*Int.J.Curr.Microbiol.App.Sci* (2020) Special Issue-11: 28-43

EXCELLENT PUBLISHERS

*International Journal of Current Microbiology and Applied Sciences*
*ISSN: 2319-7706* Special Issue-11 pp. 28-43
Journal homepage: http://www.ijcmas.com

**Original Research Article**

# Evaluation of Micro Watersheds of Coastal Navsari

**B. N. Bhanderi[*], P. K. Shrivastava, Dileswar Nayak and D. P. Patel**

College of Forestry, ACHF, Navsari Agricultural University, Navsari, India

**Corresponding author*

**A B S T R A C T**

Government investments in five year plans require precise data on demand and supply of natural resources, social, economic and regional vulnerability to disasters. The assessments of the changes that have taken place in the land use pattern are needed to prepare a land use plan. The task of evaluation and planning has become easier with the advent of remote sensing and GIS. Actual field data along with remotely sensed data could help in scientific prioritization of watersheds. In this study, nine micro watersheds belonging to 5B2F1C watershed of coastal Navsari were selected to monitor their spatial and temporal changes. The study focussed on identifying the problem of each micro watershed which consequently helped in prioritizing the micro watersheds in which government investments could be made in order to initiate development work for welfare of coastal communities. The study was taken up with the objectives of characterizing, identifying major problems, assessing land use changes and prioritizing the selected watersheds. The morphological characteristics of the micro watersheds under study were identified. Stream order was found to be 3 in all the micro watersheds whereas total stream length and relief ranged from 7 km to 16 km and 9 m to 15 m respectively. Micro watershed 1C2 with ruggedness number 24.58 was found to be most prone to erosion compared to other micro watersheds. Drainage density varied from 0.84 in 1C1 to 1.62 in 1C2. The highest values of form factor, circulatory ratio and elongation ratio were 0.57, 0.85 and 0.86 in 1C1, 1C2 and 1C1 respectively. According to hydrological characterization, micro watershed 1C8 should get top priority followed by 1C4 and least priority should be given to 1C1. With respect to availability of water in form of water bodies and canal water supply, 1C3 required top priority whereas on the basis of soil and water parameters, 1C7 required top priority. 1C8 and 1C9 required top priorities based on their socio-economic condition. The overall priority showed that micro watershed 1C2 needed top priority followed by 1C3, 1C9, 1C8, 1C4, 1C1, 1C7, 1C5 and 1C6. This prioritization could be used by government departments, NGO's and funding agencies while planning and executing projects to fulfil specific mandates. It was concluded that all the micro watersheds needed groundwater recharging to combat sea water intrusion and brackish water aquaculture should be avoided where it is possible to harvest rain water and cultivate sweet water fish. Evaluation and assessment of changes in watersheds over a period of time could help in rectifying the follies committed in the past and necessary steps could be taken in prioritized micro watersheds.

**Keywords**

Geographic Information System, Morphological characteristics, Prioritization, Remote sensing, Watershed

## Introduction

Gujarat has 1600 km of coastline which is the longest coastline among all states of India, accounting for 22 % of the country. Due to over exploitation of ground water resource, sea water has infiltrated deep within the aquifers of coastal districts making the water unsuitable for drinking and irrigating. Perennial water demands coupled with erratic monsoon patterns and global warming is creating recurring water crisis in India which aggravates in coastal areas due to incoming coastal salinity through ground water. Depleting water table is indication of vanishing rainwater harvesting with ponds, lakes and wells, poor awareness and reduced green cover. As per Central Water

Commission (CWC) estimates by 2050, an average annual water requirement will be 1180 BCM and the average annual water availability 1140 BCM (Anonymous, 2016).

Saline water storage in surface areas is bound to have its detrimental effect on sweet water aquifers, which aggravates already scarce situation of quality drinking water. In many coastal villages drinking water is supplied through tankers on weekly basis. Thus, management of water resources is of prime importance to keep the balance for sustaining the biodiversity of coastal areas. Land use plan of coastal areas is need of the day when improvement of coastal regions is to be planned as well as to sustain the quality of natural resources, when there are erratic climatic changes taking place due to global warming. To prepare a land use plan, assessments of changes that have taken place in the land use pattern were needed to be carried out. The rate of changes provides information on much needed focus in the form of government investments to sustain and improve the deteriorating situation.

Waikar and Nilawar (2014) carried out study on Charthana area of Parbhani district of Maharashtra state in India to determine morophometric characteristics of watershed. . The GIS based morphometric analysis of this drainage basin revealed that the Charthana is $4^{th}$ order drainage basin and drainage pattern was mainly in sub-dendritic to dendritic type thereby indicating homogeneity in texture and lack of structural control. The drainage density of study area was 1.45 $km/km^2$.This study would help the local people to utilize the resources for sustainable development of the basin area. Shaikh and Birajdar (2015) identified morphological features of the Eru river Basin, sub watershed of Mahi river, Rajasthan, India. The study area covered 71.40 $km^2$ comprising of 3 sub-watersheds. The drainage network of 3 sub-watersheds was delineated using Landsat ETM remote sensing data and standard Survey of India topographical maps on 1:50,000 scale. The drainage network showed that the terrain exhibited dendritic to sub-dendritic drainage pattern. The highest stream order was fourth order. Estimated drainage density and mean bifurcation ratio was approximately 1.82 and 3.70 respectively indicating uniform geological structure and lithology in watershed area. The study showed that GIS techniques proved to be a competent tool in morphometric analysis.

Rawat and Kumar (2015) illustrated the spatio-temporal dynamics of land use/cover of Hawalbagh block of district Almora, Uttarakhand, India. Landsat satellite imageries of two different time periods viz. year 1990 and year 2010 were used to quantify the changes in the Hawalbagh block by ERIDAS software. The results indicated that during the last two decades, vegetation and built-up land had increased by 3.51% (9.39 $km^2$) and 3.55% (9.48 $km^2$) while agriculture, barren land and water body have decreased by 1.52% (4.06 $km^2$), 5.46% (14.59 $km^2$) and 0.08% (0.22 $km^2$), respectively in digital change detection techniques for nature and location of change of the Hawalbagh block..

