analysis of the basin.

Total number of streams and cumulative length

The relation between the total number of streams and cumulative length indicate permeability (low/high) depth of soil and soil drainability.

- If the total number of streams of a particular basin/watershed exceeds over the cumulative length, it implies that soils are of low permeability and have structural disturbances.

Total and Cumulative length of streams

Sub Basin	Total no.of streams	Cumulative length (km)
1	141	84.89
2	143	99.82
3	47	45.84
4	85	75.48
5	125	108.91
6	60	63.73
7	22	37.69
8	115	130.25
9	43	51.12
10	28	25.3
11	64	52.94
12	46	53.43
13	97	113.39
14	64	66.99
15	265	250.37
16	312	273.08
17	54	40.9
18	100	70.38
19	64	79.17

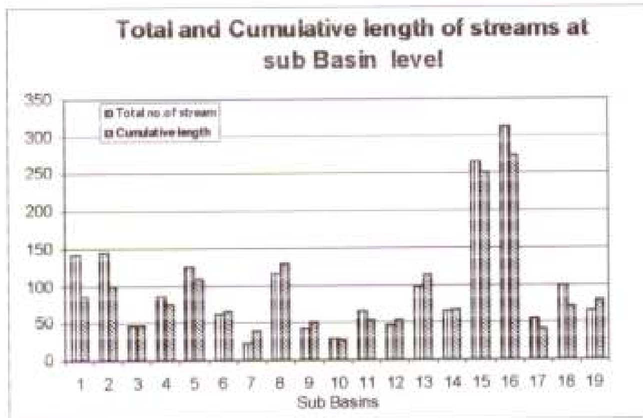


Fig. 4

- Presence of more number of Ist and 2nd order streams indicate low infiltration rate and existence of shallow soils under excessive drainage.
- If the cumulative length of stream is more than the total number of streams, it is understood that sub-basins/watersheds are favourable for longer flow and good infiltration, and the soils are of moderate to deep, with good soil drainage and good hydro-geomorpholoigcal conditions.

Area Vs Cumulative length of streams:

The relationship between the total area of the basin and total length of the streams indicates the drainage density in a particular sub-basin. The drainage density is a measure of the length of the stream segment per unit area. The drainage density is directly related to water percolation and surface run-off.

Sub Basin	Area(sq km)	Length(km)
1	25.22	84.89
2	34.68	99.82
3	23.39	45.84
4	30.98	75.48
5	51.31	108.91
6	32.58	63.73
7	21.62	37.69
8	56.36	130.25
9	31.56	51.12
10	12.76	25.2
11	28.83	52.94
12	27.95	53.43
13	63.54	113.39
14	33.68	66.99
15	131.27	250.37
16	127.26	273.08
17	15.65	40.9
18	33.87	70.38
19	51.08	79.17

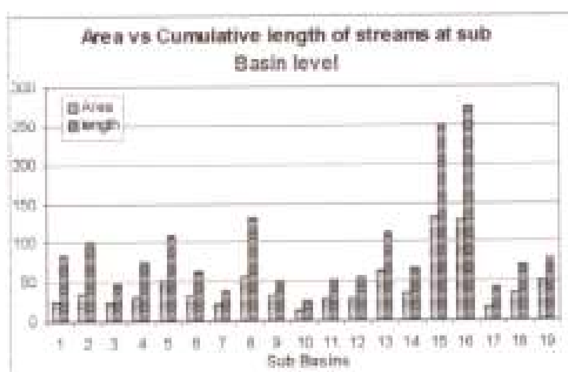


Fig. 5

- If the total length of the streams exceeds considerably over area (2 to 3 times), it indicates the basin is experiencing high intensity of surface run-off. It implies that soils that are occurring in such of the basins are having shallow to moderate soil depth and moderate soil drainage.

- If the total length of stream increases marginally as compared to the area, it is clear that such basins/watersheds are having low structural disturbances, high permeability, moderate soil depth under well drainage conditions.

Drainage density: Drainage density and area of sub-basin or watershed have good correlation.

- High drainage density (>2.5) indicate impermeable sub-surface materials, sparse vegetation, shallow soils and high relief areas.
- The low drainage density is in association with relatively larger areas, permeable sub-surface, good vegetation cover and low relief.
- The smaller the area the higher the drainage density, which leads to low infiltration and high run-off.

Drainage Density vs Area

Sub Basin	Drainage density (Km/km2)	Area (Sq km)
1	3.37	25.22
2	2.88	34.60
3	1.96	23.39
4	2.44	30.98
5	2.12	51.31
6	1.96	32.56
7	1.74	21.62
8	2.31	56.36
9	1.12	31.55
10	1.98	12.76
11	1.88	28.63
12	1.91	27.56
13	1.78	63.54
14	1.99	33.68
15	1.91	131.28
16	2.15	127.26
17	2.61	15.65
18	2.08	33.82
19	1.55	51.08

Fig. 6

Cumulative length of streams Vs Drainage density:

Cumulative length of streams and drainage density of a given sub-basin/watersheds reveal that, high cumulative length and high drainage density indicates more number of drainage lines in a smaller area. It clearly indicated that such of the sub-basins/watersheds are characterized by low permeability, high resistance under sparse vegetation, shallow to very shallow soils, well drained and low to medium soil AWC.

