Sustainability Of Natural Resources In Chandel District, Manipur

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ABSTRACT
The present paper explores how population change is shaping the use and health of natural resources in Chandel District, Manipur. We assessed ecological sustainability through footprint accounting and water quality tests. Data on population (1951-2011), land and forest cover and shifting-cultivation records were analysed to estimate ecologically productive land per capita (EPLC) and ecological deficit land per capita (EDLC) against a 2 ha global benchmark. Overall land and forest resources show a narrow surplus, but the spread of jhum with shorter fallows has created sizeable ecological deficits. Population rose from 24,049 in 1951 to 144,028 in 2011 and annual growth stayed above the 0.5% sustainability mark, peaking at 6.66% in 2001. Water from eight sources was evaluated using the Weighted Arithmetic Water Quality Index of springs, taps and tube wells scored excellent to good, while wells and hand pumps were poor, and ponds and rivers very poor because of turbidity, nutrient loads and faecal pollution. Results stress the urgency of moderating growth, restoring resources and improving water governance.

Introduction

Population growth and environmental sustainability are closely interlinked in ecologically fragile regions such as Northeast India. Chandel District of Manipur, characterized by hilly terrain and rich biodiversity, has undergone significant demographic changes over the past six decades. Rapid population growth, particularly between 1971 and 2001, has intensified stress on natural resources, land use systems and water availability. Similar trends have been observed globally, where population dynamics have been directly associated with environmental degradation and declining ecosystem services (Cohen, 2003; United Nations, 2019).

Water, being a critical natural resource, is highly sensitive to both natural and anthropogenic pressures. In many rural and tribal regions of Northeast India, traditional sources such as springs, wells, rivers and ponds are the primary providers of domestic water. However, increasing population density, agricultural intensification and improper waste disposal often lead to deterioration in water quality (Kumar *et al.,* 2017; Singh *et al.,* 2020). The Water Quality Index (WQI) and specifically the Weighted Arithmetic Water Quality Index (WQI), provides a quantitative measure for assessing overall water suitability for drinking purposes (Brown *et al.,* 1972; Tyagi *et al.,* 2013).

Against this backdrop, the present study evaluates the decadal population growth and sustainability status of Chandel District from 1951 to 2011, and assesses the mean water quality of major drinking water sources using WQI classification. The findings provide insights into the nexus between population dynamics and environmental sustainability in a resource-sensitive region.

Materials and Methods

Chandel District is located in the southeastern part of Manipur, India, sharing an international boundary with Myanmar. The district lies between 23°59′N to 24°28′N latitudes and 93°45′E to 94°18′E longitudes, covering a predominantly hilly terrain with scattered valleys. The population comprises diverse tribal communities dependent on agriculture and forest resources.

Secondary data on decadal population from 1951 to 2011 were collected from Census of India reports. Sustainability status was assessed based on annual growth rate thresholds following established demographic-environmental criteria (Ehrlich & Holdren, 1971; Cohen, 2003). Sustainable development based on ecologically productive land per capita (EPLC) and ecologically deficit land per capita (EDLC) were determined by following Rees (1992). The three criteria of “sustainable”, “critical” and “destructive” have been put framed for all human activities like population increase, economic development, deforestation rate,

forest coverage, agricultural development and urbanization, then explored the resources, following Murai (2005).
Water samples from major sources such as tap water, tube wells, springs, wells, hand pumps, ponds and rivers were analyzed to evaluate drinking water suitability. Some physicochemical parameters were selected as they are widely recognized as critical indicators of water quality and public health risk (WHO, 2017; Kumar *et al.,* 2017; Tyagi *et al.,* 2013).
The Weighted Arithmetic Water Quality Index (WQI) method was employed following Brown *et al.* (1972) and Tyagi *et al.* (2013). Each parameter was assigned a weight based on relative importance to human health and WQI values were computed using the formula:

WQI=(qi x wi)/ wi

Where, q_i is the quality rating of the i^{th} parameter, and w_i is its unit weight.
The computed WQI values were categorized into classes (Excellent < 25, Good 26–50, Poor 51–75, Very Poor 76–100, Unsuitable > 100) to assess the suitability of drinking water across sources(Gaur *et al.,* 2022).

Results and Discussion

The decadal population growth and sustainability status of Chandel District between 1951 and 2011 displayed in Table 1 and the population of Chandel District exhibited a consistent upward trajectory between 1951 and 2011, rising from 24,049 in 1951 to 1,44,028 in 2011 (Fig. 1).

