The impact of geographical aspects on public health in Uttar Pradesh: A review

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Abstract

Uttar Pradesh (UP), India's most populous state, displays marked physiographic diversity spanning the sub-Himalayan Bhabar–Terai belt, the Ganga–Yamuna alluvial plains, the eastern flood-prone lowlands, and the drought-affected Bundelkhand plateau. This diversity in terrain, hydrology, and climate is closely mirrored by spatial variation in the state's disease burden and health-service performance. This review synthesises peer-reviewed literature on the geography–health relationship in UP, examining vector-borne disease clustering in the Terai, geogenic arsenic and fluoride contamination across the Ganga plain, flood-related morbidity in the eastern districts, drought-linked undernutrition in Bundelkhand, and the compounding influence of climate change and uneven health-infrastructure distribution. Findings indicate that geography operates not as a background variable but as a proximate determinant of disease exposure, health-seeking behaviour, and service accessibility, producing persistent east–west and rural–urban disparities in indicators such as infant and maternal mortality. The review concludes that geographically targeted, geospatially informed public health planning rather than uniform state-wide programming is essential to narrow these disparities and strengthen resilience to emerging climate-linked health risks.

Keywords: Uttar Pradesh, Health geography, Geogenic contamination, Vector-borne disease, Flood, Climate change, Health disparities

1. Introduction

Health outcomes are never distributed randomly across space; they are shaped by the physical environment in which populations live, work, and seek care. Health geography the study of how place, environment, and spatial organisation of services influence disease occurrence and health-care access has become central to understanding regional health disparities within large, environmentally heterogeneous countries such as India (Bhunia *et al*., 2011) [5]. Uttar Pradesh (UP), with a population exceeding 200 million, is India's most populous state and one of its most physiographically varied, stretching from the forested sub-Himalayan foothills in the north to the semi-arid Bundelkhand plateau in the south.

Despite decades of national health programming, UP continues to record some of the poorest maternal and child health indicators in the country, alongside persistent inter-district variation (Anand, 2014; Halli *et al*., 2024) [4, 9]. A substantial body of evidence now links this variation not merely to socio-economic status but to the underlying terrain, hydrogeology, drainage pattern, and climate of different parts of the state. This review brings together recent peer-reviewed literature to examine how the geography of Uttar Pradesh its river systems, aquifers, floodplains, and drought-prone uplands shapes patterns of infectious and non-communicable disease, nutritional status, and access to health services, and to identify implications for geographically targeted public health planning.

2. Geographical profile of Uttar Pradesh

Uttar Pradesh can be broadly divided into four physiographic zones. In the north, the Bhabar–Terai belt forms a narrow, humid, forest-fringed tract abutting the Himalayan foothills, characterised by a high water table and dense vegetation that favours the breeding of disease vectors. South of this lies the vast Ganga–Yamuna alluvial plain, which occupies the bulk of the state and is further divided into the upper, middle, and eastern Ganga plains; this zone is intensively irrigated by tube wells drawing on deep alluvial aquifers. The eastern and south-eastern districts, drained by the Ganga, Ghaghara, Rapti, and Saryu rivers, form a low-lying, poorly drained floodplain that is inundated almost every monsoon. Finally, the Bundelkhand region in the south-west sits on the hard-rock Vindhyan plateau, receiving comparatively low and erratic rainfall and lacking the groundwater recharge capacity of the alluvial plains (Hazard Profile of Uttar Pradesh, n.d.; Frontiers, 2026) [8].

These zones differ not only in relief and hydrology but also in population density, cropping pattern, and infrastructure development, all of which interact with the physical environment to produce distinct disease and nutrition profiles, summarised in Table 1 and Figure 1.

3. Materials and Methods

This is a narrative review. Peer-reviewed articles, systematic reviews, and government/WHO technical reports addressing the intersection of geography, environment, and public health

in Uttar Pradesh (and, where UP-specific literature was limited, the broader Ganga basin) were identified through PubMed, Web of Science–indexed journals, and publisher databases (Springer, Elsevier ScienceDirect, PLOS, Frontiers, MDPI). Search terms combined "Uttar Pradesh" or "Ganga plain" or "Terai" or "Bundelkhand" with "health," "disease," "arsenic," "flood," "kala-azar," "encephalitis," "malnutrition," and "climate change." Priority was given to studies published within the last two decades, supplemented by foundational earlier work where relevant. Findings were synthesised thematically around the major physiographic zones of the state.

