Sediment Yield and Soil Loss Estimation using GIS based Soil Erosion Model: A Case Study in the MAN Catchment, Madhya Pradesh, India

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Introduction

❑ Soil erosion has been accepted as a serious problem arising from agricultural intensifi-cation, land degradation and possibly due to global climatic change.

❑ Sediment yield to river channels and reservoir is probably the most problematic off-site consequence of soil erosion.

❑ It is estimated that out of the total geographical area of 329 Mha of India, about 167 Mha is affected by serious water and wind erosion.

❑ In the previous studies claimed that Geographical Information System (GIS) and the Revised Universal Soil Loss Equation (RUSLE) applied to predict the annual average soil loss rate.

❑ According to study of various researchers has been done on Geographical Information System (GIS) and Revised Universal Soil Loss Equation (RUSLE) techniques makes soil erosion estimation and its spatial distribution feasible with less parameter with better accuracy in larger areas than Physical based models.

Study Objectives

❑ Revised Universal Soil Loss Equation (RUSLE) Integrated with Geographical Information System (GIS) and Remote Sensing has been attempted in this study to estimate detailed study of RUSLE, collection of the Topographical, Hydrological, Geological and Remote Sensing data for study area.

❑ Evaluation of soil erosion rate, gross soil erosion and gross sediment yield from RUSLE.

❑ Identification of area of MAN Catchment which needs Treatment based on Average Annual Soil Erosion Rate.

Study Area

❑ The whole study is conducted in MAN project which is being constructed at village Jeerabad of Manawar tehsil of district Dhar, Madhya Pradesh, India.

❑ The total catchment area at MAN Project site is 713.76 km².

❑ The geographical location of the MAN catchment is 22°24'20" N latitude and 75°05'40" E longitude.

❑ The mean annual rainfall is 781.05 mm. the general climate is sub-tropical.

❑ A major part of the area has steep to very steep slopes associated with undulating landscapes.
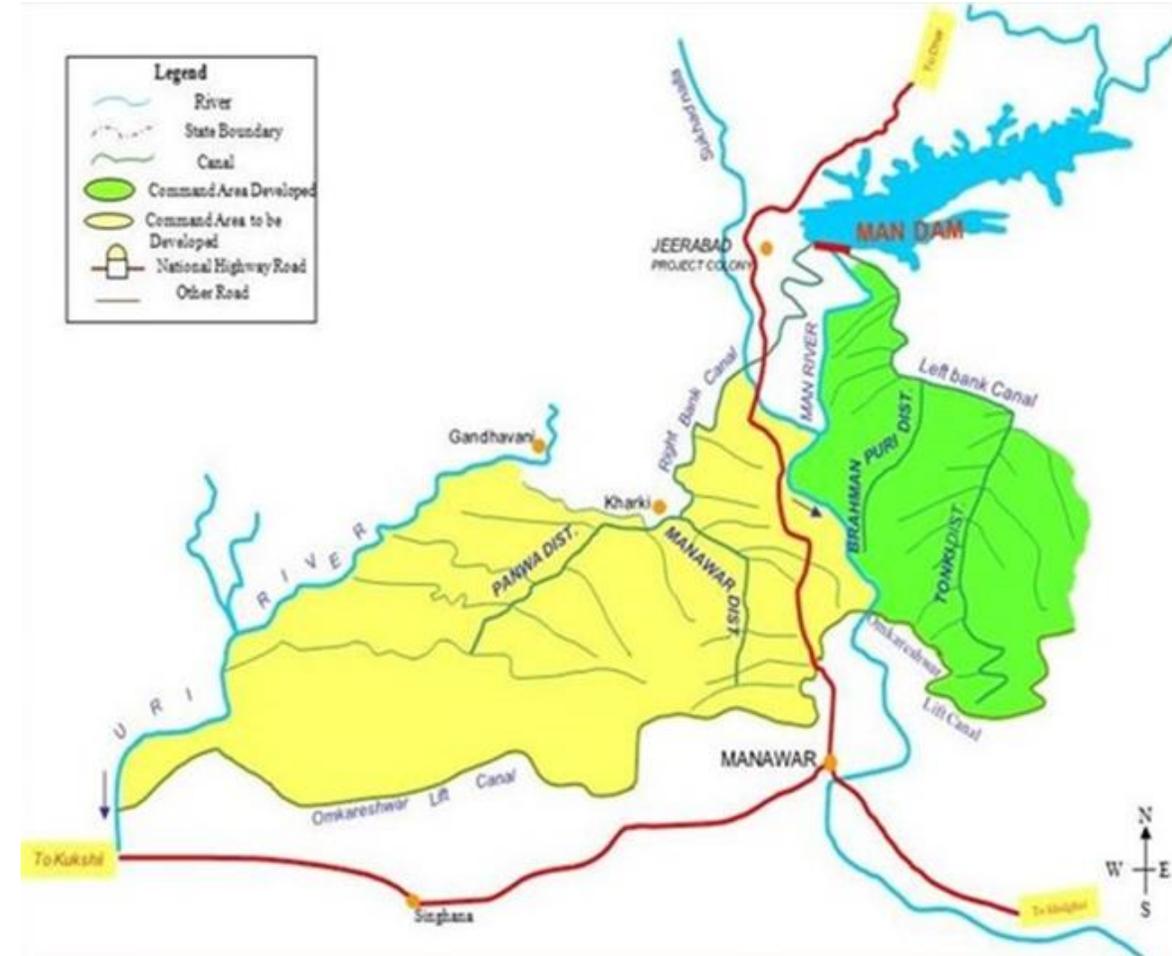
Features of the MAN Catchment project

