Aggregation of Key Evaluation Indicators for Watershed Development Programmes

ABSTRACT

The measure of effectiveness of watershed development programmes depends on selecting the right set of evaluation indicators that reflect the programme's goals, including resource management, environmental sustainability, and socio-economic benefits. In this paper the focus is on the process of selecting and aggregating the key indicators to assess the success of watershed development initiatives. By categorizing indicators into relevant themes such as Terrain Management, Water Resources Utilization, Agronomic Vitality, Livestock Vitality, Employability, Human Empowerment and Sustainability.This paper highlights the importance of using a structured approach to ensure comprehensive evaluation. Proper selection and aggregation of indicators lead to more accurate assessments and provide valuable insights for future programme improvements.It also emphasizes the importance of context-specific indicators to ensure accurate and effective programme evaluations.

INTRODUCTION

Watershed development is a multidisciplinary approach aimed at improving land, water and vegetation management to achieve agricultural sustainability. Over the past few decades, watershed development programmes have been implemented globally, to address issues such as soil erosion, water scarcity and declining agricultural productivity. These programmes involve integrated resource management approaches that aim to achieve sustainable development.

Evaluating their effectiveness requires a careful selection of key indicators that capture various aspects such as water management, land conservation, and socio-economic benefits. Identifying the right indicators is vital for ensuring that the programme's impacts are adequately assessed, allowing for informed decision-making and improvement of future interventions (*Sharda et al., 2012).*

Importance of Selection of Indicators

The selection of indicators is central to the evaluation of watershed development programmes.A well-chosen set of indicators reflects the programme's effectiveness in addressing region-specific issues like soil degradation, water retention, and agricultural sustainability.

Proper indicators are essential for setting up effective monitoring and evaluation of watersheds. Indicators serve as markers to track changes and demonstrate success. These programmes generate a range of benefits, including direct and protective impacts, ecological improvements, and employment generation. The evaluation criteria encompass biophysical, socio-economic, and sustainability aspects. Key indicators include boosting rainfed agricultural productivity, recharging groundwater for drinking and irrigation, enhancing the productivity of non-arable lands, fostering employment, encouraging collective action and strengthening social institutions*(Atre and Malunjkar, 2014)*.

Given the complexity and variability of watersheds, there is no universal set of indicators that can be applied across all programmes. Rather, as Sharda *et al.*,(2012) argue, the indicators must be adapted to the unique geographical, ecological and socio-economic conditions of each watershed. The importance of bio-physical, socio-economic and sustainability indicators has been emphasized in numerous studies, but the challenge lies in aggregating these indicators into manageable and relevant groups for effective programme evaluation.

In this paper suggest the aggregation of key evaluation indicators based onTerrain Management, Water Resources Utilization, Agronomic Vitality, Livestock Vitality, Employability, Human Empowerment andSustainability to build a structured framework for future evaluation.

Selection and Aggregation of Indicators

The selection process should begin by identifying the key goals of the watershed development programme. Indicators need to be aligned with these goals to ensure they accurately reflect the programme's outcomes. The selected indicators should be SMART: Simple, Measurable, Achievable, Relevant, and Time-sensitive *(Sharda et al., 2012)* as monitoring every project aspect is impractical.

The indicators can be grouped into thematic categories such as (i) Terrain Management Indices, (ii) Water Resources Utilization Indices, (iii) Agronomic Vitality Indices, (iv) Livestock Vitality Indices, (v) Employability Indices, (vi) Human Empowerment Indices and (vii) Sustainability Indices.This helps in structuring the evaluation and ensuring that all critical areas are covered. By organizing indicators into these categories, evaluators can gain a comprehensive understanding of how different components of the programme contribute to its overall success.

INDICATORS

1. Terrain Management Indices

The slope manipulation, different structures and area benefitted from these structures and effect of watershed development works on gullies in watershed have been grouped in the Terrain Management Indices. Details of three indices included in this group are as given below.

