A Seminar Report

on

Assessing Sustainable Development Goals 15.3.1 (SDGs) of Maharashtra State Using QGIS Software

by

Shubham Yogesh Jangle

20BME162D

Under the Guidance of

Dr Ravi Kant

Assistant Professor, Mechanical Engineering,

Submitted to

Mechanical Engineering,

School of Technology,

Pandit Deendayal Energy University

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CERTIFICATE

This is to certify that the seminar report entitled "**Assessing Sustainable Development Goals 15.3.1 (SDGs) Of Maharashtra State Using QGIS Software**" submitted by **Shubham Yogesh Jangle**, has been conducted under the supervision of **Dr. Ravi Kant, Assistant Professor**, and is hereby approved for the partial fulfillment of the requirements for the award of the degree of Bachelor of Engineering in the Department of **Mechanical Engineering** at Pandit Deendayal Energy University, Gandhinagar. This work is original and has not been submitted to any other institution for the award of any degree.

Sign:

Name of Guide: Dr. Ravi Kant

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Designation: Assistant Professor

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DECLARATION

I hereby declare that the seminar report entitled "**Assessing Sustainable Development Goals 15.3.1 (SDGs) Of Maharashtra State Using QGIS Software**" is the result of my own work and has been written by me. This report has not utilized any language model or natural language processing artificial intelligence tools for the creation or generation of content, including the literature survey.

The use of any such artificial intelligence-based tools was strictly confined to the polishing of content, spellchecking, and grammar correction after the initial draft of the report was completed. No part of this report has been directly sourced from the output of such tools for the final submission.

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Date: 21-11-2023
Place: Gandhinagar

List of Tools Used for the Report with Purpose:

- ChatGPT : Correcting Grammar.

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Abstract

This research study aims to provide a comprehensive analysis of the progress, challenges, and strategies related to achieving Sustainable Development Goal 15.3.1 in Maharashtra, India. The study evaluates the state's performance in preventing land degradation, stopping biodiversity loss, and safeguarding and restoring forest ecosystems. The methodology involves land cover analysis, land productivity assessment, and monitoring soil organic carbon. The results indicate significant changes in land cover, improved land productivity, and stable soil organic carbon levels. The research contributes to the understanding of Maharashtra's efforts in attaining SDG 15.3.

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- SDG: Sustainable Development Goal
- SOC: Soil Organic Carbon
- NVDI: Normalized Difference Vegetation Index

Chapter 1: Introduction

Among the most precious resources on Earth are forests, which sustain biodiversity, offer vital ecosystem services, and support the livelihoods of millions of people throughout the globe. The United Nations set a particular aim under Sustainable Development Goal (SDG) 15, 15.3.1, to prevent desertification, stop and reverse land degradation, and end biodiversity loss., which recognizes the vital importance of forests. Within the framework of India's sustainable development agenda, Maharashtra—a state characterized by great geographic, ecological, and cultural diversity—serves as a key reference point for evaluating the level of progress towards attaining SDG 15.3.1.[1]

The goal of Sustainable Development Goal 15.3.1 is to "By 2030, combat desertification, restore degraded land, and soil, including land affected by desertification, drought and floods, and strive to achieve a land-degradation-neutral world." [2] Preventing desertification and land degradation is the main focus, and it emphasizes the importance of conservation, sustainable management, and restoration of terrestrial ecosystems. In Maharashtra, achieving this aim is crucial for safeguarding the environment as well as more general issues like livelihood stability, adjusting to climate change, and fortifying oneself against growing environmental uncertainty.[3]

This study report looks at the many aspects of Maharashtra's journey to achieve SDG 15.3.1. Its objectives are to evaluate the state's performance in stopping land degradation, stopping biodiversity loss, and safeguarding and reestablishing forest ecosystems.[4]

In order to accomplish this goal, the article will conduct a thorough examination of many dimensions:

Forest Conservation and Restoration: Analyzing the programs and policies Maharashtra's government and non-governmental organizations have implemented to preserve and revitalize forest ecosystems.

Mitigation of Land Degradation and Desertification: Evaluating the state's efforts to stop desertification and land degradation, especially in sensitive areas.

Biodiversity Conservation: Analyzing the steps taken to protect biodiversity in wooded regions and their effects on the local flora and fauna

Challenges and Prospects for the Future: Outlining the obstacles Maharashtra must overcome to fulfill SDG 15.3.1 and suggesting plans for a more sustainable future.

Understanding the social and economic effects of forest conservation and restoration initiatives, as well as the ramifications for local communities and indigenous people, is important.

In order to eradicate poverty, safeguard the environment, and guarantee prosperity for all by 2030, there is a global call to action known as the Sustainable Development Goals (SDGs). The varied population and economic significance of Maharashtra make it a particularly promising state with unique challenges in attaining the SDGs. Evaluation of the state's coordination efforts with these international goals is the aim of this research work.[5]

Chapter 2: Literature Survey

Global Significance of SDG 15.3.1:

SDG 15.3.1 is a component of the global community's pledge to address biodiversity loss and land degradation. It is in line with international efforts to protect ecosystems, fight climate change, and advance sustainable land management techniques.

The Ecological Diversity of Maharashtra: Maharashtra encompasses a wide range of biomes, from semi-arid areas to tropical rainforests. The state's ecosystems sustain a wide variety of plants and animals, aid in agriculture, and act as vital water catchment areas.