The present investigation of coastal watersheds was taken up with the objectives of characterizing selected micro watersheds, identifying major problems of the micro watersheds, prioritizing micro-watersheds for sustainable use and assessing land use changes in micro watershed.

## Study area

Study area consisted of watersheds ‘5B2F1C’ near Dandi coast in the Jalalpore Taluka of Navsari District in Southern Gujarat at 72.78° E to 72.96° E longitude, 20.86° N to

20.96° N latitude and 3 to 18 m altitude. There are 9 micro watersheds namely 1C1, 1C2, 1C3, 1C4, 1C5, 1C6, 1C7, 1C8 and 1C9 in the watershed '5B2F1C'. The location of micro-watersheds in Jalalpore taluka located in Navsari district is shown in Fig. 1

## Materials and Methods

Primary data were collected from selected villages by spot sampling of the soil and water samples. The temporal changes were observed through analysis of remotely sensed imageries as well as from secondary data collected from Government records. Each micro watershed was characterized using geo morphological analysis using RS & GIS for which ERDAS software, Quantum GIS and Microsoft office were used. Ground truthing was done by collecting samples on monthly basis and later analyzing the same in the laboratory of Natural Resource Department for further calculations. Relevant parameters were graphically presented for interpretation and discussion. Problems of each micro-watershed were identified with the help of laboratory analysis, field observations and personal conversation with residents as well as government records. The analysis done from ground truthing was later matched with the information obtained from satellite imageries to draw conclusive solutions of each identified problems for each micro watershed.

### Morphometric analysis of watersheds

Morphometry is the measurement and mathematical analysis of the configuration of the surface, shape and dimensions of its landforms. In the present study, the morphometric analysis for the parameters namely stream order, stream length, bifurcation ratio, stream length ratio, basin length, drainage density, stream frequency, elongation ratio, circularity ratio, form factor, relief ratio, relative relief and ruggedness number has been carried out using the formulae given in Table 1.

### Prioritization of watersheds

The prioritization was carried out by assigning weights out of the scale of 10. In most of the parameters, highest weight was indicative of least priority, whereas, lowest weight indicated top priority. Such type of index was used by Bera *et al.,* (2013) for prioritization of watersheds. The allotment of weighs and fixation of priority based on various parameters selected in the study are given in Table 2 to Table 5.

### Land use / Land cover change detection

Landsat Thematic Mapper at a resolution of 30 m of November 2000 and November 2015 were used for land use/cover classification. The satellite data covering study area were obtained from Land sat Look viewer (http://http://landsatlook.usgs.gov/viewer.html) and earth explorer site (http://earthexplorer.usgs.gov/). These data sets were imported in ERDAS Imagine Professional (Leica Geosystems, Atlanta, U.S.A.), satellite image processing software to create a false colour composite (FCC). To work out the land use/cover classification, unsupervised classification method with maximum likelihood algorithm was applied in the ERDAS Imagine Professional, 2013. The classification of unsupervised data through ERDAS Image helped in identifying the terrestrial objects in the Study Image (SSC).

## Results and Discussions

The results regarding the morphometric analysis, prioritization, identification of problems, land use detection, water quality and measures for sustainable use of prioritizes of prioritized micro-watersheds are given in this section.

## Morphometric analysis of watershed

The stream number and order affects the time of concentration of runoff at the outlet thus impacting the design to handle the flow at the outlet. The total number of streams was highest in 1C8 and lowest in 1C7 while bifurcation ratio (Rb) was found to be highest in 1C1 and lowest in 1C3. Higher Rb indicates a strong structural control on the drainage pattern, while the lower value indicate micro watershed are not affected by structural disturbances. Maximum and minimum stream length ratios of 4.35 and 1.18 were obtained in 1C3 and 1C1 micro watershed. The change of stream length ratio from one order to another indicated their late youth stage of geomorphic development. The linear, relief and aerial characteristics are given in Table 6, 7 and 8 respectively.

Relief indicates the maximum vertical distance between the lowest and the highest points, in the watershed, higher the relief higher will be the velocity of water. The highest and lowest relief ratio of 1.76 and 0.69 was obtained in 1C5 and1C3 respectively. The higher values indicated steep slope while lower values indicated lesser slopes impacting discharge at the outlet. Ruggedness number of the micro watershed suggests the proneness to erosion. The highest and lowest value of ruggedness number of 24.58 and 7.52 were found in 1C2 and 1C1 micro watersheds.

Drainage density varied from 0.84 to 1.62. According to Nag (1998), low drainage density generally resulted in the area of highly resistant or permeable sub soil material, dense vegetation and low relief. High drainage density was the result of weak or impermeable sub surface material, sparse vegetation and mountainous relief. The highest and lowest stream frequency of 2.32 and 1.02 were found in 1C8 and 1C7. The highest values of form factor, circulatory ratio and elongation ratio were 0.57, 0.85 and 0.86 respectively in micro watershed 1C1, 1C2 and 1C1 whereas, the lowest values of form factor, circulatory ratio and elongation ratio were 0.20, 0.34 and 0.50 respectively in micro watershed 1C3. Form factor, circulatory ratio and elongation ratios describe the shape of the basin which affects the flow pattern in the watershed. Length of overland flow is inversely related to the average slope of the channel. Maximum length of overland flow was observed in micro watershed 1C1. The maximum and minimum constant channel maintenance of 1.2 and 0.62 were found in 1C1 and 1C2 respectively.

## Prioritization of watersheds on different criteria

Priority was fixed by summation of scores under each broad category of classification needed for prioritization. Prioritization based on hydrology, water availability, water quality and socio economic criteria are r given in Table 9, 10, 11 and 12 respectively. Highest score was given the lowest priority and vice versa. However, for population parameter, priority was given to highest score, as more people were affected.

According to hydrological characterization, micro watershed 1C8 should get top priority followed by 1C4 and the least priority in 1C1.

With respect to availability of water in the form of water bodies and canal water supply, 1C3 should get top priority followed by 1C1, 1C4 and 1C4, whereas 1C8 should be given least priority.

1C7 required top priority followed by 1C9, whereas 1C5 should be given least priority on the basis of soil and water parameters. In socio economic category also 1C8 and 1C9 should be given priorities.