- On the contrary, the low cumulative length and low drainage density are favourable factors for high infiltration and low surface run-off, moderately deep soils, well to moderately well drained and high soil AWC.

Cumulative length vs Drainage density

Sub Basin	Cumulative length (km)	Drainage density (km/ km^2)
1	84.89	3.37
2	99.82	2.88
3	45.84	1.96
4	75.48	2.44
5	108.91	2.12
6	63.73	1.96
7	37.69	1.74
8	130.25	2.31
9	51.12	1.62
10	25.30	1.98
11	52.94	1.86
12	53.43	1.91
13	113.39	1.78
14	66.99	1.99
15	250.37	1.91
16	273.08	2.15
17	40.90	2.61
18	70.38	2.08
19	79.17	1.56

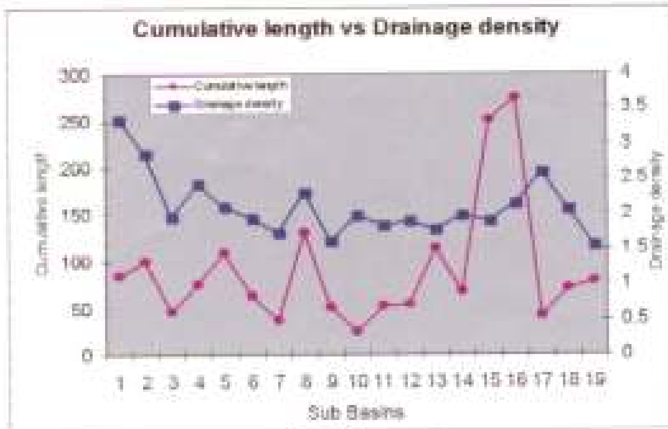


Fig. 12

Cumulative length of streams Vs Form factor:

The cumulative length and form factor analysis reveals the following.

- The relation of High form factor with low cumulative length of streams indicates that the total volume of water is running into a few channels in a shorter duration.
- Such basins are in association with shallow to moderately deep soils, well drained and low to medium soil AWC, and such soils are more susceptible for soil erosion and sedimentation load.
- Conversely the sub-basins having low form factor and high cumulative length of streams indicate longer duration of surface water flow, such watersheds are under moderately deep to deep soil, well drained and high to very high soil AWC.

Cumualtive vs Form factor

Sub Basin	Cumulative length (km)	Form factor
1	84.89	0.12
2	99.82	0.18
3	45.84	0.43
4	75.48	0.27
5	108.91	0.40
6	63.73	0.41
7	37.69	0.35
8	130.25	0.26
9	51.12	0.46
10	25.30	0.31
11	52.94	0.57
12	53.43	0.34
13	113.39	0.29
14	66.99	0.31
15	250.37	0.42
16	273.08	0.43
17	40.90	0.21
18	70.38	0.38
19	79.17	0.36

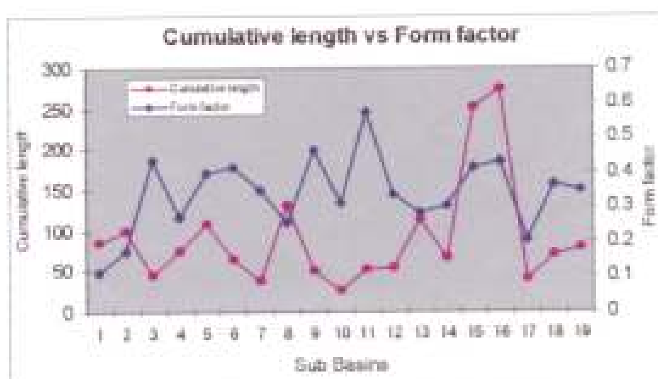


Fig. 13

Form factor Vs Circulatory ratio:

Circulatory ratio is the ratio between the area of the basin and the area of the circle having the same parameter as that of the basin.

The analysis of form factors and circulatory ratio of the sub-basins shows that circulator ratio is increasingly exponential over the form factor with high correlation.

- The basins having tense to circular shape experience low time to water flow. This rapid run-off leads to existence of extremely shallow to shallow soils under well drainage with low soil AWC as well as rill and sheet erosion.
- Conversely the sub-basins having low form factor and low circulatory ratio also possess extremely shallow to shallow soils, low to medium soil AWC because of the existence of impermeable lithology, steep slopes and sparse vegetation.

