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ENVIRONMENTAL IMPACT ASSESSMENT OF WATERSHED – A CASE STUDY OF OHAR WATERSHED DIST. AURANGABAD

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ABSTRACT

The environmental impact assessment of the ohar watershed using Battelle environmental evaluation system (EES) and method of overlays has been done. In Battelle environmental evaluation system the watershed is assessed based on ecology, esthetics, environmental quality aspects and human interest. For the evaluation using Battelle EES general data was acquired from Soil and water conservation department, Maharashtra and primary data pertaining to water quality, ground water level, soil quality, ecology, quality of soil and water conservation structures and questionnaire survey of residents was collected from field survey, sampling and testing. In the method of overlays the comparison of the land use land cover changes for two time frames from 2012 and 2017 using LISS III satellite digital image in Arc.GIS 102.2 was done and it is observed that there is positive change of 2.34% in vegetation and 2.08 % in agricultural land whereas it shows negative change of 4.43% in barren land with the total accuracy 79.25% and kappa coefficient of 0.74. The overall Impact of project on environment is 183.5 units using Battelle Environmental evaluation system.

Keywords: *Environmental impact assessment, Battelle, Overlays, GIS, Watershed, Soil and water conservation*

INTRODUCTION

Environmental impact assessment (EIA) is like a planning tool by which the assessment is done to forecast impacts for new project and evaluate impacts of existing projects (Ortolano & Shepherd, 1995). Environmental impact is an estimate or judgment of significance value of environmental effects on physical, biological, social and economical environment (Jones, 1997). The EIA have an important role in addressing environmental issues related to development of project especially projects related to irrigation (Gadissa, 2019). In order to predict the environmental impacts of any project and then to mitigate the negative impacts and enhance positive impacts the environmental impact assessment (EIA) procedure was developed in 1970s. The steps involved in the process of EIA are screening, scoping, prediction and mitigation, management and monitoring and audit (Food and Agriculture Organization of United Nations, 1996).

There are various method of environmental impact assessment such as Ad hoc methods, checklists and matrices, Sectoral guidelines which include guidelines developed by Asia development bank (ADB), the World Bank, and economic and social commission for Asia & Pacific (ESCAP), sequential approach (SSA), Networks, Simulation modeling, spatial analysis method, rapid assessment techniques (Jones, 1997). Various methods for evaluation of EIA are complicated and need much more data when compared to Battelle method (Wagh & Gujar, 2014).

In this study, the Battelle environmental evaluation system and the method of overlays are used for assessing the impacts of the watershed development works. The Battelle method of environmental impact assessment is useful in determining the environmental impacts for water resource projects. In this method, the environmental evaluation system is divided into four levels as Environmental categories, Environmental components, Environmental parameters and Environmental measurements. The Environmental evaluation system (EES) is important tool for measurement or estimation of environmental impacts related to water resources. The EES is broadly classified into four major sections as ecology, environmental pollution, esthetics and human interest. Further these four sections are subdivided into 78 parameters. The EES provide a score in terms of Environmental impact units (EIU) and the difference obtained by the EIU score of with and without project condition is the environmental impact. The importance of EES is that the adverse or negative impacts called as red flags are derived which are of concern as this include elements which needs more attention. The EES is hierarchical structure including four levels as General - Environmental categories, Intermediate - Environmental components, Specific - Environmental parameters, Most specific (Data) - Environmental measurements. In First the parameter estimates are transformed into environmental quality, environmental quality is defined in the range of 0 to 1 in which 0 denotes very bad and 1 denotes very good quality. Then the parameters are weighted, the parameter importance units (PIUs) of 1000 are distributed among all four categories of EES and in the third step commensurate units are obtained. (Dee Norbert, Janet Baker, 1973), (Ferreira et al., 1982), (Wagh & Gujar, 2014)

The assessment of watershed using method of overlays consists of the comparison of the changes in the land use land cover of the watershed in selected time frames. In this method the digital images of the study area are acquired from the satellite imaginary for two or three time frames as

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per the extent and objective of the study. This digital image can be classified using supervised classification technique or unsupervised classification technique. The supervised classification technique using the maximum likelihood method is generally preferred and more the classes sampling points more the accuracy in the classification. This image is generally classified into various classes as land under settlements, water bodies, agriculture, vegetation, dense forest, barren land etc. After developing the land use land cover image, its accuracy assessment is done using statistical analysis, for which more ground truth points should be taken to evaluate the accuracy more precisely (Chowdhury et al., 2018), (Choto & Fetene, 2019), (Degife et al., 2019), (Paudyal et al., 2019).