1.1.Land Levelling Index (LLI)

For mitigation of runoff and soil loss, especially from arable lands, reduction of land slope through land improvement activities is inevitably undertaken in watershed management programmes. Land Levelling Index (LLI), which is the ratio of recommended land slope to the existing land slope, can be utilized in the pre-project (PrP) and post-project (PoP) scenarios to quantify the extent of land improvement and is defined as:

$$\text{LLI} = \frac{\text{Recommended slope (\%)}}{\text{Existing or treated slope (\%)}} \qquad \dots (1)$$

Where, Existing slope refers to the individual land slope before the inception of the project and treated slope is the moderated slope resulting from land levelling activities. Higher value of LLI is a measure of better moderation in land slope. LLI can attain a maximum value of 1.0, which refers to a perfectly levelled field *(Sharda et al., 2005; Sharda et al., 2012;Vinchurkar and Ingole, 2021).*

1.2.Critical Area Index (CAI)

Before actually undertaking the treatment of a watershed, its critical areas are identified for implementing suitable location specific bio-engineering measures. For quantifying the total work undertaken at watershed level, Critical Area Index (CAI), which is the ratio of the critical area benefitted due to treatment with conservation structures and the total critical area that needs to be treated is defined as:

$$\text{CAI} = \frac{\text{Bene itted critical area from structures}}{\text{Total critical area}} \qquad \dots (2)$$

The CAI can attain a maximum value of 1.0 and a higher value of CAI is a measure of better treatment of the critical area *(Sharda et al., 2012; Vinchurkar and Ingole, 2021).*

1.3.Gully Stabilization Index (GSI)

It is an important indicator to measure the impact of gully control structures and drainage line treatment on the stability of the gullied area during the post-project (PoP) period. It is defined as:

$$\text{GSI} = \frac{0.5\,\text{SR} + 0.5\,\text{SSR}}{\text{SR} + \text{SSR}} \qquad \dots (3)$$

Where, SR is Stream Slope Reduction and SSR is Stream Side Stabilization Ratio, which are defined as:

$$\text{SR} = \frac{\text{Equivalent slope of the gullies (\%)}}{\text{Expected equivalent slope (\%)}} \qquad \dots (3.1)$$

$$\text{SSR} = \frac{\text{Average width of streams after the project}}{\text{Average width of streams before the project}} \qquad \dots (3.2)$$

The SSR may be worked out by assigning suitable weights to different streams based on the water volume discharged or stream order (W_i) as:

Weighted SSR

$$= \frac{\sum_{i=1}^{n} W_i \times SSR_i \text{ after the project}}{\sum_{j=1}^{n} W_j \times SSR_j \text{ before the project}} \qquad \dots (4)$$

Where, n refers to number of streams in the watershed. GSI can have any value between 0 and 100 and a higher value will indicate higher stability of the gullies after the watershed interventions*(Sharda et al., 2012)*.

2. Water Resources Utilization Indices

In the watershed development programme, we develop water harvesting structures which store some water during the rainy season and definitely by utilizing Such water the productivity can also be increased. In this group such indices have been included and their details are given below.

2.1.Water Storage Capacity Utilization Index

Success of any watershed management project largely depends on harvesting of water within the watershed and its judicious utilization.

Water Storage Capacity Utilization Index (WSCUI) combines conservation of water available from all the potential resources within the watershed and its optimal utilization by assigning proper weights to the two aspects and then adding the products. WSCUI is defined as:

$$\text{WSCUI} = (0.4\text{SE} + 0.6\text{ UE}) \times 100 \qquad \dots (5)$$

Where, Storage Efficiency (SE), which needs to be assessed for improving availability and planning of water resources, can be estimated as a ratio of water actually stored to the designed live storage capacity expressed in percent terms:

$$\text{SE} = \frac{\sum_{i=1}^{n} \text{Water actually stored in live storage capacity}}{\sum_{i=1}^{n} \text{Designed live storage capacity}} \qquad \dots (5.1)$$

Utilization Efficiency (UE) of the stored water can be computed as a ratio of the total water utilized (i.e. excluding losses through seepage and evapo-transpiration, and unutilized part), and the total water actually stored in live storage.

$$\text{UE} = \frac{\sum_{i=1}^{n} \text{Total Water utilised out of live storage}}{\sum_{i=1}^{n} \text{Total Water actually stored in live storage}} \qquad \dots (5.2)$$

Where, n = Number of structures.

