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Contents

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ENVIRONMENT AND HUMAN WELL-BEING: REVISITING LINKAGES AND MAJOR ISSUES

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Abstract

Ensuring a better state of well-being has become the core of the national building process since the decolonisation period of the 1950s. Improved Quality of Life (QoL) is possible only with a pristine availability of air, water, soil, forest and social settings. Environmental well-being is a situation where all the physical elements along with social components in-and-around the society are favourable to ensure the necessities for individuals and households for their development, growth and higher aspirations for the future. The current investigation aims to conceptualise the intertwined interaction between environmental variables and human well-being, particularly concerning Indian rural areas. The study is based on an analysis of a systematic review of selected literature, and the results are supplemented with various secondary data inputs. The study shows that states with low Human Development Index (HDI) are performing poorly with multiple indicators of environmental quality. An increasing number of suicides in high-income states is a serious concern to the sustainability of human environments. The study's findings underscore a strong association between the natural and social environment and individual, household and societal well-being.

Key Words: Environment, Water, Social Capital, Economy, Well-being

Introduction

Human beings are living in the dynamic interfaces of man- environment relationships since the beginning of early civilisation. This intertwined association is well reflected in transforming the symbiotic relationship between human adaptation and his environment. Modifying the environment for the expansion of his capabilities is a rudimentary characteristic of modern human beings. The basic material essential for a good life includes adequate income, household assets, food, water and shelter. Man is continuing his social tie-ups to avail these basic necessities. In modern society, the concerns over the quality of life have increased, when the life quality proportionately fluctuates with technological progress that has contributed to an improved income level. The circumstances which allow the growth of human life are the physical as well as the cultural environment (Van Kamp et al., 2003). It is assumed that the higher the quality of the environment, higher the state of well-being of the people. Here, human well-being refers to everything important to people's lives, ranging from basic elements required for human survival (food, water, shelter) to the highest level of achievement of personal goals and spiritual fulfilment. Human well-being is a multi-dimensional concept which includes quality of life (QoL). This gradient reflects the spatio-temporal variability of material (food, water and shelter) and non-material needs (good health, social cohesion, security). Achieving well-being is possible by increasing the pace of the development process in a society (Singh and Chothodi, 2015).

The term' development' has undergone paradigm shifts in meaning and objectives in the last seven decades. The primary objective of the term' development' (before 1980s) was limited to the economic perspective by the maximisation of output and later the term become synonymous with the achievement of high rate of growth in Gross Domestic Product (GDP). It became highly significant in developing nations since the post-liberalisation periods of 1970s. The QoL and well-being have emerged as core areas of discussion since 1990s, when the world economic pool shifted towards developing nations. Improved QoL and a better state of well-being of the people are the major goals for states; the idea is adopted by the third world from the developed world since 1980s. Development as an enhancement of human freedom involves diverse concerns but incorporates the expansion of social opportunities and the QoL (Drèze and Sen, 2002). Many of the human freedoms and components of the QoL are dependent on the integrality of the environment (involving the air we breathe, the water we drink, the epidemiological surroundings in which we live, and so on), development cannot, but, be sensitive to the quality of the environment (Drèze and Sen, 2002). In a few circumstances, the better state of life was accessed at the cost of a better environment (Fig. 1). In the modern scenarios of development, therefore has a strong negative correlation between environmental quality and economic growth. On the contrary, the Sustainable Development Goals (SDG) 2030 aims for good health, clean water, gender equality and a better state of well-being of the people that are highlighted in the agenda.

