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Tracking Rural Changes in Meghalaya through Sustainability Trends: A District-Level Analysis

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ABSTRACT

This study was conducted to track trends in various rural change indicators through a sustainability lens at the district level in the state of Meghalaya, using secondary data collected from various state-level and national-level published sources. The results revealed that most districts in the state experienced improvements in economic sustainability indicators, including crop productivity, irrigated area, per capita food crop output, and livestock density. However, food grain distribution through the Public Distribution System has decreased in most districts. The social sustainability indicators related to education, health and rural infrastructure have also improved in the majority of districts. Although the state has registered a slight decline in forest cover, crop diversification has improved over the years, indicating a shift toward sustainable agriculture. East Khasi Hills (0.588 and 0.910) and West Khasi Hills (0.587 and 0.728) districts performed better in terms of economic and social sustainability but faltered in ecological sustainability. On the other hand, East Garo Hills (0.709) and Jaintia Hills (0.627) excelled in terms of ecological sustainability but underperformed in the case of economic sustainability. Hence, this study recommends that to improve the economic and social sustainability of South Garo Hills, Jaintia Hills, and Ri-Bhoi districts, higher investment is needed in infrastructure, schools, and healthcare centres. In contrast, East Khasi Hills' and WKH's ecological sustainability can be improved by creating more forest areas in these districts. These concerted efforts are necessary for attaining balanced development in the state in the long run.

Keywords: Sustainable development, rural transformation, climate change, socio-economic resilience, regional development

JEL codes: O15, Q01, Q12, Q56, R58

I

INTRODUCTION

Meghalaya is located in the Northeastern Hill (NEH) region of India. At present, the State is divided into 12 districts under three divisions: Jaintia Hills Division (2), Khasi Hills Division (5) and Garo Hills Division (5); out of which five are relatively new. There are 10 smaller towns, and Shillong, the state's capital and Tura in West Garo Hills (WHG) are the two major towns. The total population of the State was 29.67 lakh, out of which 79.93 per cent lived in rural areas (Census, 2011). About 80 per cent of its population were primarily dependent on agriculture for their livelihood (GoI, 2022a). Meghalaya is predominantly an agriculture-based economy. According to the latest estimate, agriculture contributes 21.6 per cent of Meghalaya's Gross State Value Added (GSVA), which is a close proxy for the state's Gross State Domestic Product (GSDP), amounting to Rs. 66,645 crore. However, real GSDP has grown at an average rate of only 2.1 per cent, compared to the national average of 5.6 per cent, during the period from 2012-13 to 2021-22 (MOSPI, 2023). The climate of

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the state supports the cultivation of various agricultural and horticultural crops. Rice is the major crop cultivated in the State. Other important crops include rapeseed and mustard, pineapple, potato, ginger, maize, areca nut, and bamboo. Shifting cultivation and terrace or bun cultivation are the two major farming methods practised by the people of Meghalaya (Upadhaya *et al*., 2020). However, the state's agriculture is distinguished by its low productivity and limited use of modern methods (Rymbai *et al*., 2012). Difficult terrain, traditional *jhum cultivation* (shifting agriculture), inadequate infrastructure, poor marketing activities, and a lack of intensive extension services make agricultural development efforts in the state very challenging (Lahiri and Das, 2010). Nongbri *et al.* (2021) observed that the majority of the people in the state follow a monotonous diet consisting mainly of cereals, with rice at the top of the list. Approximately 78.79 per cent of the total area used for food grain cultivation is under rice crops (GoM, 2020). However, the cultivation of rice is considered one of the major causes of the rising level of methane gas in the atmosphere, which ultimately contributes to climate change. This phenomenon adversely affects various planetary systems, including agriculture and livelihoods, particularly in developing economies (Priyadarshini and Abhilash, 2019). To address all these problems, the concept of 'sustainable agriculture' has come into use nowadays, the term first being used by Wes Jackson in his publication *New Roots for Agriculture* in 1980. Sustainable agriculture is an approach to farming that aims to produce food while preserving ecosystems and natural resources for the long term (Brodt *et al*., 2011). It primarily comprises three components: ecological sustainability, economic sustainability, and social sustainability. Sustainability in agriculture aims to adopt farming practices that meet the present generation's needs without compromising the ability of future generations to meet their own needs. However, most modern agricultural practices, such as mechanisation, monocultures, improved crop varieties, and heavy use of agrochemicals for pest control and fertilisation, have disturbed the balance of the natural ecosystem. The restoration of on-farm biodiversity can be achieved through diversified farming systems that mimic natural processes (Lithourgidis *et al*., 2011).

Against this background, policies must focus on rural areas to achieve higher growth for the state, which can be attained by improving developmental indicators at the district level. This paper tracks the trends of different rural change indicators through a sustainability lens at the district level. A sustainability index was also constructed using a variety of economic, social, and ecological indicators. The outputs of the paper will help the policy makers to comprehend which areas contribute to the goal of sustainable agriculture and which areas require improvement, so that farmers and the entire state population do not have to suffer in the future and can live a decent and healthy life.