4. Geography and Disease patterns

4.1 The terai belt: Vector-borne disease clustering

The Bhabar–Terai tract of northern and eastern UP has long been recognised as a hotspot for vector-borne disease. Acute Encephalitis Syndrome (AES), including Japanese encephalitis, has produced recurrent seasonal outbreaks in the Gorakhpur–Basti division since 1978, sustained by the region's dense paddy cultivation, pig-rearing practices, and mosquito-breeding wetlands; case-fatality rates have fallen from roughly one-third of cases in the early outbreak years to markedly lower levels following syndromic surveillance and vaccination efforts, though the syndrome remains a major cause of childhood morbidity and mortality in the belt (Srivastava *et al*., 2022) [13].

This spatial specificity has informed India's kala-azar elimination programme, which has achieved a marked national decline in reported cases over the past two decades, although sustaining elimination in ecologically favourable pockets of eastern UP requires continued vector surveillance (Kumar *et al*., 2025, PLOS NTD).

4.2 The Ganga plain: Geogenic contamination of groundwater

The alluvial aquifers of the middle and upper Ganga plain in eastern UP present a distinct geogenic health hazard: naturally occurring arsenic mobilised from Himalayan-derived sediments. A landmark survey of tube wells in Ballia, Varanasi, and Ghazipur districts found that nearly half of more than 4,780 samples exceeded the WHO guideline value of 10 µg/L, with concentrations reaching over 3,000 µg/L in some wells; clinical screening in affected villages identified arsenical skin lesions, including melanosis and keratosis, in roughly one in five adults examined (Ahamed *et al*., 2006) [1]. Subsequent basin-wide assessment estimates that approximately 15 million people in UP are exposed to hazardous groundwater arsenic levels, making it the third most affected state in India after West Bengal and Bihar (Chakraborti *et al*., 2018) [6].

The problem is compounded by the state's continuing reliance on hand pumps and tube wells for drinking water in rural areas, where piped, tested supply remains limited, leaving exposure levels and awareness highly uneven across even neighbouring villages (Ahamed *et al*., 2006) [1]. Fluoride contamination, driven by different but co-located geochemical processes, adds a further layer of geogenic water-quality risk in parts of the plain, though its distribution is less extensively mapped than that of arsenic.

4.3 Eastern floodplains: Flooding and child health

Eastern UP's low gradient and confluence of major Himalayan rivers make it one of India's most flood-prone regions; roughly a quarter of the state's geographical area is flood-affected in an average monsoon, and UP is classed, along with Bihar, Assam, and West Bengal, among the states with the largest share of "very high" or "high" flood-risk districts nationally (Uttar Pradesh State Disaster Management Authority, n.d.). A study conducted in Bahraich district found that recurrent flooding was associated with a significantly elevated prevalence of diarrhoea among children under five, consistent with the broader epidemiological literature linking flood exposure to waterborne and faecal–oral disease transmission through contamination of shallow water sources and disruption of sanitation infrastructure (Joshi *et al*., 2011; Ahern *et al*., 2005) [10, 2].

Beyond acute morbidity, floods disrupt routine maternal and child health service delivery antenatal check-ups, institutional delivery, and immunisation sessions are frequently postponed or inaccessible when roads and health sub-centres are submerged compounding the eastern districts' already weaker baseline health infrastructure (Ahern *et al*., 2005) [2]. Globally, flood exposure is also increasingly linked to injury, mental-health harms, and longer-term nutritional consequences in children, effects that are amplified in settings, like eastern UP, with high baseline poverty and limited health-system redundancy (Wu *et al*., 2024) [14].

4.4 Bundelkhand: Drought, Water Scarcity, and Undernutrition

In direct contrast to the flood-prone east, the Bundelkhand region of south-western UP is characterised by hard-rock geology with poor groundwater recharge, low and erratic rainfall, and chronic drought. Repeated agrarian distress cycles have been linked to reduced dietary diversity, seasonal food insecurity, and distress out-migration of working-age adults, leaving women, children, and the elderly disproportionately exposed to the health consequences of resource scarcity (Climate Change and Uttar Pradesh: Issues, Challenges, 2021). District-clustering analyses of preschool nutritional anthropometry across UP have found that better-performing clusters concentrate in the more prosperous western and eastern plains, while drought-prone and geographically marginal districts show poorer child growth indicators, a pattern the authors attribute in part to underlying ecological and livelihood conditions rather than administrative boundaries alone (nutritional anthropometric clustering study, PMC3657902).

