Major Composite Indicators for Environmental Impact Assessment of Watershed Management Projects

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Watershed management has become an accepted tool for development and utilisation of natural resources of land, water and plants, especially perennial ones, on a continuing basis. It is planned and implemented to provide desired goods and services to human societies including domesticated livestock/animals, to meet their basic needs as well as to fulfill enlarging aspiration.

Sustainability of natural resources base is thus essential both from ecological angle besides that of socio-economics. Thus evaluating environmental impact of a watershed management project has become a necessity for appropriate investment decisions. This can substantially be done by two composite indicators namely Watershed Eco Index (WEI) and Hydrologic Performance Index (HPI).

The sustainability of watershed ecosystem will depend on achieving a dynamic balance amongst the processes of

- Production vs Consumption or utilisation and
- Regeneration / replenishment vs depletion through harvests

Plants are primary producers which only can use directly the main energy source i.e., sunrays and then transmit it to other life forms. As a direct indicator of watershed degradation the ratio of Production (of energy) to Respiration (use of energy) has been advanced. In a simple form it could be a ratio of O_2 released and made available to the watershed eco system to the CO_2 exhaled by life forms and absorbed by the plants. If the ratio is equal to or more than one, the watershed could be considered environmentally stable. This would depend on extent of area under plants and quality of their stands (Odum 1975, 83).

This also take care if the concerns expressed on decreasing soil carbon pool (Lal *et al*., 1999).

WEI rests on this hypothesis. It is computed as a ratio of Total Green Area, in forests and outside forests, to the Total Geographical Area and expressed in percentage. In other words

$$\text{WEI} = \frac{\text{Existing Forest Area + New Green Area created}}{\text{Total watershed Area}} \times 100$$

The objective statement of India's National Forest Policy stipulates that country should have one third of its area under forests. While hills and mountains should have 60 percent or more and plains should have 20 percent of its area under perennial cover (Tiwari, 1986). Using these stipulations and in consideration of current scenario of denudation due to urbanisation, industrialization, overgrazing and extensive cultivation, a sliding scale for WEI has been prepared and is given in Table 1 (AFC, 2000; Das *et al*., 2000).

Table 1 Norms to assess if land has improved ecologically through watershed management

Type of watershed terrain	Immediate Desirable WEI	Long term desirable WEI
Plains	(F + NGA)/ A = 10 %	20 %
Rolling and Undulating terrain	(F + NGA)/ A = 20 %	35 %
Foot hills and Sub mountain areas	(F + NGA)/ A = 35 %	50 %
Higher elevation - Mountains and Slopes	(F + NGA)/ A = 50 %	70 % plus

F= Forest Area, NGA – New Green Area and in most cases on non-forest areas

A = Total Area of Watershed

From details given in Table 1, WEI will have two components i.e. one for forest areas (WEI_F) and the other for new green area developed through afforestation and tree planting on non-forest areas (WEI_{NGA}). WEI_F relates to *in-situ* or natural green areas while WEI_{NGA} refers to induced and *ex-situ* green areas.

In plains due to steady increase in urbanization and industrial development the extent of natural or regenerated forest area is generally small and often negligible. Here green cover has to come on non-forest areas through tree planting deterring different types of land degradation and pollution. Thus the paper will illustrate the approach for computation of the WEI_{NGA} part only.

In western plains in Gujarat State, considerable areas outside forests, were afforested under World Bank supported integrated watershed development project. The concept, approach and method for computation of WEI_{NGA} were illustrated through an exercise for four watersheds namely Vatrak, Narmada, Macchu and Bhadar, each having total area around 20,000 ha. The summary of the exercise is given in Table 2.

Table 2 Computation of watershed eco-index due to afforestation/tree planting on non-forest areas of 4 watersheds of central west, state of Gujarat, India

Sl.No.	Type of Afforestation or Tree Planting	Watersheds and Area Brought under Perennial Cover			
		Vatrak	Narnada	Macchu	Bhadar
1.	Total Geographical Area (TWA)	20,230	20,147	19,960	19,963
2.	Non-Forest Areas Afforested/ Planted with Perennial Plants				
2.1	Multi-tier (canopy) Village Wood lot	1,401	2,132	2,569	2,954
2.2	Farm Forestry	1,445	1,010	1,655	2,134
2.3	Silvi-Pasture	1,356	643	386	1,595
2.4	Horticultural Plants	292	631	314	170
Total New Green Area (NGA)		4,494	4,416	4,924	6,853
3.	WEI_{NGA} = NGA/TWA	22.21	21.92	24.67	34.33
3.1	Adjusted for survival percentage (60%) – first level adjustment	19.33	13.15	14.80	20.80
3.2	Adjusted WEI_{NGA} for lower eco-characteristics of the green stands – Second level adjustment by 0.5	9.66	6.57	7.40	10.30
	As percent of proposed norm given in Table-1 - 20%	48.3	32.57	37.0	51.50

The computed values with gross areas afforested alone ranged from 22 to 34 percent. But survival rate of planted species ranged from 45 to over 80 percent for various types of plantation works. Thus the WEI_{NGA} values were adjusted with an average survival percent figure of 60 percent. The first level adjusted WEI_{NGA} values ranged from 13 to 21 percent. In the face of extensive urbanisation, industrialisation etc. and large live stock population, these enhancements could be considered significant. But the stands would get desirable ecological quality after quite some years. Thus there is a need to make a second level adjustment for real eco-characteristics of the stand of the perennial green cover which are created outside forests and on non-forest areas which are degraded and of low productivity. The tress planted are yet to mature, the stands have yet to develop into a stratified cover with adequate ground flora. Thus it is proposed to correct it by a factor of 0.5 when the WEI_{NGA} values for four watersheds would range from 6.6 to 10 percent. The first attempt in greening through watershed development could attain the targeted norm of 20 percent in the range of 51.5 to 33 percent. For a populated developing country like where pressure on land is intense and per capita availability of land is declining, this is a significant achievement.