Prior Research on Land Degradation and Biodiversity Conservation in Maharashtra: An examination of previous studies and reports offers important background information for comprehending the state of land degradation, desertification, and biodiversity conservation in Maharashtra at the moment.[6]

Chapter 3: Methodology

Land cover is the categorization and representation of different land types and land surface elements within a given geographic region. Data on land cover can include both physical and biological characteristics of the surface of the Earth, such as marshes, farms, forests, urban areas, and water bodies. Land cover analysis is necessary for land use planning, urban planning, natural resource management, and environmental assessment, among other uses.

Land productivity is the capacity of a certain plot of land to provide agricultural or other natural resource outputs. Assessing and mapping a piece of land's suitability for different land use activities—most notably agricultural ones—is what land productivity analysis entails in the context of QGIS, a geographic information system (GIS) application.

Soil organic carbon (SOC) which is a representation of the carbon concentration of organic matter in the soil, such as decomposed plant and animal debris. The geographical data pertaining to the distribution and concentration of organic carbon in the soil across a certain geographic region is referred to as soil organic carbon data in QGIS software.[7]

Data Collection: A variety of sources, including official publications, satellite images, surveys, and scholarly works, provided data for this research study. These sources include both quantitative and qualitative information that may be used to evaluate the state's advancement toward SDG 15.3.1.[8]

Chapter 4: Procedures, Setup, Manufacturing, Fabrication, etc.

Area of Study

This section provides detailed procedures and setups for the analysis, including QGIS applications, GIS technology, and data collection methods

Encouraging concerns including social injustice, economic inequality, and environmental degradation were addressed when the United Nations issued the 2030 Agenda for Sustainable Development in 2015. SDG 15, one of the 17 Sustainable Development Goals (SDGs), focuses on safeguarding, repairing, and improving terrestrial ecosystems for sustainable use. In particular, Target 15.3.1 is relevant to this overarching goal as it focuses on halting the loss of biodiversity, restoring damaged land, and preventing desertification.

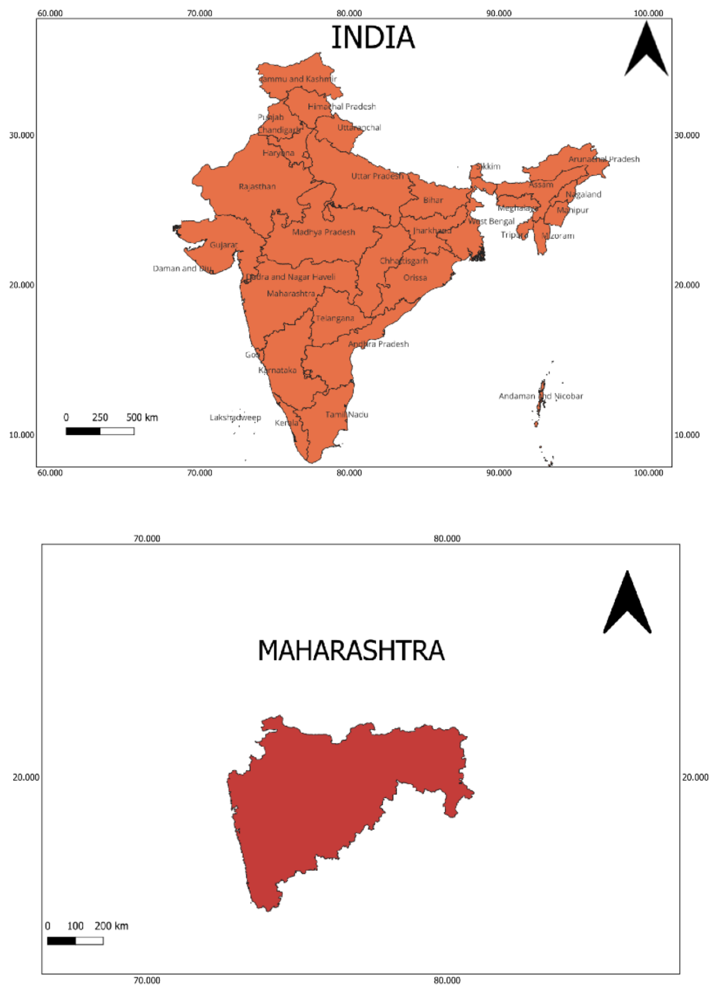

Fig 1: Location Of Study Area

One of the most populous and economically important states in India, Maharashtra represents a distinctive mosaic of geographical and biological variety. The state's habitats, which range from the dry plateaus of Vidarbha to the lush forests of the Western Ghats, greatly contribute to the biodiversity and environmental health of the country. This essay analyzes Maharashtra's progress toward SDG 15.3.1 and considers what it means for the region's sustainable development.

Maharashtra's capital is Mumbai. Maharashtra is home to the Godavari, Krishna, Taps source in the Satpura Range. It facilitates agricultural activity, Bhima, Mula Mutha, Wardha, and Chandrapur rivers. The Wardha River, an important waterway for the area, flows through the district of Chandrapur in Maharashtra.

Source : (https://www.mapsofindia.com/maps/maharashtra/rivers/wardha.html

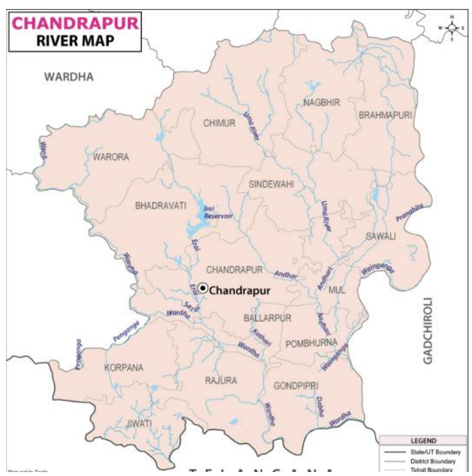

Fig 2: Godavari River

Maharashtra has an average elevation of 560 meters (1,837 feet) above sea level. Maharashtra comprises the mountain ranges of Satpura, Ajanta, Bhima Shankar, Harishchandra gad, and the Western Ghats. A UNESCO World Heritage Site, the Ajanta range is renowned for its extraordinary rock-cut cave temples.