Water scarcity in Bundelkhand also indirectly affects health through reduced hand-washing and hygiene practice, increased reliance on distant or contaminated sources, and heightened physical burden on women and girls tasked with water collection a geography-driven pathway to ill health distinct from, but complementary to, the flood- and contamination-related pathways operating elsewhere in the state.

4.5 Climate change: Heat waves and compounding extremes

Climate change is now amplifying several of the geographic health risks described above. Regional climate modelling using

the PRECIS framework projects intensifying heat-wave frequency and severity across UP, with implications for heat-related mortality, agricultural productivity, and energy demand for cooling risks that fall hardest on the state's large rural population with limited access to health care and cooling infrastructure (Frontiers, 2026) [8]. At the national level, changing monsoon patterns and increasingly intense single-day rainfall events are projected to worsen flood risk in the Ganga basin even as some tracts, including parts of UP, face growing groundwater stress and drought risk, producing a state that must simultaneously plan for flood and drought resilience (Health SDGs are at risk from climate change, PLOS One, 2025; Climate Change and Uttar Pradesh, 2021). Lightning-related fatalities, heat-wave hospitalisations, and vector range-shifts linked to rising temperatures further illustrate how climate change interacts with UP's existing physiographic vulnerabilities rather than introducing an entirely separate hazard profile (npj Climate Action, 2025).

5. Geography and health system access

Geography shapes not only disease exposure but also the spatial distribution of health-care infrastructure itself. District-level composite indices consistently find that eastern UP districts lag behind western districts in the availability of health infrastructure, household amenities, and health-care affordability, even though eastern districts often carry a heavier infectious-disease and flood burden (Anand, 2014) [4]. Analyses of specialist staffing at Community Health Centres between 2002 and 2012 found that the overall shortage of specialists reached 80.7% of requirement by the end of the study period, with within-district inequality rather than between-district inequality alone accounting for the majority of total variation, and with roughly half of this within-district inequality concentrated in only twenty districts, most located in eastern and central UP (Singh, 2019) [11].

Spatial-accessibility modelling using the Three-Step Floating Catchment Area method in Pratapgarh and Kanpur Dehat districts found that 40% and 90% of villages, respectively, faced a shortage of in-patient care facilities, with distance to the nearest urban agglomeration emerging as the strongest predictor of poor access a direct geographic mechanism independent of raw facility counts (application of GIS in public health in India, ResearchGate/PMC review).

These infrastructural gradients translate into measurable outcome disparities. State-wide data show UP's infant mortality rate (62 per 1,000 live births) and maternal mortality ratio (197 per 100,000 live births) markedly exceeding those of better-served states such as Kerala (6 and 8, respectively), a gap attributable to combined effects of health-care access, female literacy, and socio-economic conditions that themselves vary geographically within UP (UPSC Mains Geography, 2023; see Figure 2). A recent GIS-based Maternal and Child Health Index integrating nine NFHS-5 indicators through an AHP–TOPSIS framework similarly found substantial inter-district clustering of poor performance, information the authors argue should directly inform spatially targeted resource allocation rather than uniform state-wide programming (Ahmed *et al*., 2026). Complementary work on family-planning coverage found modern contraceptive use ranging from 39.3% in Faizabad division to 72.4% in Jhansi division, with inequality persisting down to the sub-district ASHA-worker catchment level (Halli *et al*., 2024) [9].

Table 1: Physiographic zones of Uttar Pradesh and their associated public health consequences

Physiographic zone	Dominant geographic / Environmental feature	Principal public health consequence
Bhabar–Terai (sub-Himalayan belt)	High water table, forest fringe, humid microclimate, sand-fly and mosquito breeding habitat	Kala-azar (visceral leishmaniasis); Acute Encephalitis Syndrome / Japanese encephalitis; zoonotic spill-over
Upper & Middle Ganga Plain (central Doab)	Alluvial aquifers with geogenic arsenic and fluoride; dense population, intensive tube-well irrigation	Arsenicosis, skin and internal cancers, fluorosis; groundwater-linked chronic disease burden
Eastern UP floodplain (Ganga–Ghaghara–Rapti–Saryu system)	Low-lying, flood-prone, poor drainage, seasonal river overflow	Post-flood diarrhoeal outbreaks, drowning and injury, disruption of antenatal and immunisation services
Bundelkhand (southern plateau / Vindhyan fringe)	Undulating hard-rock terrain, low and erratic rainfall, chronic water scarcity	Drought-linked child and maternal undernutrition, distress migration, limited facility access