1	**Total Catchment Area at the proposed Dam site**	713.76	km²
3	Average Annual Rainfall	958.00	mm
4	Maximum Annual Rainfall (Weighted)	1716.00	mm
5	75% dependable rainfall	792.00	mm
6	Yield at 75% dependability	113.37	m³
7	Design Flood	10254.00	m³

Hydrologic features of MAN project

Reservoir features

1	**Full Reservoir Level (FRL)**	**297.65**	**m**
2	Maximum Water Level (MWL)	297.65	m
3	Minimum Drawdown Level (MDDL)	278.30	m
4	Sill level of canal outlet	277.00	m
5	Gross storage	145.03	mm³
6	Dead Storage at RL 278.30 m	18.16	mm³
7	Live storage	126.87	mm³
8	Storage at LSL	15.48	mm³
	Radial gates	9 Nos.	(12m x 12m)
	Water spread (sq.km) Full Reservoir level		
9	Maximum drawdown level	10.94	km²
		2.83	km²
10	Gross Utilization	126.87	mm³

Methodology

❑ Toposheet Georeferencing using ArcGIS software

❑ Basemap and Digitization of MAN River using ArcGIS software

❑ Rain gauge Station Selection and Calculation of soil loss factors

❑ Slope and steepness

❑ Focal Analysis

Reference Erosivity factor

S. No.	R factor
1	$R = 79 + 0.363P$
2	$R = P \times 0.5$
3	$R = 81.5 + 0.375 * r$