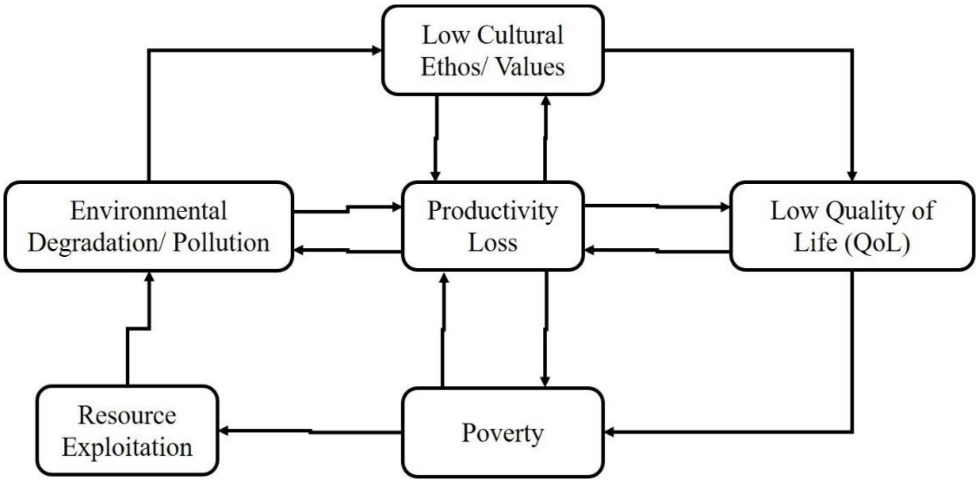

Figure 1. Environmental Degradation and Poverty

The post-world war economic growth was dependent on the implementation, application and marketing of science and technology. This advantage was largely dominated by the developed world up to the 1980s and in the 1990s the developing world accessed the technology at a large scale. This change has increased the pressure on the natural environment and made crucial changes in the social environment of the rural landscape, the world over especially in India. The development was equated always to economic growth with industrialisation and industrialisation with investment in physical capital formation.

Economic modernisation enhances the revolutionary changes in the social system. The urban ecosystems of the European Union are facing the problems such as segregation, neighbourhood, degradation, increased road traffic, socio-economic deprivation and inequalities in health that create inequalities in well-being. (Van Kamp et al., 2003). However, the temptation in public discussions to think of 'development' and 'environment' in antagonistic terms, the deteriorating environmental trends are linked with heightened economic activity (Drèze and Sen, 2002) (Figure 1).

The developmental initiatives, especially after the independence, gave a modern face to the rural areas of India. Reflections are visible in the improved QoL of the individuals in rural areas. The credit goes to the liberalisation initiatives of the late 1960s and the economic reforms of the early 1990s. Along with the infrastructural development, the social welfare policies of the state-sponsored have pushed up the growth of human capital. Economic growth is important to the development sequences, it is essential because economic welfare precedes developments related to well-being (Van Kamp et al., 2003). The exploitation of natural resources is integral to the physical capital formations. Environmental degradation is a major development issue that is inextricably and casually linked to the problems of poverty, hunger, gender inequalities and poor health. Various economic theories clearly show how continuous improvements in income depend on growing levels of assets, or wealth. If wealth does not grow, income will eventually fall. Ecological disturbances finally reduce the overall productivity in the majority of the rural scenarios. The low state of income in rural areas may be because of ecological disturbances that lead the poor productivity and withdraw the rural economy from further expansion, ultimately leading to negative growth (Conger et al., 2010) and causing outmigration.

The gap between access to services and opportunities has increased rural-urban migration and disturbs the equilibrium of the development processes (ILO, 2010). This gap is the difference in economic status, education, health care, sanitation, social relations, integrations, etc., making the few advanced and the rest backward and marginalised in the developmental paradigm (Singh and Satheesh, 2011). Changing nature of the climate, poor soil nutrients and quality, deforestation, and vulnerable land use convert rural life into pathetic, which converts the rural environment into a basket of physio-cultural turbulences. Numerous studies have already been made on various indicators of environmental quality, QoL and well-being. But the association between environmental variables and well-being are missing in the development studies. The current study aims to examine the status of indicators of the environment that influences human well-being at a large scale, particularly with reference to rural Indian circumstances. The study was based on systematically pursued literature surveys (content analysis method) (Fig 3) and the arguments are supplemented by secondary data inputs in the form of tables, graphs and maps.

Environmental conditions and human well-being

The concept of 'human well-being' intends to refer to the conditions of the environment in which people successfully live and have the opportunity to expand their capabilities (Singh and Chothodi, 2015). Well-being is the actual degree of satisfaction of the needs and wants of the community. The most critical one is to lead a long and healthy life, be educated and enjoy a decent living standard (McGillivary and Noorbaksh, 2004). The surrounding physical and cultural environments of individuals and households influence the levels of human development (Singh and Chothodi, 2015). It includes the quality of air, water (pollution status), health, housing, sanitation facilities and other aspects such as social qualities including education, communal and caste harmony, crime status and victimisation.