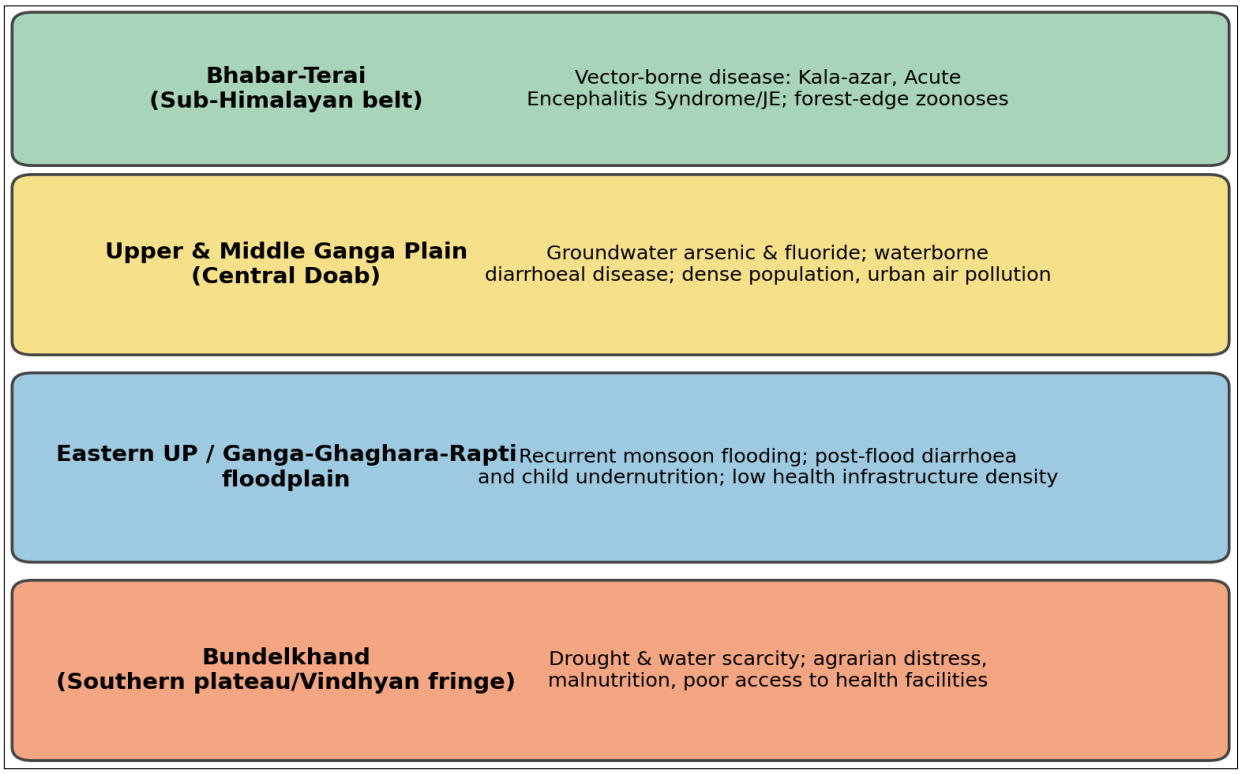

Fig 1: Schematic representation of the major physiographic zones of Uttar Pradesh and their principal public health associations. (Author-generated schematic; not to scale)

Table 2: Selected geography-linked health and infrastructure indicators, Uttar Pradesh compared with other states

Indicator	Uttar Pradesh	Comparator
Infant Mortality Rate (per 1,000 live births, SRS 2018)	62	Kerala: 6
Maternal Mortality Ratio (per 100,000 live births, SRS)	197	Kerala: 8
Districts with groundwater arsenic > WHO limit (10 µg/L)	25 of 75 districts	Bihar: 22 of 38 districts
Estimated population exposed to hazardous groundwater arsenic	~15 million	West Bengal: ~28 million; Bihar: ~21 million
Kala-azar–endemic districts (of national total, 4-state belt)	6 of 75 districts	Bihar: 33 of 38 districts
Specialist shortage at Community Health Centres (2012–13 est.)	80.7% of requirement unmet	Gini index of specialist distribution: 0.74

Sources: SRS 2018 (cited in UPSC Mains Geography, 2023); Ahamed *et al*. (2006) [1]; Chakraborti *et al*. (2018) [6]; World Health Organization (n.d.); Singh (2019) [11]