STUDY AREA AND ITS FEATURES

Ohar watershed is taken as the study area for the assessment in this study. This watershed is the part of Kham river catchment in Aurangabad district of Maharashtra state in India. Harsul Lake is on the downstream reach of this study area. The population of the watershed as per the census of 2011 is 2,032. The study area is in the North western part of Aurangabad taluka and lies between 19.978957° Latitude and 75.324817° Longitude North and 19.929142° Latitude and 75.310196° Longitude South. The geographical area of the watershed is 1478 hectors and located at 11 km's from Aurangabad city. This study area is under the toposheet no. 47 M/5 Geological survey department of Government of India. The average annual rainfall in the watershed is 625 millimeters. The slope of the watershed is towards south east and varies from 814 to 549 meters. This watershed is part of catchment of Kham River, which is the tributary of Godavari River. The details of the study area are shown in Figure 1 and 2.

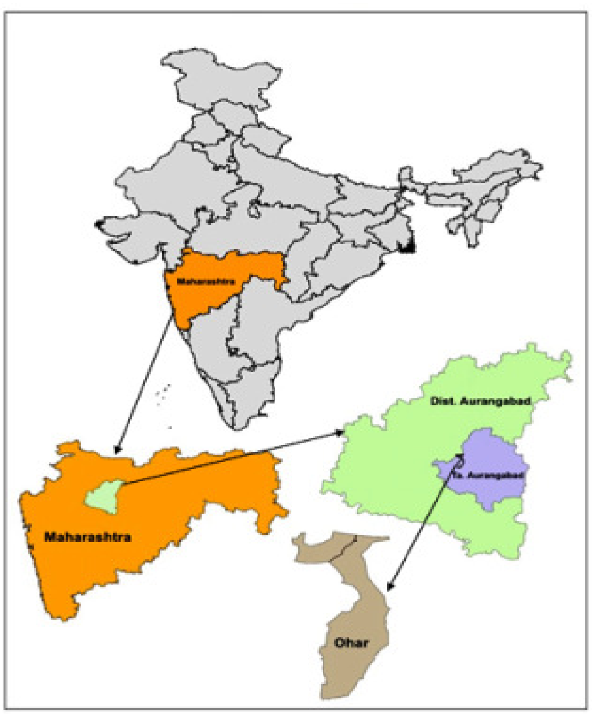


Fig. 1: Study area Details

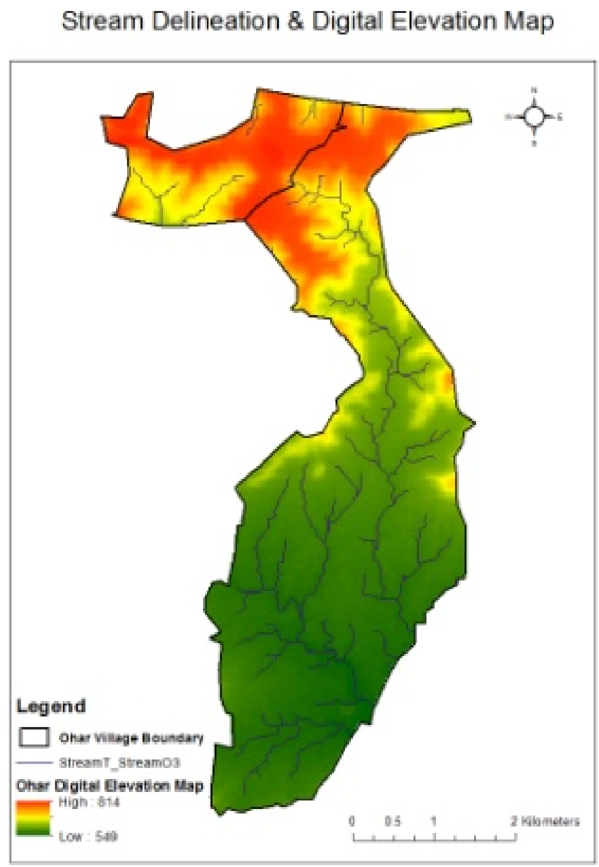


Fig 2: Stream delineation and Digital elevation map

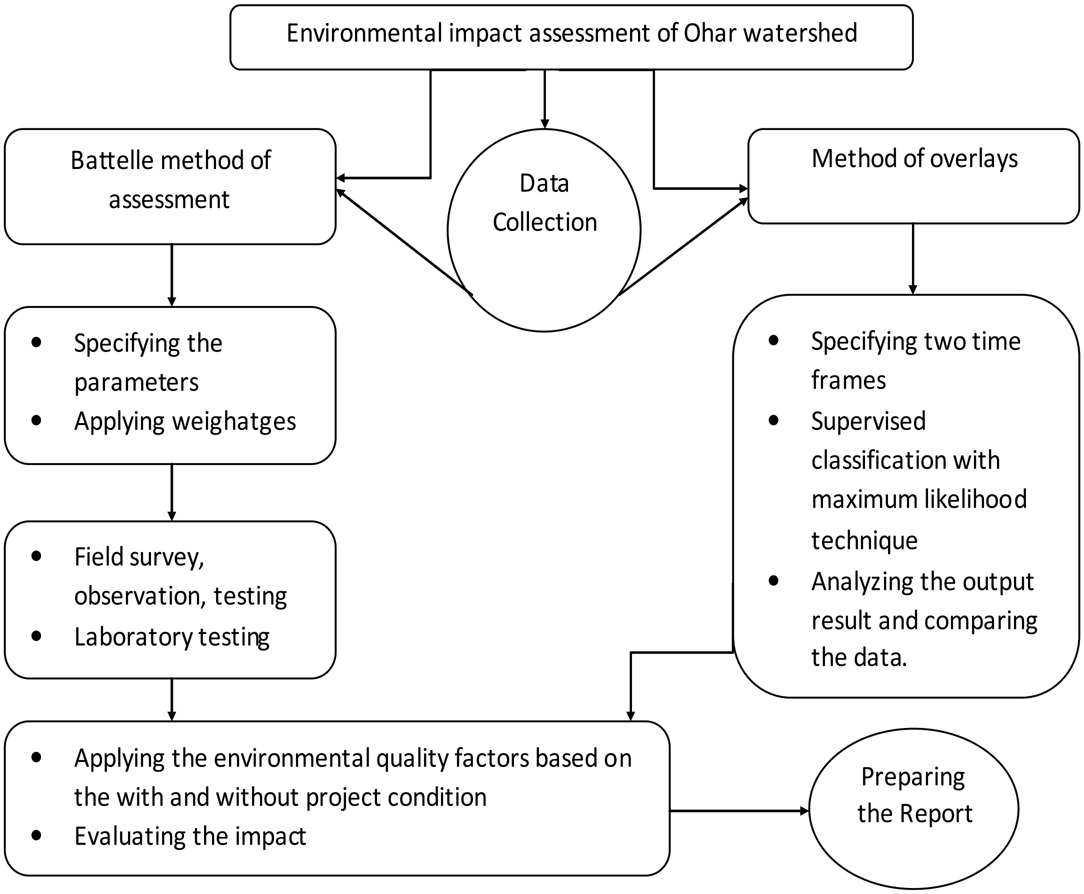
METHODOLOGY

The detailed methodology flow chart is shown in Table 1

Method of assessment through Battelle environmental evaluation system

1. Modifying the parameters under four categories.
2. Applying the weights to individual parameters called as parameter importance units (PIUs), summation of which is 1000 for entire system.
3. Assessing the study area for bio-physical, ecological and socio-economical indicators by field survey, field observations, field testing and laboratory testing of the parameters.
4. Applying environmental quality factors (EQs) in range of 0 to 1 to individual parameters based on the judgment of effective impacts evaluated in step 3.
5. The EQs are evaluated for with and without project condition based on the judgment of the evaluator.
6. The environmental quality factors (EQs) are then multiplied with parameter importance units (PIU) to get the environmental impact units for two scenarios with project and without project.

Table 1: Methodology for Environmental impact assessment



The entire impact of the project on the environment is the difference between {(EIU)i – (EIU)ii} that is the difference between the impacts for with and without project condition. This is evaluated by the equation stated below.