Bifurcation ratio Vs Elongation ratio:

The term bifurcation ratio is used to express the ratio of the number of streams of any given order to the number of streams in the next high order.

The elongation ratio is the ratio between the diameter of the circle having the same area (as that of basin) and the maximum length of the basin.

- The sub-basins which have suffered less structural disturbance and the drainage pattern has not been distorted due to the structural disturbances possess lower values of bifurcation ration.
- Higher bifurcation ratio values indicate high structural complexity and low permeability of the terrain. The value also indicates that the elongated basins/watersheds have more bifurcation ratio. In other words, higher bifurcation and lower elongation ratio are associated with less infiltration capacity, high run-off and severe eroded lands.
- Conversely, the sub-basins/watersheds having lower bifurcation ratio and higher elongation ratio are highly favourable for more infiltration, longer duration of surface water flow which in turn, indicate the moderately shallow to deep soils, moderately well to well soil drainage, medium to high soil AWC and slight to moderate eroded lands.

Bifurcation ratio vs Elongation ratio

Sub Basin	Bifurcation Ratio	Elongation Ratio
1	3.79	0.38
2	5.18	0.47
3	5.14	0.74
4	4.00	0.59
5	4.32	0.71
6	3.31	0.73
7	6.00	0.67
8	4.84	0.57
9	5.67	0.77
10	3.50	0.63
11	5.78	0.85
12	3.67	0.66
13	3.79	0.60
14	4.00	0.62
15	3.77	0.73
16	4.20	0.74
17	4.67	0.52
18	4.11	0.68
19	4.73	0.67

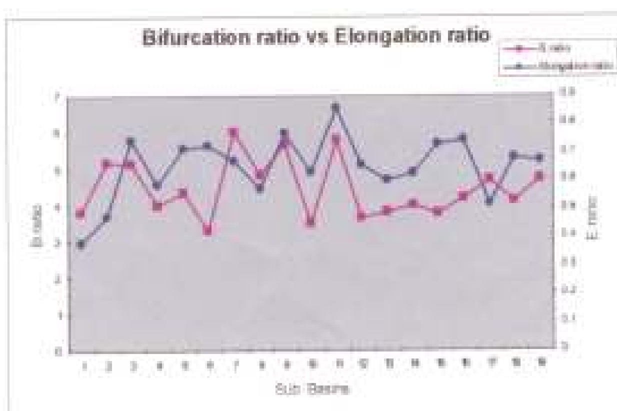
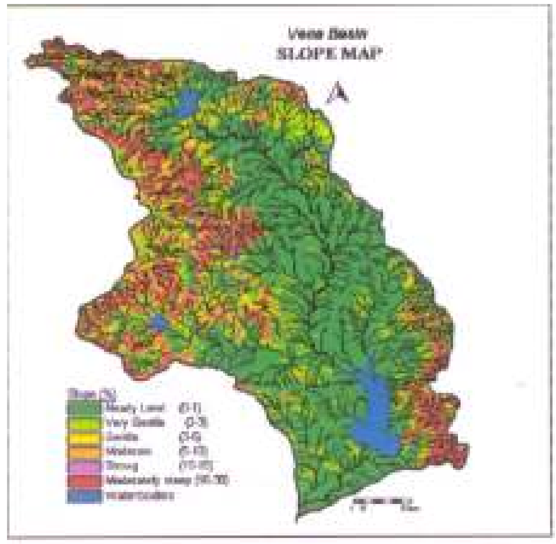


Fig. 16

Slope

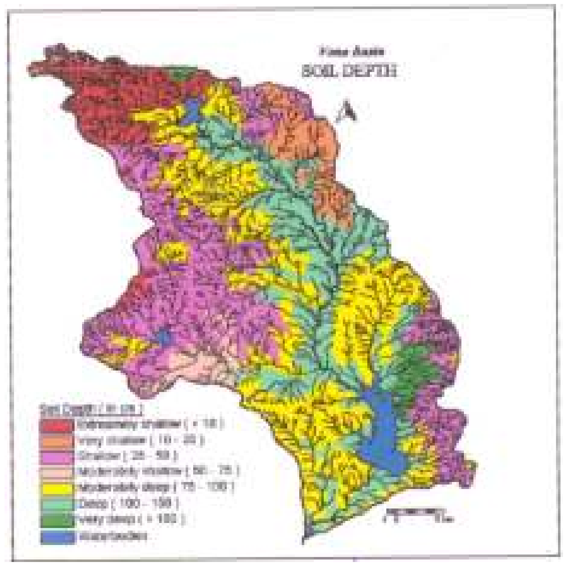


The slope analysis reveals that the north-western, western and south-eastern parts of the study area are having moderate (5-10%), strong (10-15%) and moderately steep slopes (16-30%) gradients with an area of about 9.63 per cent, 4.89 per cent and 8.05 per cent respectively. This area is mainly covered with dissected ridges, plateau spurs and escarpments. The foot slopes of the dissected ridges and upland areas are associated with gentle (3-5%) to very gentle slopes (2-3%) slopes and account for 7.53 per cent and 14.56 per cent respectively. The majority of the area is under nearly level to level slopes (0-1%) and accounts for nearly 52.08 per cent of the study area.