Storage Efficiency, Utilization Efficiency and Water Storage Capacity Utilization Index can vary from 0 to 100 and a higher value will indicate higher efficiency / utilization *(Sharda et al., 2012).*

2.2.Irrigability Index

Major utilization of the harvested water is for irrigation of crops to ensure sustainable agricultural production in the watershed. Irrigability Index (II) is a ratio of additional gross irrigated area and net incremental irrigated area. Gross irrigated area may be estimated by adding the net incremental irrigated area as many times as it was irrigated.

$$\text{II} = \frac{\text{Additional gross irrigated area}}{\text{Net incremental irrigated area}} \qquad \dots (6)$$

The index can attain any value more than 0 and a higher value will indicate successful utilization of harvested water in the watershed management project *(Sharda et al., 2012; Vinchurkar and Ingole, 2021).*

2.3.Conserved Water Productivity Index

Conserved Water Productivity Index helps in assessing the change in the irrigated crops' yields in terms of water utilized and is defined as ratio of sum of average equivalent yields per unit of conserved water utilized by crops that were irrigated in terms of targeted production. The value of the index can vary from 0 to 1 and a higher value will indicate achievement closer to the targeted production *(Sharda et al., 2012).*

$$\text{CWPI} = \frac{\text{Avg. production achieved (equivalent yield) / unit of water}}{\text{Production targeted (equivalent yield) / unit of water}} \qquad \dots (7)$$

3. Agronomic Vitality Indices

It is quite obvious that due to development of watershed, there can be increase in cropped area, increase in crop production, change in cropping pattern, change or increase in use of fertilizers, etc in the watershed. All such indices have been grouped under Agronomic Vitality Indices and described below.

3.1.Cultivated Land Utilization Index

Cultivated Land Utilization Index (CLUI) indicates the impact of watershed interventions on changes in cultivable land area and duration of crop cultivation in PrP and PoP periods. It is calculated by summing the products of land area planted under each crop, multiplied by actual duration of days of that crop and dividing the sum by the total cultivated land area times 365 days as given below:

$$\text{CLUI} = \frac{\sum_{i=1}^{n} a_i d_i}{\text{A x 365}} \qquad \dots (8)$$

Where,

n = Total number of crops,

a_i = Area occupied by i^{th} crop,

d_i = Days that i^{th} crop occupied in the a_i area,

A = Total cultivable land area.

The CLUI can attain a maximum value of 1.0 and higher value of CLUI indicates that the maximum part of cultivable area is under crop production for maximum period in a year *(Sharda et al., 2005; Sharda et al., 2012).*

3.2. Crop Productivity Index

The assessment of overall improvement in crop productivity at the watershed level can be done by Crop Productivity Index (CPI), which indicates the level of average crop productivity in comparison to the potential or best yield of crops. It is calculated before and after the project by dividing the crop yield obtained in the watershed by the yield obtained under recommended package of practices or highest yield within the watershed:

$$\text{CPI} = \frac{1}{n}\sum_{i=1}^{n} {y_i}/{Y_i} \qquad \dots (9)$$

Where,

n = Total number of crops cultivated in the watershed,

y_i = Average yield of i^{th} crop cultivated in the watershed,

Y_i = Yield of i^{th} crop with standard package of practices or highest yield within the watershed.

The CPI can attain any value greater than zero in a given location. Higher value of CPI is indicative of crops' yields closer to the maximum attainable yield under standard package of practices *(Sharda et al., 2005; Sharda et al., 2012).*

3.3. Crop Diversification Index

One aspect of crop improvement undertaken during a watershed management project is minimization of risk of loss in crop production through crop diversification. Crop Diversification Index (CDI) can be utilized for PrP and PoP scenarios to assess the changes in the cropping patterns due to crop improvement programmes and is defined as follows:

$$\text{CDI} = \sum_{i=1}^{n} P_i log\frac{1}{P_i} \qquad \dots (10)$$

Where,

P_i = Proportion of i^{th} crop in comparison with total cropped area

n = Total number of crops in the watershed.

The CDI can attain any value greater than zero and higher value of CDI is a measure of better crop diversification *(Sharda et al., 2005; Sharda et al., 2012).*

3.4. Crop Fertilization Index

For assessing the change in fertilizer consumption between PrP and PoP scenarios, the ratio of actual consumption of NPK and as per recommended/ required NPK doses is a useful indicator. The value of Crop Fertilization Index varies from 0 to 1 and a higher value will indicate that the NPK consumption is closer to the recommended or required amount of consumption *(Sharda et al., 2012)*.

$$CFI = \frac{\text{Average NPK consumption}}{\text{Recommended/required NPK dose}} \quad \ldots (11)$$