In socio economic category also 1C8 and 1C9 should be given priorities compared to other micro-watersheds.

Finally, overall priority was determined by taking average of each category in each micro watershed. It shows that micro watershed 1C2 should be given top priority followed by 1C3, 1C9, 1C8, 1C4, 1C1, 1C7, 1C5 and 1C6 in that order as given in Table 13. The major problems of the top 3 prioritized micro-watersheds namely 1C2, 1C3 and 1C9 are given in Table 14.

The land use maps and data pertaining to land use change of micro-watershed 1C2 are given in Fig. 2 and Table 15 respectively. The data analysis showed that in year 2001, about 63.62 % (635.65 ha), 19.97 % (199.59 ha), 8.67 % (86.66 ha) and 7.74 % (77.30 ha) was under water body, vegetation, built up and barren land respectively. The land use pattern of year 2015 was different from that of year 2001 as 38.72 % (386.87 ha), 18.28 % (182.68 ha), 7.69 % (76.79 ha) and 35.32 % (352.96 ha) was under water body, vegetation, built up and barren land respectively. The land use pattern of water category had reduced by 24.9 %. It could be inferred that area under brackish water or sea water or the river joining the sea has decreased, whereas barren land has increased up to 27.59 %. This showed that in 1C2 micro-watershed, silt had deposited and owing to nearness to sea it had become saline and therefore, it could not hold any vegetation.

The land use maps and data pertaining to land use change of micro-watershed 1C3 are given in Fig. 3 and Table 16 respectively. The spatial distributional pattern of data for MW-1C4 revealed that in 2001, about 24.94 % (208.86 ha), 28.91 % (242.08 ha) and 46.15 % (386.41 ha) were under water body, vegetation and barren land respectively. The land use pattern of 2015 was different from that of 2001 period as 59.54 % (498.54 ha), 28.23 % (236.42 ha) and 12.23 % (102.43 ha) were under water body, vegetation and barren land. The land use pattern under vegetation category had reduced by 0.68 per cent. Barren class reduced by 33.91 %, but water classes increased by 34.59 %. It could be inferred that area under water body had increased.

The land use data revealed that in 2001, about 3.59 % (24.57 ha), 25.29 % (173.07 ha), 15.78 % (108.00 ha), 48.25 % (330.20 ha), and 7.09 % (48.52 ha) area was under water body, vegetation, built-up land, agriculture land and barren land respectively. The land use pattern of 2015 was 1.56 % (10.70 ha), 23.92 % (163.67 ha), 28.80 % (197.07 ha), 40.23 % (275.33 ha) and 5.49 % (37.59 ha) under water body, vegetation, built-up land, agriculture land and barren land respectively. The land use pattern under agriculture category had reduced by 8.02 %. Water, vegetation and barren land had reduced by 2.03 %, 1.37 % and 1.60 % respectively while built up area recorded an increase of 13.02 %.In micro-watershed 1C9, population pressure could be seen by the construction activity at the cost of all the other land use patterns (Fig.4 and Table 17).

## Measures for sustainable use of prioritized micro-watersheds

### Micro watershed - 1C2

1. Regulation on saline water aquaculture to preserve underground water
2. Efforts are needed to conserve rain water
3. Plantation of Mangroves to protect from tidal waves.
4. Ponds for harvesting rain water to prevent sea water ingress and to attract birds.

**Micro watershed - 1C3**

There is ample scope of developing large sweet water ponds that may help in raising salinity resistant species which may attract migratory birds and could be developed into bird sanctuary

**Table.1** Morphometric parameters used for watershed characterizations

| Sr. No. | Morphometric parameters | Formula | Reference |
|---|---|---|---|
| 1 | Stream Order | Hierarchical | Strahler (1964) |
| 2 | Stream Length, Km (Lu) | Length of stream | Horton (1945) |
| 3 | Mean stream length (Lsm) | Lsm = Lu/Nu<br>Where, Lu=total stream length of order u<br>Nu= Total number of stream segments of order ‘u’ | Strahler (1964) |
| 4 | Stream Length ratio (RL) | RL = Lu/(Lu-1)<br>Where, Lu= Total stream length of order ‘u’<br>u-1=total no of stream segments of its Next lower order | Horton (1945) |
| 5 | Bifurcation ratio (Rb) | Nb = Nu/(Nu+1)<br>Where, Nu= Total stream length of order ‘u’ Nu+1=Number of segments of next higher order | Schumn (1956) |
| 6 | Mean bifurcation ratio(Rbm) | Average of bifurcation ration of all orders | Strahler (1957) |
| 7 | Length of main channel (Lm) Km | Length along longest water course form the outflow point of designated sub-basin to the upper limit of catchment boundary | Horton (1945) |
| 8 | Drainage Density (Dd) | Dd = Lu/A<br>Where, Lu=Total stream length of all orders, km<br>A=Area of the Basin,$km^2$ | Horton (1932) |
| 9 | Length of overland flow (Lg) | Lg = 1/ $Dg^2$<br>Where, Dd = Drainage Density | Horton (1945) |
| 10 | Basin length (Lb) Km | Distance between outlet and farthest point on basin boundary | Horton (1945) |
| 11 | Basin perimeter (P) Km | Length of watershed divide which surround the Basin | Horton (1945) |
| 12 | Fineness ratio (Rfn) | Rfn = Lb/P<br>Where, Lb = Basin length, km<br>P = Basin perimeter, km | Melton (1957) |

| | | | |
|---|---|---|---|
| 13 | Basin/drainage area (A) | Area enclosed within the boundary of watershed divide | Horton (1932) |
| 14 | Constant of channel maintenance (C) | $C=1/D$<br>Where, D=Drainage Density, $km/km^2$ | Horton (1932) |
| 15 | Stream frequency (Fs) | $Fs = Nu/A$<br>Where, Nu= Total number of stream segments of all order<br>A = Area of the Basin, $km^2$ | Horton (1932) |
| 16 | Circulatory ratio (Rc) | $Rc = 2 R x A / P^2$<br>Where, Rc=Circularity Ratio<br>A=Area of the basin,$km^2$ | Miller (1953) |
| 17 | Elongation ratio (Re) | $Re = 2R / Lb$<br>Where, A = Area of the basin,$km^2$<br>R=radius of circle whose area equal to basin area, Lb =Basin length | Schumm (1956) |
| 18 | Form Factor(Rf) | $Rf = A / Lb$<br>Where, A = Area of the basin,$km^2$<br>Lb = Basin length | Horton (1932) |
| 19 | Total relief (H) | H = is the maximum vertical distance between the lowest (outlet) and the highest (divide) points in the watershed. | Schumm (1956) |
| 20 | Relief ratio (Rh) | $Rh= H/Lb$<br>Where, H =basin total relief, Lb = basin Length | Schumm (1956) |
| 21 | Relative relief (Rp) | $Rp = H / P$<br>Where H = total relief, P = Perimeter | Melton (1957) |
| 22 | Ruggedness number (Rn) | $Rn = H X Dd$<br>Where, H = Total relief<br>Dd = drainage density | Strahler (1957) |