Mathematically it is stated as,

$$\sum EIU = \sum_{i=1}^{m} (EQi)_1 \cdot PIUi - \sum_{i=1}^{m} (EQi)_2 \cdot PIUi$$

Where,

EIU – Environmental impact units

(EQi)1 – Environmental quality factor for parameter i with project

(EQi)2 - Environmental quality factor for parameter i without project

PIU – Parameter importance unit or relative weight

m – Total number of environmental indicators

Methodology of assessment by the method of overlays

For the assessment of the impacts using the method of overlays following steps are followed.

1. Acquiring the digital image of LISS III dataset from Bhuvan, ISRO. The study area falls in the border zone of two tiles. The tiles downloaded for the analysis of LULC are of 17 February 2012 and 2 February 2017 to analyze the variations in the land use land cover due to soil and water conservation measures in the watershed.
2. The acquired image is imported into Arc.GIS 10.2.2 and tiles are combined to extract the study area and image converted to standard false Color composite. The study area is extracted from the dataset for further process for both the time frames.
3. The supervised classification is done using maximum likelihood technique by generating training samples for each class for two consecutive time frames (Degife et al., 2019), in case when the classes are less than 12 in numbers 50 training samples are generated for each class. In this study, more than 50 training samples for each class are generated and the signature file is stored for two consecutive time frames and the LULC map is obtained.
4. The Land use land cover map is classified into five classes as land under settlements, water bodies, agriculture, vegetation and barren land.
5. Accuracy assessment of the obtained LULC map with the ground truth points is done by generating the error matrix and the kappa coefficient value

RESULTS

Assessment results by method of overlays

The LULC map is as shown in Figure 3 and 4

The LULC map variation from 2012 to 2017 for the Ohar watershed is then graphically analyzed with the changes and shift of area from one class to other and the percentage variation in the five years span which reflects the impact of soil and water conservation measures on the physical land use of the study area. The graphical representation is shown in figure 5 and 6.

It can be clearly stated from the figure 6, that the area under various classes changed in the span of five years. The residential area in the year 2012 was 402.84 ha and it increased by 3.69 ha to 406.53 ha in the year 2017 which can be linked to the increase in population. The area under the water bodies in the year 2012 was 106.11 and it shrink by 3.69 ha to 102.42 ha in the year 2017, it can be correlated as the rainfall was more in 2012 than 2017 and along with it due to increased soil and water conservation measures the infiltration of water increased thereby reducing the water surface area. The area under vegetation shows the positive impact of the soil and water conservation measures as the area in the year 2012 was 544.59 ha and it increased by 61.56 ha to 606.15 ha in the year 2017. The variation of the area under vegetation can be linked to barren land as in the year 2012 was 969.48 which decreased