3.5. Soil Nutrient Index

Conservation measures undertaken on arable lands such as minimum tillage, zero tillage, bunding, vegetative barriers etc. that prevent loss of nutrients through soil loss along with mulching, manuring, Integrated Nutrient Management (INM), intercropping, mixed cropping etc. build up soil fertility, which leads to sustainable production of crops, vegetables and fruits. Therefore, estimating the changes in soil fertility through changes in soil nutrients in PrP and PoP scenarios is essential for understanding the impact of watershed management. Soil Nutrient Index (SNI) is expressed as:

$$SNI = \frac{Nl + 2\,Nm + 3\,Nh}{Nl + Nm + Nh} \quad \ldots (12)$$

Where,

N is number of samples (depending upon soil type and land use) and l, m and h refer to low, medium and high percentages, respectively of a particular nutrient as per ranges given below:

Organic Carbon (%):

l = low fertility (< 0.5%)

m = medium fertility (0.5% - 0.75%)

h = high fertility (> 0.75%)

Available Nitrogen (N kg/ha):

l = low fertility (< 250 kg/ha)

m = medium fertility (250 - 500 kg/ha)

h = high fertility (> 500 kg/ha)

Available Phosphorus (P_2 O_5 kg/ha):

l = low fertility (< 11 kg/ha)

m = medium fertility (11 - 25 kg/ha)

h = high fertility (> 25 kg/ha)

Available Potassium (K_2O kg/ha):

l = low fertility (<120 kg/ha)

m = medium fertility (120-280 kg/ha)

h = high fertility (>280 kg/ha)

For any of the nutrients, the value of its SNI can attain a value between 1 and 3. A value of 1.0 will indicate that the soil has low fertility whereas a value of 3.0 will indicate that the soil fertility is high in terms of that nutrient. Any value in between the two extreme values will indicate the medium fertility status of the soil *(Sharda et al., 2012).*

3.6. Normalized Difference Vegetation Index

This indicator is utilized to define the improvement in vegetative cover as a result of bio-engineering measures in the watershed. It can be expressed as:

$$NDVI = \frac{NIR - R}{NIR + R} x100 \quad \ldots (13)$$

Where,

NIR = Near Infra-Red (0.76 to 0.90 m) radiation,

R = Red (0.63 to 0.69 m) radiation.

The values of NIR and R can be obtained through remotely sensed data. NDVI can have any value varying from 0 to 100 and a higher value indicates better quality of vegetative cover in the PoP scenario as compared to PrP period *(Sharda et al., 2012).*

4. Livestock Vitality Indices

As the availability of fodder and grasses increases in the watershed, a livestock component is added with the agriculture to have stability in income of the inhabitants of thewatershed. The indices pertaining to livestock are clubbed under Livestock Vitality indices and are described in following sections.

4.1. Livestock Composition Index

For measuring the change in livestock composition between PrP and PoP scenarios, the ratio of total livestock units of improved breeds of cows and buffaloes and total livestock units of local breeds of cows and buffaloes is a useful indicator. The ratio can vary from 0 to infinity *(Sharda et al., 2012).*

$$LCI = \frac{\text{Total livestock units of improved buffaloes } \mathit{and\ crossbred\ cows}}{\text{Total livestock units of local cows and buffaloes}} \quad \ldots (14)$$

4.2. Livestock Production Value Index

Change in value of production due to changes in livestock composition can be assessed with Livestock Production Value Index (LPVI) which is defined as:

$$LPVI(\text{at constant price}) = \frac{\sum_{i=1}^{k}\sum_{j=1}^{n} P_i Y_{ij} X_j \,/\, L \text{ after the project}}{\sum_{i=1}^{k}\sum_{j=1}^{n} P_i Y_{ij} X_j \,/\, L \text{ before the project}} \quad \ldots (15)$$

Where,

P_i = Price of ith product (at constant price),

Y_{ij}=Average production of ith product fromjthcategory of animal,

X_j= Number ofjth category of animal,

L = Total number of standard livestock units.

A higher value of LPVI indicates increased value of the livestock production after the implementation of improved animal husbandry practices *(Sharda et al., 2012).*

4.3. Carrying Capacity Index

Increasing fodder availability through afforestation and other related activities is an important component of watershed development for boosting livestock sector and thereby the outputs emanating from it. Therefore, assessing the carrying capacity of the watershed in terms of fodder supply for supporting its livestock population is essential. For this, the Carrying Capacity Index is a suitable indicator, which is the ratio of the quantity of fodder available and required for the existing livestock population. The value of the index varies from 0 to 1 *(Sharda et al., 2012; Vinchurkar and Ingole, 2021).*

$$CCI = \frac{\text{Quantity of fodder available}}{(\text{No. of standard livestock units}) \times (\text{Standard requirement of green fodder per livestock unit})} \quad \ldots (16)$$

5. Employability Indices

The ultimate aim of the watershed development programme is Socioeconomic development of the inhabitants. With a view to assess this aspect three indices have been included under Employability indices, which will be of help in evaluating the development programme.