Coast of the Arabian Sea in Maharashtra, Over 300 species of birds, 46 species of reptiles, 8 species of amphibians, 635 kinds of plants, 37 species of mammals, and more than 2000 types of insects may be found on its 258.71 km2 of land. Since it was established in 1965, the sanctuary has gained recognition for its capacity to conserve and safeguard mostly Asiatic Lions (Panthera leo persica).

Land Cover

The distribution and makeup of different man-made and natural features on Earth's surface are referred to as land cover. It includes many different types of landscapes, including marshes, agricultural fields, urban areas, woods, and aquatic bodies. Classifying and representing land cover is crucial for numerous applications, including urban planning, natural resource management, and environmental monitoring.[9]

Programs like QGIS may be used to collect, analyze, and present land cover data by leveraging geospatial technologies like geographic information systems (GIS). Researchers, lawmakers, and land managers may use this knowledge to make well-informed decisions about land use, conservation efforts, and disaster risk assessment. [10]

	Area(sq km)	**Percent of total land area**
Total land area:	3,44,671.5	100.00%
Land area with improved land cover:	2,915.19	0.85%
Land area with stable land cover:	3,38,373.53	98.17%
Land area with degraded land cover:	3,382.77	0.98%
Land area with no data for land cover:	0.00	0.00%

Table 1: Land Cover Change Matrix

Land Productivity

The ability of a specific piece of land to produce agricultural or natural resource outputs is referred to as land productivity. In order to determine the property's potential for certain applications, this evaluation entails the examination of geographic data layers, including those pertaining to soil types, climate, land cover, and terrain. Users of QGIS and other geographic information systems may assess whether a piece of land is suitable for forestry, grazing, or crop development by layering and balancing various aspects.[11]

		Land cover type in final year							
		Tree-covered	**Grassland**	**Cropland**	**Wetland**	**Artificial**	**Bare land**	**Water body**	*Total:*
Land cover type in initial year	**Tree-covered**	30,938.59	75.61	401.46	0.80	4.30	0.00	2.27	*31,423.03*
	Grassland	309.98	6,189.68	99.37	3.88	86.74	0.00	10.28	*6,699.93*
	Cropland	1,976.62	159.35	2,14,311.31	14.34	745.97	0.07	18.81	*2,17,226.46*
	Wetland	0.37	0.07	1.09	158.71	3.42	0.00	1.82	*165.48*
	Artificial	0.00	0.00	0.00	0.00	814.59	0.00	0.00	*814.59*
	Bare land	0.00	0.00	0.00	0.00	0.22	4.36	0.07	*4.65*
	Water body	0.51	1.75	11.72	5.32	3.71	0.00	1,000.60	*1,023.61*
	Total:	*33,226.06*	*6,426.47*	*2,14,824.95*	*183.04*	*1,658.94*	*4.43*	*1,033.85*	***2,57,357.76***

Table 2: Land Productivity: Area of land with improving productivity by type of land cover transition (sq. km)

In Table 2 in the final year, the land cover types and their respective areas are as follows: Tree-covered (33,226.06 sq. km), Grassland (6,426.47 sq. km), Cropland (2,14,824.95 sq. km), Wetland (183.04 sq. km), Artificial (1,658.94 sq. km), Bare land (4.43 sq. km), Water body (1,033.85 sq. km), with a total land area of 2,57,357.76 sq. km. The table also provides information on land cover transitions, indicating changes in land productivity over time.

		Land cover type in final year							
		Tree-covered	Grassland	Cropland	Wetland	Artificial	Bare land	Water body	*Total:*
Land cover type in initial year	**Tree-covered**	14,738.69	62.38	352.91	0.72	1.60	0.00	3.09	*15,159.39*
	Grassland	76.22	1,606.79	80.97	1.18	42.22	0.00	13.24	*1,820.62*
	Cropland	329.51	41.23	50,604.75	5.51	738.71	0.58	38.66	*51,758.95*
	Wetland	0.37	0.22	0.51	50.51	1.31	0.00	1.31	*54.23*
	Artificial	0.00	0.00	0.00	0.00	530.26	0.00	0.00	*530.26*
	Bare land	0.00	0.00	0.00	0.00	0.00	3.34	0.43	*3.77*
	Water body	0.36	1.39	2.33	2.12	1.75	0.00	330.32	*338.27*
	Total:	*15,145.15*	*1,712.01*	*51,041.48*	*60.04*	*1,315.85*	*3.92*	*387.05*	***69,665.49***

Table 3: Land Productivity**:** Area of land with stable productivity by type of land cover transition (sq. km)

Table 3 represents the land cover transitions with stable productivity in the final year. The major land cover types include Cropland (51,041.48 sq. km), followed by Tree-covered (15,145.15 sq. km) and Grassland (1,712.01 sq. km). The total land area with stable productivity is 69,665.49 sq. km.