HPI rests on the fact that water is a critical and direct input to all primary production systems such as cultivation, tree planting pasture/range land, forests and plantations. It is also the medium for other production input. Water however, comes with ecological hazards too such as run off, soil loss, water stress. HPI also gives an assessment of increased availability of rainwater and its enhanced utilisation on watershed itself. From an impact assessment of two watersheds in arid north-west State of Rajasthan, India, the various elements of HPI such as reduction in (1) eco-logical risks, (2) increased land utilisation and (3) improved hydrologic status have been summarized in Table 3 (Das, 1999).

Table 3 Parameters considered for computation of Hydrologic Performance Index (HPI) for two Watersheds in Sahibi Catchment, State of Rajasthan, India

Sl.No.	Parameters	Unit	Watersheds	
			Tatarpur	Pithalpur
1	Ecological Risks Reduction			
1.1	Runoff Reduction	Percent	17	37
1.2	Erosion and Sediment Production	ha • m/100 km^2/yr	2.46	2.85
1.3	Neutralization of Water Stress Conditions			
	(a) carry over weekly rainfall (inherent to a site)	Percent of annual rainfall	43.5	43.00
	(b) Deficit weeks benefited	No. of weeks	5	5
2	Land Utilisation			
2.1	Increase in Crop land	% of pre-project area (ha)	2.00 (35)	6.9 (70)
2.2	Increase or improved forest and green cover in non-forest area	% of pre-project area (ha)	21.5 (521)	21.1 (343)
2.3	Land reclaimed and brought under cultivation	% of pre-project area (ha)	1.41 (35)	1.12 (20)
2.4	Increase in irrigated area	% of pre-project area (ha)	2760 (138)	1820 (91)
3	Improved Hydrologic Status			
3.1	Increase in number of wells	% of pre-project (No)	88	28
3.2	Increase in effective weekly retention and thus water availability in a year	% of annual rainfall (mm)	9.6 (48.05)	34.4 (172.49)
3.3	Increased Utilisation of water of crop and other lands	% of annual rainfall (mm)	81.4 (407.2)	66.7 (333.48)

Assessment Ratings:

Below 10% - Poor, Between 10% and 20% - Fair, Between 20% and 50% - Good, Over 50% - Very Good

With these data for two watersheds namely Tatarpur and Pithalpur of Sahibi catchment in the State of Rajasthan, the concept, approach and methodology for computing HPI have been illustrated and the abstract is given in Table 4.

Table 4 Computation of Overall Hydrologic Performance Index (HPI) for the watersheds of Sahibi catchment, state of Rajasthan, India

Sl.No.	Parameters	Matrix			
		Tatarpur Watershed		Pithalpur Watershed	
		Score	Grade	Score	Grade
	Ecological Risks				
1	Runoff Reduction	4.5	F	6.5	G
2	Erosion and Sedimentation	5	F	4.5	F
3	Neutralization of Water Stress	7.5	G	7.5	G
	Land Utilisation				
4	Increase in Crop Land	1	P	1	P

Continued

Sl.No.	Parameters	Matrix			
		Tatarpur Watershed		Pithalpur Watershed	
		Score	Grade	Score	Grade
5	Increase in Green Area	5	G	5	G
6	Land Reclaimed & Brought Under Cultivation	1	P	1.2	P
7	Increase in Irrigated Area	9.5	VG	9	VG
	Improved Hydrologic Status				
8	Increase in number of wells	9.5	VG	3	F
9	Increase in effective weekly retention and thus water availability	1	P	6	G
10	Increased Utilisation of Water on Crop and Other Land	9.5	VG	8.5	VG
	Total	53.5 or 5.3	3- VG 2- G F-2 P-3	52.2 or 5.2	2- VG G – 4 F-2 P-2

Assessment Matrix Ratings Scale

Grade	Matrix	Score (Between 0-10)
Poor—P	Below – 10%	Below 2
Fair—F	Between 10 and 20%	Between 2 and 5
Good—G	Between 20 and 50%	Between 5 and 8
Very Good	VG Over 50 %	Over 8 and upto 10

It may be voted that score help put different values on varied achievement within a matrix grade. HPI values computed for two watersheds have a matrix rating of good. While score for Tatarpur was 6.83 against 6.66 for Pithalpur out of 10 for Pithalpur. The ratings are creditable because the watersheds were highly degraded with high degree of water stress. These were also prone to cause floods on occasions of high daily rainfall. The package of treatments helped moderate these problems through improved hydrologic status and responses. Besides enlarging and intensifying cultivation through irrigation and reclamation of degraded land.

It could be concluded that both the composite indicators are process related, easy to adopt and thus can become useful tools to determine sustainability and equity of a watershed development project.

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