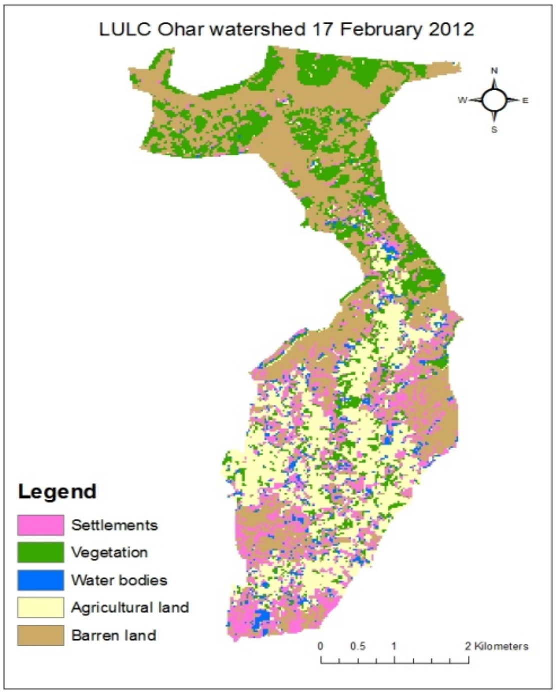


Fig. 3: Land use land cover map for year 2012 in Arc.GIS 10.2

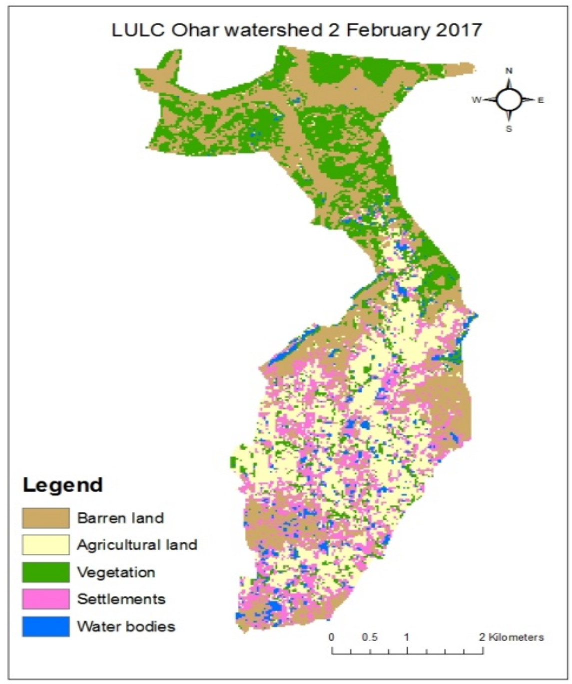
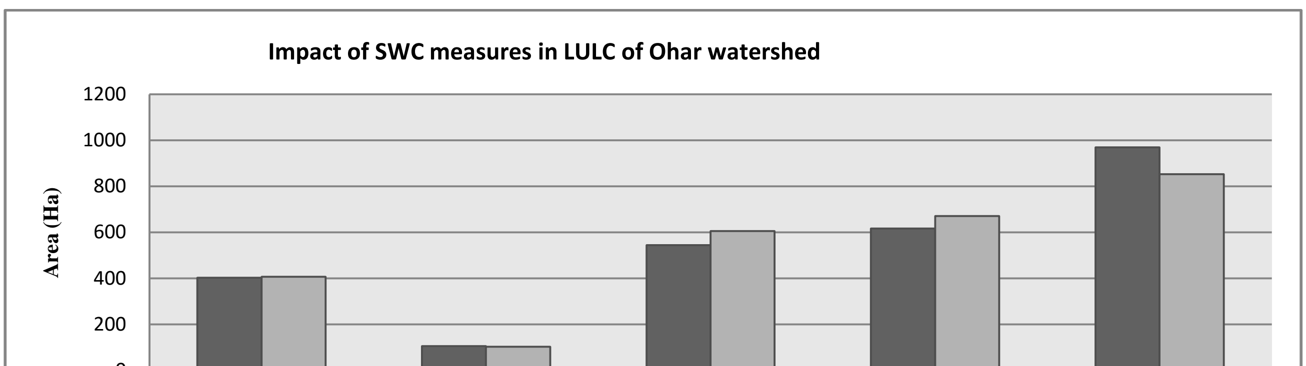


Fig 4: Land use land cover year 2017 in Arc.GIS 10.2



	Residential	Water	Vegetation	Agricultural	Barren
2012	402.84	106.11	544.59	616.14	969.48
2017	406.53	102.42	606.15	670.77	852.12