Geomorphology

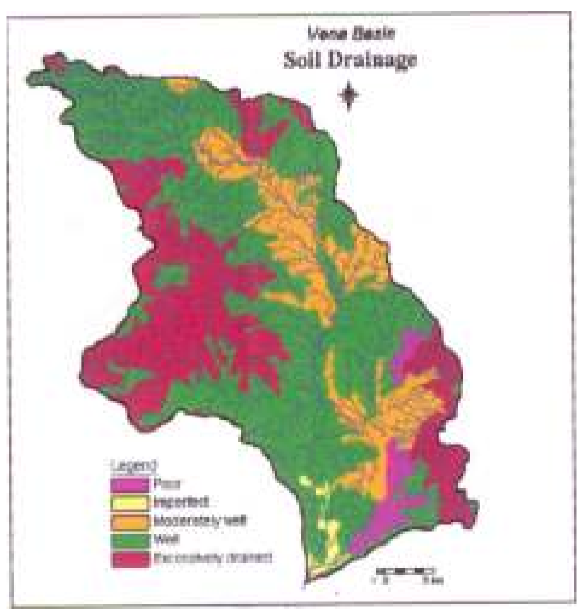
In the present study the geomorphological analysis reveals that dissected ridges, isolated mounds, linear ridges, escarpments and plateau spurs were identified and mapped under denudational landforms. Plateau plains (upper sector), middle sector, lower sector (pediplains), narrow valley fills and main valley floors were analysed and mapped under depositional land forms. The gneiss of denudational landforms are influenced by the underlying lithology, slope and morphometry (Subramanyan, 1981). These landforms are associated with high drainage density, bifurcation ratio and high cumulative length of 1st, 2nd and 3rd order streams. The depositional landforms are formed by the influence of permeable lithology, moderate to nearly level plains, medium to low drainage density (<2.0), low cumulative length of streams and are in association with 4th and 5th order streams. It reveals that the type of morphometry, underlying lithology and slope factors have greatly influence the gneiss of landforms.

Soil Depth



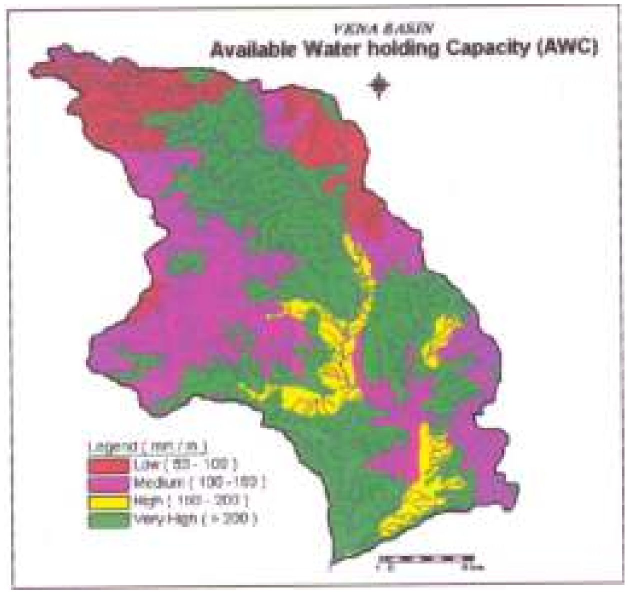
The relationship among morphometry, geomorphology and soils determine the pedological processes, resulting the evolution of present landscape. It is also well known fact that different geomorphic features in conjunction with type of parent materials and local drainage pattern influence greatly the type of soils formed in topographic sequence under specific geo-pedological environmental conditions (Das and Roy, 1979, and Reddy *et al,* 1999). It is observed that, soils in the 1,2,3 and 4 sub basins in association with dissected ridges and plateau spurs are extremely shallow underlain by weathered basalt. The soils in the upper parts of 7 and 9 sub basins are under very shallow and shallow soils exists in the upper parts of 13,14,15,16,17 and 18 sub basins. The escarpments and plateau spurs and high drainage density and steep to very steep slopes are the causative factors for shallow soils. The soils in the upper and lower sector of 5,8,13,16 and 19 sub basins are under moderately deep. The soils in lower parts of narrow valleys and main valley floor are predominantly under deep. The less drainage density, level slopes and longer flow of surface water are the influencing factors for existing deep soils. In the main valley floor soils are predominantly fluvial in nature and deep to very deep under well drained condition.