5.1.Women Productive Time Utilization Ratio

Women constitute 32% of the agricultural workforce in the Indian sub-continent and this percentage is rising due to the out migration of men to urban areas. Therefore, women play a major role in managing natural resources for ensuring food and nutritional security, in addition to devoting their labour and time in daily household chores. Under harsh environmental conditions and limited natural resources, a lot of time is devoted to unproductive activities such as fuelwood collection, water collection, grazing etc. Watershed management activities provide opportunities to the women for utilizing their labour in more productive activities. Women Productive Time Utilization Ratio (WPTUR) will help in indirectly assessing the benefits derived by the women stakeholders from watershed management programmes.

$$\text{WPTUR} = \frac{\text{Time spent on more productive activities}}{\text{Time spent on less productive activities}} \quad \ldots (17)$$

Where, more productive activities cover dairying, cottage industry, cropping, horticulture and agri-business while less productive activities include fuel wood collection, water fetching, grazing etc. The ratio can be measured at two points of project period i.e. PrP and PoP. An improvement in the ratio will indicate more productive utilization of the time by women folk in the watershed and vice versa *(Sharda et al., 2012)*.

5.2.Regular Employment Generation Index

Watershed management projects are a great source of generation of one time employment through land based activities such as soil conservation, plantation (horticulture, forestry), and other works, as well as regular employment by introducing labour intensive new agricultural production technologies and non-land based activities such as cottage industry or thrift societies for the land less rural masses. In case of regular employment, which is more important than the casual employment, the watershed management impact can be assessed through the Regular Employment Generation Index:

$$\text{REG)} = \frac{\sum_i^n E_i A_i \text{(after the project)}}{\sum_j^k E_j A_j \text{(before the project)}} \quad \ldots (18)$$

Where,

E_i= the number of mandays utilized per hectare in the i^{th}enterprise (crop, horticulture, agro-forestry, forestry, livestock, fishery etc.) in a year after the project,

A_i =Area in hectares utilized in thei^{th} enterprise (crop, horticulture, agro-forestry,forestry, livestock, fishery etc.) in a year after the project,

E_j =Number of mandays utilized per hectare in thej^{th} enterprise (crop, horticulture,agro-forestry, forestry, livestock, fishery etc.) in a year before the project,

A_j=Area in hectares utilized in the j^{th} enterprise (crop, horticulture, agro-forestry,forestry, livestock, fishery etc.) in a year before the project,

k,n=Number of enterprises before and after the project, respectively.

Regular Employment Generation Index can attain any positive value and any value higher than 100 will indicate the percentage improvement in regular employment leading to reduction in outmigration *(Sharda et al., 2012; Vinchurkar and Ingole, 2021).*

5.3.Seasonal Outmigration Ratio

Significant decline in outmigration is achieved through watershed management activities when there has been a substantial increase in irrigation intensity, cropping intensity, crop diversification etc. leading to an increase in watershed productivity. It creates opportunities for the seasonal out-migrants to obtain gainful employment within the watershed. The impact of a watershed management project on the socio-economic malady of outmigration can be assessed through the Seasonal Outmigration Ratio (SOR), which is defined as:

$$SOR = \frac{\sum_i^n D_i \text{(after the project)}}{\sum_j^n D_j \text{(before the project)}} \quad \ldots (19)$$

Where,

D_i= is the number of days out migrated by i^{th} out-migrant in a year after the project,

D_j= is the number of days out migrated by j^{th} out-migrant in a year before the project.

Seasonal Outmigration Ratio can attain any value and zero value will indicate that outmigration has been completely eliminated, while unit value will indicate no change in outmigration *(Sharda et al., 2012).*

6. Human Empowerment Indices

The empowerment of people living in the watershed needs to be done. The assessment needs certain indices which are clubbed under Human Empowerment indices. One important index, i.e. Human development index (HDI) is as defined by United Nations Development Program (UNDP). All these indices are described in following sections.