II

STUDY AREA AND DATA

The present study was conducted in the state of Meghalaya, which is located at a longitude of 85°49’ E to 92°52’ E and at a latitude of 25°1’ N to 26°5’ N. Assam borders it on the north and east, while Bangladesh borders it on the west and south side. The total geographical area of the State is 22,429 sq. km., which accounts for only 0.68 per cent of India's total area (FSI, 2019). The temperature varies between 2°C and 36°C, depending on the season and altitude (GoM, 2019a). Mawsynram, a town in Meghalaya, receives the highest amount of rainfall in India. The rivers of the state are perennial in nature. Up to 2012, the state had seven districts, namely Ri Bhoi, East Khasi Hills (EKH), West Khasi Hills (WKH), Jaintia Hills (JH), East Garo Hills (EGH), WGH and South Garo Hills (SGH). However, in 2013, four new districts were formed: North Garo Hills, East Jaintia Hills, South West Khasi Hills, and South West Garo Hills. Eastern West Khasi Hills was formed in 2021, bringing the total number of districts to 12. The state had 40.75 per cent of its land area covered by forest as of 2018-19 (GoM, 2020). Meghalaya has a population of about 29.67 lakh, comprising 14.92 lakhs of males and 14.75 lakhs of females (Census, 2011).

Secondary data on various indicators for the seven old districts were collected, as data for the new districts are largely unavailable for most variables. Data regarding the area (in 000 ha) under cultivation, production (in 000 MT) and productivity (MT/ha) of food crops were gathered from several published documents of the Directorate of Economics and Statistics (DES), Shillong, Meghalaya. Data on district-level sustainability indicators were collected from various published documents of government departments, including the Ministry of Home Affairs, India; the Ministry of Health and Family Welfare, India; and the Ministry of Rural Development, India. Since the last census was conducted in 2011, recent data for certain indicators, including female literacy, sex ratio, infant mortality rate, rural workforce participation rate, and population of Meghalaya, have not been available. Hence, projections for these indicators were made using an arithmetic progression and linear regression forecasting method, with the help of older data available on the website of the Census of India. The details about the data source are given in Annexure.

2.1 District Level Sustainability

Agricultural sustainability was studied by measuring three dimensions: economic, social, and ecological sustainability. Each of the sustainability dimensions includes various indicators, and secondary data were collected for each of the indicators. The dimensions of sustainability, along with their indicators and measurements, are discussed below.

2.2 Measurement of District-Level Economic Sustainability

A. Economic Sustainability: Different sustainability indicators used in the economic dimension are given below.

Sl. No.	Indicators	Measurement	Unit	Relationship with economic sustainability	Source
1	Productivity of food crops	Production /area	kg/ha	High – positive Low – negative	(Kareemulla *et al*., 2017)
2	Per capita output of food crops	Total food crop production/total population	MT/annum	High – positive Low– negative	(Devi, 2016)
3	Livestock density	Number of livestock per square kilometre.	(number/sq.km.)	High – positive Low– negative	(Devi, 2016)
4	Public distribution system (PDS)	The amount of food grains distributed through PDS	MT	High– positive Low – negative	(Devi, 2016)
5	Irrigated area	Net irrigated area/ net cropped area	per cent	High – positive Low – negative	(Suresh *et al.*, 2022)

Productivity of food crops: It is estimated by taking the ratio of production and the area of total food crops. Food crop productivity plays a significant role in achieving economic independence for any region. It is directly proportional to economic sustainability; the higher the productivity of food crops, the higher the economic sustainability.

Per capita output of food crops: It is measured by dividing the total production of food crops by the total population. A high per capita output of food crops makes a positive contribution to food security. As in the state of Meghalaya, the population is continuously increasing, and there is limited agricultural land, which makes food security one of the most critical concerns. So, an increase in per capita output of food crops will have a positive effect on economic sustainability.

Livestock density: It is estimated as the number of livestock per sq. km. Livestock contributes positively to farmers' income by providing various products such as milk, butter, ghee and meat. Thus, it is expected that an increase in livestock density will lead to improved economic sustainability in the districts.

Public distribution system (PDS): It is a crucial component of the poverty alleviation programme. It shows the supply of food grains to the poor at a subsidised price through PDS. Additionally, it contributes to the effective distribution of food to the poor and the eradication of hunger. It is anticipated that increasing the amount of food grains supplied through it will contribute to the economic sustainability of the districts as well as the state.

Irrigated area: Proper irrigation in any agricultural field results in better productivity, while also helping to mitigate the risks involved in farm production, and thus serves as a critical component of sustainable agricultural strategies. It is the ratio of net irrigated area to net cropped area and is expressed as a percentage.

B. Social Sustainability: Different indicators used to construct the social sustainability index are given below:

Sl. No.	Indicators	Measurement	Unit	Relationship with social sustainability	Source
1	Female literacy	(literate females / total population of females) * 100	per cent	High – positive Low – negative	(Devi, 2016)
2	Infant mortality rate	(no. of deaths of infants under 1 year of age / no. of live births) * 1000	per cent	High – negative Low– positive	(Singh *et al.,* 2022)
3	Sex ratio	no. of females / 1000 males	number	High – positive Low – negative	(Suresh *et al.*, 2022)
4	Rural road connectivity	rural road length in km.	km	More – positive Less – negative	(Devi, 2016)
5	Rural workforce participation rate	total rural workforce/ total population * 100	per cent	High – positive Low – negative	(Suresh *et al.*, 2022)

Female literacy: Female literacy plays a crucial role in empowering women as well as in social development. The goal of poverty alleviation cannot be accomplished without women's active participation. Thus, female literacy also contributes to population stabilisation, and eventually, high literacy can improve social sustainability.

Infant mortality: It depicts the awareness and status of health in the society. There has to be stabilisation of the age composition of the population for population stabilisation, and mortality affects the age distribution of the population. Therefore, social sustainability is negatively affected by the high infant mortality rate.

Sex ratio: If there is equal access to resources, markets, land, and participation in agricultural activities for women, just as for men, that could unlock human potential to a transformational level. This indicator indicates the number of females per 1,000 males.