Soil Drainage



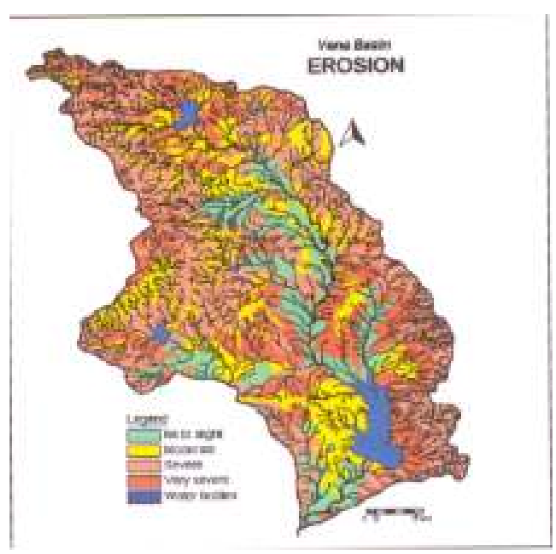
The analysis of soil drainage reveals that soils in dissected ridges, isolate mounds and linear ridges of the upper parts of 5,8,13,14,15,17 and 18th sub basins are very shallow to shallow, excessively drained and underlain by weathered basalt. The escarpments with steep to very steep slopes, have shallow and excessive drained soils. The soils in the parts of plateau spurs, dissected ridges, narrow valleys, middle and lower sectors and main valley floors are under well drained condition. The soils in the middle and lower sectors in the lower parts of 9,11 and 16 sub basins are under moderately well drained condition. The poor drained soils are mostly in unclassified area of the basin. The soils in flooding zone of 19th sub basin are under imperfect drainage because of its local topography and very less drainage density.

Available Water holding Capacity



The Available Water holding Capacity (AWC) of the soils is dependent upon the intensity of rainfall, morphometry, infiltration, permeability, depth and volume of the soils. The AWC helps in deciding the length of growing period which is essential parameter for crop planning in an area more particularly under rained conditions. In the present study the analysis of soil AWC reveals that the zone of very low soil AWC (50-100) is in association with high drainage density, high stream frequency and steep slopes in the sub basins of 1 and 2. These prevailing conditions affect the rate of infiltration of 4,5,8,11,14,15,17 and 18 sub basins the soil AWC (100-150) is medium and it coincides with moderate drainage density, stream frequency, high bifurcation ratio and moderate elongation ratio. The high soil AWC (150-200) zone is mainly under unclassified area with low drainage density, moderate slopes and good vegetation cover. The very high soil AWC (>200) zone is in association with very low drainage density, low stream frequency and low texture ratio in the sub basins of 12 and 19. The lower part, the majority of sub basins have very high soil AWC conditions.

Eroded lands

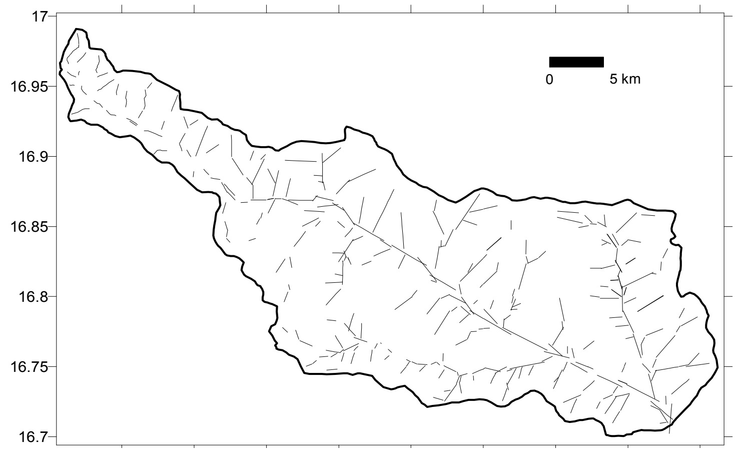


Based on the slope gradient, morphometry, broad soil physical characteristics, vegetation cover and image characteristics four categories of eroded lands i.e., very severe, severe, moderate and nil to slight were delineated from the standard FCC imagery of IRS-ID, LISS-III data at 1:50,000 scale in conjunction with the collateral and ground truth information. The nil to slightly eroded lands are in association with very gently sloping lands with moderate drainage density, low form factor, flat surfaces with much incipient loss of surface soil, double cropped area in the lower parts of 8, 13 and 15 sub basins. The moderately eroded lands are in the unclassified area, which consists of very gentle to gentle sloping lands with moderate vegetal cover and low drainage density. The severely eroded lands are in association with gently to moderately sloping lands, escarpments, plateau spurs and upper plateau plains with occasional gullies and rills, exposed to place showing sub-soil horizon and weathered parent material. These lands occur in the sub basins having high drainage density (>2.0), high bifurcation ratio (>4.0), high form factor (>0.4) and high texture ratio (>2.5). These factors are manifestation of the underlying lithology, moderate to high runoff and sparse vegetation cover. The very severely eroded lands are in the areas of dissected to undulating topography with steep to very steep slopes, at places very less vegetation cover associated with gullies, mainly covered with waste lands and occasional rock outcrops. The severe eroded lands are in association with very high drainage density (>2.5), very high stream frequency (>3.0) and less circulatory ratio (<0.5).