		Land cover type in final year							
		Tree-covered	Grassland	Cropland	Wetland	Artificial	Bare land	Water body	*Total:*
Land cover type in initial year	Tree-covered	15.71	0.00	0.15	0.00	0.51	0.00	0.87	*17.24*
	Grassland	0.00	50.59	0.29	0.07	5.52	0.36	2.66	*59.50*
	Cropland	0.00	0.87	141.18	0.22	21.99	0.00	10.38	*174.64*
	Wetland	0.00	0.00	0.00	2.70	0.15	0.00	0.15	*2.99*
	Artificial	0.00	0.00	0.00	0.00	13.82	0.00	0.00	*13.82*
	Bare land	0.00	0.00	0.00	0.00	0.00	1.46	0.00	*1.46*
	Water body	0.00	0.22	0.36	0.07	1.02	0.00	42.57	*44.24*
	Total:	*15.71*	*51.68*	*141.97*	*3.06*	*43.01*	*1.82*	*56.63*	***313.88***

Table 4: Land Productivity**:** Area of land with stressed productivity by type of land cover transition (sq. km)

Table 4 shows land cover transitions with stressed productivity, where Cropland (141.97 sq. km) is the largest category, followed by Grassland (51.68 sq. km) and Water body (56.63 sq. km). The total area with stressed productivity is 313.88 sq. km.

		Land cover type in final year							
		Tree-covered	Grassland	Cropland	Wetland	Artificial	Bare land	Water body	*Total:*
Land cover type in initial year	**Tree-covered**	240.98	2.26	21.94	0.00	0.07	0.00	0.00	*265.24*
	Grassland	3.92	77.06	6.69	0.00	5.53	0.00	0.93	*94.13*
	Cropland	9.67	3.33	3,045.30	0.58	91.09	0.14	18.85	*3,168.96*
	Wetland	0.07	0.00	0.22	7.59	0.66	0.00	0.44	*8.97*
	Artificial	0.00	0.00	0.00	0.00	33.43	0.00	0.00	*33.43*
	Bare land	0.00	0.00	0.00	0.00	0.07	1.75	0.14	*1.97*
	Water body	0.00	0.22	0.59	0.07	0.29	0.00	28.04	*29.22*
	Total:	*254.64*	*82.87*	*3,074.73*	*8.24*	*131.14*	*1.89*	*48.41*	***3,601.92***

Table 5: Land Productivity**:** Area of land with moderate decline for productivity by type of land cover transition (sq. km)

In Table 5, land cover transitions with moderate decline in productivity are highlighted. The dominant categories include Cropland (3,074.73 sq. km), followed by Tree-covered (254.64 sq. km) and Grassland (82.87 sq. km). The total area with moderate decline is 3,601.92 sq. km.

		Land cover type in final year							
		Tree-covered	Grassland	Cropland	Wetland	Artificial	Bare land	Water body	*Total:*
Land cover type in initial year	Tree-covered	236.94	0.14	33.58	0.00	1.60	0.00	1.36	*273.62*
	Grassland	3.66	90.57	5.47	1.26	30.91	0.51	6.93	*139.32*
	Cropland	5.44	8.97	1,652.74	4.06	379.47	0.50	65.99	*2,117.17*
	Wetland	0.44	0.00	0.14	22.21	0.51	0.00	0.59	*23.89*
	Artificial	0.00	0.00	0.00	0.00	210.30	0.00	0.00	*210.30*
	Bare land	0.00	0.00	0.00	0.00	0.00	6.64	0.00	*6.64*
	Water body	0.00	0.29	0.22	0.07	0.44	0.00	39.95	*40.98*
	Total:	*246.49*	*99.97*	*1,692.16*	*27.60*	*623.23*	*7.65*	*114.83*	***2,811.92***

Table 6: Land Productivity**:** Area of land with declining productivity by type of land cover transition (sq. km)

Table 6 illustrates land cover transitions with declining productivity. The largest categories are Cropland (1,692.16 sq. km), Tree-covered (246.49 sq. km), and Grassland (99.97 sq. km). The total area with declining productivity is 2,811.92 sq. km.

		Land cover type in final year							
		Tree-covered	Grassland	Cropland	Wetland	Artificial	Bare land	Water body	*Total:*
Land cover type in initial year	Tree-covered	44.93	0.72	4.22	0.00	0.58	0.00	61.05	*111.50*
	Grassland	1.39	70.35	2.76	0.22	0.95	0.00	116.91	*192.58*
	Cropland	3.23	1.58	539.20	2.20	5.98	0.00	50.83	*603.02*
	Wetland	0.00	0.07	0.29	25.02	0.95	0.00	10.68	*37.01*
	Artificial	0.00	0.00	0.00	0.00	17.62	0.00	0.00	*17.62*
	Bare land	0.00	0.00	0.00	0.00	0.00	1.67	0.93	*2.61*
	Water body	1.02	19.96	16.28	29.54	7.06	0.00	9,882.34	*9,956.19*
	Total:	*50.57*	*92.69*	*562.76*	*56.97*	*33.13*	*1.67*	*10,122.74*	***10,920.53***

Table 7: Land Productivity**:** Area of land with no data for productivity by type of land cover transition (sq. km)

Table 7 displays land cover transitions with no data for productivity, where the Water body category dominates with 10,122.74 sq. km, followed by Cropland (562.76 sq. km) and Grassland (92.69 sq. km). The total area with no data for productivity is 10,920.53 sq. km.