**Table.2** Weight allotment to standard water classification and its priority

| **EC** | **Weight** | **Priority** | **SAR** | **Weight** | **Priority** |
|---|---|---|---|---|---|
| <1 | 10 | 3 | <0.5 | 10 | 3 |
| 1.0- 2.0 | 5 | 2 | 5.0 - 12 | 5 | 2 |
| >2 | 0 | 1 | >12 | 0 | 1 |
| **RSC** | **Weight** | **Priority** | **CL** | **Weight** | **Priority** |
| <1.5 | 10 | 3 | <6 | 10 | 3 |
| 1.5 - 2.5 | 5 | 2 | 6.0 - 12 | 5 | 2 |
| >2.5 | 0 | 1 | >12 | 0 | 1 |

**Table.3** Weight allotment to soil and water supply classification and its priority

| **Canal** | **Weight** | **Priority** | **Water Body** | **Weight** | **Priority** |
|---|---|---|---|---|---|
| Water supply | 10 | 3 | sweet | 10 | 3 |
| Occasional supply | 5 | 2 | Saline | 0 | 2 |
| No supply | 0 | 1 | no | 5 | 1 |
| **Soil EC** | **Weight** | **Priority** | **OC** | **Weight** | **Priority** |
| < 0.8 | 10 | 4 | > 10 | 10 | 3 |
| 0.8 - 1.6 | 7.5 | 3 | 5.0 - 10.0 | 5 | 2 |
| 1.6 - 2.5 | 5 | 2 | <5 | 0 | 1 |
| > 2.5 | 0 | 1 | | | |

**Table.4** Allotment of weights to demographic classification and its priority

| **Population** | **Weight** | **Priority** | **Scheduled Caste** | **Weight** | **Priority** |
|---|---|---|---|---|---|
| 7000 – 5000 | 2.5 | 1 | >250 | 0 | 1 |
| 5000 – 3000 | 5 | 2 | 250 - 150 | 2.5 | 2 |
| 3000 – 1000 | 7.5 | 3 | 150 - 100 | 5 | 3 |
| >1000 | 10 | 4 | 100 - 50 | 7.5 | 4 |
| | | | <50 | 10 | 5 |
| **Scheduled tribe** | | | **Weight** | **Priority** | **Scheduled tribe** |
| >1000 | | | 0 | 1 | >1000 |
| 1000 - 750 | | | 2.5 | 2 | 1000 - 750 |
| 750 - 500 | | | 5 | 3 | 750 - 500 |
| 500 - 250 | | | 7.5 | 4 | 500 - 250 |
| <250 | | | 10 | 5 | <250 |

**Table.5** Weight allotment to economic and nearness to city classification and its priority

| **Economic** | **Weight** | **Priority** | **Nearness to City HQ** | **Weight** | **Priority** |
|---|---|---|---|---|---|
| High | 10 | 3 | City | 10 | 4 |
| Medium | 7.5 | 2 | Adj. city | 7.5 | 3 |
| Low | 2.5 | 1 | 5 Km away | 2.5 | 2 |
| | | | >5 Km | 1 | 1 |

**Table.6** Linear characteristics of the selected micro watershed

| Parameter | Micro Watersheds | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1C1 | 1C2 | 1C3 | 1C4 | 1C5 | 1C6 | 1C7 | 1C8 | 1C9 |
| **Stream order** | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| **Total stream length of all orders (km)** | 9.07 | 16.16 | 10.2 | 16.11 | 9.16 | 9.62 | 6.95 | 13.09 | 6.96 |
| **Mean stream length (m)** | 0.78 | 1.45 | 1.74 | 0.86 | 0.69 | 0.93 | 0.85 | 0.58 | 0.61 |
| **Total stream of all orders (Nu)** | 12 | 15 | 9 | 21 | 14 | 10 | 8 | 22 | 12 |
| **Bifurcation ratio (Rb)** | 3 | 2.41 | 1.25 | 2.6 | 1.54 | 2.5 | 2.25 | 2.02 | 2.83 |
| **Stream length ratio (Rl)** | 1.18 | 3.93 | 4.35 | 3.2 | 2.17 | 3.05 | 3.02 | 1.25 | 2.69 |
| **Total** | 16.18 | 21.34 | 14.6 | 26.8 | 17.71 | 15.55 | 13.27 | 25.27 | 17.52 |
| **Priority** | **6** | **3** | **8** | **1** | **4** | **7** | **9** | **2** | **5** |

**Table.7** Relief characteristics of the selected watershed

| Parameter | Micro Watersheds | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1C1 | 1C2 | 1C3 | 1C4 | 1C5 | 1C6 | 1C7 | 1C8 | 1C9 |
| **Total relief** | 9 | 15 | 9 | 12 | 15 | 12 | 9 | 9 | 9 |
| **Relief ratio** | 1.03 | 1.71 | 0.69 | 1.11 | 1.76 | 1.11 | 0.87 | 0.92 | 0.81 |
| **Relative relief** | 0.65 | 1.23 | 0.51 | 0.65 | 1.22 | 0.76 | 0.65 | 0.68 | 0.65 |
| **Ruggedness Number** | 7.52 | 24.58 | 11.04 | 13.49 | 15.99 | 11.55 | 7.99 | 12.42 | 9.16 |
| **Total** | 9.2 | 27.52 | 12.24 | 15.25 | 18.97 | 13.42 | 9.51 | 14.02 | 10.62 |
| **Priority** | 9 | 1 | 6 | 3 | 2 | 5 | 8 | 4 | 7 |