Rural road connectivity: Roads are very crucial for the state’s economic and social development. Poor road connectivity has contributed to the backwardness of the NEH region. Good road connectivity leads to higher social sustainability.

Rural workforce participation rate: A higher workforce participation rate indicates the number of working-age individuals contributing to income-generating activities.

It has a positive relationship with sustainable agriculture, as the involvement of more local people in such activities helps achieve the Sustainable Development Goals more easily. It is computed by taking the ratio of total workers to the total population and multiplying it by 100.

C. Ecological Sustainability: Different indicators to study ecological sustainability are given below:

Sl. No.	Indicators	Measurement	Unit	Relationship with ecological sustainability	Source
1	Population density	No. of population/area	number of persons/sq.km	High – negative Low – positive	(Kareemulla *et al*., 2017)
2	Forest area covered	Forest cover area /geographical area *100	per cent	High – positive Low– negative	(Rao *et al*., 2019)
3	Cropping intensity	Gross cropped area/net cropped area *100	per cent	High– negative Low – positive	(Devi, 2016)
4	Crop diversification	Simpson Index of Diversification (SID)	number	Diversified – positive Single cropping / fewer crops - negative	(Rao *et al*., 2019)

Population density: It is calculated as the number of persons per sq. km. It displays the level of ecological pressure because of humans. There will be a negative effect on ecological sustainability due to the high population.

Forest area covered: Forests are beneficial to farmers both directly and indirectly. Directly, it provides food, shelter, fuel in the form of wood, and many more products to the farmers that they use in their day-to-day activities. In an indirect sense, forests benefit the environment in a variety of ways, including carbon dioxide sequestration from the atmosphere, water cycle maintenance, wildlife conservation, and the protection of a diverse range of flora and fauna, ultimately serving as an essential component of ecological sustainability, which is critical for human survival. It is calculated by measuring the extent of land under forests to the total available geographical area.

Cropping intensity: Cropping intensity refers to the number of crops grown on the same land by a farmer in a given agricultural year. High cropping intensity creates pressure on the same land and depletes its nutrients, which negatively affects ecological sustainability. It is expressed as a percentage and calculated as the ratio of gross cropped area to net cropped area.

Crop diversification: It is measured using SID. It refers to the addition of a new crop to an existing cropping system. It is directly proportional to ecological sustainability, as it helps mitigate soil erosion problems, maintain biodiversity, and protect the soil from the exhaustion of a single nutrient.

2.3 Sustainability index

The sustainability index was constructed following the human development index and the vulnerability index. The first step involved normalising the indicators for aggregation, rendering them as a number with no units (Feroze *et al.,* 2014). However, just normalising the values would only lead to the calculation of absolute sustainability. Henceforth, appropriate weights were assigned to the normalised indicator values using the method proposed by Iyengar and Sudarshan (1982) to determine relative sustainability. Subsequently, the composite sustainability index was estimated by taking the simple mean value of the three individual sustainability indices.

III

RESULTS AND DISCUSSION

3.1 Economic Sustainability

3.1.1 Descriptive Statistics For Economic Sustainability Indicators

The descriptive statistics for economic sustainability indicators are presented in Table 1. During 2018-22, in Meghalaya, the irrigated area accounted for 39.30 per cent of the total cultivated area, which was 21.79 per cent during 2008-14. WKH recorded the highest area under irrigation (63.01%), followed by Ri Bhoi district (62.92%) and JH district (58.03%). However, during 2008-14, Ri Bhoi district ranked first with an irrigated area of 52.57 per cent. The irrigated area has increased in all the districts of the State between 2008-14 and 2018-22. The livestock density has risen from 247.92 no./sq.km. during 2008-14 to 261.73 no./sq.km. during 2018-22 in the state. Livestock density was highest in EGH (565.11 no./sq.km.) during 2018-22, while during 2008-14, it was highest in WGH (423.41 no./sq.km). EKH, JH, and WGH witnessed a decline in livestock density over the years, while the other districts, namely Ri Bhoi, WKH, EGH, and SGH, registered an increase. The productivity of food crops in the state has improved from 3,507.79 kg/ha to 4,596.94 kg/ha during the same period. A similar trend could be observed in all the districts. EKH consistently reported the highest productivity of food crops for both time periods, with 8,553.36 kg/ha in 2008-14 and 10,003.68 kg/ha in 2018-22. Per capita output in the state has improved slightly from 0.26 MT/annum to 0.30 MT/annum between 2008-14 and 2018-22. The per capita output was highest in WGH (0.37 MT/annum) for the period of 2018-2022, while it was the EKH district that ranked first in 2008-2014. Only JH reported a decrease in per capita output from 0.20 MT/annum in 2008-14 to 0.16 MT/annum in 2018-22, while all the other districts reported an increase. Food grains supplied through the Public Distribution System (PDS) registered a decrease in the state, i.e., from 136.84 thousand MT during 2008-14 to 116.66 thousand MT during 2018-22. This decreasing trend was observed in Ri Bhoi, EKH, EGH and WGH districts. In contrast, WKH, JH and SGH witnessed an increase in the distribution of food grains through PDS over the two time periods. The highest PDS distribution was recorded in WGH (31266.02 MT), followed by EKH (24338.66 MT) and JH (17669.90 MT) districts during the period 2018-2022.