Soil Organic Carbon

Soil organic carbon (SOC) is crucial for both soil fertility and overall health. As a result of plant and animal waste breaking down, organic elements are incorporated into the soil to form its composition. In addition to providing a home for many microorganisms involved in the cycling of nutrients, SOC is crucial for sustaining plant growth. Additionally, maintaining the soil's structure and moisture retention aids in the practice of sustainable agriculture. Because SOC absorbs carbon dioxide from the atmosphere, it also helps to lessen the consequences of climate change. Due to its impact on productivity, soil quality, and the overall health of terrestrial ecosystems, SOC levels must be monitored and controlled for sustainable land management.

		Tree-covered	**Grassland**	**Cropland**	**Wetland**	**Artificial**	**Bare land**	
Land cover type in initial year	**Tree-covered**	0.00	0.00	-0.08	0.00	-0.25		*-0.33*
	Grassland	0.00	0.00	-0.16	0.00	-0.37	-0.14	*-0.68*
	Cropland	0.04	0.08	0.00	0.17	-0.50	-0.40	*-0.61*
	Wetland	0.00	0.00	-0.11	0.00	-0.21		*-0.32*
	Artificial					-0.07		*-0.07*
	Bare land					0.00	0.00	*0.00*
		0.04	*0.08*	*-0.35*	*0.17*	*-1.40*	*-0.55*	***-2.01***

Table 8: Conversion Coefficient for Land Cover Changes

Table 8 provides conversion coefficients for land cover changes, representing the impact of transitions from one land cover type to another. The values in the table indicate the change in productivity associated with each transition. For example, transitions from Cropland to Tree-covered and from Wetland to Cropland have positive coefficients, suggesting an improvement in productivity. Conversely, transitions from Tree-covered to Cropland and from Grassland to Artificial have negative coefficients, indicating a decline in productivity.

Degradation in any of these three sub-indicators classifies the selected land as degraded.

Land Productivity	Land Cover	SOC	SDG 15.3.1
Improving	Improving	Improving	**Improving**
Improving	Improving	Stable	**Improving**
Improving	Improving	Declining	**Declining**
Improving	Stable	Improving	**Improving**
Improving	Stable	Stable	**Improving**
Improving	Stable	Declining	**Declining**
Improving	Declining	Improving	**Declining**
Improving	Declining	Stable	**Declining**
Improving	Declining	Declining	**Declining**
Stable	Improving	Improving	**Improving**
Stable	Improving	Stable	**Improving**
Stable	Improving	Declining	**Declining**
Stable	Stable	Improving	**Improving**
Stable	Stable	Stable	**Stable**
Stable	Stable	Declining	**Declining**
Stable	Declining	Improving	**Declining**
Stable	Declining	Stable	**Declining**
Stable	Declining	Declining	**Declining**
Declining	Improving	Improving	**Declining**
Declining	Improving	Stable	**Declining**
Declining	Improving	Declining	**Declining**
Declining	Stable	Improving	**Declining**
Declining	Stable	Stable	**Declining**
Declining	Stable	Declining	**Declining**
Declining	Declining	Improving	**Declining**
Declining	Declining	Stable	**Declining**
Declining	Declining	Declining	**Declining**

Table 9: Combining The Three Sub-Indicators

Table 9 presents a classification of land productivity changes based on three sub-indicators: Soil Organic Carbon (SOC), SDG 15.3.1 (Sustainable Development Goal related to land degradation), and an overall land productivity indicator. The combinations in the table represent different scenarios, such as "Improving" in all three sub-indicators indicating positive changes, and "Declining" in all three indicating negative changes. Table 8 likely provides the conversion coefficients used to quantify the impact of various land cover changes on the three sub-indicators. These coefficients play a crucial role in assessing the overall impact of land cover transitions on soil organic carbon, progress towards SDG 15.3.1, and overall land productivity.

Chapter 5: Result Analysis and Discussion

Land Cover

Table 10&11: Land Cover Change by Cover Class describes the changes in land cover by various land cover classes between 2001 and 2020. Fig. 3 illustrates the changes brought about by land cover conversion. Table 10 displays the extent of land covered in square kilometers for each kind of land cover change.[12]

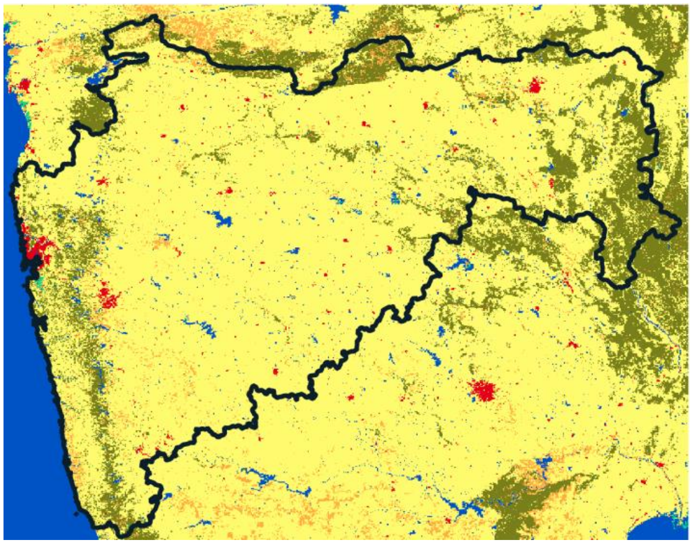

Fig 3: Land Cover Changes of Maharashtra

	Initial area (sq. km)	Final area (sq. km)	Change in area (sq. km)	Change in area (percent)
Tree-covered	47,250.02	48,938.62	1,688.59	4%
Grassland	9,006.07	8,465.68	-540.38	-6%
Cropland	2,75,049.20	2,71,338.05	-3,711.15	-1%
Wetland	292.57	338.94	46.37	16%
Artificial	1,620.03	3,805.30	2,185.27	135%
Bare land	21.09	21.39	0.30	1%
Water body	11,432.50	11,763.51	331.00	3%
Total:	*3,44,671.49*	*3,44,671.49*		