Relation between slope and P factor

Slope (%)	0-2	2-5	5-8	8-12	12-16	16-20	20-25	25-above
P factor	0.6	0.5	0.5	0.6	0.7	0.8	0.9	1
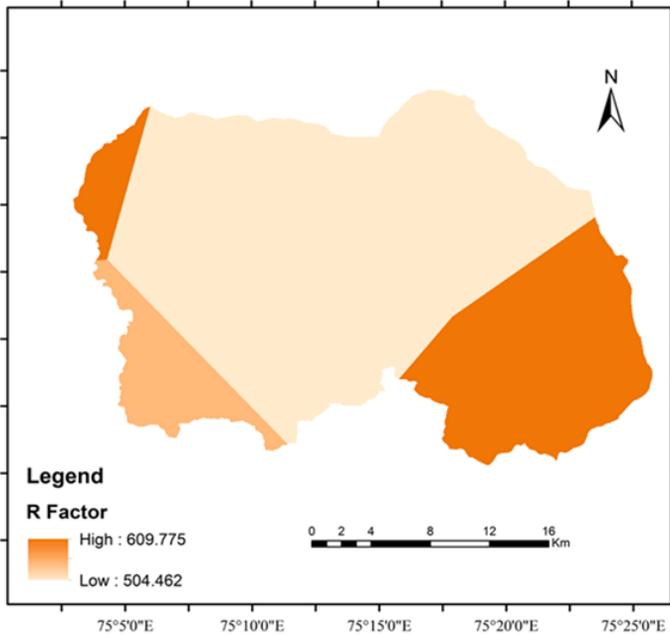
Rainfall Erosivity Factor R
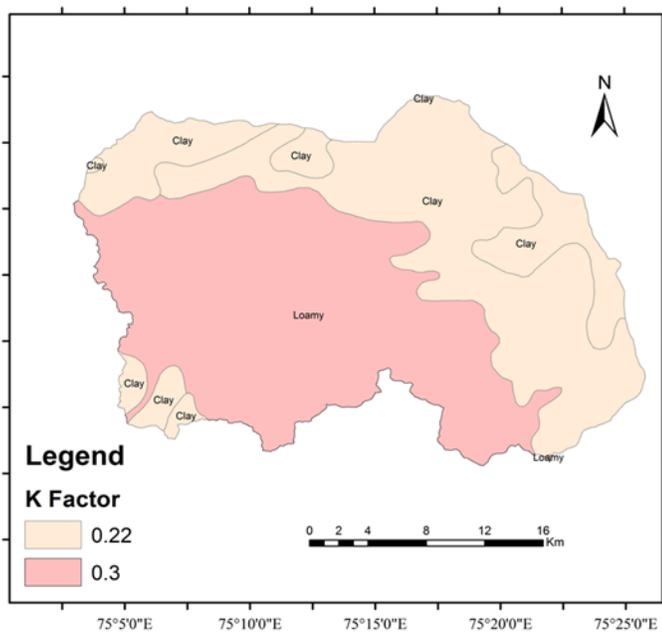
Soil Erodibility Factor K
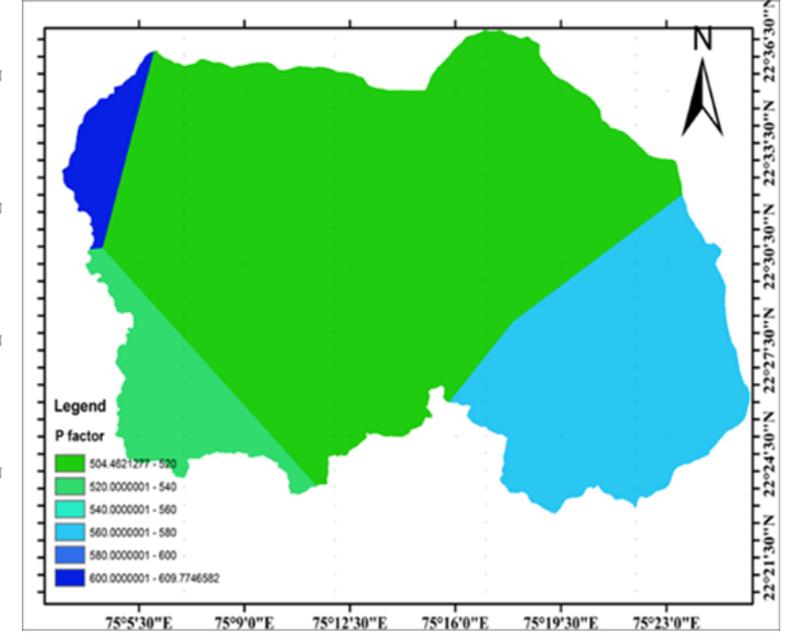
Practice management Factor P
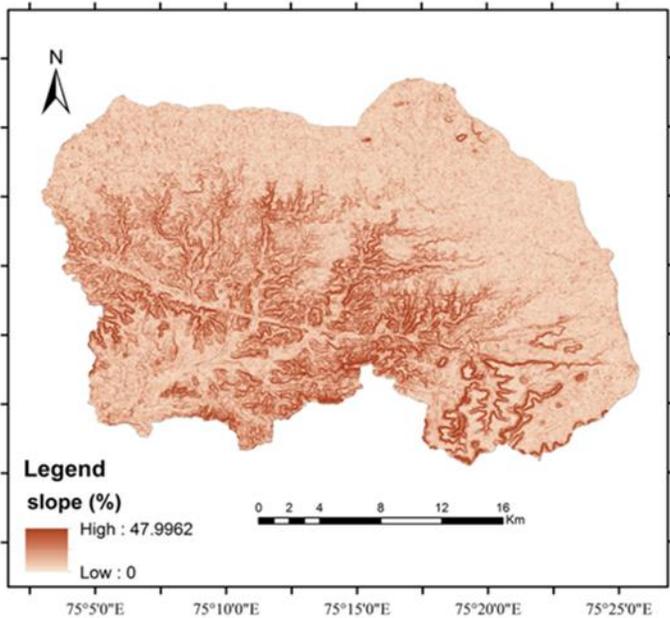
Slope of MAN catchment
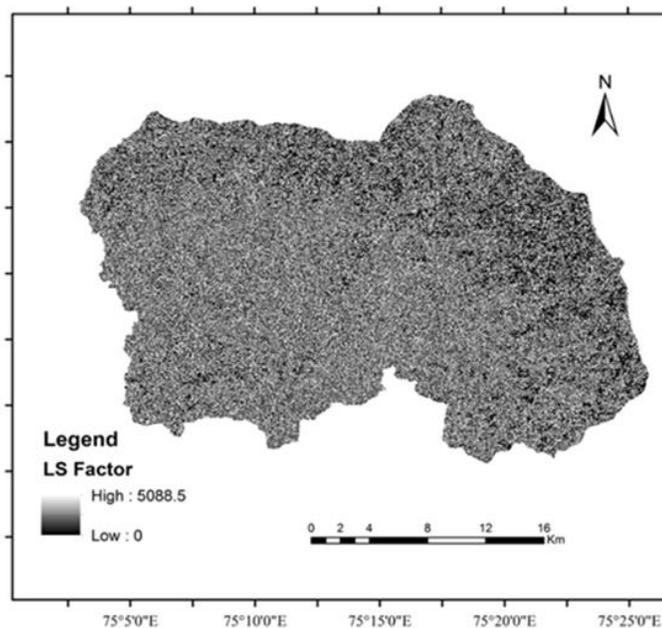
Slope Steepness Factor LS.
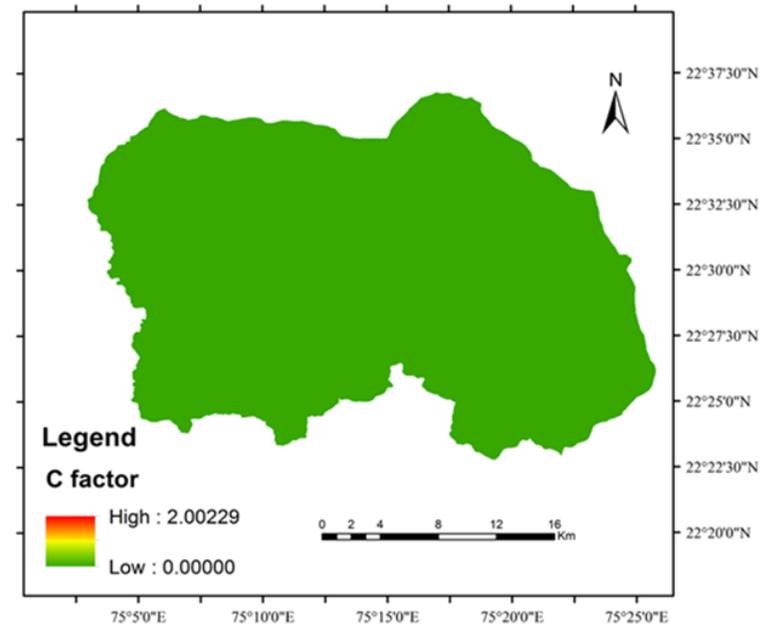
Cover management Factor C