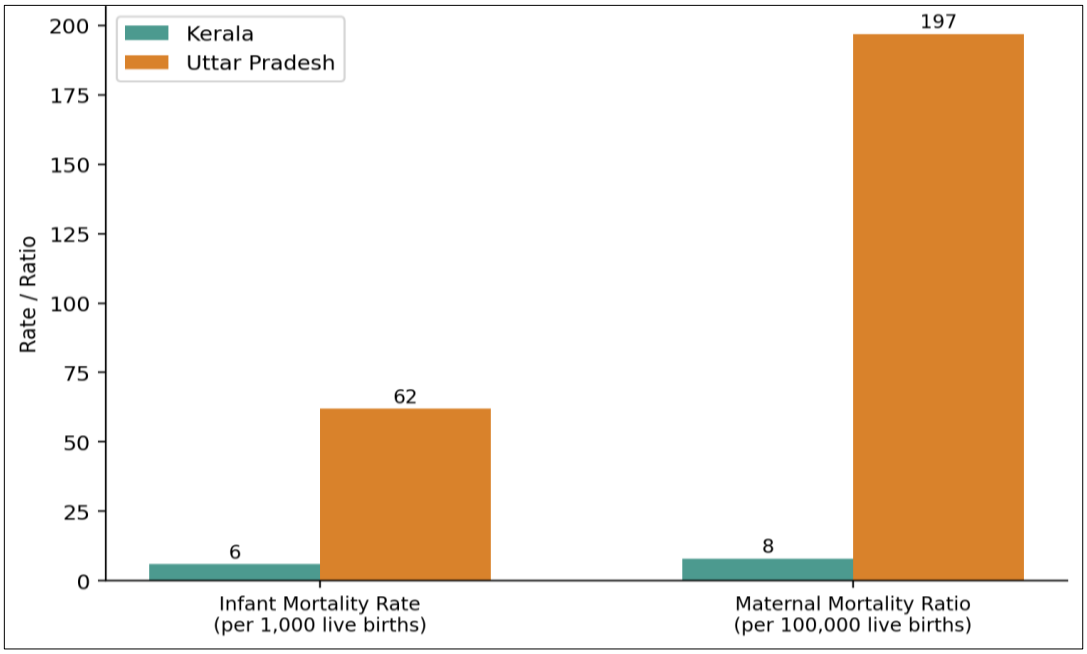

Fig 2: Regional disparity in maternal and child health outcomes: Uttar Pradesh versus Kerala (SRS, 2018)

6. Discussion

The evidence reviewed here indicates that geography in Uttar Pradesh functions as a proximate, not merely a background, determinant of health. Four distinct geographically bounded risk profiles emerge: an infectious-disease risk concentrated in the humid Terai; a chronic geogenic-contamination risk concentrated in the Ganga plain aquifers; an acute flood-and-diarrhoeal risk concentrated in the eastern lowlands; and a chronic undernutrition and access risk concentrated in drought-prone Bundelkhand. Health infrastructure distribution does not consistently compensate for these differential exposures indeed, some of the districts with the heaviest environmental disease burden also show the weakest specialist staffing and facility access, suggesting a doubling rather than an offsetting of geographic disadvantage (Singh, 2019; Anand, 2014) [11, 4]. Scaling up such geospatially informed surveillance and resource-allocation systems, integrated with climate projections for heat and flood risk, represents a logical next step for state health planning. Equally important is recognising that administrative boundaries (districts, divisions) do not always align with the ecological boundaries that actually drive disease transmission or vulnerability, meaning that health planning units may sometimes need to be redrawn along watershed, floodplain, or agro-climatic lines rather than purely administrative ones.

7. Conclusion

Geography terrain, hydrology, climate, and the spatial organisation of settlements and services exerts a demonstrable and multi-pathway influence on public health outcomes across Uttar Pradesh. From sand-fly-borne kala-azar in the Terai to arsenic-laden aquifers in the Ganga plain, monsoon flooding in the east, and drought-linked undernutrition in Bundelkhand, the state's disease and nutrition burden closely tracks its physiographic diversity. Because health infrastructure does not automatically compensate for these environmental gradients, and may in places compound them, future public health strategy in UP would benefit from explicitly geography-informed, geospatially targeted planning integrating environmental hazard mapping, climate-risk projection, and health-service accessibility modelling rather than uniform, state-wide programme design.

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