Table 10: Changes in Land Cover by Cover Class

		Tree-covered	Grassland	Cropland	Wetland	Artificial	Bare land	Water body	*Total:*
Land cover type in initial year	**Tree-covered**	46,215.84	141.12	814.24	1.52	8.66	0.00	68.64	*47,250.02*
	Grassland	395.17	8,085.03	195.56	6.61	171.87	0.88	150.95	*9,006.07*
	Cropland	2,324.46	215.34	2,70,294.48	26.89	1,983.20	1.30	203.54	*2,75,049.20*
	Wetland	1.25	0.36	2.26	266.73	6.99	0.00	14.98	*292.57*
	Artificial	0.00	0.00	0.00	0.00	1,620.03	0.00	0.00	*1,620.03*
	Bare land	0.00	0.00	0.00	0.00	0.29	19.22	1.58	*21.09*
	Waterbody	1.89	23.83	31.50	37.19	14.27	0.00	11,323.82	*11,432.50*

Table 11: Land Area Sorted by Transitional Land Cover Type

When comparing the data from 2001 to 2020, Table 5 shows that the areas covered with trees and artificial surfaces have the fastest rates of increase. A total of 2,185.27 km2, or 135% of the total area of land cover degradation, was caused by the increase in artificial areas.[13]

Land Productivity

Changes in land productivity cause the land to deteriorate, as seen in Figure 4. A summary of these changes is included in Table 12.[14]

We may infer from Figure 4 that the majority of the state of Maharashtra's land area has been enhanced, and there has been very little land degradation. But in much of the state, production has increased throughout the mentioned years.

According to Table 6, Maharashtra's land production has grown by 74% while falling by just 1.86%. Twenty-three percent of the total land area is consistently productive.

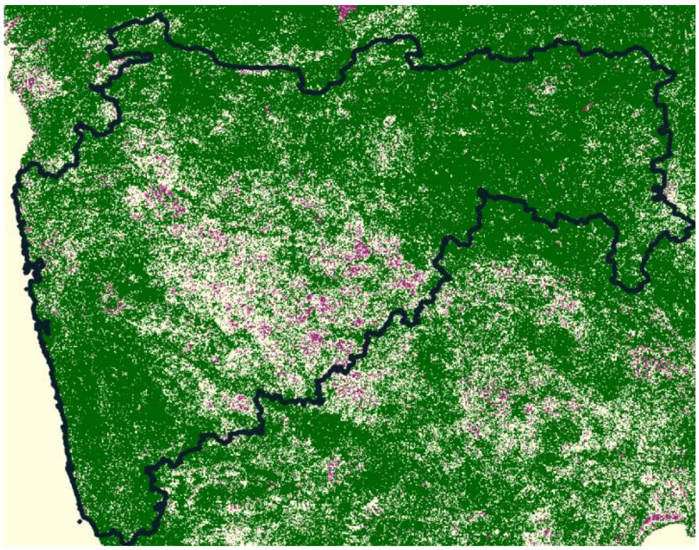

Fig 4: Land Productivity Changes of Maharashtra

Figure 4 shows the land productivity changes of Maharashtra from 2000 to 2020. The map is divided into three categories: increasing, decreasing, and no change.

Maharashtra Land Productivity Changes, Fig 4: Image of Land Productivity Changes of Maharashtra, Fig 4

The green areas on the map show the areas where land productivity has increased. These areas are concentrated in the western and central parts of the state, where agriculture is the dominant land use. The increase in land productivity in these areas is likely due to a number of factors, including improved agricultural practices, irrigation, and the use of high-yielding crop varieties.

The purple areas on the map show the areas where land productivity has decreased. These areas are concentrated in the eastern and northeastern parts of the state, where forest cover is high.

The decrease in land productivity in these areas is likely due to a number of factors, including deforestation, soil erosion, and climate change.

The yellow areas on the map show the areas where land productivity has not changed significantly. These areas are scattered throughout the state.

	Area (sq km)	**Percent of total land area**
Total land area:	3,44,671.5	100.00%
Land area with improved productivity:	2,57,357.76	74.67%
Land area with stable productivity:	69,979.37	20.30%
Land area with degraded productivity:	6,413.83	1.86%
Land area with no data for productivity:	10,920.53	3.17%

Table 12: An Overview of Productivity Changes

Table 12 provides a comprehensive overview of productivity changes in the specified region. The total land area is 3,44,671.5 sq. km. Notably, 74.67% of the total land area has experienced improved productivity, covering 2,57,357.76 sq. km. Additionally, 20.30% of the land area remains stable in terms of productivity, totaling 69,979.37 sq. km. A smaller proportion, 1.86% or 6,413.83 sq. km, has witnessed degraded productivity. Lastly, 3.17% of the total land area, equivalent to 10,920.53 sq. km, has no available data for productivity changes. This table offers a concise summary of the diverse productivity trends across the landscape.

13.3 Soil Organic Carbon

The SOC degradation-related land degradation is depicted in Fig. 5, and the variations in SOC degradation are summarized in Table 13. It is evident from the graph that land area with stable organic carbon is more i.e. 98.90%, and 0.81% of the land area is degraded soil organic carbon. Improved soil organic carbon is just 0.10% and 0.18% with no data.