3.1.2 Ranking of Districts Based on Economic Sustainability Index

EKH achieved the first rank with an index value of 0.118 during the period of 2018-2022 (Table 1). High productivity of food crops for both time periods, as well as remarkable performance in terms of food grains supplied through PDS and per capita output of food crops, were the key factors contributing to EKH's first rank. WKH secured the second rank, with an index value of 0.117 during 2018-22, which was a substantial improvement over its fifth rank during 2008-14. The district demonstrated impressive progress in terms of irrigated area within the two time periods under study. Its strong performance in terms of food crop productivity and per capita food crop output was the reason for its improvement in the ranking over the years. WGH, which ranked second from 2008 to 2014, drifted to the third position from 2018 to 2022.

3.1.3 Correlation of Various Indicators with Economic Sustainability

During 2018-2022, the productivity of food crops (0.72) as well as the per capita output of food crops ($r = 0.83$, $p < 0.05$) showed a strong and positive correlation with economic sustainability (Table 2). On the other hand, livestock density (0.03) demonstrated a weak positive correlation with economic sustainability. Surprisingly, irrigated area (-0.36) showed a negative correlation, although it was statistically insignificant. Meghalaya reported the lowest composite water index score (26) among all Indian states in 2016-17, indicating poor water management practices in the state (Jain and Makkar, 2019). This could be one reason for its negative correlation with economic sustainability. During 2008-2014, the variable PDS exhibited a significantly positive correlation ($r = 0.91$, $p < 0.01$) with economic sustainability; however, during 2018-2020, the correlation coefficient (0.55, $p = 0.20$) turned out to be moderate and insignificant. This change may be attributed to the overall reduction in food grains supplied through PDS between these two time periods (Table 1).

TABLE 2. CORRELATION OF VARIOUS ECONOMIC SUSTAINABILITY INDICATORS WITH ECONOMIC SUSTAINABILITY INDEX

Variables	2008-14		2018-22	
	Index value	p value	Index value	p value
Irrigated area	-0.22	0.63	-0.36	0.42
Livestock density	0.68	0.09	0.03	0.94
Productivity of food crops	0.71	0.07	0.72	0.06
PDS	0.91***	0.00	0.55	0.20
Per capita output of food crops	0.78**	0.03	0.83**	0.02

Note: *** and ** indicate $p<0.01$ and $p<0.05$, respectively

TABLE 1 DESCRIPTIVE STATISTICS FOR DIFFERENT ECONOMIC SUSTAINABILITY INDICATORS AND INDICES ACROSS THE DISTRICTS OF MEGHALAYA

Districts	Irrigated area (%)		Livestock density (no./sq.km.)		Productivity of food crops (kg/ha)		Per capita output of food crops (MT/annum)		PDS (MT)		Economic sustainability index	
	2008-14	2018-22	2008-14	2018-22	2008-14	2018-22	2008-14	2018-22	2008-14	2018-22	2008-14	2018-22
Ri-Bhoi District	52.6	62.9	226.3	252.9	3060.3	4039.1	0.20	0.2	15978.4	9145.5	0.07	0.07
East Khasi Hills	18.3	30.8	308.6	231.7	8553.4	10003.7	0.31	0.3	40809.1	24338.7	0.15	0.12
West Khasi Hills	30.3	63.0	150.3	153.5	3766.0	6541.0	0.24	0.4	12653.3	16138.8	0.06	0.12
Jaintia Hills	25.7	58.0	109.6	101.0	3203.6	3239.8	0.20	0.2	14711.5	17669.9	0.03	0.05
East Garo Hills	26.6	34.0	368.4	565.1	2605.9	3347.2	0.25	0.3	13565.6	12001.1	0.08	0.08
West Garo Hills	11.8	27.2	423.4	378.9	2332.0	3159.2	0.30	0.4	33526.7	31266.0	0.11	0.10
South Garo Hills	14.4	46.4	230.9	296.4	2249.2	3509.8	0.26	0.3	5599.1	6098.4	0.04	0.07
Meghalaya	21.8	39.3	247.9	261.7	3507.8	4596.9	0.26	0.3	136843.8	116658.4	0.08	0.09

3.2 Social Sustainability

3.2.1 Descriptive Statistics Of Social Sustainability Indicators

The descriptive statistics of social sustainability indicators are given in Table 3. Female literacy in the state of Meghalaya was 69.69 per cent during 2018-22, representing a significant improvement from 59.06 per cent during 2008-14. EKH consecutively reported the highest female literacy rate for both periods, *i.e.*, 77.11 per cent during 2018-22 and 70.03 per cent during 2008-14. All the districts have seen an improvement in female literacy over the years. Meghalaya recorded an average infant mortality rate of 7.10 per cent, which was relatively high as compared to the all-India average of 3.0 per cent during 2018-22 (GoI, 2022b). During the same period, SGH had the lowest infant mortality rate of 6.00 per cent among all the districts, indicating that health facilities are relatively better in the district. During 2008-2014, it was EKH that had the lowest infant mortality rate of 6.70 per cent. All districts in the state observed a decrease in infant mortality rates over the years, except for Ri Bhoi and EKH districts, which reported an increase in rates. Meghalaya witnessed a rise in sex ratio in favour of females per 1000 males from 988.76 during 2008-14 to 1005.22 during 2018-22. EKH recorded the highest sex ratio of 1043.59, followed by JH (1033.74) and WGH (996.71) during 2018-22. However, during 2008-14 highest sex ratio was reported at JH (1013.01), followed by EKH (1010.77). So, an interchange between the positions of JH and EKH was observed between these two time periods. All the districts of the state witnessed an increase in sex ratio between the study period, except SGH, which registered a minor decrease from 945.25 during 2008-14 to 939.16 during 2018-22. The rural workforce participation rate in Meghalaya decreased from 41.05 per cent during 2008-14 to 37.99 per cent during 2018-22. This trend was also observed in all the other districts, implying that rural people are moving to more developed areas in search of employment, rather than working in their villages. For both time periods, the highest rural workforce participation rate was reported in WKH, *i.e.*, 43.59 per cent during 2008-14 and 42.23 per cent during 2018-22. In terms of rural road connectivity, Meghalaya experienced a significant increase in the length of rural roads, rising from 861.56 km during 2008-14 to 2,197.43 km during 2018-22. EKH accounted for the longest rural road length of 479.45 km, followed by SGH (463.78 km) and WGH (395.03 km) during the period 2018-2022. However, during 2008-14, GH reported the longest rural road length of 242.76 km. EGH has consecutively reported the lowest rural road length for both time periods, at 22.05 km during 2008-2014 and 39.21 km during 2018-2022.