**Table.8** Aerial characteristics of the selected watershed

| Parameter | Micro Watersheds | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1C1 | 1C2 | 1C3 | 1C4 | 1C5 | 1C6 | 1C7 | 1C8 | 1C9 |
| **Area of watershed (sq. km)** | 10.82 | 9.99 | 8.37 | 14.33 | 8.6 | 9.63 | 7.84 | 9.49 | 6.84 |
| **Perimeter** | 13.87 | 12.17 | 17.5 | 18.41 | 12.31 | 15.69 | 13.84 | 13.32 | 13.8 |
| **Drainage density** | 0.84 | 1.62 | 1.23 | 1.12 | 1.07 | 0.96 | 0.89 | 1.32 | 1.02 |
| **Stream frequency** | 1.1 | 1.5 | 1.08 | 1.47 | 1.63 | 1.04 | 1.02 | 2.32 | 1.75 |
| **Form factor** | 0.57 | 0.52 | 0.2 | 0.49 | 0.47 | 0.33 | 0.29 | 0.4 | 0.22 |
| **Circulatory ratio** | 0.71 | 0.85 | 0.34 | 0.53 | 0.71 | 0.49 | 0.51 | 0.67 | 0.45 |
| **Elongation ratio** | 0.86 | 0.81 | 0.5 | 0.79 | 0.78 | 0.65 | 0.61 | 0.71 | 0.53 |
| **Length of overland flow** | 1.43 | 0.38 | 0.66 | 0.79 | 0.88 | 1.08 | 1.27 | 0.52 | 0.96 |
| **Constant channel maintenance** | 1.2 | 0.62 | 0.82 | 0.89 | 0.94 | 1.04 | 1.13 | 0.72 | 0.98 |
| **Fineness ratio (Rfn)** | 0.31 | 0.36 | 0.37 | 0.29 | 0.35 | 0.34 | 0.37 | 0.37 | 0.4 |
| **Total** | 3.34 | 2.8 | 1.86 | 2.7 | 2.9 | 2.51 | 2.54 | 2.5 | 2.18 |
| **Priority** | 9 | 7 | 1 | 6 | 8 | 4 | 5 | 3 | 2 |

**Table.9** Prioritization based on hydrology

| Watershed | 1C1 | 1C2 | 1C3 | 1C4 | 1C5 | 1C6 | 1C7 | 1C8 | 1C9 |
|---|---|---|---|---|---|---|---|---|---|
| **Linear priority** | 6 | 3 | 8 | 1 | 4 | 7 | 9 | 2 | 5 |
| **Relief priority** | 9 | 1 | 6 | 3 | 2 | 5 | 8 | 4 | 7 |
| **Aerial priority** | 9 | 7 | 1 | 6 | 8 | 4 | 5 | 3 | 2 |
| **Average score** | 8.0 | 3.7 | 5.0 | 3.3 | 4.7 | 5.3 | 7.3 | 3.0 | 4.7 |
| **Final Priority** | 9 | 3 | 6 | 2 | 4 | 7 | 8 | 1 | 5 |

**Table.10** Prioritization based on Water Availability

| Watershed | 1C1 | 1C2 | 1C3 | 1C4 | 1C5 | 1C6 | 1C7 | 1C8 | 1C9 |
|---|---|---|---|---|---|---|---|---|---|
| **Sweet water** | 2 | 6 | 0 | 4 | 6 | 2 | 2 | 8 | 4 |
| **Canal** | 0 | 0 | 0 | 0 | 0 | 5 | 5 | 10 | 10 |
| **Saline water** | 0 | 0 | 0 | 0 | 10 | 10 | 10 | 10 | 10 |
| **Total** | 2 | 6 | 0 | 4 | 16 | 17 | 17 | 28 | 24 |

**Table.11** Prioritization based on water quality

| Watershed | 1C1 | 1C2 | 1C3 | 1C4 | 1C5 | 1C6 | 1C7 | 1C8 | 1C9 |
|---|---|---|---|---|---|---|---|---|---|
| **Water EC** | 5 | 5 | 0 | 5 | 10 | 5 | 0 | 5 | 0 |
| **RSC** | 0 | 0 | 10 | 10 | 5 | 0 | 0 | 5 | 0 |
| **CL** | 10 | 5 | 5 | 10 | 10 | 10 | 5 | 10 | 5 |
| **Soil EC** | 7.5 | 10 | 5 | 10 | 7.5 | 10 | 10 | 10 | 10 |
| **SOC** | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| **Total** | 27.5 | 25 | 25 | 40 | 37.5 | 30 | 20 | 35 | 20 |

**Table.12** Prioritization on the basis of socio economic factors

| Watershed | 1C1 | 1C2 | 1C3 | 1C4 | 1C5 | 1C6 | 1C7 | 1C8 | 1C9 |
|---|---|---|---|---|---|---|---|---|---|
| **Population** | 7.5 | 7.5 | 5 | 7.5 | 7.5 | 10 | 10 | 2.5 | 7.5 |
| **SC** | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 7.5 | 2.5 |
| **ST** | 10 | 10 | 2.5 | 10 | 10 | 7.5 | 7.5 | 0 | 2.5 |
| **Economy** | 10 | 10 | 10 | 10 | 10 | 7.5 | 7.5 | 2.5 | 2.5 |
| **Nearness to city** | 1 | 1 | 1 | 1 | 1 | 7.5 | 7.25 | 10 | 10 |
| **Total** | 38.5 | 38.5 | 28.5 | 38.5 | 38.5 | 42.5 | 42.25 | 22.5 | 25 |