Fig 5: Maharashtra's Changes in Soil Organic Carbon (SOC)

The map in Figure 5 shows the changes in Soil Organic Carbon (SOC) in Maharashtra from 1987 to 2017. The changes are represented by different colors, with red indicating a decrease in SOC, green indicating an increase in SOC, and yellow indicating no change.

The map shows that SOC has decreased in most parts of Maharashtra over the past 30 years. The largest decreases are seen in the central and western parts of the state, where agriculture is the dominant land use. However, there are some areas where SOC has increased, such as in the eastern and southeastern parts of the state, where there is more forest cover.

The decrease in SOC is a concern because SOC is important for soil health and fertility. It helps to improve soil structure, retain water, and increase nutrient availability. The decrease in SOC is likely due to a number of factors, including agricultural practices such as tillage and fertilization, deforestation, and climate change.

	Area (sq km)	Percent of total land area
Total land area:	3,33,239.0	100.00%
Land area with improved soil organic carbon:	346.71	0.10%
Land area with stable soil organic carbon:	3,29,589.53	98.90%
Land area with degraded soil organic carbon:	2,698.53	0.81%
Land area with no data for soil organic carbon:	604.22	0.18%

Table 13: An Overview of The Organic Carbon Changes in Soils

In Table 13, an overview of soil organic carbon changes in soils is provided for a total land area of 333,239.0 sq. km. The majority of the land area, comprising 98.90%, is characterized by stable soil organic carbon. This is followed by a relatively small percentage of land, 0.10%, showing improved soil organic carbon. Additionally, 0.81% of the land area is identified as having degraded soil organic carbon, while 0.18% has no available data for soil organic carbon. This table presents a comprehensive snapshot of the distribution of soil organic carbon changes across the examined land area.

13.4 SDG 15.3.1 Indicator

SDG 15.3.1 indicator is summarized in Table 14, whereas Maharashtra's land indicator is shown in Fig. 6.

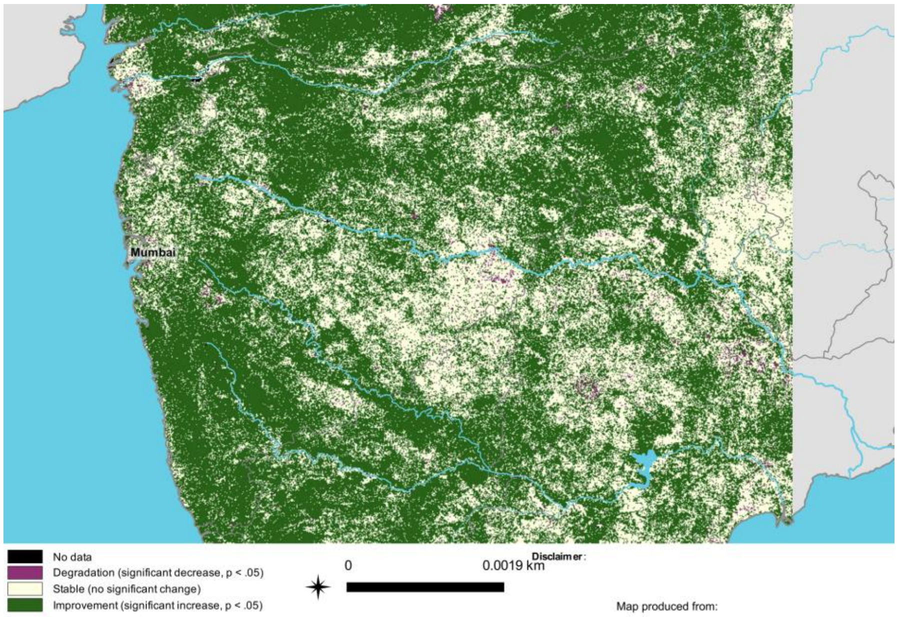

Fig 6: Land Indicator for Maharashtra

	Area (sq km)	Percent of total land area
Total land area:	3,44,671.5	100.00%
Land area improved:	2,54,796.09	73.92%
Land area stable:	67,651.27	19.63%
Land area degraded:	9,709.99	2.82%
Land area with no data:	12,514.13	3.63%

Table 14: SDG 15.3.1 Indicator Synopsis

Table 14 provides an overview of the SDG 15.3.1 indicator, summarizing land areas in relation to their productivity status. The total land area is 3,44,671.5 sq. km. The majority of the land is classified as improved, covering 73.92% (2,54,796.09 sq. km), while stable land occupies 19.63% (67,651.27 sq. km). A smaller portion is categorized as degraded, constituting 2.82% (9,709.99 sq. km). Additionally, 3.63% (12,514.13 sq. km) of the land has no data available. This information aids in assessing progress toward Sustainable Development Goal 15.3.1, which focuses on combating desertification, restoring degraded land, and ensuring sustainable land management.