3.2.2 Ranking of Districts based on Social Sustainability Index

EKH secured first rank in terms of social sustainability, with an index value of 0.182 from 2018 to 2022 (Table 3). The district performed well in terms of social indicators, such as female literacy, sex ratio, and rural road connectivity, which were the reasons for its first rank in social sustainability. It was followed by WKH, which accounted for the highest rural workforce participation in the state.

TABLE 3. DESCRIPTIVE STATISTICS OF DIFFERENT SOCIAL SUSTAINABILITY INDICATORS AND INDICES ACROSS THE DISTRICTS OF MEGHALAYA

Districts	Female literacy (%)		Infant mortality (%)		Sex ratio (number)		Rural workforce participation rate (%)		Rural road connectivity (km)		Social sustainability	
	2008-14	2018-22	2008-14	2018-22	2008-14	2018-22	2008-14	2018-22	2008-14	2018-22	2008-14	2018-22
Ri-Bhoi District	59.3	71.0	7.7	7.8	953.1	958.5	41.3	35.4	47.0	159.1	0.07	0.08
East Khasi Hills	70.0	77.1	6.7	6.9	1010.8	1043.6	41.6	40.0	167.2	479.5	0.17	0.18
West Khasi Hills	59.8	70.0	7.0	6.2	979.5	994.2	43.6	42.2	126.2	277.7	0.13	0.15
Jaintia Hills	50.4	57.7	8.1	7.6	1013.0	1033.7	39.1	34.7	103.1	383.2	0.08	0.11
East Garo Hills	57.2	69.8	7.5	6.6	971.9	979.1	41.2	36.2	22.1	39.2	0.08	0.10
West Garo Hills	51.8	67.3	9.2	9.1	984.5	996.7	40.9	39.9	153.3	395.0	0.07	0.11
South Garo Hills	53.6	68.8	8.3	6.0	945.3	939.2	38.2	28.0	242.8	463.8	0.06	0.10
Meghalaya	59.1	69.7	7.6	7.1	988.8	1005.2	41.1	38.0	861.6	2197.4	0.10	0.12

It performed well in terms of female literacy and registered a low infant mortality rate, which were among the factors contributing to its second position. WGH witnessed impressive growth, moving up from sixth rank during 2008-14 to third rank during 2018-22, which was mainly due to its improvement in female literacy, as well as rural road connectivity, over the years under study.

3.2.3 Correlation of Various Indicators with Social Sustainability

Factors such as sex ratio (0.66), rural workforce participation rate (0.57), and rural road connectivity (0.50) showed a moderate positive correlation with social sustainability during 2018-2022, but these correlations were not statistically significant (Table 4). On the other hand, female literacy showed a significant positive correlation ($r = 0.86$, $p<0.05$) with social sustainability during 2008-14, indicating that the improvement in female literacy in the society has the potential to improve the social sustainability, but the correlation turned out to be insignificant (0.52, $p=0.23$) during 2018-22. In line with our hypothesis, the infant mortality rate exhibited a significant negative correlation ($r = -0.80$, $p < 0.05$) with social sustainability during 2008-2014, implying that as infant mortality decreases, social sustainability improves. It was observed that the correlation coefficient for none of the social sustainability indicators was significant during the period 2018-2022 (Table 4).

TABLE 4. CORRELATION OF VARIOUS SOCIAL SUSTAINABILITY INDICATORS WITH SOCIAL SUSTAINABILITY INDEX

Variables	2008-14		2018-22	
	r	p value	r	p value
Female literacy	0.86**	0.01	0.52	0.23
Infant mortality	-0.80**	0.03	-0.27	0.55
Sex ratio	0.56	0.19	0.66	0.10
Rural workforce participation rate	0.62	0.14	0.57	0.18
Rural road connectivity	0.11	0.81	0.50	0.25

Note: *** and ** indicate $p<0.01$ and $p<0.05$, respectively

3.3 Ecological Sustainability

3.3.1 Descriptive statistics of ecological sustainability indicators

The descriptive statistics for two time periods, using different ecological sustainability indicators, are presented in Table 5. During 2018-22, Meghalaya had 40.75 per cent of its geographical area covered by forest, which was slightly lower than the period of 2008-14 (42.27%). The SGH district accounted for the highest percentage of area under forest (54.20%) during 2018-22 in the state, while the lowest forest area was in the EKH district (34.94%). Ri Bhoi district, EGH and SGH witnessed a marginal increase in the forest cover over the two time periods under study. However, EKH, WKH, JH and WGH reported a decline. The practice of *jhum* cultivation is one of the reasons why the forest area is depleting in Meghalaya;