**Table.13** Final prioritization based on different criteria

| Prioritized Micro-Watershed | Prioritization based on Hydrology | Prioritization based on Water Availability | Prioritization based on Soil & Water Quality | Socio Economic Criteria of Prioritization | Average |
|---|---|---|---|---|---|
| 1C2 | 3 | 4 | 3 | 5 | 1 |
| 1C3 | 6 | 1 | 5 | 3 | 2 |
| 1C9 | 5 | 8 | 2 | 2 | 3 |
| 1C8 | 1 | 9 | 7 | 1 | 4 |
| 1C4 | 2 | 3 | 8 | 6 | 5 |
| 1C1 | 9 | 2 | 4 | 4 | 6 |
| 1C7 | 8 | 7 | 1 | 8 | 7 |
| 1C5 | 4 | 5 | 9 | 7 | 8 |
| 1C6 | 7 | 6 | 6 | 9 | 9 |

**Table.14** Identification of major problems

| Micro watershed | Complaints / Issues | Problem Identified | Remarks |
|---|---|---|---|
| 1C2 (Near Dandi village) | High tide,<br>Saline water,<br>No Agriculture,<br>Health problems | Water shortage<br>Migration | Consequence of saline water aquaculture is saline water percolating into ground water thus deteriorating it quality.<br>Limited vegetable availability However, three sweet water ponds suffice better quality water to the population<br>Ponds maintained by villagers |
| 1C3 (Near Dandi village) | Saline water<br>No Agriculture | Waste land | No residents in the micro watershed |
| 1C9 (Between Hansapur & Aru village) | High noise pollution<br>Due to train and road traffic<br>Less use of organic fertilizer | Requires desilting of ponds | Better water management in the form of irrigation methods and good agricultural practices could improve the situation.<br>Proper use of animal and farm waste could help in recycling organic fertilizers to farms<br>Forest tree plantation along the road to check noise pollution |

Land use changes detected in prioritized micro watersheds through remote sensing and GIS

**Table.15** Spatial and temporal land use patterns in MW-1C2

| Land use Pattern | Area in 2001 (ha) | % of area | Area in 2015 (ha) | % of area | Change (ha) | Change % |
|---|---|---|---|---|---|---|
| Water | 635.65 | 63.62 | 386.87 | 38.72 | -248.78 | -24.90 |
| Vegetation | 199.59 | 19.97 | 182.62 | 18.28 | -16.97 | -1.70 |
| Built up & sand | 86.66 | 8.67 | 76.79 | 7.69 | -9.87 | -0.99 |
| Barren land | 77.30 | 7.74 | 352.96 | 35.32 | 275.66 | 27.59 |
| Total | 999.20 | 100.00 | 999.20 | 100.00 | | |

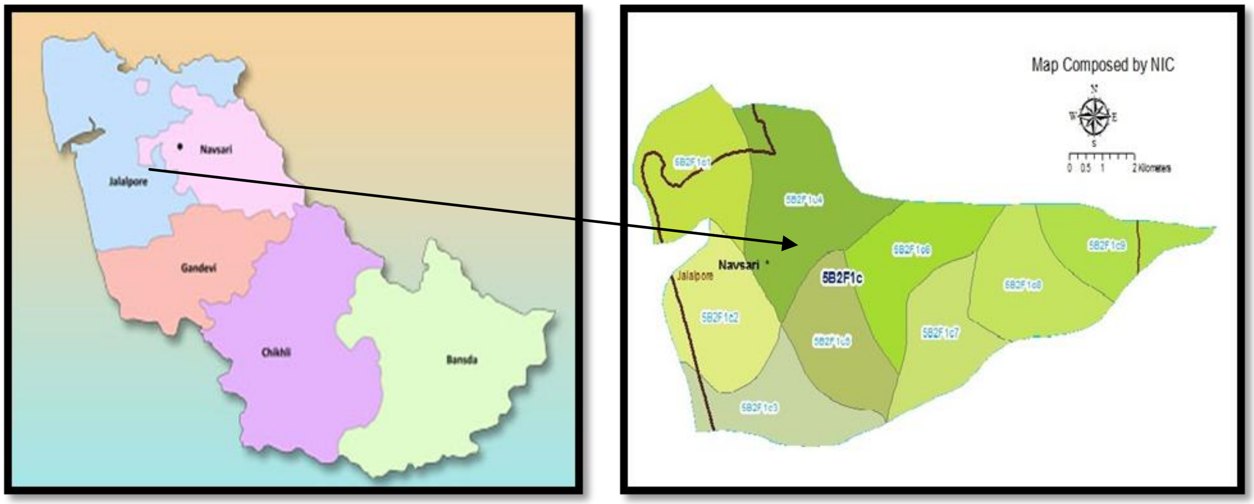
**Table.16** Spatial and temporal land use patterns in MW-1C3

| Land use Pattern | Area in 2001 (ha) | % of area | Area in 2015 (ha) | % of area | Changes (ha) | change in % |
|---|---|---|---|---|---|---|
| Water | 206.86 | 24.94 | 498.54 | 59.54 | 289.68 | 34.59 |
| Vegetation | 242.08 | 28.91 | 236.42 | 28.23 | -5.66 | -0.68 |
| Barren land | 386.41 | 46.15 | 102.43 | 12.23 | -283.98 | -33.91 |
| Total | 837.35 | 100.00 | 837.39 | 100.00 | | |

**Table.17** Spatial and temporal land use patterns in MW-1C9

| Sr. no. | Land use Pattern | Area in 2001(ha) | % of area | Area in 2015(ha) | % of area | Changes (ha) | change in % |
|---|---|---|---|---|---|---|---|
| 1. | **Water** | 24.57 | 3.59 | 10.70 | 1.56 | -13.87 | -2.03 |
| 2. | **Vegetation** | 173.07 | 25.29 | 163.67 | 23.92 | -9.40 | -1.37 |
| 3. | **Built up** | 108.00 | 15.78 | 197.07 | 28.80 | 89.07 | 13.02 |
| 4. | **Agriculture** | 330.20 | 48.25 | 275.33 | 40.23 | -54.87 | -8.02 |
| 5. | **Barren Land** | 48.52 | 7.09 | 37.59 | 5.49 | -10.93 | -1.60 |
| | **Total** | 684.36 | 100.00 | 684.36 | 100.00 | | |