Table 1: Decadal population growth and sustainability status of Chandel District (1951–2011)

Year	Population (number)	Population increase	Annual growth rate (%)	Sustainability status
1951	24,049	–	–	C (criterion)
1961	27,679	3,630	1.50	D (critical)
1971	38,723	11,044	3.99	D (destructive)
1981	56,444	17,721	4.50	D (destructive)
1991	71,014	14,570	2.58	D (destructive)
2001	1,18,327	47,313	6.66	D (destructive)
2011	1,44,028	25,701	2.17	D (destructive)

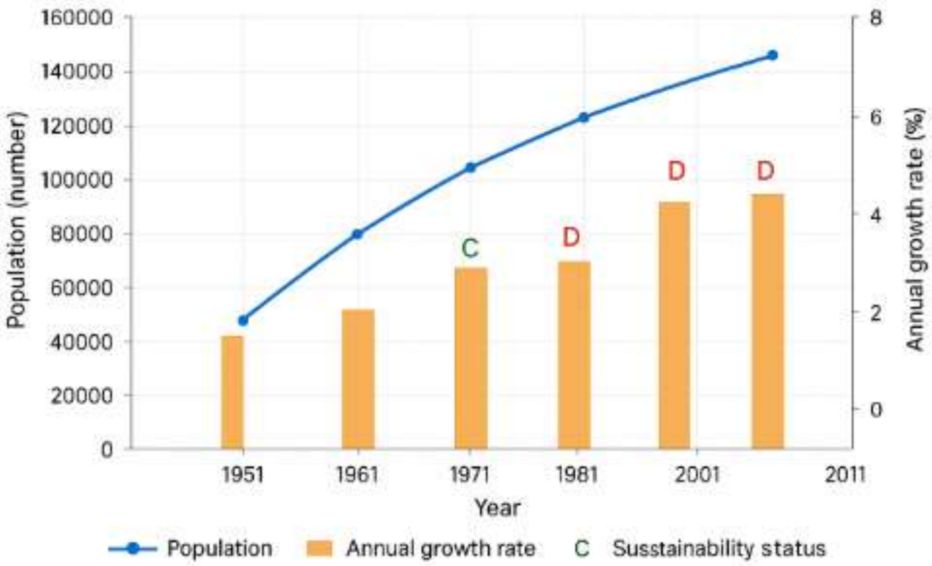

Fig. 1: Population Growth Dynamics of Chandel District (1951–2011)

Table 1 highlight a clear upward trend in population across six decades, with a more rapid increase observed from 1971 onwards. In 1951, the district had a total population of 24,049 persons, which rose steadily to 27,679 in 1961, registering an annual growth rate of 1.50%. According to the criteria set by Murai (2005), this falls within the critical category, as growth exceeded the sustainable threshold of 0.5% but remained below the destructive level. However, from 1961 onwards, the district entered a phase of accelerated population growth, consistently exceeding 2% per annum. This marked the beginning of a destructive trajectory.

Between 1961 and 1971, the population increased by 11,044 persons, corresponding to an annual growth rate of 3.99%, which pushed the district firmly into the destructive category. The following decade (1971-1981) recorded an even higher growth of 17,721 persons at an annual rate of 4.5%, further straining the carrying capacity of local resources.

A slight moderation was seen between 1981 and 1991, where the growth rate dropped to 2.58% per annum, but this still remained well above the sustainable limit. The decade 1991-2001 witnessed the most dramatic increase, with the population rising by 47,313 persons and the annual growth rate peaking at 6.66%. This represents an unsustainable demographic expansion that would have placed extraordinary pressure on land, forests and other natural resources. By 2011, growth had slowed to 2.17% per annum, yet it remained within the destructive zone.

These results indicate that for six consecutive decades, Chandel District's population dynamics have largely been unsustainable. The district shifted from a critical stage in the early post-independence period to a destructive stage from 1961 onwards, where rapid growth overwhelmed the ecological balance. This aligns with observations by Meadows (1995), who cautioned that unchecked demographic expansion leads to "overshoot and collapse" when resource use exceeds ecological capacity. The findings also resonate with Rees (1992) and Pearce (1994), who highlighted that population growth beyond the biocapacity of ecosystems leads to ecological deficits and heightened environmental stress.

These findings align with studies indicating that unchecked demographic growth in fragile hill ecosystems exacerbates land-use change, deforestation, and biodiversity loss (Sharma & Chamarik, 1994; Singh, 2006). Moreover, unsustainable growth patterns disrupt the balance between resource availability and human needs, posing significant challenges to long-term ecological resilience (Renard *et al.,* 1997; Kannan *et al.,* 2014; Sharda *et al.,* 2016).

The sustained destructive growth trend has serious implications for the district's natural resources. With fixed land and forest areas, increasing population density reduces per capita availability of ecologically productive land. This accelerates the ecological deficit, diminishes forest cover and promotes unsustainable practices such as expansion of jhum cultivation. If left unchecked, the district risks reaching irreversible ecological degradation, affecting not only environmental sustainability but also food security, livelihoods and cultural practices dependent on natural resources.

