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Regional disparity in energy poverty: A spatial analysis of Odisha

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ABSTRACT

Energy poverty is one of the major deprivations that has direct effect on the well-being of a household at micro level. At macro level, it also has significant effect and hinders the sustainable development of a nation. The binary measurement, commonly used to identify the energy poor population, has major drawbacks as it only takes accessibility of the services into consideration, whereas, in the contemporary period more emphasis should be on the affordability, quality, reliability and legal implications of energy services. The present study, therefore, tries to estimate the energy poverty condition by following a multi-dimensional approach and also tries to identify the actual energy poor by analysing the spatial disparity prevalent in the state of Odisha. A multi-dimensional framework is used to capture different aspects of energy provisioning at household level and an energy poverty index is constructed by assigning equal weights for the parameters. Spatial disparity is measured by considering proxies for the social parameters and following Gini's coefficient of disparity measurement. The results indicated persistence of disparity in energy poverty at regional, inter and intra-district levels.

1. Introduction

Energy is the prerequisite for economic expansion of a region and also important for the material well-being of a household. Energy poverty (EP) is an important phenomenon, considering the role of energy in every individual's life, and it is widely recognised by energy researchers across the globe. The multi-dimensional character of EP allows it to extend beyond the developing state boundaries. It is defined by the access to conventional solid fuels or inability of residents to access modern, safe energy services in the developing world and measured in terms of high cost of energy services or affordability in the developed regions (Tundys et al., 2021). But in general, it depicts an inability situation of the individual that hinders the realisation of its capabilities because of the absence in affordable energy services (Day et al., 2016; Sadath and Acharya, 2017). Global recognition of energy poverty or the importance of its mitigation is evident in the United Nations declaration of 'Sustainable Energy for all' in 2012 and addition of provisioning universal access to affordable and sustainable modern energy services for all in Goal-7 of the Sustainable Developmental Goals (SDG).

Mitigating energy poverty can improve the health conditions of millions of female household members by reducing the chances of respiratory diseases caused from the use of solid fuels for cooking and better electrification can remove the hindrances from children's education (Acharya and Sadath, 2019). It can also reduce the carbon-dioxide (CO_2) emissions, caused from anthropogenic activities, responsible for global warming and improve the societal gender discrimination scenario in terms of education and financial security for women.

India has taken multiple initiatives and achieved substantial gains in providing energy services through Saubhagya and PMUY schemes in the last few years, but the rate of modern fuel adoption for cooking is significantly low. Despite the universal electrification achieved in 2018, there is a significant disconnection between the grid connectivity and household's energy consumption. Results of the Government of India (GoI) survey in 2018 revealed that 50 percent of the electrified households are facing load shedding for more than 12 hours a day (Gupta et al., 2020). Also, the households provided with LPG under the 'Pradhan Mantri Ujjwala Yojana' are unable to refill their cylinders. The rising prices of LPG puts additional pressure on their affordability conditions and force them to reuse traditional fuels to meet the primary cooking needs (Dabadge et al., 2018). Thus, it is crucial to understand EP, not from the traditional binary energy access matrix, but from a multidimensional perspective that includes quality and reliability of the services, affordability of the consumers and draw proper policies and schemes to address it (Acharya and Sadath, 2019; Yadava and Sinha, 2019; Sadath and Acharya, 2017; Jain et al., 2015). Also, it is important to understand the disparity level to have a knowledge of the actual energy poor.

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2. Review of literature

Binary measurement of the energy consumption (Foster et al., 2000) and use-access matrix (Pachauri et al., 2004) are some of the earliest methods of measuring energy poverty. Energy inconvenience index (Mirza and Szirmai, 2010) considers energy mix-use and absence of sufficient energy, which requires a large amount of data that is hard to get for every geographical region. Multidimensional energy poverty index, developed from Prof. Amartya Sen's capabilities framework, assesses depreciation rather than only focusing on access (Nussbaumer et al., 2012; Nussbaumer et al., 2013; Sadath and Acharya, 2017). Further, household energy poverty index is the recent method that includes both accessibility and affordability dimensions (Gupta et al., 2020).

Few energy researchers also tried to measure the spatial aspect of energy poverty from an economic viewpoint. Metropolitan cities have a higher demand for energy because of urbanism and increasing urbanisation (Barnes et al., 2011). Households in developing countries, especially in rural areas, mostly use firewood as the major fuel for cooking and heating. Other fuels and energy sources like LPG and electricity are not widely used because of limitations in availability, accessibility and affordability (Pachauri et al., 2012). Increasing energy prices are also important factors of energy poverty and disparity, as the higher earners section are not much affected by the increased energy prices but the lower section faces the burden (Chester and Morris, 2011; Legendre and Ricci, 2015; Okushima, 2017). The residents of rural areas face this situation in the Indian context (Khandker et al., 2012) that can lead to economic instability of the poor and vulnerable (Bouzarovski, 2014). Also, those having limited access to energy services need to invest a higher proportion of their overall income to achieve energy access than those who have a better access (Groh, 2014).

Looking at energy poverty condition from gender disparity lens in the developing countries, women are mainly in charge of domestic chores like preparing dinner or taking care of children (Braunstein et al., 2019) and managing traditional energy sources such as firewood gathering (Sadath and Acharya, 2017; Kaygusuz, 2011). Most females in the rural areas also help their family members in agriculture and other field-oriented work. Because of the additional responsibilities they are not able to devote much time for their individual development, many also are deprived of education, and end up finding a small-waged position in any less energy intensive enterprises (Pueyo & Maestre, 2019). Furthermore, women are more vulnerable to consequences of energy poverty like household air pollution (HAP) and high temperatures (Sadath & Acharya, 2017), that confines their ability to obtain basic life necessities like safe drinking water, health care, education, and transportation (Kaygusuz, 2011). As a result, the human resource of women in conjunction with their health may deteriorate in energy-poor households. Women from the energy poor category have a harder time finding salaried work and have to accept one with a lower pay scale and fewer opportunities for growth (Pueyo and Maestre, 2019). Usage of safe fuels allows women a safe household environment and benefits them to gain more opportunities to work in India (Choudhuri and Desai, 2020).

Energy vulnerability results in HAP and puts human lives in jeopardy. Solid fuel combustion releases carbon monoxide and particulate matter, polluting indoor air and contributing to poor personal health (Hystad et al., 2019). Burning of solid fuels for cooking caused HAP has

Table 4.1
Ranking of districts with percentage of households using cooking energy indices.

District/ Region	Normalised values of indices (in %)						Aggregate	Rank
	Coal	Fire wood	Dung cake	Kerosene	Others	NA		
Central	**0.929**	**64.707**	**2.521**	**1.427**	**8.677**	**1.959**	**80.220**	**-**
Baleshwar	0	76.25	3.13	0	3.75	3.13	86.26	**11**
Bhadrak	0	34.38	6.88	1.88	40.63	0	83.77	**14**
Cuttack	0.53	57.98	1.6	1.6	1.6	1.6	64.91	**29**
Jagatsinghpur	6.25	53.13	5.47	0.78	10.16	8.59	84.38	**12**
Jajapur	1.25	65.63	2.5	5	6.25	0.63	81.26	**22**
Kendrapara	0	63.75	1.88	1.25	20	0	86.88	**9**
Khordha	0.63	58.13	2.5	0.63	0	1.88	63.77	**30**
Mayurbhanj	0	80	0	0	4.38	3.13	87.51	**5**
Nayagarh	0	79.69	0	0	0	0	79.69	**26**
Puri	0.63	78.13	1.25	3.13	0	0.63	83.77	**15**
Northern	**3.569**	**74.378**	**0.378**	**1.275**	**1.063**	**2.415**	**83.078**	**-**
Anugul	22.66	49.22	0	2.34	0	0.78	75	**27**
Balangir	0	87.5	0	0.78	0	1.56	89.84	**2**
Bargarh	0	86.88	0.63	0.63	0	1.25	89.39	**3**
Debagarh	0	86.46	0	1.04	0	0	87.5	**8**
Dhenkanal	1.57	70.08	3.15	1.57	1.57	3.15	81.09	**24**
Jharsuguda	10.42	61.46	0	2.08	0	6.25	80.21	**25**
Kendujhar	0	71.25	0	0.63	7.5	4.38	83.76	**16**
Sambalpur	0	69.47	0	3.16	0	1.05	73.68	**28**
Subarnapur	0	87.5	0	0	0	1.04	88.54	**4**
Sundargarh	1.04	73.96	0	0.52	1.56	4.69	81.77	**21**
Southern	**1.834**	**80.536**	**0.573**	**0.760**	**0.052**	**1.458**	**85.213**	**-**
Baudh	0	84.38	0	0	0	3.13	87.51	**6**
Gajapati	3.13	80.21	0	1.04	0	0	84.38	**13**
Ganjam	0.52	77.6	1.56	1.56	0.52	1.56	83.32	**19**
Kalahandi	0.63	90	0	1.88	0	0	92.51	**1**
Kandhamal	8.33	75	0	2.08	0	1.04	86.45	**10**
Koraput	0	75.78	0	0	0	7.81	83.59	**17**
Malkangiri	0	82.29	4.17	0	0	1.04	87.5	**7**
Nabarangpur	4.69	76.56	0	0	0	0	81.25	**23**
Nuapada	1.04	82.29	0	0	0	0	83.33	**18**
Rayagada	0	81.25	0	1.04	0	0	82.29	**20**
Odisha	**1.89**	**72.38**	**1.27**	**1.19**	**3.83**	**1.99**	**82.55**	**-**

Source: Calculated by the author using NSS Data

Table 4.2
Ranking of districts with percentage of households using lighting energy indices.