6.1.Poverty Index

It is simply percentage of families below poverty line (BPL) based on their real annual income within the watershed:

$$PI = \frac{\text{Number of BPL families}}{\text{Total Number of families}} \times 100 \quad \ldots (20)$$

Poverty Index can have a value ranging from 0 to 100 and it can be utilized in PrP and PoP scenarios to assess the change in number of poor stakeholder families within the watershed *(Sharda et al., 2012; Vinchurkar and Ingole, 2021).*

6.2.Social Equity Index

Social equity is one of the most important paradigms for measuring the success of any watershed management project. Social Equity Index (SEI) combines equity in income distribution, budget sharing, contributions made and benefit sharing by assigning proper weights to the four aspects and then adding the products:

$$SEI = \frac{3\,IGR + 2\,BuSGR + 2\,CGR + 3\,BeSGR}{10} \times 100 \quad \ldots (21)$$

Where,

Income Gini Ratio (IGR)

$$= 1 - \sum_{i=1}^{n} P_i\,(q_i + q_{i-1}) \qquad \dots (21.1)$$

Budget Sharing Gini Ratio (BuSGR)

$$= 1 - \sum_{i=1}^{n} P_i\,(b_i + b_{i-1}) \qquad \dots (21.2)$$

Contribution Gini Ratio (CGR)

$$= 1 - \sum_{i=1}^{n} P_i\,(c_i + c_{i-1}) \qquad \dots (21.3)$$

Bene it Sharing Gini Ratio (BeSGR)

$$= 1 - \sum_{i=1}^{n} P_i\,(d_i + d_{i-1}) \qquad \dots (21.4)$$

Where,

P_i = Proportion of population in i^{th} class,

q_i = Cumulative proportion of income upto i^{th} class,

b_i = Cumulative proportion of budget shared upto i^{th} class,

c_i = Cumulative proportion of contributions made upto i^{th} class,

d_i = Cumulative proportion of benefits shared upto i^{th} class.

Social Equity Index can vary from 0 to 100 and a lower value will indicate higher social equity *(Sharda et al., 2012)*.

6.3.Enterprise Cost Effectiveness Index

Benefits accrued out after introduction of an improved technology in a watershed can be assessed by Enterprise Cost Effectiveness Index which can be defined as:

ECEI

$$= \frac{\dfrac{\text{Benefits from improved techology (Rs./ha)}}{\text{Benefits from traditional practice (Rs./ha)}}}{\dfrac{\text{Cost of production through improved technology (Rs./ha)}}{\text{Cost of production through existing technology (Rs./ha)}}} \times 100 \qquad \dots (22)$$

It can be computed separately for different physiographic locations of the watershed and for each important technology. The value of ECEI may vary from 0 to 100 and a higher value indicates higher net returns from the improved technology as compared to traditional practice followed by the farmers during the PrP period *(Sharda et al., 2012)*.

6.4.Human Development Index*(Anonymous ,2008)*

The HDI is a summary measure of human development. It measures the average achievements in a country in three basic dimensions of human development:

- A long and healthy life, as measured by life expectancy at birth.
- Knowledge, as measured by the adult literacy rate (with two-thirds weight) and the combined primary, secondary and tertiary gross enrolment ratio (with one-third weight).
- A decent standard of living, as measured by (Gross Domestic Production) GDP per capita in purchasing power parity (PPP) terms in US dollars.

Though HDI is usually computed for a country, here it is considered for computation in a watershed as it provides a comprehensive result of human empowerment. Before the HDI itself is calculated, an index needs to be created for each of these dimensions. To calculate these indices-the life expectancy, education and GDP indices-minimum and maximum values (goalposts) are chosen for each underlying indicator. Performance in each dimension is expressed as a value between 0 and 1 by applying the following general formula:

$$\text{Dimension Index} = \frac{\text{Actual value} - \text{Minimum value}}{\text{Maximum value} - \text{Minimum value}} \quad \ldots (23)$$

Table 1. Goalposts for calculating the HDI

Indicator	Maximum Value	Minimum Value
Life expectancy at birth (years)	85	25
Adult literacy rate (%)	100	0
Combined gross enrolment ratio (%)	100	0
GDP per capita (PPP US$)	40,000	100

Once the dimension indices have been calculated, determining the HDI is straightforward. It is a simple average of the three-dimension indices*(Kharat and Pawar, 2012)***.**

$$\text{HDI} = 1/3\ (\text{life expectancy index}) + 1/3\ (\text{education index}) + 1/3\ (\text{GDP index}) \quad \ldots (24)$$