The mean water quality parameters and WQI classification for major drinking and surface water sources in Chandel District highlighted in Table 2.

Table 2: Mean water quality parameters and WQI classification

Source	Key observations	Mean WQI	Quality class
Tap water	Neutral pH, low turbidity, high DO, negligible coliform	32.5	Good
Tube well	Slightly alkaline, high hardness and TDS but below permissible limits	41.0	Good
Spring	Low TDS, near-neutral pH, no coliform	22.1	Excellent
Well	Moderate hardness, occasional coliform contamination	55.0	Poor
Hand pump	Similar to wells; seasonal variability in turbidity	58.3	Poor
Pond	High turbidity, high BOD/COD, faecal coliform present	87.6	Very poor
Rivers (Maha, Chakpi, Machi)	Elevated turbidity and nutrient loads, low DO during monsoon	89.5	Very poor

Table 2 summarizes the mean water quality parameters and WQI classification for major drinking and surface water sources in Chandel District. The results highlight considerable heterogeneity in water quality, ranging from excellent spring water to very poor pond and river waters.

Spring water exhibited the best quality, with a mean WQI of 22.1, categorized as excellent. Its low TDS, near-neutral pH and absence of coliforms indicate minimal anthropogenic disturbance and effective natural filtration in hilly terrains. Tap water and tube wells were rated good (32.5 and 41.0 respectively), demonstrating neutral to slightly alkaline pH, adequate dissolved oxygen and negligible coliform contamination. Tube well water, while safe, reflected higher hardness and TDS, a common characteristic of groundwater in hard-rock and alluvial aquifers (Singh *et al.,* 2018).

In contrast, wells and hand pumps showed poor quality, with WQI values of 55.0 and 58.3, respectively. These sources were characterized by moderate hardness, seasonal turbidity and occasional microbial contamination, reflecting vulnerability to shallow aquifer pollution and poor sanitary infrastructure. Such patterns are

consistent with earlier findings that open wells and shallow hand pumps in rural India are highly susceptible to microbial infiltration (Ravikumar *et al.,* 2013).
Ponds and rivers, particularly the Maha, Chakpi and Machi were classified as very poor, with mean WQI values of 87.6 and 89.5 respectively. Pond water was highly turbid, with elevated BOD and COD and consistent faecal coliform presence, indicating organic pollution and runoff from human and livestock activities. Similarly, rivers exhibited high turbidity and nutrient enrichment, especially during the monsoon, when heavy runoff reduces dissolved oxygen levels. These results mirror observations from other Indian catchments, where river systems suffer seasonal declines in quality due to untreated sewage, agricultural runoff, and soil erosion (Sharma *et al.,* 2021; Bora & Goswami, 2017).
The classification clearly demonstrates a gradient of water qualityexcellent to good (spring, tap, tube wells), poor (wells and hand pumps) and very poor (ponds and rivers). The reliance on contaminated surface sources during water-scarce periods poses significant health risks. The presence of faecal coliforms in ponds and rivers indicates direct fecal contamination, which is linked to waterborne diseases (WHO, 2017). Furthermore, increasing turbidity and nutrient load during monsoon months threaten not only human health but also aquatic biodiversity and ecosystem stability.
The findings emphasize the need for integrated water resource management in Chandel District. Protection of spring sources, regular monitoring of wells and hand pumps, and urgent interventions for surface water (ponds and rivers) through sanitation improvements, community-level treatment, and catchment management are essential. This aligns with global calls for achieving Sustainable Development Goal 6 (clean water and sanitation) in vulnerable rural regions.

Conclusion

The analysis of population dynamics in Chandel District (1951-2011) reveals a continuous increase in population, with sharp growth during the decades of 1971-2001. This rapid expansion placed considerable pressure on natural resources and sustainability, as reflected in the sustainability status, which remained largely destructive (D) across decades. Such demographic changes indicate that unchecked population growth has been a major driver of ecological stress in the region.
Parallel assessment of water quality through theWQI classification highlights critical concerns regarding safe drinking water sources. While springs and tap water exhibit excellent to good quality, traditional sources such as wells, hand pumps, ponds and rivers show poor to very poor quality due to turbidity, hardness, nutrient enrichment and microbial contamination. The contrast suggests that although natural springs remain reliable, increasing population and anthropogenic activities are degrading other water sources.
Henceforth, the findings emphasize the interconnectedness of population growth and environmental sustainability in Chandel District. Population pressure not only affects land use and resource extraction but also directly contributes to deteriorating water quality. Sustainable population management, protection of natural springs and community-based water treatment strategies are essential to ensure long-term ecological and human well-being in the region.

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