District/ Region	Normalised values of indices (in %)				Aggregate	Rank
	Kerosene	Candle	Other	NA		
Central	**13.284**	**0.063**	**0**	**0.188**	**13.535**	**-**
Baleshwar	18.13	0	0	0	18.13	**17**
Bhadrak	6.88	0	0	0	6.88	**28**
Cuttack	7.98	0	0	0	7.98	**27**
Jagatsinghpur	19.53	0	0	0	19.53	**16**
Jajapur	11.88	0	0	0	11.88	**22**
Kendrapara	3.75	0	0	0	3.75	**29**
Khordha	6.88	0.63	0	0.63	8.14	**26**
Mayurbhanj	46.25	0	0	0	46.25	**2**
Nayagarh	1.56	0	0	0	1.56	**30**
Puri	10	0	0	1.25	11.25	**23**
Northern	**22.533**	**0**	**0.078**	**0.052**	**22.663**	**-**
Anugul	9.38	0	0.78	0	10.16	**25**
Balangir	29.69	0	0	0	29.69	**8**
Bargarh	26.88	0	0	0	26.88	**10**
Debagarh	34.38	0	0	0	34.38	**7**
Dhenkanal	11.02	0	0	0	11.02	**24**
Jharsuguda	13.54	0	0	0	13.54	**20**
Kendujhar	38.75	0	0	0	38.75	**3**
Sambalpur	22.11	0	0	0	22.11	**15**
Subarnapur	14.58	0	0	0	14.58	**19**
Sundargarh	25	0	0	0.52	25.52	**12**
Southern	**29.162**	**0**	**0**	**0.156**	**29.318**	**-**
Baudh	38.54	0	0	0	38.54	**4**
Gajapati	23.96	0	0	0	23.96	**13**
Ganjam	16.67	0	0	0	16.67	**18**
Kalahandi	23.13	0	0	0	23.13	**14**
Kandhamal	50	0	0	0	50	**1**
Koraput	25	0	0	1.56	26.56	**11**
Malkangiri	27.08	0	0	0	27.08	**9**
Nabarangpur	38.28	0	0	0	38.28	**5**
Nuapada	36.46	0	0	0	36.46	**6**
Rayagada	12.5	0	0	0	12.5	**21**
Odisha	**20.79**	**0.02**	**0.02**	**0.15**	**20.98**	**-**

Source: Calculated by the author using NSS Data

taken lives of around 35 lakhs people (Lim et al., 2012). Furthermore, HAP causes low birth weight, elevated blood pressure, and decreased lung function, along with vision difficulties, house burning, and fatalities (Ahmed et al., 2019). Energy poverty also influences education by reducing the average number of years spent in school for the energy-poor households (Oum, 2019). Educational qualifications also have an inverse relation with energy poverty and other socio-economic factors (Abbas et al., 2020) and lead to greater utilisation of greener energy (Rahut et al., 2019). Empirical findings from India suggest that a ten percent increase in educational attainment results in a three percent reduction in energy poverty (Tewathia, 2014), particularly among the lower-income households (Sharma, 2016).

Looking at the multi-dimensional effects of EP on various personal and social aspects, present study tries to assess the energy poverty conditions from a multi-dimensional perspective and also tries to figure out the disparity at district and regional level.

3. Database and methodology

The study collected secondary information collected by the National Sample Survey, 68th round.[1] Further, forest cover data is extracted from the India State of Forest Report, 2019. Present study calculates energy poverty index for 30 districts of Odisha, covering 4026 no. of households, of which 73.87 percent are rural residents and rest 26.13 percent households reside in urban centres. To understand the regional disparity of energy poverty among the districts, the study followed the categorization of the 30 districts into three revenue divisions by Odisha Economic Survey, namely central, northern and southern.

3.1. Indicators selection

The first methodological deliberation was to identify few variables before the measurement of EP condition of Odisha, for which the study drew ideas from the previous works in the domain by Sadath and Acharya, 2017; Gupta et al., 2020; Acharya and Sadath, 2019; and Yadava and Sinha, 2019 etc. Secondary sources were explored for the collection of data on the variables selected. The study, based on the availability of secondary data, tried to look at energy poverty from multiple dimensions; a) use of traditional fuels or inability to use clean or environmentally friendly fuels for cooking purposes in the households, b) use of traditional fuels or inability to use clean fuels for lighting purposes in the households to understand the accessibility parameters, c) Monthly Per-capita Consumption Expenditure (MPCE) to understand the affordability aspect, and d) forest cover to understand the geographical hindrances and forest proximity of the households. It further analysed the energy poverty condition of Odisha at different levels to understand its expanse. Households usage of traditional fuel sources for cooking and lighting along with the monthly per-capita consumption expenditure were considered to obtain the aggregate information about each district. However, in the absence of exact location data on the sample population, forest cover data was considered for the whole geographical area under the district administrative unit. The dimensions are obtained considering the present energy scenario of the state and its regional differences.

[1] The National Sample Survey Office is in charge of conducting extensive all-Indian basis sample surveys in a variety of disciplines. Few studies used the data to assess the energy poverty condition are Nagothu, 2016; Nathan and Hari, 2018; Gould and Urpelainen, 2018; Nathan and Hari, 2020; Gupta et.al., 2020 and Kar et.al., 2023.

Table 4.3
Ranking of districts by all energy poverty indices.

District/ Region	Ranking of districts by energy poverty indices				
	Cooking	**Lighting**	**Reverse MPCE**	**Forest Cover**	**EP score**
Central	**80.220**	**13.535**	**1559.451**	**17.055**	**-**
Baleshwar	11 (+8)	17 (+2)	20 (-1)	27 (-8)	**19**
Bhadrak	14 (+7)	28 (-7)	8 (+13)	30 (-9)	**21**
Cuttack	29 (+1)	27 (+3)	30 (0)	19 (+11)	**30**
Jagatsinghpur	12 (+12)	16 (+8)	25 (-1)	28 (-4)	**24**
Jajapur	22 (+4)	22 (+4)	22 (+4)	26 (0)	**26**
Kendrapara	9 (+14)	29 (-6)	21 (+2)	25 (-2)	**23**
Khordha	30 (-1)	26 (+3)	29 (0)	22 (+7)	**29**
Mayurbhanj	5 (-3)	2 (0)	4 (-2)	11 (-9)	**2**
Nayagarh	26 (-6)	30 (-10)	19 (+1)	6 (+14)	**20**
Puri	15 (+7)	23 (-1)	18 (+4)	29 (-7)	**22**
Northern	**83.078**	**22.663**	**1547.609**	**32.489**	**-**
Anugul	27 (-2)	25 (0)	26 (-1)	8 (+17)	**25**
Balangir	2 (+8)	8 (+2)	12 (-2)	21 (-11)	**10**
Bargarh	3 (+11)	10 (+4)	14 (0)	20 (-6)	**14**
Debagarh	8 (-2)	7 (-1)	16 (-10)	3 (+3)	**6**
Dhenkanal	24 (+3)	24 (+3)	27 (0)	14 (+13)	**27**
Jharsuguda	25 (+3)	20 (+8)	28 (0)	23 (+5)	**28**
Kendujhar	16 (-7)	3 (+6)	15 (-6)	12 (-3)	**9**
Sambalpur	28 (-10)	15 (+3)	24 (-6)	4 (+14)	**18**
Subarnapur	4 (+12)	19 (-3)	10 (-6)	24 (-8)	**16**
Sundargarh	21 (-6)	12 (+3)	23 (-8)	7 (+8)	**15**
Southern	**85.213**	**29.318**	**1171.528**	**38.689**	**-**
Baudh	6 (-3)	4 (-1)	9 (-6)	9 (-6)	**3**
Gajapati	13 (-8)	13 (-8)	3 (+2)	2 (+3)	**5**
Ganjam	19 (-2)	18 (-1)	17 (0)	16 (+1)	**17**
Kalahandi	1 (+6)	14 (-7)	7 (0)	15 (-8)	**7**
Kandhamal	10 (-9)	1 (0)	13 (-12)	1 (0)	**1**
Koraput	17 (-5)	11 (+1)	6 (+6)	17 (-5)	**12**
Malkangiri	7 (-3)	9 (-5)	1 (+3)	10 (-6)	**4**
Nabarangpur	23 (-12)	5 (+6)	11 (0)	18 (-7)	**11**
Nuapada	18 (-10)	6 (+2)	2 (+6)	13 (-5)	**8**
Rayagada	20 (-7)	21 (-8)	5 (+8)	5 (+8)	**13**
Odisha	**82.55**	**20.98**	**1448.45**	**33.15**	**-**

Source: Calculated by the author using NSS Data and India State of Forest Report, 2019

Table 4.4
Correlation Matrix of Parameters.