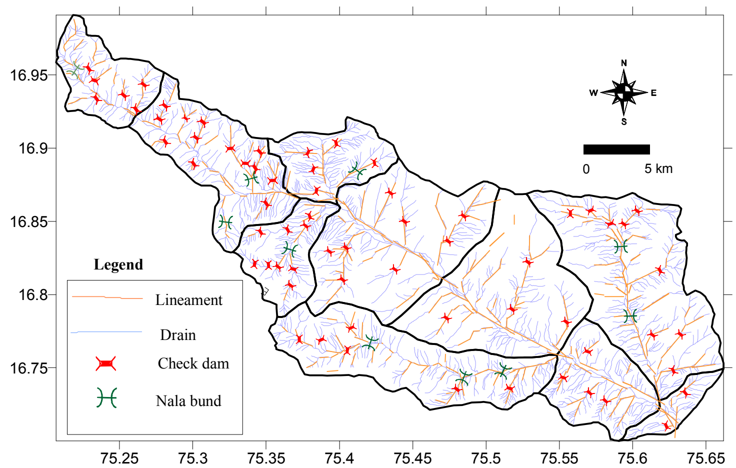
Groundwater exploration and recharge site selection

Lineament density map

In a hard rock area, the structurally controlled lineaments act as conduits for ground water movement (Anbazhagan and Ramasamy, 2006). Lineament analysis for ground water exploration in basaltic terrain has considerable importance, as joints and fractures serve as conduits for movement of ground water (Saraf and Choudhury, 1998). The lineament map(fig. 1) is prepared by using topographic sheets, drainage maps and satellite imageries. Field check was also conducted for checking the conformity of the lineaments as geologic features of interest.. In the GIS analysis, we cannot use such lineament maps directly, which should be converted into lineament density map. To do so, from such lineament data, the study area was divided into square grids of 1 Sq. Km and the total lengths of lineament falling in each grid were measured in order to determine the lineament density in Km/Sq. Km, further these were plotted on the respective grid centre and contoured. Lineaments in combination with the drainage network may be used to locate the different recharge structures (Fig. 2).

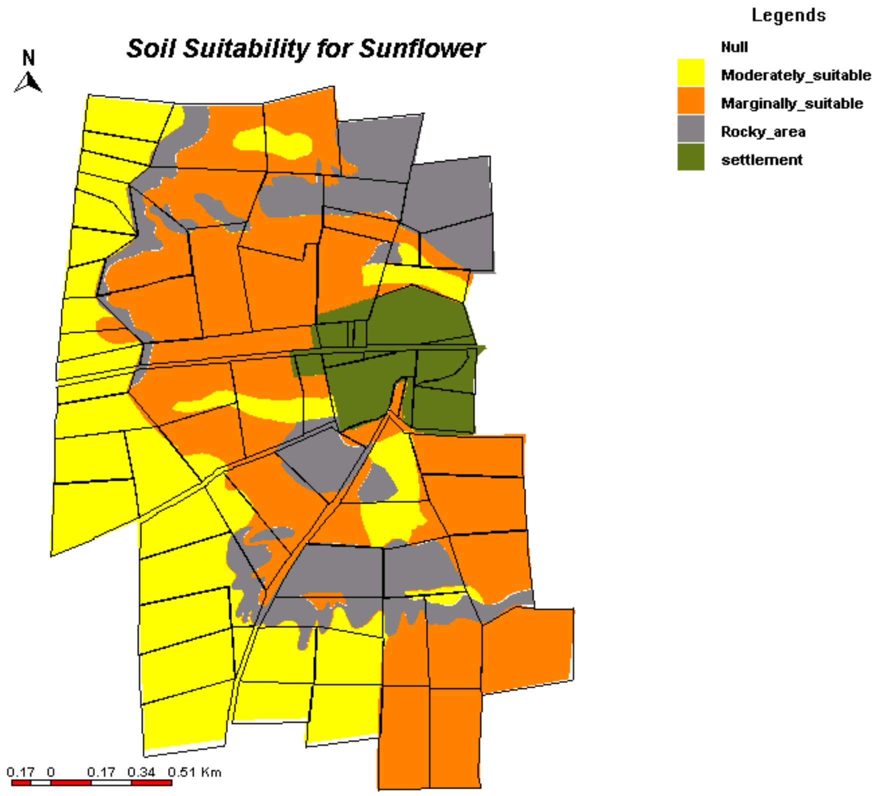


Lineament map over laid by grid map for developing lineament density map



Map showing the proposed sites for various water harvesting and recharge structures in the study area.