The living circumstances of the individuals and the households vary over space and time. However, the living environment considerably decides the state of well-being of the people. Intergenerational well-being increases over time if there is an increase in the comprehensive measure of wealth per capita. The measure of wealth includes not only manufactured capital, knowledge and human capital (education and health) but also natural capital (e.g. ecosystem). Environment connotes the sum of things or circumstances surrounding the organisms including humans. The physical environment incorporates all the natural events like climatic variations and local topographical variations. From a broader perspective, the physical environment includes air and water quality, noise, indoor, and other aspects of pollution (Smith, 1977). The physical environment has multiple dimensions: physical, chemical and biological. Economists call the natural capital (aquifers, ocean fisheries, tropical forests, estuaries, and the atmosphere as carbon sink-ecosystem generally) as a basis for human survival and growth. Therefore, the sustainability of the environment is essential for well-being.

Environmental sustainability can be defined as meeting human needs without undermining the capacity of the environment to provide those needs and support for life in the long term. Environmental resources such as the atmosphere, underground and surface water, fisheries, birds and animal species, forest, soil and soil cover are part of our capital assets. Some are pure amenities and others are providing partial services to human beings. The economics of sustainability resorted to the idea of maintaining the value of total capital intact, which usually comprises manufactured capital, natural capital and sometimes social capital (Fig 2). Natural capital encompasses everything in nature that provides human beings with well-being, from natural resources to the pollution and abortive capacity of the environment. Economic processes have been highly resource-depleting, causing crises in the marine and forest sectors and disruption of the water cycle. Modern industrial development has also been highly energy-sensitive (Chakraborty, 2009) in nature. Therefore, the sustainability concept got critical importance in contemporary world patterns.

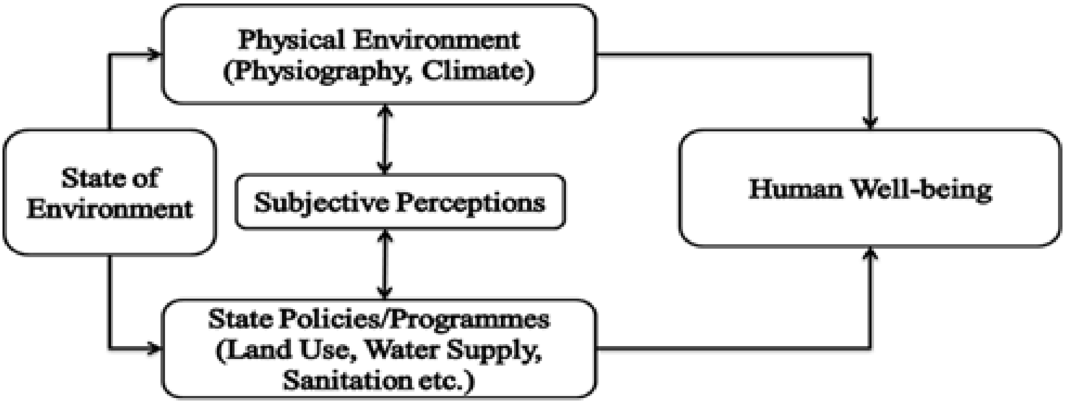

Figure 2. Environmental perspectives on human well-being

Households are not isolated units but are connected to others in a pattern that creates a fabric of social life. The social congregation and amalgamation are part of a community or societal life. However, the polluted physical environment disturbs the normal life of the human being and creates a number of social as well as health problems and disorders. Environmental degradation is a major issue that is inextricably and easily linked with problems of poverty, hunger, gender inequality, health, etc. and it represents a variety of spatial as well as locational differences. The burdens of environmental problems largely affect the middle and low-income groups (have-nots) and these burdens were largely the creation of high-income groups (haves). As the poor are dependent on nature for their livelihood, they are vulnerable to natural calamities, environmental degradation and ecological disasters. The destructive form of development and economic growth aggravates poverty and inequality in society and paralyses a section of society with new-borne diseases. Some chronic, non-infectious diseases can also be classified as mediated effects of ecosystem change, including allergies, asthma and some forms of cancer and chronic lung disease.

Well-being is controlled by both physical and cultural landscapes in the Indian rural systems (Qureshi, 2010; Adger, 2000). The dominant economic practices in the rural area are agriculture and allied practices. The post-liberalisation period (after the 1990s) witnessed a change in occupational structure in rural India. The rapid rise in purchasing power of the people causes rapid changes in the social environment. Poor social and economic conditions of the villages compel them to over-exploit the environment, leading to the vicious circle of degradation of natural resources perpetuating poverty. The prolonged absence of basic needs causes the stunted structure of human development and causes extreme poverty. Poverty further increases exploitation, which ultimately makes a low state of well-being for the people (Fig. 1). There are a number of environmental indicators that influence the well-being state of individuals because the well-being indicators are having territorial and regional dimensions and character. Thus this paper tries to undetsand the environment and human well-being of India through a certain quantifiable parameters in a spatial context.