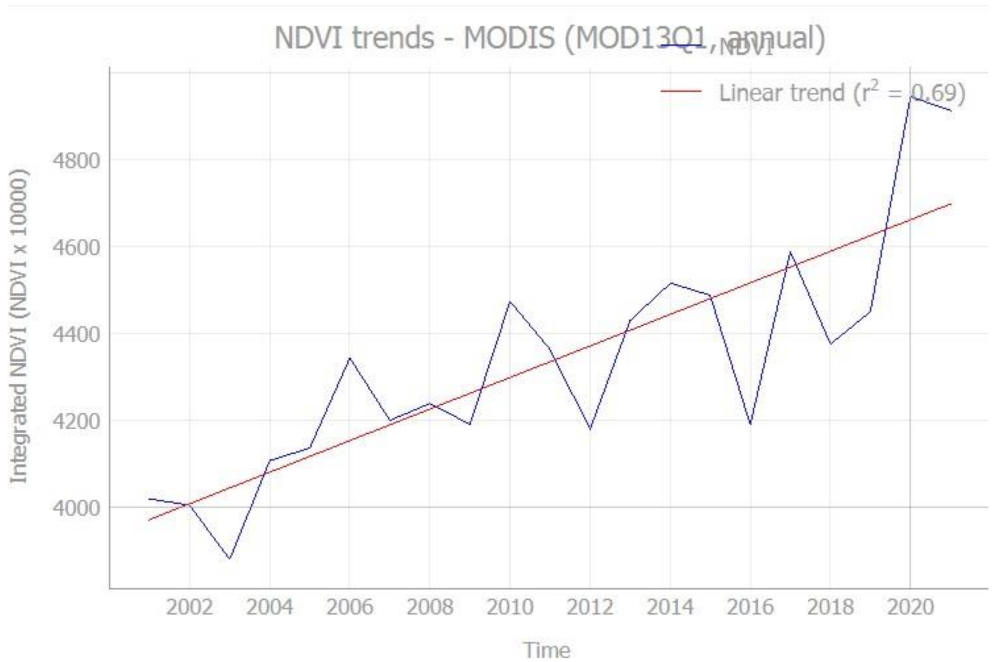

Fig 7: NVDI for Maharashtra

The Normalized Difference Vegetation Index (NDVI) is a satellite-derived measure of the amount and health of green vegetation. It is calculated as the difference between the near-infrared and red reflectance bands divided by the sum of the two bands. NDVI values range from -1 to 1, with higher values indicating more and healthier vegetation.

The line graph in Figure 7 shows the trend of NDVI for Maharashtra from 2002 to 2020. The overall trend is positive, with a linear trend coefficient of 0.69. This means that NDVI has been increasing in Maharashtra at an average rate of 0.69 units per year.

The increase in NDVI could be due to a number of factors, including increased agricultural productivity, afforestation, and urban greening. It is also possible that the increase in NDVI is due to climate change, as warmer temperatures and increased rainfall can lead to increased vegetation growth.

14. Conclusion

The detailed examination of Maharashtra's progress toward SDG 15.3.1 concludes with a dynamic picture of the state of affairs. The state's land productivity has increased by 74% with just a minor 1.86% deterioration, indicating notable improvements. Significant shifts in land cover, most notably the startling 135% increase in artificial surfaces, highlight the difficulties in striking a balance between environmental preservation and development.

Additionally, just a tiny portion of Maharashtra's land is degrading, with the state's soil organic carbon levels remaining steady throughout the rest of the area. It is clear that the state is committed to sustainable land management because the overall SDG 15.3.1 indicator shows progress on 73.92% of the land. As a useful resource for policymakers, the report emphasizes the significance of striking a balance between economic development and environmental preservation.

15. Scope for Future Work

In light of the comprehensive analysis conducted on Maharashtra's progress toward achieving Sustainable Development Goal (SDG) 15.3.1, several avenues for future research and action emerge. Firstly, there is a need for an in-depth examination of the socio-economic impacts of the observed changes in land cover, land productivity, and soil organic carbon levels. Understanding how these environmental transformations affect local communities, particularly in terms of livelihoods and resilience to climate change, can provide valuable insights for targeted interventions. Additionally, further investigations could explore the effectiveness of specific policies and initiatives undertaken by the government and non-governmental organizations in Maharashtra. This includes an evaluation of the implementation challenges faced and identifying best practices that can be replicated or scaled up for more significant impact.

Moreover, future research should delve into the integration of technology and innovative solutions in sustainable land management. Utilizing advanced remote sensing technologies, Geographic Information System (GIS) applications, and other data-driven approaches can enhance the accuracy of land assessments and provide real-time monitoring capabilities. This technological integration can contribute to more informed decision-making and adaptive management strategies.

Furthermore, it is crucial to engage local communities, indigenous populations, and stakeholders in the formulation and implementation of sustainable land management practices. Community-based approaches, considering the unique cultural and ecological context of different regions within Maharashtra, can foster a sense of ownership and enhance the long-term success of sustainability initiatives.

In conclusion, the future research agenda should focus on interdisciplinary studies that bridge the gap between environmental science, social dynamics, and technological innovation.

16. Appendices

This section outlines the sources of data and the methodology employed in the assessment of Maharashtra's progress toward Sustainable Development Goal 15.3.1.

Data Sources:

1. Satellite Imagery: High-resolution satellite images from [source] were utilized to analyze changes in land cover over the specified period.

2. Soil Organic Carbon Data: Soil organic carbon levels were obtained from [source], providing a basis for evaluating soil health and carbon sequestration.

3. Socio-Economic Indicators: Demographic and socio-economic data were sourced from [source] to understand the relationship between land use changes and human well-being.

Methodology:

1. **Land Cover Analysis**: A supervised classification technique was applied to satellite imagery, classifying land cover into categories such as forest, agriculture, and urban areas. The accuracy of the classification was validated using ground truth data.

2. **Soil Organic Carbon Assessment**: Soil samples were collected from representative locations across Maharashtra, and laboratory analysis was conducted to determine soil organic carbon content. The results were extrapolated to assess regional trends.

3. **Socio-Economic Impact Analysis**: Demographic and socio-economic indicators were correlated with land use changes to identify potential impacts on local communities. Statistical analysis and spatial modeling were employed to draw meaningful conclusions.

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