Soil site suitability for the different crops (Case study)



This sub watershed consists of about 350 ha. The soil survey was conducted by the National bureau of Soil Survey and Land Use Planning (NBSS-LUP), Bangalore. Under the project, in the Koulagi village, Profile pits were dug open atleast to a depth of 1.5 m, there were 54 such profile sites. The soils were divided into the different types based on the properties such as surface texture, surface gravel, soil depth, salinity, moisture available period, alkalinity and calcareous etc. After analysis, totally 20 soil units were demarcated in the area. Further, detailed topographic survey was carried out contour as well as slope maps were derived. For determining the soil suitability for the different crops, various thematic maps based on different soil properties viz., texture, soil depth, salinity, moisture available period etc. Further, for the major crops of the area, namely sunflower the soil suitability criteria developed by NBSS- LUP, Bangalore was used. For the analysis, four suitability classes were used, class S1- highly suitable , class S2- moderately suitable. Class s-3 marginally suitable and class n non suitable.

Land use requirement			Rating			
Land quality	Soil-site characteristic	Unit	Highly suitable S1	Moderately suitable S2	Marginally suitable S3	Not suitable N
Temperature regime	Mean temperature in growing season	°C	24–30	30–34; 20–24	34–38; 16–20	>38; <16
Moisture availability	Length of growing period	days	>90	80–90	70–80	<70
Oxygen availability to roots	Soil drainage	class	welldrained	moderately well drained	imperfectly drained	poorly drained
Nutrient availability	Soil reaction	pH	6.5–8.0	8.1–8.5; 5.5–6.4	8.6–9.0; 4.5–5.4	>9.0; <4.5
Nutrient retention	Texture	class	l, cl, sil, sc	scl, sic, c	c >60%, sl	ls, s
Rooting conditions	Effective soil depth	cm	>100	76–100	50–75	<50
	Gravel content	% by vol.	<15	15–35	>35	
Soil toxicity	Salinity (EC saturation extract)	dS m^{-1}	<1.0	1.0–2.0	2.0–4.0	>4.0
	Sodicity (ESP)	%	<10	10–15	>15	
Erosion hazard	Slope	%	<3	3–5	5–10	>10

Characterization of Rainwater and Management Practices

Rainwater :

- The probability of occurrence of deficit rainfall is 76 per cent and its spatial and temporal variability ranges from 31 to 64 per cent.
- High insolation (18.9-21.0 MJ/M2/day) and desiccating wind (20 km/hr) cause annual potential evaporation of 1574 mm that far exceeds rainfall by 988 mm. The eidity index is of 62 per cent.
- Drought generally occurs twice in every five years, while the severe droughts that persist for 3-4 years occur nearly once in 30 years.
- Since 16th century, drought has occurred 423 times. Out of them severe drought has occurred for 73 times.

Case Study :

Rainwater and soil resources of both the districts were characterized.

Rainfall :

- The mean annual rainfall over the study area varied from 518 mm in the extreme Southern Taluka of Badami to 639 mm in the Central region
- The following rainfall characteristics were identified.
- Long period analysis of annual rainfall (from 1901 to 2000) indicated a jump in rainfall during the 1960s, resulting in higher rainfall in the last four decades.
- Two phases on either side of this shift *i.e.*, Phase-I (1930 – 1970) and Phase-II (1970-2000) were segregated.
- Mean and Co-efficient of variation of seasonal and annual rainfall were determined and were found significant.
- The study area had the following rainfall characteristics like:

  I Increased rainfall and low variability.

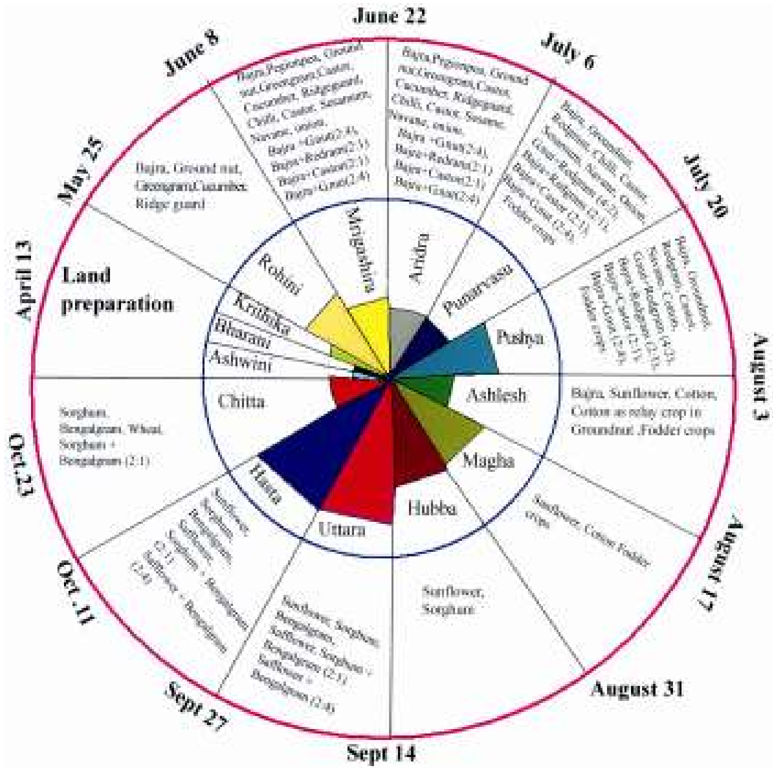
  II Decreased rainfall and high variability and