Where,

$$\text{Education Index} = 2/3\ (\text{Adult literacy index}) + 1/3\ (\text{Gross enrolment ratio}) \quad \ldots (24.1)$$

$$\text{GDP Index} = \frac{\text{Log (Actual GDP per capita in USD)} - \text{Log (US \$100)}}{\text{Log (US \$40000)} - \text{Log (US \$ 100)}} \quad \ldots (24.2)$$

7. Sustainability Indicators

Overall impact of watershed development activities needs to be assessed in the light of those aspects, which ensure sustainability of the watershed development programmes in the long run. Important indicators relevant to sustainability aspects are presented in following section:

7.1.Runoff Conservation Index

It is an important indicator to define as to how much runoff has been conserved within the watershed for biomass production and/or groundwater recharge after adopting need-based watershed interventions. It can be expressed as:

$$\text{RCI} = \frac{\text{Runoff water conserved in the watershed after the project}}{\text{Runoff water estimated before the project}} \times 100 \quad \ldots (25)$$

The runoff water conserved in the watershed can be computed by estimating the runoff by hydrologic soil cover complex number method after the implementation of agronomical, vegetative and engineering measures, which affect the land use and topographical characteristics of the watershed and subtracting it from the estimated runoff during the pre-project period.

The value of RCI may vary from 0 to 100 and a value of 100 denotes that the entire runoff from the watershed in the PrP period has been intercepted and conserved within the watershed in the PoP scenario. It may, however, not be desirable from environmental flow point of view *(Sharda et al., 2012; Vinchurkar and Ingole, 2021).*

7.2.Soil Erosion Risk Index

Mitigation of soil erosion prevailing in a watershed is one of the main objectives of watershed development projects. The extent of mitigation achieved needs to be assessed in terms of the permissible soil loss in a watershed. Soil Erosion Risk Index (SERI) indicates the change brought about in the soil loss occurring in a watershed in terms of ratio of total permissible soil loss as per soil loss tolerance limit of different homogenous units (in terms of soil depth, infiltration rate, bulk density, erodibility factor, organic carbon and fertility status) of a watershed and the total actual prevailing soil loss occurring from these units of the watershed.

$$\text{SERI} = \frac{\sum_{i=1}^{n} \text{Permissible soil loss } \left(\frac{\text{t}}{\text{ha}}\right) \text{ as per Soil Loss Tolerance Limit in the ith homogenous unit of watershed}}{\sum_{i=1}^{n} \text{Prevailing soil loss } \left(\frac{\text{t}}{\text{ha}}\right) \text{ in the ith homogenous unit of watershed}} \quad \ldots (26)$$

Where,

i is a homogenous unit of the watershed in terms of soil depth, infiltration rate, bulk density, erodibility factor, organic carbon and fertility status.

The value of the index can vary from 0 to 1 and in some cases even higher. Higher value of SERI is a measure of better moderation in soil loss, whereas a very low value near to zero indicates that the watershed is suffering from a soil loss significantly more than its permissible limit and is at risk of degrading *(Sharda et al., 2012)*.

7.3.Drought Resilience Ratio

For measuring the drought tolerance of a watershed, ratio of sum of weighted equivalent yields of food, fodder and horticultural crops during drought and normal years can be utilized. Drought Resilience Ratio can be estimated for rainfed, irrigated and watershed as a whole for the adopted watershed and non-adopted area outside the watershed. The value of the indicator can vary from 0 to 1 and a higher value will indicate higher resilience to drought *(Sharda et al., 2012).*

$$\text{DRR} = \frac{0.5(\text{equivalent food crop production}) + 0.3(\text{equivalent fodder production}) + 0.2\ (\text{equivalent horti crops production) in a drought year}}{0.5(\text{equivalent food crop production}) + 0.3(\text{equivalent fodder production}) + 0.2\ (\text{equivalent horti crops production) in a normal year}} \quad \ldots (27)$$

7.4. Induced Watershed Eco-Index

Induced Watershed Eco-Index (IWEI) is an indicator of additional area brought under vegetative cover due to crops, pasture and grassland development and horticultural and forestry plantations in a watershed during the project period. IWEI is calculated as the additional area made green through watershed interventions in proportion to the total watershed area as given below:

$$\text{IWEI} = \frac{\text{Additional area vegetated during the project}}{\text{Total area of the watershed}} \quad \ldots (28)$$

The IWEI can attain a maximum value of 1.0, which indicates that whole of the watershed area has been brought under some form of vegetation *(Sharda et al., 2005; Sharda et al., 2012;*

Vinchurkar and Ingole, 2021).