	Traditional Fuel Use for Cooking	Traditional Fuel Use for Lighting	MPCE	Forest Cover
Traditional Fuel Use for Cooking	1			
Traditional Fuel Use for Lighting	.432*	1		
	0.017			
MPCE	-.719**	-.517**	1	
	0	0.003		
Forest Cover	0.031	.481**	-0.231	1
	0.87	0.007	0.219	

Source: Calculated by the author using NSS Data
* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

3.2. Computing the Energy Poverty Index

To construct the index for analysing EP, it was important to normalise the variables, presenting information in different units. The aggregate variable values were transformed into z-scores, where a larger value depicts more energy poverty in the district/region. Z-score values of MPCE, being a negative variable of energy poverty (Sadath and Acharya, 2017; Acharya and Sadath, 2019; Pradhan, 2013), are inverted in order to change the values into positive scores for energy poverty. EP index is, thus, calculated by assigning values to the variables.

Energy Poverty Index (EPI) = (0.25 * Inability to use clean fuels for cooking) + (0.25 * Inability to use clean fuels for lighting) + (0.25 * Affordability) + (0.25 * Forest proximity)

Inability to use modern clean fuels for cooking and lighting depicts the dependence of the household on traditional energy sources, depicting the energy poverty situation. MPCE depicts the economic condition or purchasing power of the household. Better MPCE depicts a household's ability to afford the energy services, therefore, a smaller MPCE will limit the household's energy choice and increase the dependence on traditional energy services, putting all the family members at risk. Forest proximity apart from being a hindrance for the transmission of energy services, entices the households, especially in remote locations and rural areas, to use traditional fuels locally available to them. Considering the effect of social, economic and geographical factors and consideration of multiple dimensions namely, accessibility of the households, affordability of the households and geographical factors, all the four variables were given equal weights to compute the index depicting the EP situation of the households in Odisha.

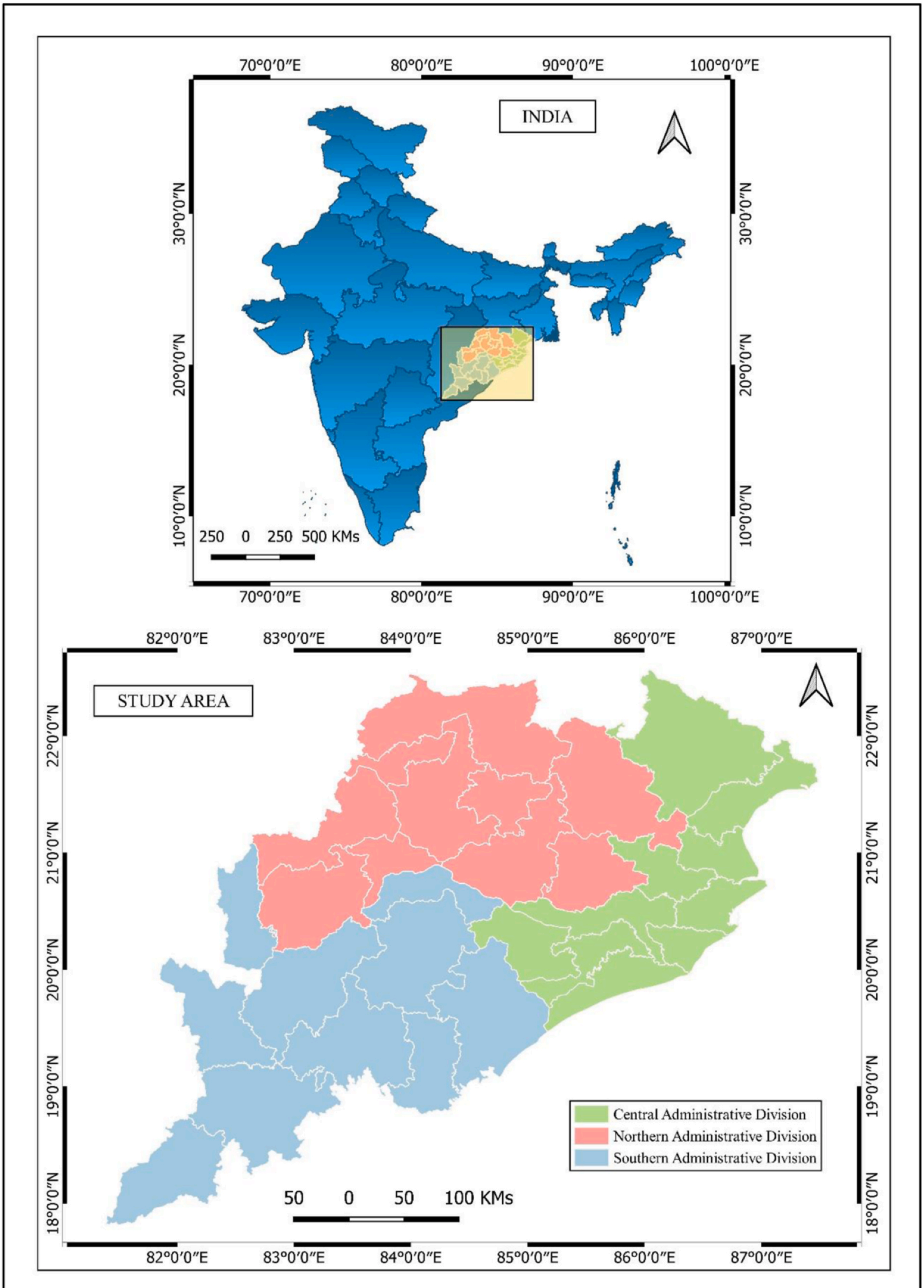

Fig. 3.1. Study Area Map.
Source: Prepared by the author using QGIS

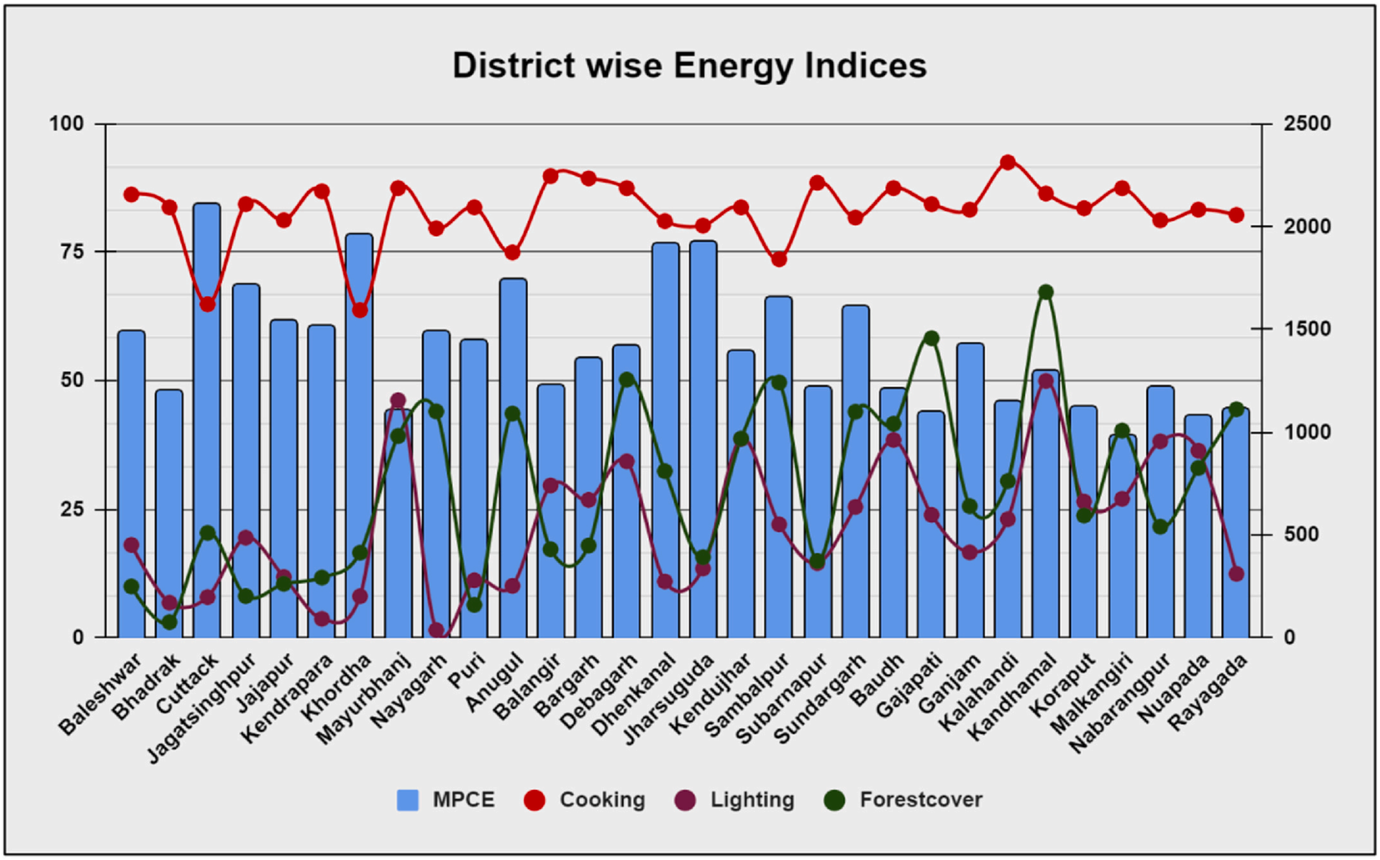

Fig. 4.1. District-wise Energy Indices.
Source: Prepared by the author using NSS data