**Fig.1** Location of the study area




Navsari district

Watersheds in Jalalpore Taluka

**Fig.2** Land use/land cover map of micro watershed 1C2 of year 2001 and year 2015

**Micro-watershed 1C2**

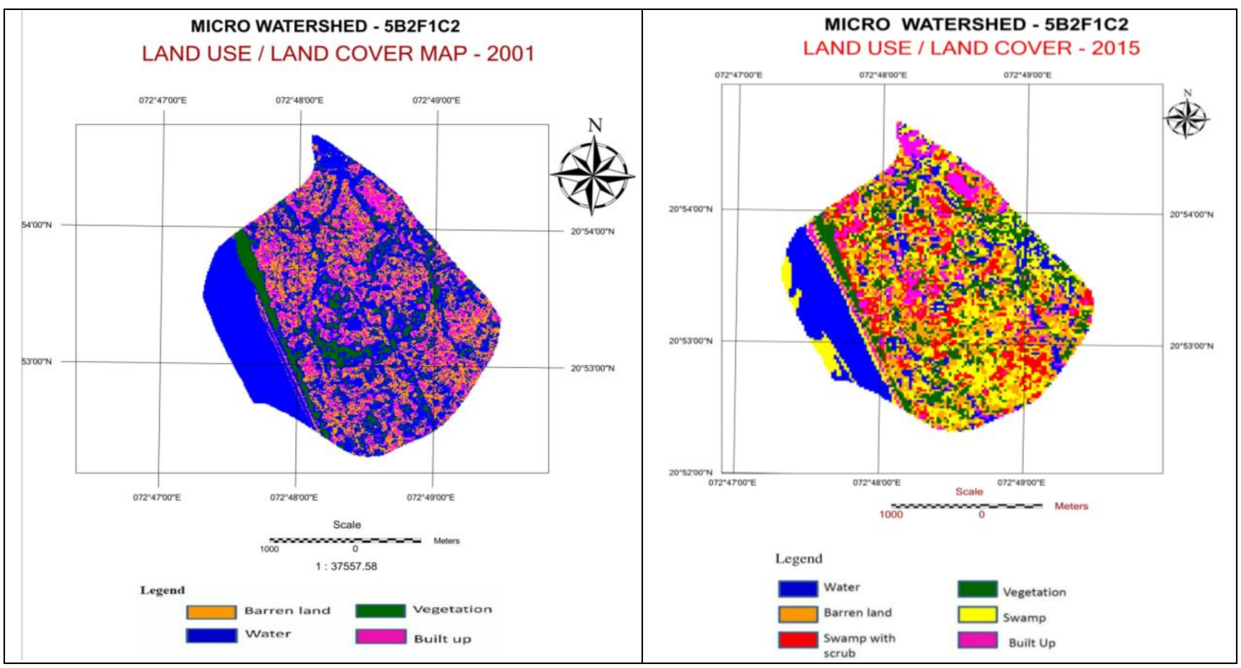


**Fig.3** Land use/land cover map of micro watershed 1C3 of year 2001 and year 2015

**Micro-watershed 1C3**

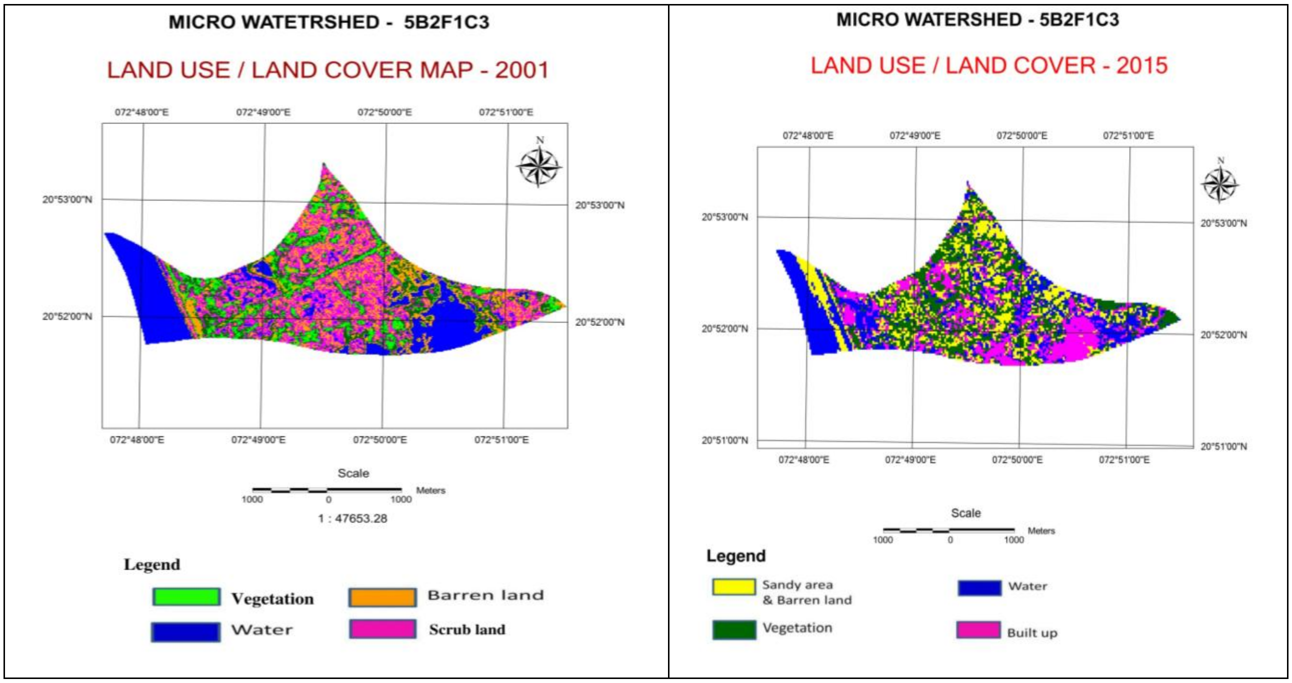
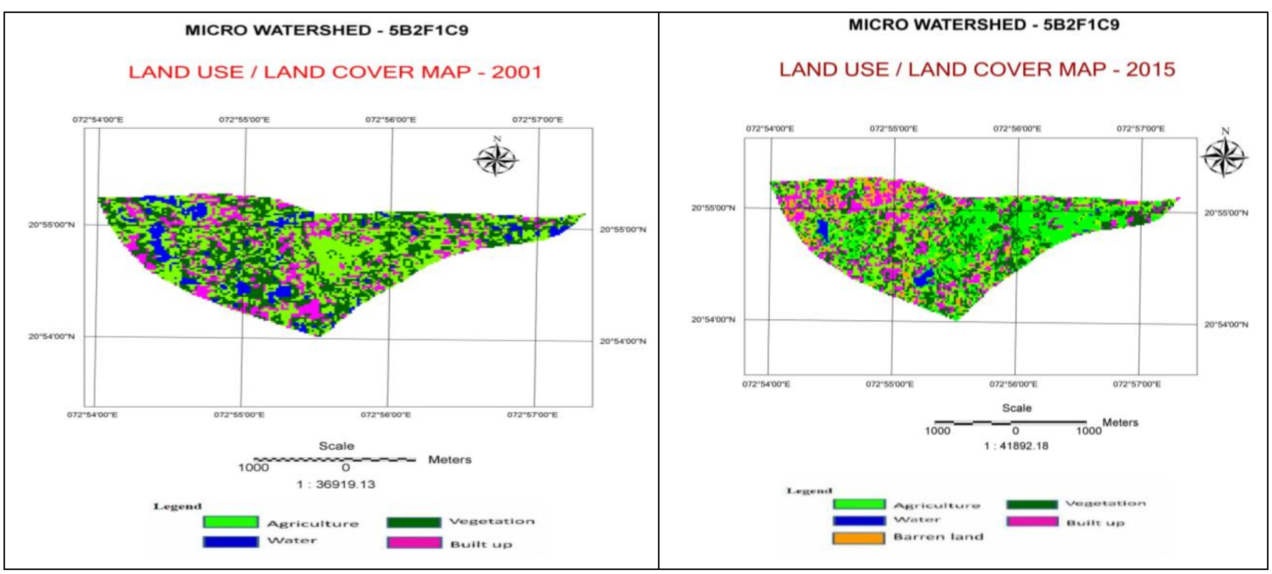