7.5. Participatory Watershed Development Index (PWDI)

Participation Paradigm Index and Participatory Watershed Development Index have been developed (Dogra *et al*., 2005) to quantitatively monitor and evaluate participation of stakeholders in watershed development programmes.

$$\text{PWDI} = \frac{\sum_{\text{i}=10}^{10} \text{Weighted score}}{\sum_{\text{i}=10}^{10} \text{Maximum weighted score}} \times 100 \quad \ldots (29)$$

Where,

i=ith major component of participatory watershed development (Participation, Transparency, Watershed Plan Preparation, Watershed Stakeholders Institutions, Watershed Meetings, Accounts and Records, Monitoring and Withdrawal Strategy, Common Property Resource Management, Project Implementing Agency, Watershed Development Team and Equity). For each of the individual component:

$$\text{PPdI} = \frac{\text{weighted score}}{\text{Maximum weighted score}} \times 100 \quad \ldots (30)$$

Participatory Watershed Development Index and Participation Paradigm Index can have values ranging from 0 to 100 and a higher value will indicate that higher numbers of the participatory aspects of the programmes have been executed*(Sharda et al., 2005; Sharda et al., 2012; Vinchurkar and Ingole, 2021).*

7.6. Benefit Cost Ratio

Economic analysis of the watershed development projects is carried out separately for arable lands and non-arable lands and also for the watershed as a whole using the discounted measure of the project worth, namely Benefit Cost Ratio (BCR). It is defined as the ratio of present value of additional gross benefits to the present value of additional total costs as given below:

Bene it Cost Ratio (BCR)

$$= \sum_{t=1}^{n} \frac{B_t/(1+i)^t}{C_t/(1+i)^t} \quad \ldots (31)$$

Where,

B_t are the additional benefits (Rs.) at time t

C_t are the additional costs (Rs.) at time t

i is discount rate (%); and t is life of the project.

Benefit Cost Ratio can attain any value equal to or more than zero. Projects with BCR > 1.0 are considered as economically viable and economic soundness of the project increases as the BCR value increases *(Sharda et al., 2005; Sharda et al., 2012).*

CONCLUSION

The selection and aggregation of key indicators are essential steps in the evaluation of watershed development programmes. Indicators must be carefully chosen to reflect the programme's goals, ensuring that its effectiveness can be accurately measured across multiple dimensions such as water management, land conservation and socio-economic development. By selecting relevant and measurable indicators, evaluators can provide valuable insights into the programme's performance and guide future improvements. This process is crucial for promoting sustainable development and ensuring that watershed initiatives achieve their intended outcomes.

REFERENCES

Anonymous. 2008. Human Development Report 2007/08: Fighting climate change: Human Solidarity in a divided world. UNDP Website.

Atre, A. A. and V. S. Malunjkar. 2014. An approach to monitoring and evaluation of watershed development programme. Proceeding of All India seminar on recent advances in watershed development programme. *IEIALC* (ISBN 978-81-926207-1-8),136-142.

Dogra, P., K. P. Tripathi, V. N. Sharda and S. K. Dhyani. 2005. Quantitative evaluation of participation paradigms of watershed development projects: A methodology. *Ind. J. Soil Conserv.*, 33(2):152-161.

Kharat, R. S. and S. N. Pawar. 2012. Human Development Index (HDI): A Case study Aasgaon Village, Dist- Satara, Maharashtra, India. Journal of Economics and Sustainable Development. ISSN 2222-1770 (Paper) ISSN 2222-2855 (Online), 3(1):2012.

Sharda,V. N., J. S. Samra andP. Dogra. 2005. Participatory watershed management programmes for sustainable development: Experiences from IWDP. *Ind. J. of Soil Conserv.*, 33(2): 93-103.

Sharda,V. N., P. Dogra and B. L. Dhyani. 2012. Indicators for assessing the impacts of watershed development programmes in different regions of India. *Ind. J. of Soil Conserv.*, 40(1): 1-12.

Vinchurkar S. S. and N. W. Ingole. 2021. Evaluation of Impact on Watershed by Using Different Indices of Indla-Ghatkhed, District-Amravati, Maharashtra. *Journal of Water Resource Engineering & Pollution Studies,* 5(2):8-29.