3.3. Measuring disparity

To measure the spatial inequality, both at intra and inter-district levels, we considered usage of safe energy sources by the households, namely LPG connection for cooking and usage of electricity for lighting. Binary data proxies were taken for the responses to the questions on each energy indices. Based on the proxy values, spatial inequality was measured at both intra and inter district levels by computing the Gini coefficient. Gini coefficient or Gini index, in the current instance, depicts the extent to which the consumption of clean energy services among the households in the districts of Odisha deviate from a perfect equal distribution. A perfect equal distribution (Gini index = 0) explains a situation of all the households in a geographical distribution having access to safe energy services, i.e., LPG and electricity connections for cooking and lighting purposes respectively.

3.4. Study area

Odisha carries a large share of the energy poor population, nearly 83% of its population resides in 51,349 villages. The economy is primarily an agrarian one that is gradually transforming to a service and industries driven economy. The state, like others in the country, faces social discrimination issues and continuously focuses on the all-round development of the marginalised categories through various welfare measures that includes various aid, rehabilitation and housing facilities and reservations. The National Multidimensional Poverty Index (MPI) 2021, calculated by NITI Aayog based on three dimensions, i.e. health, education, and living standard, indicates only 5 of the 30 districts have a poverty rate less than 20 percent. Odisha is also considered as the third-worst state in cooking fuel use and cleanliness, with 65.3% and 39.5% of the population respectively lacking both necessities.

4. Results and discussion

Inability to use clean energy for cooking or dependence on the traditional fuels for household chores significantly affects the energy poverty levels. 27 of the 30 districts in the study area have more than three quarter households depending on conventional fuels for cooking, reflecting the energy poverty scenario of the state. Also, analysing the district wise traditional fuel usage for cooking, a very large disparity among the districts is evident. Jharsuguda, Nayagarh, Anugul, Sambalpur, Cuttack and Khordha are the districts with the lowest share of households using traditional fuels for cooking whereas, Kalahandi (92.5%), Balangir (89.8%), Bargarh (89.3%), and Subarnapur (88.5%) have the highest. Firewood is the dominant fuel used for cooking in all districts along with coal/ charcoal usage primarily seen in Anugul and Jharsuguda.

Table 4.1 presents information on the cooking energy indices for 30 districts and three regional divisions. The districts are ranked as per their dependence on traditional fuel sources for cooking, thus, a higher rank (smaller numerical) depicts more dependence on traditional fuels and higher energy poverty. The central division, compared to the other two, is at a better position based on the energy sources used for cooking by the households, i.e., a larger share of the households is using cleaner energy. The primary reasons for the condition must be the accumulation of larger urban centres and awareness among the households in central division.

Disparity among the districts and between regions is widely observed while analysing traditional fuel use for lighting among the districts. Kandhamal (50%), followed by Mayurbhanj (46.25%), has the highest share of households depending on traditional fuels for lighting. Nayagarh (1.56%), Kendrapara (3.75%), Bhadrak (6.88%), Cuttack (7.98%) and Khordha (8.14%) have the least share of dependence on traditional fuels for lighting. Kerosene is the primary traditional fuel used by households.

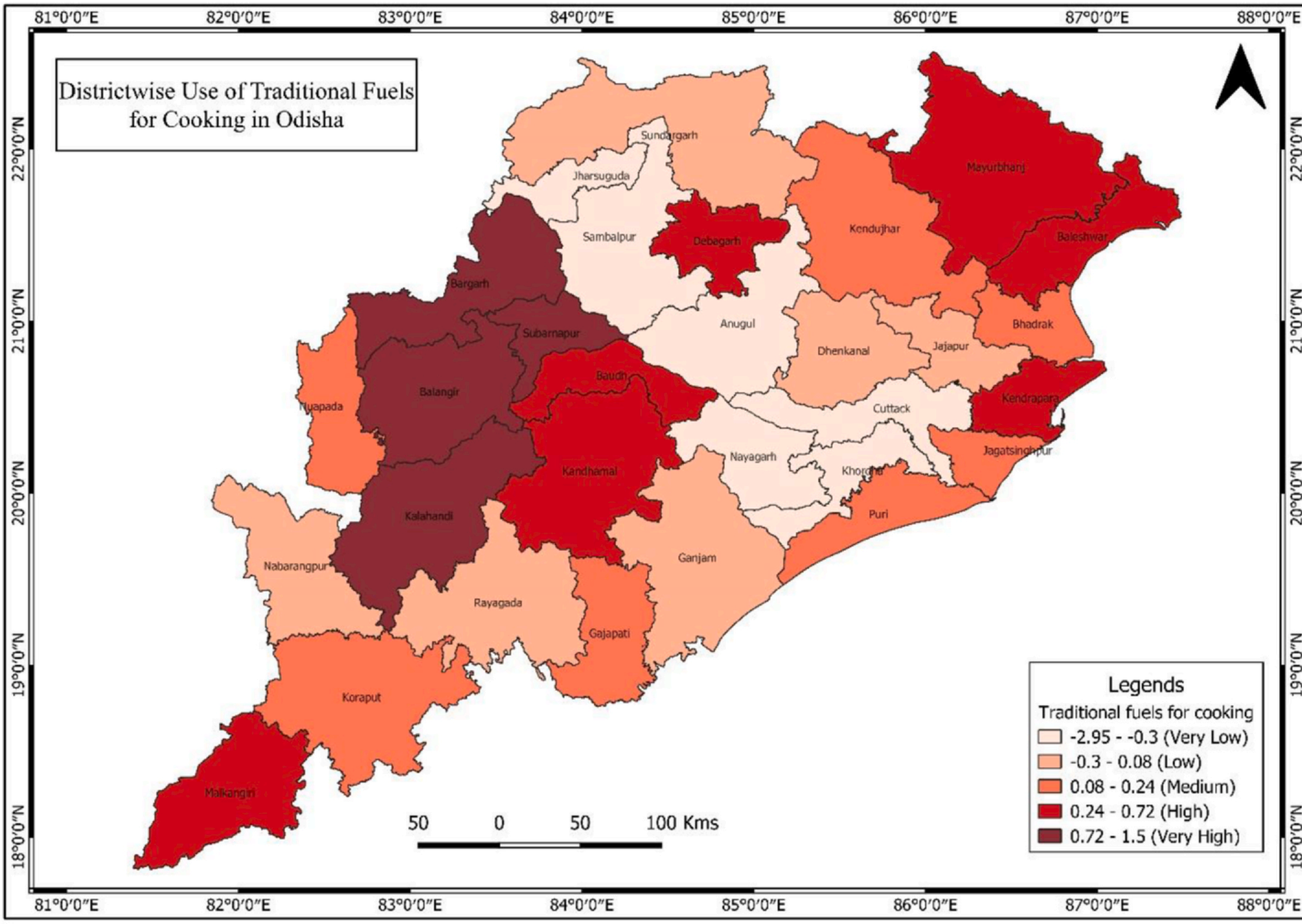

Fig. 4.2. District-wise Use of Traditional Fuels for Cooking in Odisha.
Source: Prepared by the author using QGIS

Energy usage for lighting among the households of Odisha is significantly better than the energy usage for cooking, larger share is using electricity for lighting. Table 4.2 presents rank wise classification of the districts in traditional fuel usage for lighting purposes. A smaller numerical rank depicts more dependence of the district on traditional fuels, thereby, more energy poverty.

Analysing the district wise MPCE, indices selected for measuring affordability of the households, intra-region and inter-region differences are observed between the central, the northern and the southern division districts. Less affordability signifies a household's inability to obtain better technology or services, contributing to energy poverty. Malkangiri, Nuapada, Gajapati, Mayurbhanj, Rayagada, Koraput, Kalahandi and Bhadrak are the districts with lowest average MPCE, whereas, Cuttack, Khordha, Jharsuguda and Dhenkanal has the highest.