however, government efforts to encourage farmers to adopt alternative methods, such as agroforestry, have contributed to some improvement in the state's situation (Shangpliang, 2019). Cropping intensity was 122.54 per cent during 2018-22 in Meghalaya. WKH recorded the highest cropping intensity of 134.40 per cent during 2018-22, while the lowest cropping intensity was found in JH (101.75%) during 2018-22. Except for EGH, all the other districts in the state registered an increase in the cropping intensity over the two time periods under study. Farmers in Meghalaya are gradually shifting towards cultivating a variety of crops, rather than practising monocropping, which will ultimately contribute to crop diversification in the state. The calculated Simpson Index of Diversification (SID) for the whole state, in terms of area under food crops, was 0.61 for the period of 2018-2022, which represented an improvement over the period of 2008-2014 (0.56). All the districts witnessed a growth in terms of SID over the two time periods. It was East Khasi Hills, which reported the highest crop diversification consecutively for two time periods, i.e., SID of 0.65 in 2008-14 and 0.67 in 2018-22, while Ri Bhoi district reported the lowest crop diversification in the state (SID = 0.42 during 2018-22). Meghalaya had a population density of 171.46 persons per square kilometre during 2018-22, which was relatively low compared to the all-India average of 431.11 persons per square kilometre (UN, 2022). SGH registered the lowest population density of 95.15 no./sq. km. in 2018-22; whereas in 2008-14, it was WKH which had the lowest population density in the state. EKH consecutively recorded the highest population density for both time periods, *i.e.*, 300.55 persons per square kilometre during 2008-2014 and 373.25 persons per square kilometre during 2018-2022 (Table 5).

TABLE 5. DESCRIPTIVE STATISTICS OF DIFFERENT ECOLOGICAL SUSTAINABILITY INDICATORS AND INDICES ACROSS THE DISTRICTS OF MEGHALAYA

Districts	Forest area covered (%)		Cropping intensity (%)		Crop diversification (SDI)		Population density (no./sq.km)		Ecological sustainability	
	2008-14	2018-22	2008-14	2018-22	2008-14	2018-22	2008-14	2018-22	2008-14	2018-22
Ri-Bhoi District	35.51	35.57	113.04	114.33	0.34	0.42	105.74	151.04	0.086	0.091
East Khasi Hills	38.95	34.94	120.03	131.09	0.65	0.67	300.55	373.25	0.090	0.069
West Khasi Hills	39.73	35.82	120.63	134.40	0.54	0.57	73.08	95.95	0.131	0.103
Jaintia Hills	40.35	40.22	101.01	101.75	0.45	0.52	103.46	138.52	0.155	0.157
East Garo Hills	47.87	49.29	114.73	113.74	0.44	0.59	122.13	157.80	0.140	0.177
West Garo Hills	44.88	43.17	126.35	127.21	0.47	0.56	174.95	225.04	0.092	0.110
South Garo Hills	54.05	54.20	121.97	128.07	0.39	0.50	75.43	95.15	0.144	0.157
Meghalaya	42.27	40.75	118.74	122.54	0.56	0.61	132.28	171.46	0.120	0.123

3.3.2 Ranking of Districts based on Ecological Sustainability Index

In the case of ecological sustainability, the ranks were somewhat different compared to those observed in economic sustainability and social sustainability. EGH ranked first from 2018 to 2022 with an index value of 0.177 (Table 5). The district performed well in terms of most ecological indicators, including a high forest area, low cropping intensity, and high crop diversification. Jaintia Hills, which held the top position from 2008 to 2014, secured the second rank from 2018 to 2022. On the other hand, SGH ranked third in both time periods. Notably, SGH exhibited the highest forest area coverage and the lowest population density in the state during 2018-22. EKH, which secured first rank in both economic and social sustainability, exhibited the worst performance in terms of ecological sustainability, ranking seventh among all the districts, which was due to its low forest area, high cropping intensity, and high population density in the state.

3.3.3 Correlation of Various Indicators with Ecological Sustainability

During 2018-2022, forest area ($r = 0.79$, $p < 0.05$) showed a significant positive correlation with ecological sustainability, whereas cropping intensity (-0.52) and population density (-0.59) showed moderate negative correlations, which were statistically insignificant (Table 6). According to Singh *et al.* (2022), forest areas play a crucial role in reducing the adverse effects of socio-economic activities and climate change on ecological services, highlighting that an increase in forest area contributes to improved ecological sustainability. Contrary to our assumption, crop diversification showed a weak and statistically insignificant negative correlation with ecological sustainability ($r = -0.18$, $p = 0.70$). The districts that performed better in terms of crop diversification had a lower forest area in the state; this was instrumental in making the coefficient of crop diversification negative. Similarly, Perz (2004) also noted a negative correlation between agricultural diversity and forest cover but suggested that once crop diversification reaches a certain threshold, further increases do not lead to a decline in forest cover.