Results

In the present study, it is found that gross erosion from MAN catchment is 928607.89 (Ton/year) and average annual soil erosion rate is 13.01 (Tons/ha/yr) for 19 rainfall year.

Year	Total Soil Erosion (Ton/year)	Soil Erosion Rate (Ton/ha/year)
1994-1995	1302644.60	18.25
1995-1996	887444.33	12.43
1996-1997	958862.56	13.43
1997-1998	1138276.65	15.95
1998-1999	954664.33	13.38
1999-2000	833734.65	11.68
2000-2001	492483.70	6.90
2001-2002	723704.91	10.14
2002-2003	779310.03	10.92
2003-2004	1298710.26	18.20
2004-2005	489670.28	6.86
2005-2006	606727.83	8.50
2006-2007	1176059.15	16.48
2007-2008	1254114.25	17.57
2008-2009	635964.78	8.91
2009-2010	883475.64	12.38
2010-2011	1178661.35	16.51
2011-2012	1110678.09	15.56
2012-2013	938362.58	13.15
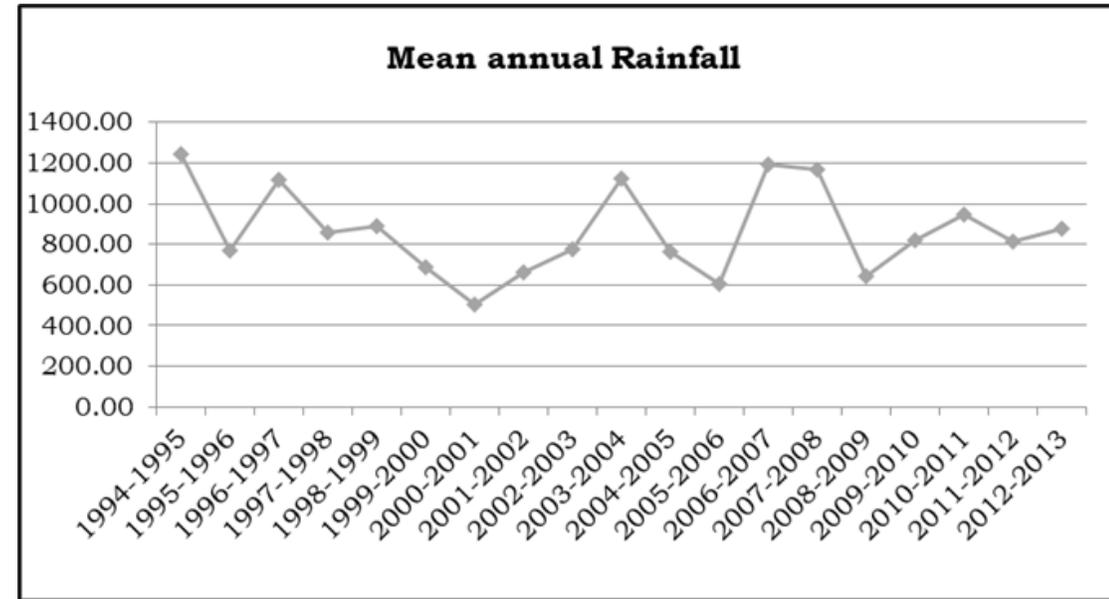
Gross soil erosion

Annual rainfall from 1994-2013

Annual Sediment Yield

❑ Sediment yield = Average annual soil erosion × Sediment delivery ratio.
❑ Sediment delivery ratio = 0.627 × SLP 0.403.
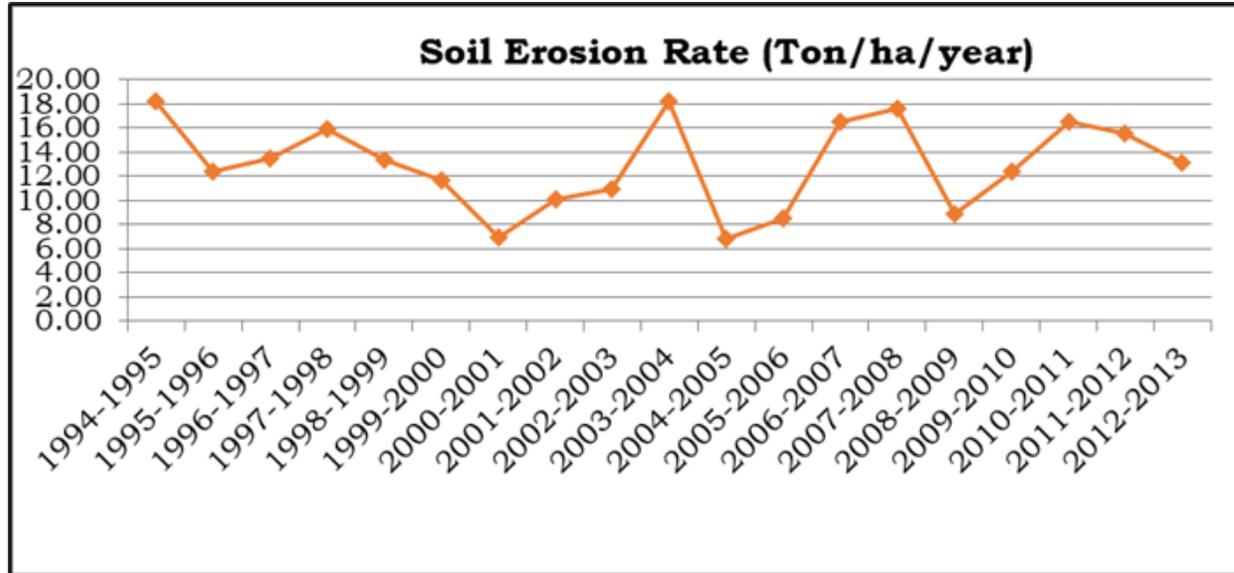
The following results has been found:
❑ Length of MAN River is 57.68 km.
❑ MAN river ridge point elevation is 720 m.
❑ MAN river outlet point elevation is 257 m.
❑ Sediment Yield for MAN dam site is 532870.05 (Tons/yr).