Forest cover is considered as a hindrance for the development and connectivity of a region. Evaluating the forest survey data, Kandhamal, followed by Gajapati and Debagarh has more than 50% forest cover. Only 12 out of 30 districts have forest cover of more than 33% of its geographical area, revealing the variation in the accessibility or rather development. Majority of the central division districts have less forest cover. Bhadrak (3.11%), followed by Puri (6.47%) and Jagatsinghpur (8.17%) has the least share of geographical area covered with forest.

Rank wise classification of the districts puts Kandhamal on top of the energy poverty ladder, signifying the highest energy poverty, followed by Mayurbhanj. Districts performing better in aggregate energy poverty score (less households depending on traditional fuels) not necessarily securing the same position in every energy index. The changes in their positions are presented in Table 4.3, changes in ranks contributing to their energy poverty conditions are marked in positive (+) and indices where the district has a better condition than their aggregate energy poverty are marked by negative (-) signs.

To understand the correlation between the parameters undertaken for measuring the energy poverty of the micro regions (districts), Pearson's r coefficients of linear correlation were measured. The bivariate comparison shows (Table 4.4) a moderate positive correlation between traditional fuel use for cooking and traditional fuel use for lighting. MPCE has a high significant negative relation with traditional fuel use for cooking and moderate negative significant relationship with traditional fuel use for lighting. Forest cover has a moderate significant positive relationship with traditional fuel use for lighting, however, failed to establish any significant relation with traditional fuel use for cooking or MPCE.

Evaluating the energy poverty condition, the study found variation among the districts in terms of energy poverty. Cuttack (-1.42) with a very low energy poverty score, followed by Khordha (-1.4), has the best condition, whereas, Kandhamal (1.61) and Mayurbhanj (1.32) secures the bottom positions. The central division, considered as the most developed region of the state, districts are having very low energy poverty scores, barring Mayurbhanj. Also, four of the bottom five positions are acquired by districts from the southern revenue division, signifying the relation between development of a region and energy poverty. Districts from the northern division that are closer to the central division (for ex. Dhenkanal and Anugul) are in a better position than the distant districts.

Considering the categorical divisions of energy poverty index Cuttack and Khordha are placed in the very low energy poverty

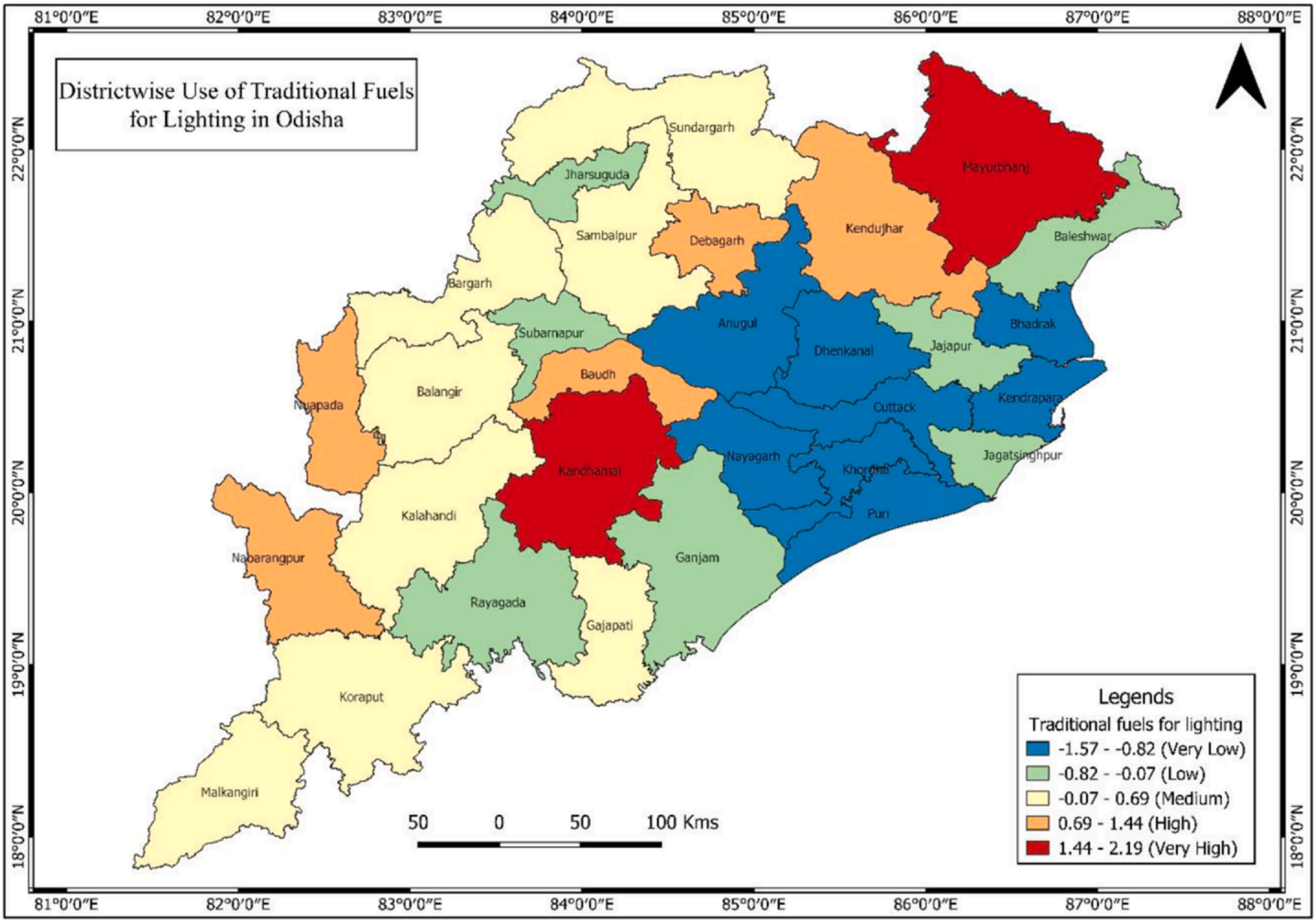

Fig. 4.3. District-wise Use of Traditional Fuels for Lighting in Odisha.
Source: Prepared by the author using QGIS

category. Jharsuguda, Anugul, Dhenkanal, Jajpur, Bhadrak, Kendrapara, Jagatsinghpur and Puri are categorised in the low energy poverty category, whereas, Sundargarh, Sambalpur, Sonepur, Nayagarh, Ganjam and Baleshwar are categorised as medium energy poor districts. Bargarh, Nuapada, Balangir, Kalahandi, Nabarangpur, Koraput, Rayagada, Deogarh and Keonjhar are considered as high energy poor districts and Kandhamal, Mayurbhanj, Boudh, Gajapati and Malkangiri are districts with very high energy poverty.

Intra-district disparity in safe energy usage is evident alongside inter-district and inter-region disparity. A graphical representation of the Gini coefficient is presented in Fig. 4.7. We considered the binary data for the indices as a proxy to measure the disparity index. The data shows that disparity in cooking indices are more than the other variables, meaning there is a larger disparity among the households using safe sources for cooking. Disparity in use of electricity is highest in Kandhamal and Mayurbhanj, two of the energy poorest districts. Regional disparity in the cooking and lighting indices are also evident, central division has less disparity than the northern division and southern division has the highest disparity. But, the differences in disparity levels are negligible in terms of MPCE.

Fig. 4.8 presents the difference on the selected energy indices in rural and urban areas for the districts of Odisha. Considering safe energy sources for cooking, a stagnant disparity level is observed in rural areas of the districts in Odisha. In urban areas, the disparity values drop drastically, especially in Cuttack, Anugul and Khordha. Most disparity in use of safe energy sources for cooking in urban areas is visible in the northern region that includes the districts with highest disparity, i.e., Bargarh, Debagarh and Balangir. Disparity in terms of safe sources of lighting in the rural areas of the districts is very much evident and the intensity varies for different regional administrative divisions. The southern division has the highest disparity in the usage of clean energy for lighting purposes by the households. The central division districts have very less disparity, except Mayurbhanj that has the second highest disparity in safe sources used for lighting, after Kandhamal, in rural areas. The northern division falls in between the two. There is minimal disparity observed in the urban areas in usage of safe energy sources for lighting, except Debagarh. Similarly, there is some disparity observed in the affordability of the households to use safe energy sources, more in urban spaces than rural, among districts and regional administrative divisions.