TABLE 6. CORRELATION OF VARIOUS ECOLOGICAL SUSTAINABILITY INDICATORS WITH ECOLOGICAL SUSTAINABILITY INDEX

Variable	2008-14		2018-22	
	r	p value	r	p value
Forest area	0.50	0.25	0.79**	0.03
Cropping intensity	-0.45	0.31	-0.52	0.16
Crop diversification	-0.20	0.66	-0.18	0.70
Population density	-0.61	0.14	-0.59	0.16

Note: *** and ** indicate $p<0.01$ and $p<0.05$, respectively

3.3.4 Ranking of Districts based on Overall Sustainability Index

The districts of Meghalaya were ranked using sustainability indices and are presented in Table 7 for two time periods: 2008-2014 and 2018-2022. The overall sustainability of the districts was assessed based on the Composite Sustainability Index (CSI). EKH ranked first in overall sustainability for both the time periods under study. This was mainly due to its first rank in both economic and social sustainability dimensions. Following closely, WKH and EGH acquired second and third ranks, respectively, during both time periods. EGH displayed average performance in economic and social sustainability; however, due to its top rank in ecological sustainability, it attained a third rank in overall sustainability. Ri Bhoi district scored the lowest rank, ranking as the worst performer among all the districts in the state. WGH slipped from fourth to fifth position, and SGH showed improvement by moving from sixth to fourth position between 2008-14 and 2018-22. However, all the other districts maintained the same ranks over the two time periods in terms of overall sustainability. Relative sustainability was calculated only after assigning appropriate weights to the indicators. Although changes were observed in the index value of the districts, the ranks remained consistent with those observed in the absolute sustainability index (Table 7).

TABLE 7. RELATIVE SUSTAINABILITY OF VARIOUS DISTRICTS OF MEGHALAYA

Sl. No.	Districts	Overall sustainability			
		2008-14		2018-22	
		Index value	Ranks	Index value	Ranks
1	Ri-Bhoi District	0.078	VII	0.082	VII
2	East Khasi Hills	0.137	I	0.123	I
3	West Khasi Hills	0.107	II	0.122	II
4	Jaintia Hills	0.088	V	0.105	VI
5	East Garo Hills	0.099	III	0.118	III
6	West Garo Hills	0.090	IV	0.107	V
7	South Garo Hills	0.082	VI	0.110	IV
	Meghalaya	0.097		0.110	

3.3.5 Rank Correlation between Sustainability Components

Table 8 presents the rank correlation among various sustainability dimensions. During the period from 2018 to 2022, a strong positive correlation was observed between economic and social sustainability (r = 0.75). On the other hand, the rank correlation between ecological sustainability and economic sustainability (-0.50) and social sustainability (-0.43) exhibited a moderate negative correlation. This suggests that improvements in social indicators can contribute to enhancing economic sustainability, and vice versa. Whereas, if efforts are solely focused on improving social and economic aspects without considering the ecological context, it can potentially harm ecological sustainability in the long run. A substantial and significant correlation was found between composite sustainability and economic sustainability ($r = 0.86$, $p < 0.05$) during the period from 2018 to 2022. Similarly, it exhibited a moderate positive correlation ($r = 0.68$) with social sustainability during the same period. However, the correlation between composite sustainability and ecological sustainability ($r = -0.21$, $p = 0.65$) was negative but statistically insignificant. The negative correlation could be attributed to the fact that the districts which excelled in terms of economic and social dimensions did not perform well in terms of ecological sustainability. Similarly, Devi (2017) also suggested that composite sustainability can be improved by strengthening economic sustainability; however, this would come at the expense of ecological sustainability. The sign of the correlation coefficients remained the same for all the correlations over two time periods; however, some variations in their magnitude were observed (Table 8).

TABLE 8. RANK CORRELATION BETWEEN SUSTAINABILITY DIMENSIONS FOR THE YEARS 2008-14 AND 2018-22

	Sustainability components	2008-14		2018-22	
		r	p value	r	p value
1	Economic and Social Sustainability	0.21	0.65	0.75	0.05
2	Economic and Ecological Sustainability	-0.71	0.07	-0.50	0.25
3	Social and Ecological Sustainability	-0.14	0.76	-0.43	0.33
4	Composite Sustainability and Economic Sustainability	0.54	0.21	0.86**	0.01
5	Composite Sustainability and Social Sustainability	0.75	0.05	0.68	0.09
6	Composite Sustainability and Ecological Sustainability	-0.11	0.81	-0.21	0.65

Note: *** and ** indicate $p<0.01$ and $p<0.05$, respectively

IV

CONCLUSIONS

The economic sustainability assessment of the districts revealed that Meghalaya experienced notable improvements in crop productivity, as irrigated areas have increased in all seven districts. This has improved the state's per capita food crop output. The livestock density also increased over the years, though three districts registered declines. However, the supply of food grains through the PDS decreased in the state over the study period, with four out of seven districts registering a decline. Social sustainability indicators of Meghalaya demonstrated significant improvement during the study period. The female literacy rates increased in all districts; the sex ratio improved in six districts, and infant mortality rates improved in five districts. Rural road connectivity has expanded in all districts, thereby enhancing mobility in the state. A decline in the rural workforce participation rate was observed in all districts of the state, indicating that people are moving towards more developed areas over time. Meghalaya has witnessed a marginal decrease in forest area coverage over the years. However, the increase in crop diversification in the state is a positive sign for ecological sustainability. EKH and WKH districts performed better in terms of economic and social sustainability but faltered in ecological sustainability. The JH and EGH districts excelled in terms of ecological sustainability but underperformed in terms of economic sustainability. The overall sustainability index of the state could be strengthened by focusing on both economic and social sustainability, but this approach may lead to a trade-off with ecological sustainability. This study specifically recommends that efforts are required to improve the economic sustainability of the JH district, which underperformed in most economic indicators. The state needs to improve its health infrastructure to address the challenge of a higher infant mortality rate, particularly in the WGH district, which recorded the highest infant mortality rate in the state. To strengthen economic and social sustainability in SGH, JH, and Ri Bhoi districts, higher investment is needed in infrastructure, schools, and healthcare by the state government. The ecological sustainability of the EKH and WKH districts can be improved by 'going green' in district planning and creating new forest areas in these districts. This study was based on the collection of secondary data. The problem of non-availability of data for the desired indicators for a specific period and the mismatch of data in two different sources was attempted to be overcome through rationalisation. This research focused on estimating the sustainability at the district level within Meghalaya; upcoming studies might prioritise conducting sustainability assessments at the farm level to gain deeper insights into on-ground realities. Moreover, future work could explore a broader range of indicators across the economic, social and ecological dimensions compared to those utilised in this study.