  III Increased rainfall and increased variability

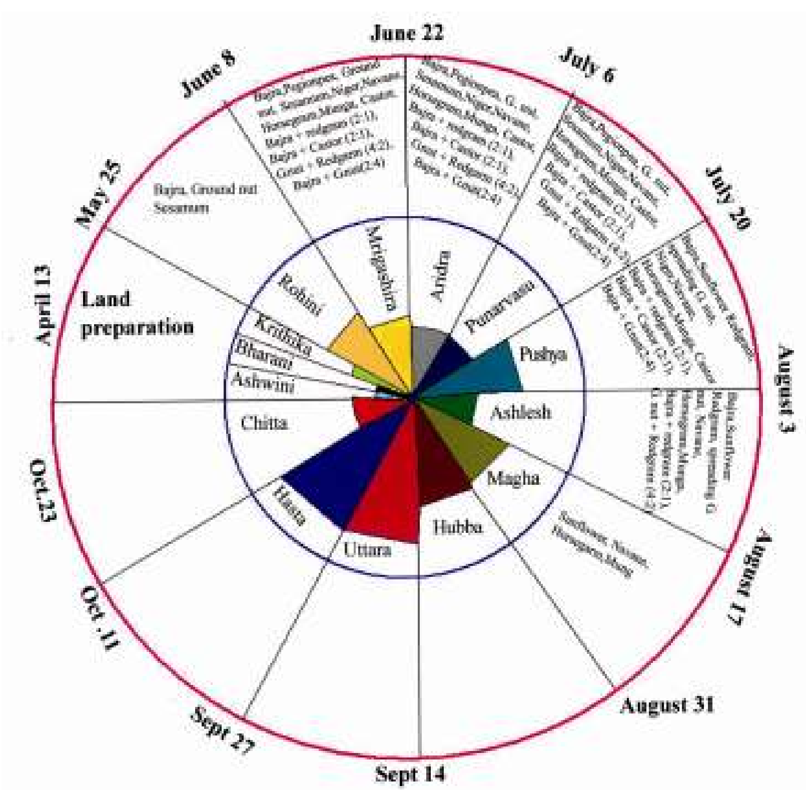
- In addition to the climatological variations, the spatial variations in intra-seasonal fluctuations for all the talukas of two districts have been identified.

- This information is important for effective micro-level planning and implementation

Management Practices



Crops and cropping systems for medium to deep black soil



Crops and cropping systems for shallow black and red soils

Increased rainfall and low variability

- Terrace and inter-terrace land management practices.
- Sequence and relay cropping system of high value crops

Increased rainfall and increased variability

- Terrace and inter-terrace land management practices.
- Wider row spacing with frequent inter-cultivation.
- Green manuring and green leaf manuring.
- Setrow cultivation.

Agronomic Practices for spatial variation in intraseasonal fluctuations

Rainfall Situation			**Crop Suggested**	
No.	High	Low	Red soils / Shallow black soils	Medium to deep black soil
1	June, July	August	Groundnut, Pearlmillet, Sesamum	Greengram, Sesamum and Sunflower, Sunflower + Greengram
2	June, August	July	Groundnut + Pearlmillet, Groundnut + pigeonpea, Groundnut + Sesamum	Sunflower and Sesamum with 135 cm row spacing and sowing the conservation furrow
3.	July	June, August	Pearlmillet with 135 cm spacing, Groundnut with 75 to 90 cm spacing, sesamum with 135 cm spacing. Sowing should be in the conservation furrow for these situations.	*Kharif* – fallow *Rabi* – Sorghum, Sunflower and chickpea
4	June	July, August		
5	August	June, July		

Decreased rainfall and high variability

- Terrace and inter-terrace land management practices.
- Zing conservation bench terraces
- Entire land grading to 0.1 – 0.2 % with rainwater impounding and surplus structures through inter-plot rainwater harvesting technique.
- Gravel sand mulching and pebble mulching.
- Farm pond water utilization technique through micro-irrigation systems.
- Agri-horti system.

Conclusion

The present challenge of dryland agriculture is to manage spatial and temporal variability associated with rainwater and soil resources by applying suitable technology and principles and to relocate both the resources appropriately with other inputs and practices to localized condition within a field to achieve improved crop production and environment quality.