5. Conclusions

Reducing energy poverty can have numerous positive impacts. It can improve the health conditions of millions of female household members by reducing the indoor air pollutants and further chances of respiratory diseases caused by solid fuels usage. Absence of safe energy services, like LPG and electricity, hinders the individual development of household members. Also, use of clean and affordable energy resources by the actual energy poor population is decisive for eradicating poverty conditions and promotion of overall well-being (Acharya and Sadath, 2019). The study establishes the existence of EP at district and regional levels with varying intensity. Disparity is also observed with varying intensity between rural and urban sectors of the districts and different regional divisions. The results coincide with the idea of Khandker et al. (2012), income poverty and energy poverty are substantially correlated

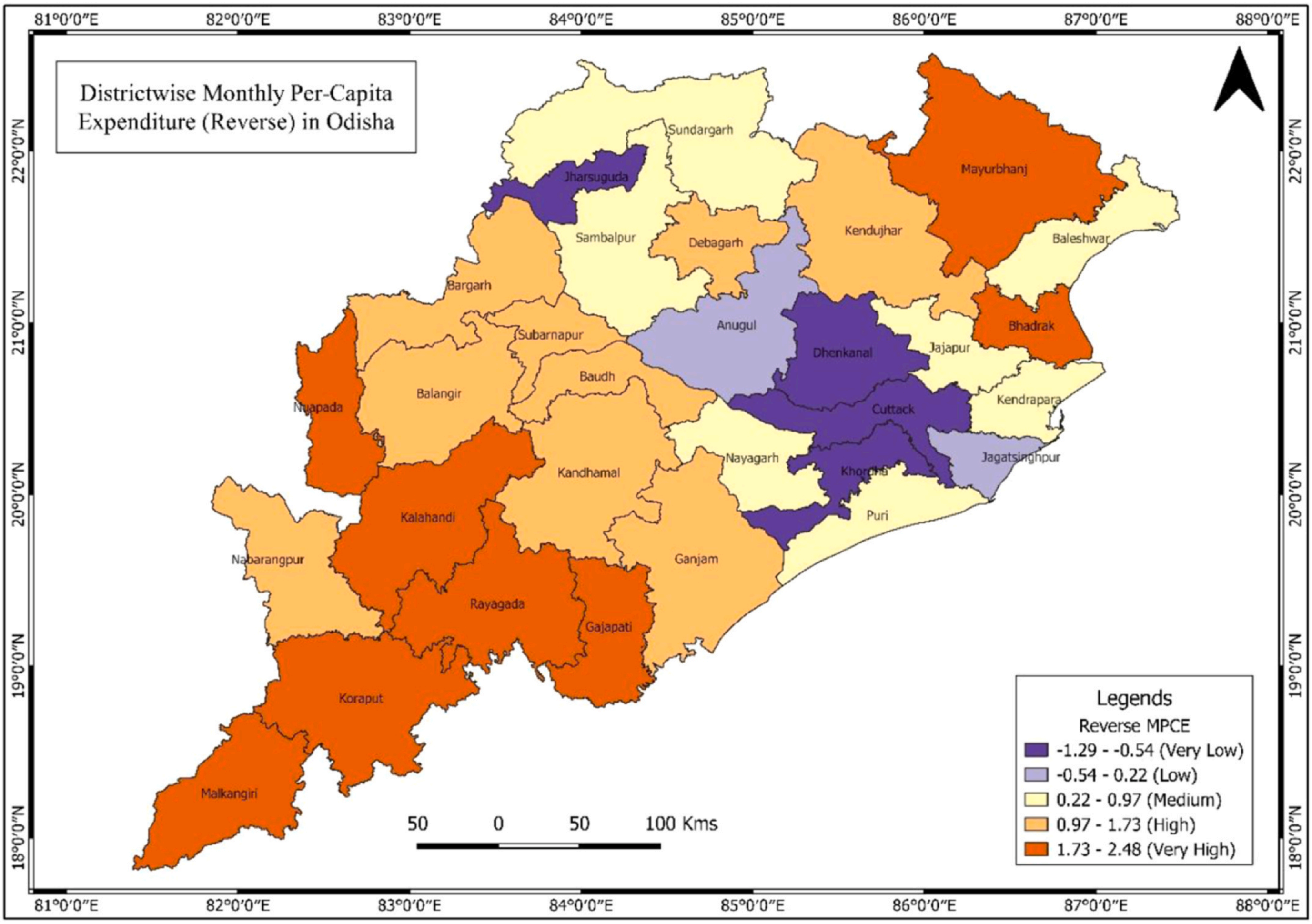

Fig. 4.4. District-wise MPCE (Reverse) in Odisha.
Source: Prepared by the author using QGIS

in urban regions, but not in rural India. Higher disparity among the households is observed in urban areas in usage of LPG for cooking and MPCE, but the use of electricity for lighting in rural areas of the districts have wider disparity among them. Urban areas have a higher demand for energy to sustain the additional facilities of its population. Though administrations have taken different steps to incentivise electrification and LPG connection to the poorer sections and tried to bridge the gap, making the services available for one time will not serve the purpose of achieving transformations in energy consumption, rather, more robust and sustainable welfare policy measures need to be implemented. It is also important to understand the geographical and social background of the population and drive measures to cater their needs.

The high prices for modern energy are problems need attention from researchers, developers, administrators and policy makers. The higher earning residents in urban areas can afford to pay greater prices for their energy needs, but often this is a problem for the lower economic class. Thus, the growing economic difference among urban and rural areas, even different economic classes in the urban areas, is one of the central antecedents of EP conditions. Further, availability of lesser options, lower economic and educational standards, lack of awareness among the residents also plays pivotal roles in determining the energy usage condition in the backward areas of northern and southern administrative divisions. These challenges can be undertaken and resolved through both top-down (provision of financial and instrumental support to eradicate the disparity of energy poverty) and bottom-up (considering local challenges and other prevailing hindrance for policy formulation) approaches. Installing modern energy requires high initial investments, that the poorer section will not be able to make, but it can be addressed through pro-poor policies, providing off-grid technologies and creating awareness at grassroot levels.

Geographical factors put challenges for development strategies and policy implementation, but decentralised policy making can target the specific problems that persist in a region. Also, the historically developed social differences can be overcome by regular policy framing and proper implementation, that the government is committed to by launching different welfare measures including legal aid, rehabilitation and housing facilities, special employment exchange and reservations etc. for the marginalised communities. Energy policies need to invest on more important parameters like validity, security, reliability and affordability of energy services rather than the binary parameters of access. For more sustained and robust outcomes, these need to be evaluated and updated regularly.

With the globe progressing towards the completion of Sustainable development goals' (SDG) official term, more emphasis should be given to the aspects that can create multiplier effect on the positive outcomes. Mitigation of energy poverty is not only will increase clean energy use and help achieving SDG7, but it will also help in eradication of poverty (SDG1), improving health and well-being (SDG3) and quality of education (SDG4), reducing inequalities (SDG10), promote sustainability (SDG11) and also tackling climate change (SDG13). Thus, it is vital to recognise the antecedents of EP and formulate planning and policy measures to control them and promote universal access to affordable modern energy.

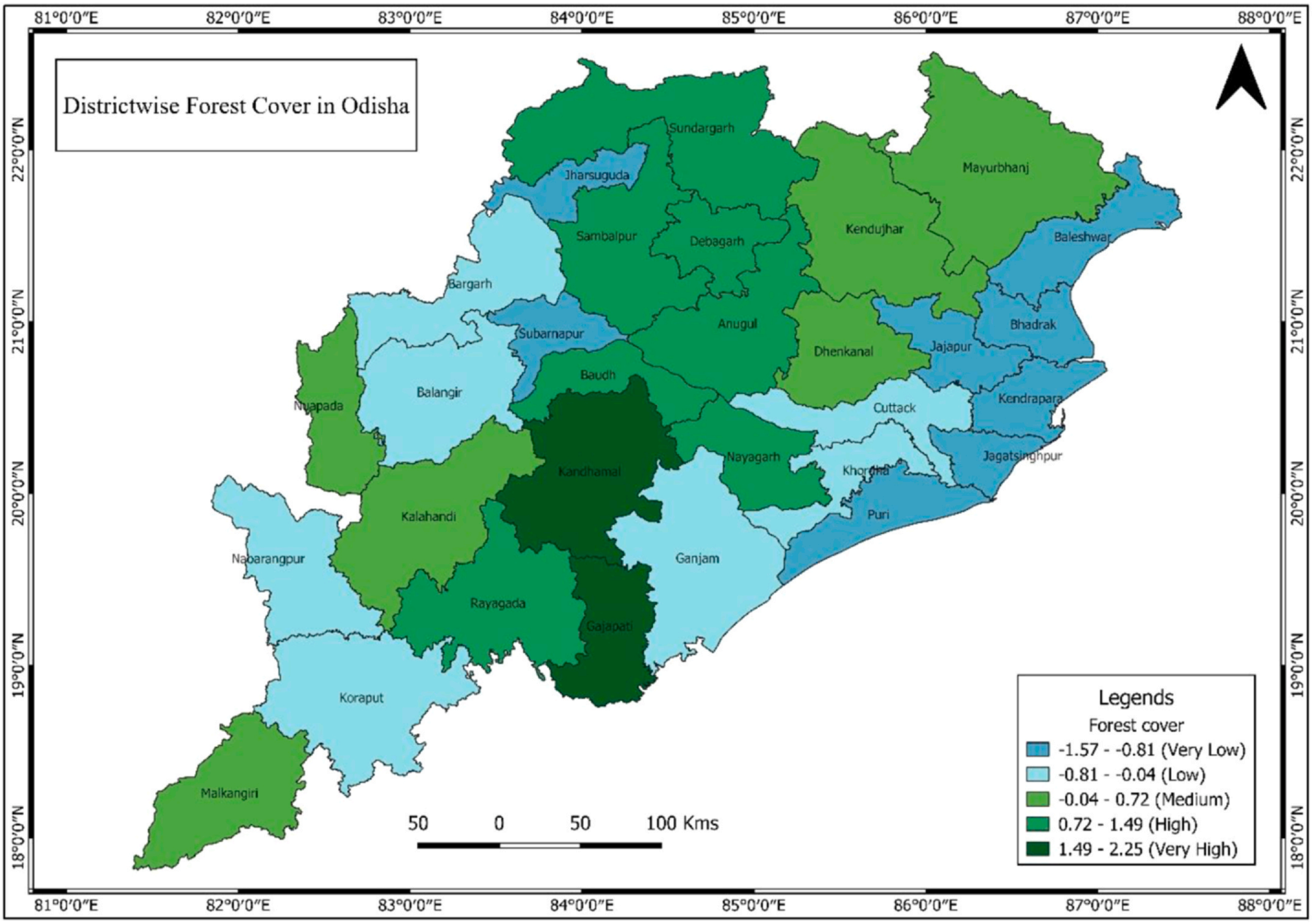

Fig. 4.5. District-wise Forest Cover in Odisha.
Source: Prepared by the author using QGIS