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ANNEXURE

SOURCES OF DATA FOR VARIOUS INDICATORS USED FOR CONSTRUCTING COMPOSITE SUSTAINABILITY INDEX

Sl. No.	Indicators	Year	Source
A	Economic dimension		
1	Irrigated area (%)	2008-09 2018-19	Area, Production and Yield of Principal Crops in Meghalaya (2007-08 to 2012-13) Volume-IV, DES, Shillong, Meghalaya (GoM, 2017) State Level Crop Statistics Report, 2019-20, Directorate of Economics and Statistics, Shillong, Meghalaya (GoM, 2021a)
2	Livestock density (number/sq.km)	2012 2019	District-wise Livestock Population as per 19th Livestock Census (2012), Animal Husbandry and Veterinary Department, Meghalaya (GoM, 2021b) District-wise Livestock Population as per 20th Livestock Census (2019), Animal Husbandry and Veterinary Department, Meghalaya (GoM, 2021c)
3	Productivity of food crops (kg/ha)	2009-10 2019-20	Area, Production and Yield of Principal Crops in Meghalaya (2007-08 to 2012-13) Volume-IV, DES, Shillong, Meghalaya (GoM, 2017) State Level Crop Statistics Report, 2019-20, Directorate of Economics and Statistics, Shillong, Meghalaya (GoM, 2021a)
4	PDS (Public Distribution System) (MT)	2014-15 2022-23	Statistical Handbook Meghalaya, 2019, DES, Shillong, Meghalaya (GoM, 2019b) AePDS, Food Civil Supplies and Consumer Affairs Department, Government of Meghalaya (GoM, 2023)
5	Per capita output of food crops (MT/annum)	2009-10 2019-20	Area, Production and Yield of Principal Crops in Meghalaya (2007-08 to 2012-13) Volume-IV, DES, Shillong, Meghalaya (GoM, 2017) State Level Crop Statistics Report, 2019-20, DES, Shillong, Meghalaya (GoM, 2021a) Table A-2 Decadal variation in population since 1901, Office of the Registrar General and Census Commissioner, Ministry of Home Affairs, India (GoI, 2014)
B	Social dimension		
1	Female literacy (%)	2011 2021P	2001 – Provisional Population Totals, Series-18, Meghalaya, Office of the Registrar General and Census Commissioner, Ministry of Home Affairs, India (GoI, 2001a) C-08: Educational level by age and sex for population age 7 and above (Total), Meghalaya – 2011, Office of the Registrar General and Census Commissioner, Ministry of Home Affairs, India (GoI, 2011a)
2	Infant mortality rate (%)	2011 2021 P	Indirect Estimates of District wise IMR and Under 5 Mortality using Census 2011 data – Draft, National Health System Resource Centre, Ministry of Health and Family Welfare, India (GoI, 2015)
3	Sex ratio (number of female per 1000 male)	2011 2021 P	Table A-2 Decadal variation in population since 1901, Office of the Registrar General and Census Commissioner, Ministry of Home Affairs, India (GoI, 2014)
4	Rural road connectivity (km.)	2011 2021	Pradhan Mantri Gram SadakYojna, Online Management, Monitoring and Accounting System (OMNAS), Ministry of Rural Development, India (GoI, 2023)

Annexure (*Contd.*)

ANNEXURE (CONLD.)

Sl. No.	Indicators	Year	Source
5	Rural workforce participation rate (%)	2011 2021 P	B-01: Main workers, marginal workers, non-workers seeking/available for work classified by age and sex (all), Meghalaya – 2001, Office of the Registrar General and Census Commissioner, Ministry of Home Affairs, India (GoI, 2001b) Primary Census Abstract C.D. Block wise, Meghalaya - 2011, Office of the Registrar General and Census Commissioner, Ministry of Home Affairs, India (GoI, 2011b)
C	Ecological dimensions		
1	Population density (number of persons/sq.km)	2011 2021 P	Land Use Statistics for the year 2018-19, DES, Shillong, Meghalaya (GoM, 2021a) Table A-2 Decadal variation in population since 1901, Office of the Registrar General and Census Commissioner, Ministry of Home Affairs, India (GoI, 2014)
2	Forest area covered (%)	2008-09 2018-19	Land Use Statistics for the year 2018-19, DES, Shillong, Meghalaya (GoM, 2021a) Area, Production and Yield of Principal Crops in Meghalaya (2007-08 to 2012-13) Volume-IV, Directorate of Economics and Statistics, Shillong, Meghalaya (GoM, 2017)
3	Cropping intensity (%)	2008-09 2018-19	Land and Use Statistics for the year 2018-19, DES, Shillong, Meghalaya (GoM, 2021a) Area, Production and Yield of Principal Crops in Meghalaya (2007-08 to 2012-13) Volume-IV, Directorate of Economics and Statistics, Shillong, Meghalaya (GoM, 2017)
4	Crop diversification (SID)	2009-10 2019-20	Area, Production and Yield of Principal Crops in Meghalaya (2007-08 to 2012-13) Volume-IV, DES, Shillong, Meghalaya (GoM, 2017) State Level Crop Statistics Report, 2019-20, Directorate of Economics and Statistics, Shillong, Meghalaya (GoM, 2021a)