Fig 5: Graphical representation in changes in LULC in Ohar watershed

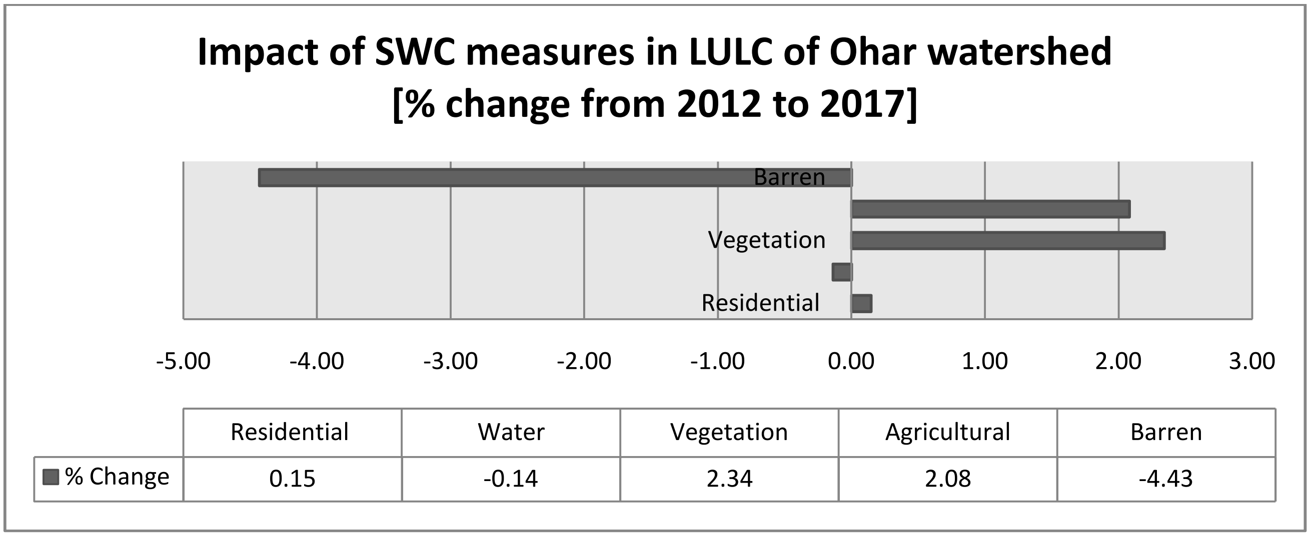


Fig.6: Percentile variation in the land use land cover map of the watershed

by 117.36 ha to 852.12 ha. The area under the agriculture in the year 2012 was 616.14 ha and it increased by 54.63 ha to 670.77 ha in the year 2017. Thus it can be clearly stated that the barren area broadly transferred to the area under the vegetation and agriculture in the span of 5 years which shows the positive impact of the soil and water conservation measures.

The barren land decreased by 4.43 % and the land under the vegetation thus increased by 2.34 % in 5 year span. The area under the water bodies decreased by 0.14 %. The agricultural area increased by 2.08 % and the residential area or the area under the settlements increased by 2.75 % as shown in figure 7.

The accuracy assessment of the derived land use land cover map is done using the error matrix method which is generated in Arc.GIS 10.2.2. The obtained error matrix is evaluated using M.S. Excel software and the accuracy by using the solution to the error matrix and the Kappa coefficient is calculated. The obtained error matrix is shown in Table 2

$$\therefore \textit{Overall accuracy} = \frac{Total\ No.of\ correct\ classification}{Total\ No.of\ classifications}$$

$$\therefore \textit{Overall accuracy} = \frac{(69+81+100+38+52)}{(429)}\ x\ 100 = 79.25\ \%$$

Thus, the overall accuracy of the LULC analysis is 79.25 % when compared to ground truth points in the map.

Here in the above error matrix the Kappa value is computed as,

$$\therefore \textit{Kappa value} = \frac{(340\ X\ 429) - [(96\ X\ 75) + (89\ X\ 106) + (107\ X\ 125) + (60\ X\ 62) + (77\ X\ 61)]}{429^2 - [(96\ X\ 75) + (89\ X\ 106) + (107\ X\ 125) + (60\ X\ 62) + (77\ X\ 61)]}$$
$$= 0.74$$

Thus, the Kappa value for the above error matrix is 0.74.

Battelle environmental evaluation system calculations

The Environmental impact using Battelle EES is evaluated with field observation, survey, sampling and testing of the parameters included in the system. These parameters are water quality, ground water table depth, soil quality, ecology, agriculture, soil and water conservation structures evaluation and residents questionnaire survey. The detailed calculation of for the computation of the impacts is as shown in Table 3.

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Table 2 – Obtained error matrix for the LULC based on the ground truth points

	Barren	Agricultural	Vegetation	Settlement	Water	Total
Barren	69	5	9	11	2	96
Agricultural	0	81	3	5	0	89
Vegetation	1	6	100	0	0	107
Settlement	4	8	3	38	7	60
Water	1	6	10	8	52	77
Total	75	106	125	62	61	429

The watershed development works have a positive impact on the environment and the residents too. Thus, the Battelle environmental evaluation system used to assess the overall impact on the bio-physical, ecological and socio-economical aspects of the watershed shows a positive impact of 183.5 Units for the watershed development works undertaken in the watershed.