**Fig.4** Land use/land cover map of micro watershed 1C9 of year 2001 and year 2015

**Micro-watershed 1C9**



**Micro watershed - 1C9**

1. Better water management in the form of irrigation methods and good agricultural practices could improve the situation.

2. Efficient water management along with preservation of existing water bodies is the need of day for sustainable and green Navsari.

3. Hard soils could also be improved by application of organic fertilizers at regular intervals.

4. Proper use of animal and farm waste could help in recycling organic fertilizers to farms

5. Forest tree plantation along the road to check noise pollution

In conclusion, Stream order was found to be 3 in all the micro watersheds whereas total stream length and relief ranged from 7 km to 16 km and 9 m to 15 m respectively. Micro watershed 1C2 with ruggedness number 24.58 was found to be most prone to erosion compared to other micro watersheds. Drainage density varied from 0.84 in 1C1 to 1.62 in 1C2. The highest values of form factor, circulatory ratio and elongation ratio were 0.57, 0.85 and 0.86 in 1C1, 1C2 and 1C1 respectively.

According to hydrological characterization, micro watershed 1C8 should get top priority followed by 1C4 and least priority should be given to 1C1. With respect to availability of water in form of water bodies and canal water supply, 1C3 required top priority whereas on the basis of soil and water parameters, 1C7 required top priority. 1C8 and 1C9 required top priorities based on their socio-economic condition. The overall priority showed that micro watershed 1C2 needed top priority followed by 1C3, 1C9, 1C8, 1C4, 1C1, 1C7, 1C5 and 1C6.

## References


Anonymous (2016) Central Ground Water Board (CGWB) website report published.

Bera, Kartic and Jatisankar B. (2013) Prioritization of Watershed using Morphometric Analysis through Geo-informatics technology: A case study of Dungra sub-watershed, West Bengal, India. *Int. Journal of Advances in Remote Sensing and GIS*, 2(1): 1-8.

Horton, R.E. (1932) Drainage basin characteristics. Trans. Amer. Geophys. Union 13, 350–361.

Horton, R.E. (1945) Erosional development of streams and their drainage basins: hydrophysical approach to quantitative morphology. Bull. Geo. Soc. Am. 56, 275–370.

Melton, M. A. (1957). *An analysis of the relations among elements of climate, surface properties, and geomorphology* (No. CU-TR-11). COLUMBIA UNIV NEW YORK.

Miller, V.C. (1953) A Quantitative Geomorphologic Study of Drainage Basin Characteristics in the Clinch Mountain Area, Virginia and Tennessee, Columbia University Department of Geology, ONR Geography Branch, New York. Project NR 389042, Tech Rept 3.

Nag, S. K. and Lahari, A. (2011). Morphometric analysis of Dwarakeswar watershed, Bankura district, West Bengal, India, using spatial information technology. *Int. J Water Res. Env. Engi.*, 3 (10): 212-219

Rawat, J.S. and Kumar, Manish. (2015) Monitoring land use/cover change using remote sensing and GIS techniques: A case study of Hawalbagh block, district Almora, Uttarakhand, India. *The Egyptian Journal of Remote Sensing and Space Sciences*.18: 77–84

Schumn SA. (1956) Evolution of drainage systems and slopes in badlands at Perth Amboy, New Jersey, Geological Society of America Bulletin.67(5):597-646.

Shaikh, M. A. J., & Birajdar, F. (2015, February). Groundwater assessment and feasibility of artificial recharge structures on over-exploited miniwatersheds of MR-12, Osmanabad District. In: *Technologies for Sustainable Development (ICTSD), 2015 International Conference on* (pp. 1-5). IEEE

Strahler, A. N. (1957). Quantitative analysis of watershed geomorphology. Transactions American Geophysical Union, 38: 913-920.

Strahler, A.N. (1964). Quantitative geomorphology of drainage basins and channel networks. In: V.T. Chow (ed), Handbook of Applied Hydrology. McGraw Hill Book Company, New York, section 4-II.773.

Waikar, M.L. and Nilawar Aditya P. (2014) Morphometric Analysis of a Drainage Basin Using Geographical Information System: A Case study. *Int. J of Multidisciplinary and Current Research*, (2): 179-184.