The annual soil loss of the MAN catchment is minimum of 6.20 in year of 2000-01 to higher rate of erosion 18.25 in 1994-95 the average annual rate of erosion is 13.01 (Tons/ha/year)

Area wise Soil Erosion Rate

Erosion Class	Potential Erosion	Area (ha)	Area (%)
Less than 2	Negligible	38058.21	53.32
2 to 5	Very Slight	7909.29	11.08
5 to 10	Slight	6493.86	9.10
10 to 15	Moderate	3754.53	5.26
15 to 20	Moderately Severe	2731.86	3.83
20 to 40	Severe	6623.64	9.28
40 to 80	Very severe	4131.54	5.79
above 80	Extremely severe	1673.55	2.34

The results shows that more than 50 percent area is under no erosion zone, around 20 percent area is under very slight and slight erosion but few areas under severe erosion which have high priority of immediate treatment.

Proposed Treatment Details

Erosion Class	Proposed Soil Conservation Activity Treatment
Less than 2	Negligible
2 to 5	Negligible
5 to 10	Field bunding, Pasture Development
10 to 15	Contour Cultivation, Strip Cropping, Contour strip Cropping, inter cropping, vegetative bunding
15 to 20	Inter cropping, Contour Bunding, Vegetative bunding, Diversion of drainage chennels.
20 to 40	Graded bunding,land leveling, Gully Control Structure, Vegetative hedges, Pasture development
40 to 80	Afforestration, Gully Control Structure, Graded bunding, Pasture development
above 80	Afforestration, Gully Control Structure, Graded bunding, bench Trenching, Terracing

According to the erosion classification the proposed treatment plan is indicated in the table in which around 65 percent area does not need any major treatment and rest of the area have required necessary treatment.

The Average annual soil erosion rate as estimated for MAN catchment comes out to be 13.01 Tons/ha/year.

The adopted value of soil erosion rate for a useful life of reservoir of 100 years is 9.93 Tons/ha/year by Central Water Commission, New Delhi.

Conclusion

❑ Based on the results obtained in the present study following major conclusions can be made. The average annual soil erosion rate for MAN catchment is 13.01 Tons/ha/year which is higher than that of adopted and recommended values for the project. (9.93 Tons/ha/year by Central Water Commission, New Delhi).

❑ The useful life of reservoir considering the estimated by present study soil erosion rate will be 76 years instead of 100 years. Analyzing current ASTER GDEM it is found that Water Resource Structure has been constructed at Nalcha which contribute water to MAN catchment.

❑ So present study estimates the Present length of the MAN river 57.68 km instead of 48.92 km and Present MAN catchment Area is 713.76 km2 instead of 690 km2. It is found from present study is that 53% area of MAN catchment has negligible soil erosion rate (less than 2 tons/ha/yr).

❑ It is found from present study is that 26% area of MAN catchment has moderate to ex-tremely severe soil erosion rate (greater than 10 tons/ha/year).

❑ This area must be treated by catchment area treatment activity. According to the shape of the watershed and results indicate that only few areas generating higher soil erosion problems, so distributed approach of watershed treatment will give better results both for proper management point of view and in economic aspect.

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