6. Policy recommendations

Energy system is a cornerstone of modern life and thus energy poverty is a major concern. Secure, efficient and environmentally friendly energy technologies are essential for sustainable development. But the high investment required for modern energy services are unaffordable for a large chunk sitting at the bottom of the economic ladder. The paper proposes to identify the energy poor population by obtaining a modern multi-dimensional lens rather than considering access matrix as the sole identifier.

To ease the transition away from solid fuels, this policy recommendation focuses on the net climate benefits of scaling up LPG and promoting alternative environmentally friendly lighting solutions in rural areas. Majority of the population still cooks with solid fuels, including wood, charcoal, and biomass. LPG is thought as a highly scalable transitional cooking solution, until more affordable and easily available renewable options are available in the market, and has a net positive climate impact compared to using firewood. Cooking with a single 14.2 kg LPG cylinder reduces the need to burn 176 kgs of firewood (Gould and Urpelainen, 2018). So, even though LPG is a fossil fuel, switching from solid fuels to it might reduce the net warming effect by 74% (Kar et al., 2023). Nonetheless, the cost barrier prevents customers in developing nations with high rates of inflation from switching to LPG as their major fuel source.

For the population that has already made the switch to clean cooking fuels, affordability concerns are also causing a reversion in solid fuel usage. As a result, it is critical that the administration create a fund to provide financial and infrastructural assistance to emissions reductions associated with the transition from non-renewable biomass to an established and sustainable technology like LPG. Additionally, the government should support efforts to increase capacity and exchange knowledge by offering best practices and roadmaps for scaling up the use of LPG in areas where a significant portion lacks access to clean cooking energy and where non-renewable biomass is prevalent. Implementation of an information repository to calculate the best possible subsidy for various regions, interested in promoting the primary and exclusive use of LPG, taking into consideration factors such as purchasing power and particular needs.

The electricity sector, which accounts for over 40% of India's overall carbon emissions, is confronted with many difficulties. Mani et al. (2021) argues that India's distribution firms, or discoms, face several challenges, including low cost recovery, inefficient billing and metering, a heavy cross-subsidy load, increased transmission & distribution losses, and a lack of infrastructure investment (India Climate & Energy Dashboard, 2024). The distribution sector's inefficiencies have an effect on the overall financial stability of the electricity industry. The primary source of difficulties for the discoms is residential customers. Tyagi and Kuldeep (2023) report that over 70% of homes use less than 100 kWh per month. By providing low-cost solar services to the subsidized consumers, distributed solar can assist reducing the average supply cost and serve an essential part in the economic turnaround of the discoms (Mani et al., 2021). The Rooftop Solar programs initiated by the Ministry of New and Renewable Energy (MNRE) may be amended to include community systems, installed at public spaces, but

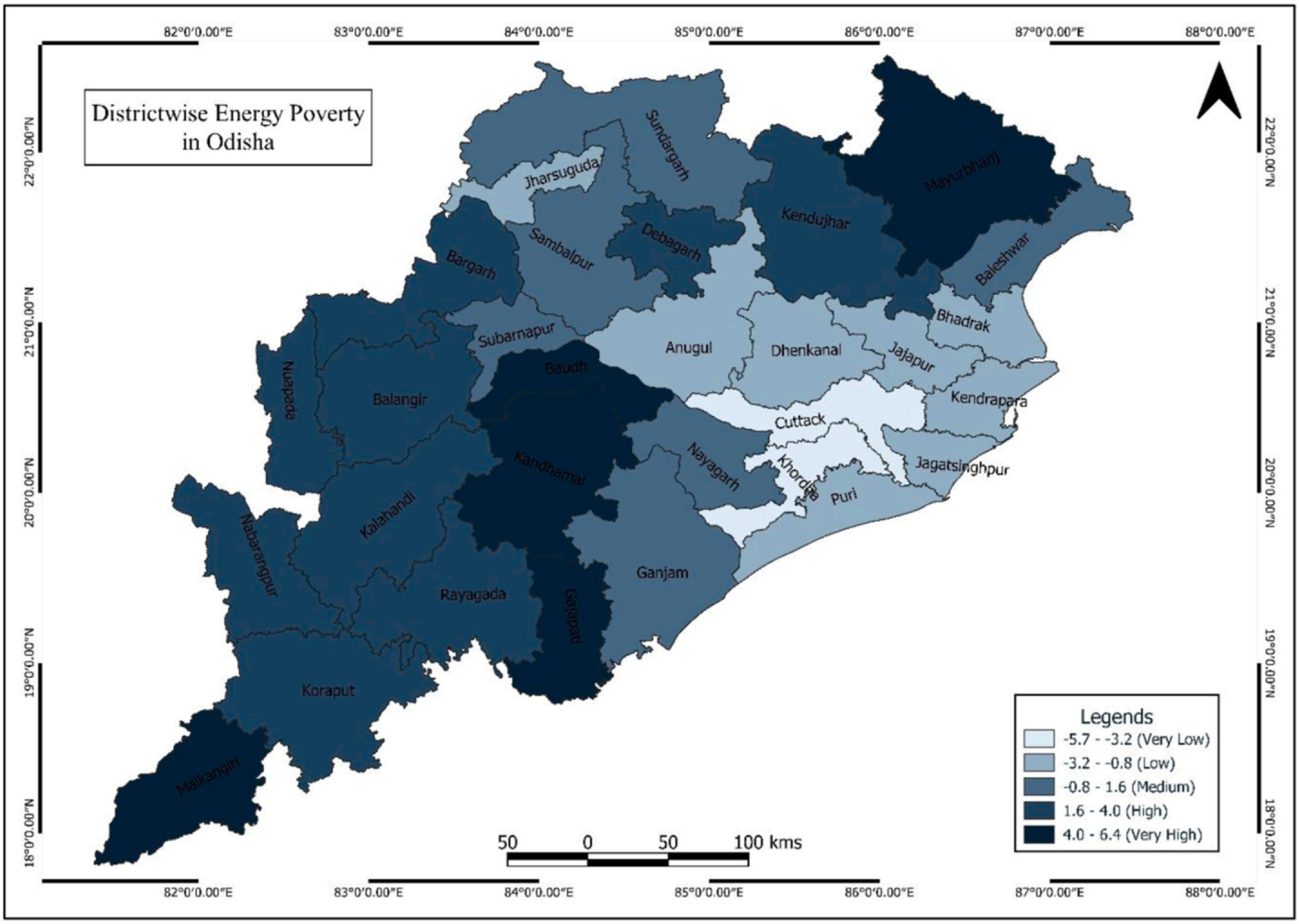

Fig. 4.6. District-wise Energy Poverty in Odisha.
Source: Prepared by the author using QGIS

nevertheless assist or service to residential customers. A specific community solar program could be proposed by MNRE or the states, focusing on low-income customers in rural and semi-urban regions who receive large electricity subsidies. Combining community solar with battery storage could multiply discoms' advantages.

Additionally, the national administration should establish connections with several energy material exporters to negotiate volume-based discounts, price guarantees to protect against external shocks, and other price stability mechanisms in order to mitigate the high rates of inflation and price shocks caused by global variations. Although rural areas only utilize a small portion of the overall amount of power and fossil fuels used, they tend to be largely ignored from the national energy and development initiatives. In India, assessing the availability of electricity is particularly challenging due to issues with unauthorized connections, transmission and distribution losses, and other issues. Furthermore, the lack of reliable data and indicators that measure quality parameters contributes to the continued extreme irregularity of the energy supply's quality and reliability. The population's dependence on solid fuels in developing nations increases the energy poverty condition and further impedes the advancement of several SDGs like SDG1, SDG3, SDG4, SDG5, SDG7, SDG10, SDG11 and SDG13. Thus, considering the multifaceted nature of energy poverty and its hindrance to achieve SDGs, the study recommends policymakers and energy suppliers to use a bottom-up approach to design and implement interventions, that will address the challenges locally, will enhance inclusivity and help in creating awareness about using modern energy services.