Table 3 – Battelle system calculations

	PIU	EQI1	EQI2	EIU		PIU	EQI1	EQI2	EIU
Ecology {200}	**Sub Total = 31.5**				**Environmental quality aspects {125}**	**Sub Total = 6**			
Forest species					*Water quality [95]*				
Flora [100]					*Surface water quality [20]*				
					1. Electrical conductivity	5	0.8	0.6	*1*
1. Natural vegetation	*55*	*0.8*	*0.5*	*16.5*	*2 pH*	5	0.8	0.6	*1*
2. Species diversity	*45*	*0.7*	*0.6*	*4.5*	*3 Temperature*	5	0.8	0.8	*0*
					4 Total dissolved solids	5	0.8	0.6	*1*
Fauna [70]									
					Ground water quality [75]				
1. Birds & its diversity	*35*	*0.8*	*0.6*	*7*	*1. Temperature*	5	0.8	0.8	*0*
2. Wild life & its diversity	*35*	*0.6*	*0.5*	*3.5*	*2. pH*	5	0.8	0.7	*0.5*
					3. Electrical conductivity	10	0.8	0.7	*1*
Aquatic species [30]					*4. Total dissolved solids*	10	0.8	0.7	*1*
					5. Nitrate	15	0.2	0.3	*-1.5*
1. Species diversity	*30*	*0.6*	*0.6*	*0*	*6. Hardness*	15	0.7	0.5	*3*
					7. Fluoride	15	0.2	0.4	*-3*
Esthetics {525}	**Sub Total = 114.5**								
Land [20]					*Land quality [30]*				
1. Topographic character	*10*	*0.7*	*0.6*	*1*	*Soil quality/Characteristics*				
2. Sediment yield in structures	*10*	*0.5*	*0.8*	*-3*					
					1. N,P,K (Macro-nutrients)	20	0.5	0.4	*2*
Agriculture [105]					*2. pH*	10	0.4	0.4	*0*
1. Crops	*25*	*0.7*	*0.5*	*5*					
2. Crop yield	*25*	*0.7*	*0.5*	*5*	**Human Interest {150}**		**Sub Total = 31.5**		
3. Livestock	*20*	*0.6*	*0.5*	*2*	*Awareness / Education [80]*				
4. Water availability	*20*	*0.9*	*0.6*	*6*	*1. Ecological*	40	0.9	0.7	*8*
5. Associated businesses	*15*	*0.8*	*0.5*	*4.5*	*2. Hydrological*	40	0.9	0.6	*12*
Water [110]									
1. Drinking water supply scheme	*20*	*0.9*	*0.6*	*6*	*Life Pattern [40]*				
2. Frequency/ duration of drinking water supply	*20*	*0.9*	*0.6*	*6*	*1. Employment opportunity*	15	0.9	0.6	*4.5*
					2. Housing	15	0.8	0.6	*3*
3. Appearance of water	*10*	*0.8*	*0.6*	*2*	*3. Social Interaction*	10	0.8	0.7	*1*
4. Odour & floating	*10*	*0.6*	*0.5*	*1*					*0*
5. Water surface area	*10*	*0.7*	*0.5*	*2*	*Other factors as Infrastructure, Education & Health facilities [30]*		*0.8*	*0.7*	*3*
6. Ground water table	*40*	*0.9*	*0.5*	*16*					
					Soil & Water conservation measures [215]				
Land use land cover changes [75]					*1. Density of structures*	50	0.8	0.5	*15*
1. Residential land	*15*	*0.8*	*0.6*	*3*	*2. Present quality of structures*	50	0.7	0.5	*10*
2. Agricultural land	*15*	*0.8*	*0.6*	*3*	*3. Extent of siltation*	35	0.5	0.7	*-7*
3. Land under vegetation	*15*	*0.9*	*0.5*	*6*	*4. O & M of structures*	35	0.8	0.6	*7*
4. Barren land	*15*	*0.9*	*0.5*	*6*	*5. Water storage /recharge efficiency*	45	0.8	0.5	*13.5*
5. Land under water	*15*	*0.9*	*0.6*	*4.5*					
Total EIU = 183.5 Units									

CONCLUSION

The Battelle method when correlated and combined with the method of overlays increases the accuracy and coverage of the impact assessment. In this study, various indicators such as bio-physical, agricultural, socio-economical and ecological included in the Battelle environmental evaluation system shows positive impact of the soil and water conservation works in the watershed. The analysis by the method of overlays in the time frame of five years from 2012 to 2017 shows increase in the land under vegetation, agricultural land and residential land, whereas there is reduction in the barren land. The Battelle environmental evaluation system based on ecology, esthetics, environmental quality aspects and human interest gives the value of 183.5 Units as the impact of the watershed development works on the environment.

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