7. Limitations and future scope

The study only tried to identify the spatial inequalities persisting at intra and inter-district levels. Implications of energy poverty concerning the use of renewable energy or its impact on the national economy, environment and the achievement of SDG can be understood further. Also, the study tried to look at energy poverty from a very traditional lens, usage of traditional fuels, that needs to be expanded. Another limitation of the research also was the use of the secondary data, although it used the latest data available by the secondary organisations, they are very old and many changes in the energy poverty condition of the state have taken place in these few years that the study is not able to present, that can be addressed by using primary survey techniques.

Multi-dimensional framework used for the study considers accessibility, affordability and geographical dimensions to measure the energy poverty condition, but the framework needs more attention to be a robust one. Future researches should focus more on the quality and reliability aspect of the energy services, so that the inequality persisted in the distribution of energy services can be addressed. It is also important not to look on the energy challenges only with an economic lens at macro scale, rather looking at the social implications of available safe energy sources at different levels will be helping the economies to attain the objectives of sustainable development goals in true sense.

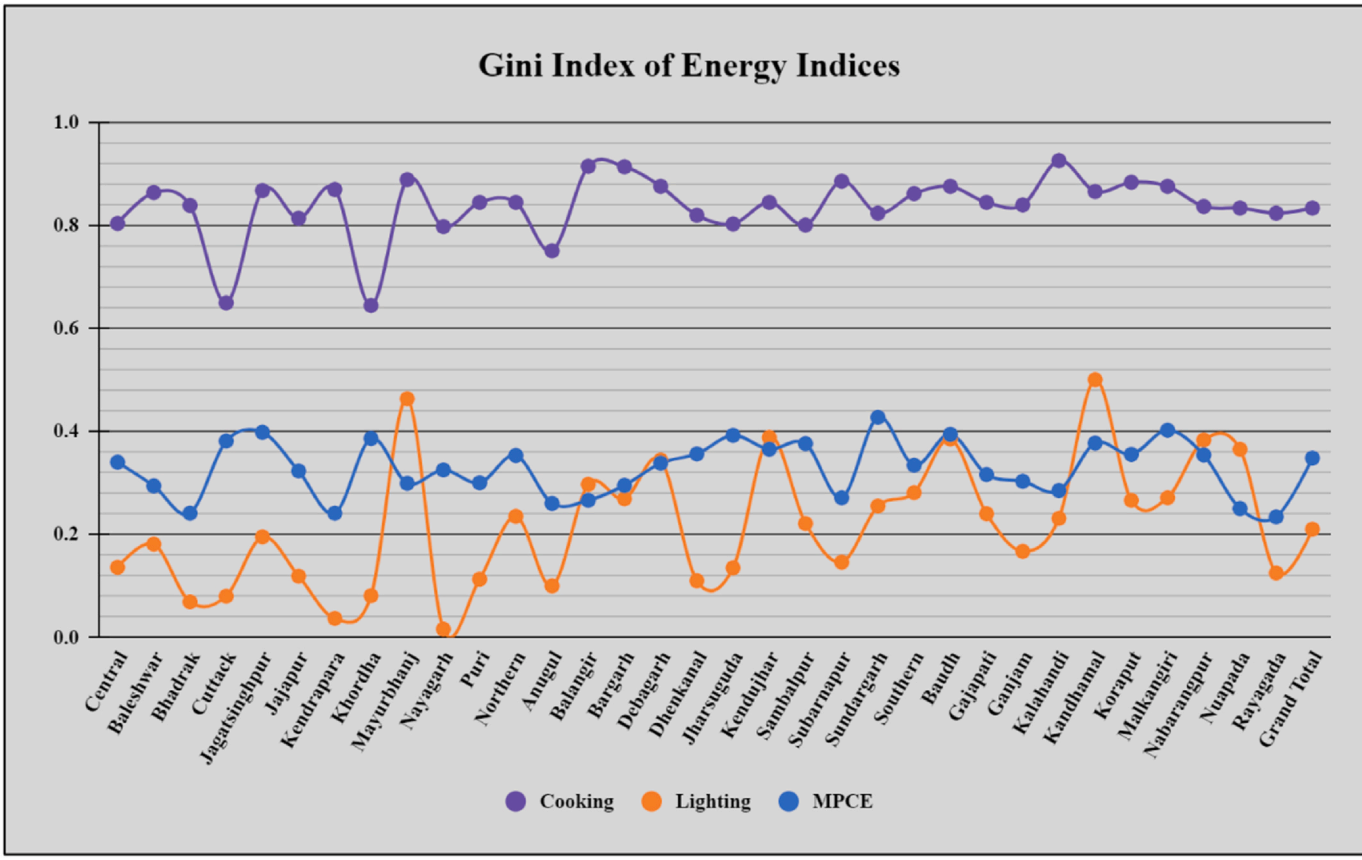

Fig. 4.7. District-wise Gini index of Energy Indices.
Source: Prepared by the author using NSS data

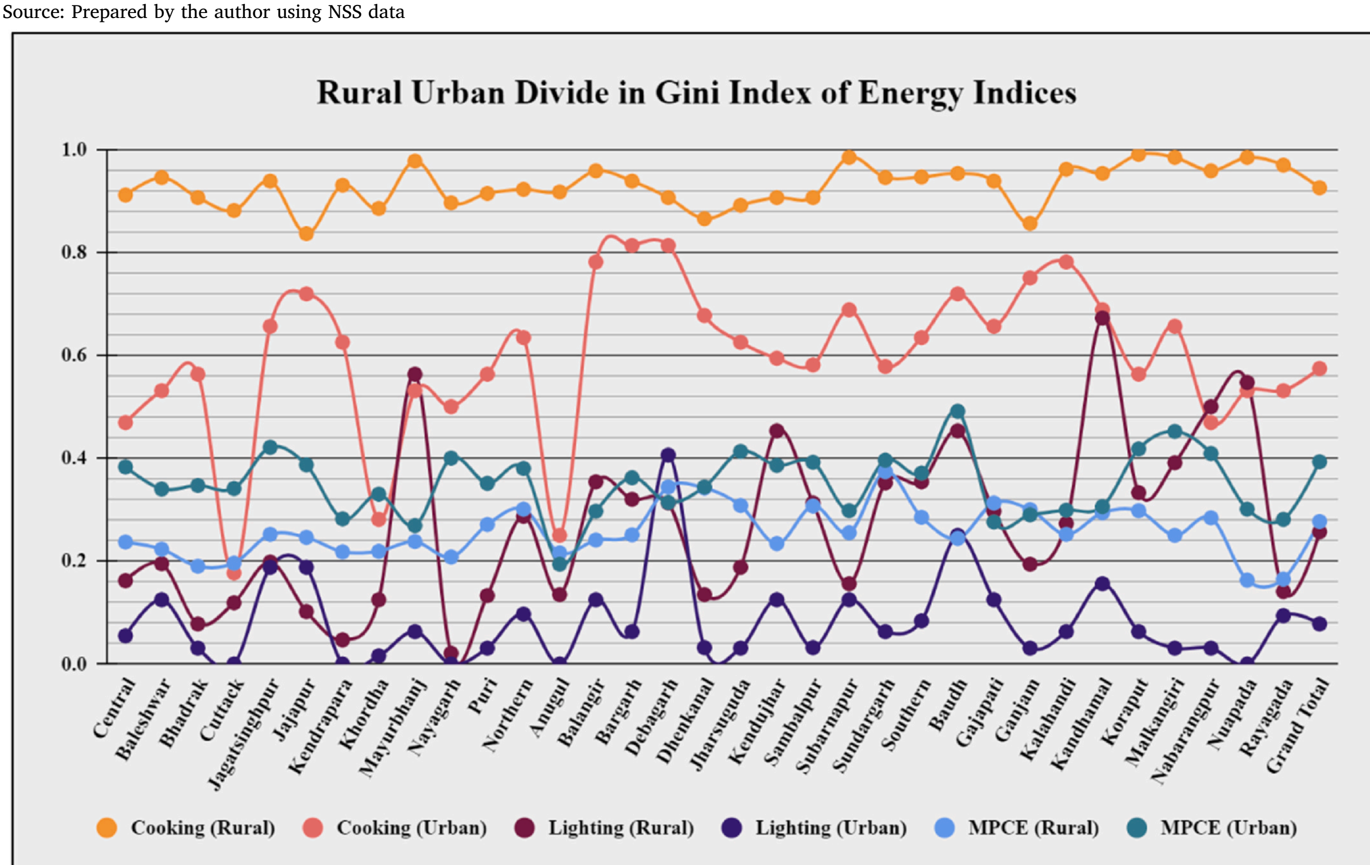

Fig. 4.8. Rural Urban divide in Gini index of Energy Indices.
Source: Prepared by the author using NSS data

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