Proxies of environment and human well-being

Environmental qualities have individual perceptions as 'environmental quality is a complex issue including individuals' subjective perceptions, attitudes and values which vary among the groups and individuals' (Van Kamp et al., 2003). Subjective indicators allow for gaining insight into the well-being/satisfaction of a person, and also into what people consider important. It indicates the commitment of individuals to the environment and the creation of public support. Through objective indicators, the evaluation of environmental quality is so hard that they form the point of departure for the environmental policy and enable the validation of subjective measures (Van Kamp et al., 2003).

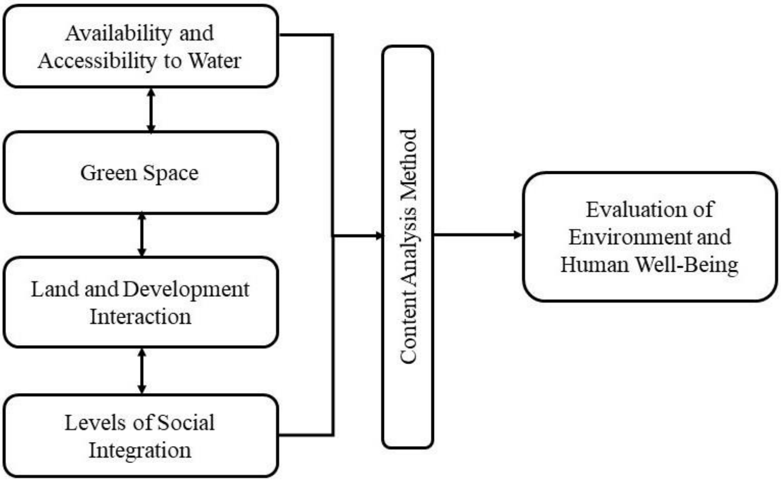

Figure 3. The conceptual flow of environment and human well-being

The concept of an individual's well-being is the amalgamation of objective and subjective approaches (Costanza et al., 2007). The distribution of the objective indicators of environmental qualities has spatial as well as temporal similarities and differences all over the world and the variations in the subjective differences are truly different over space and time, especially between the individuals, who however have certain commonalities over the group and societies. Therefore, the state of the environment is an integration of bio-physical and socio-economic indicators needed to assess the spatial interactions and inferences of various processes, which ultimately express the pattern of human imprint on the environment. The discussion in this paper is oriented with following variables of environment and human well-being that directly involve deciding the levels and layers of well-being of the Indian rural masses.

1. Water Resources

Water is a fundamental necessity for survival as well as an asset for the growth and development processes of human society. Modernity and extensive developmental initiatives have increased the consumption and demand of water. Quality of water is closely linked to water quantity, which has economic, environmental and social importance. It has many aspects (physical, chemical, microbial, biological) and can be defined in terms of water suitability for various uses (OECD, 2001). The surface as well as groundwater are subject to pollution due to the extensive deposition of solid and liquid pollutants into the sources of water. As per United Nations International Children's Emergency Fund (UNICEF, 2022), water-borne diseases are imposing an economic burden of 600 million USD on the Indian economy. The extensive utilisation of ground and surface water reduces the amount of availability and increases the intensity of drought circumstances. Modern commercial agriculture consumes large amounts of water, which again contributes to worsening the situation. Contaminated water from industrial recharge, household waste, extensive use by domesticated animals and sewage pollution are the sources of water pollution in rural areas. The mounting density of the population and economic activities also increase water scarcity and reduce the quality of life in rural India.

The use of chemical fertilisers, which recorded an increase of more than 80% between 1984 and 1996, added to the salinity problem in the surface and groundwater reservoirs. The increased use of chemical fertilisers rapidly enhances the pH level of the water. This is harmful to the growth of flora and fauna (Fig. 4b). The extensive water shortage reduces agricultural productivity and increases the cost of agriculture production which includes livestock protection and growth. This has further alarmed the health risk to the population and negatively affects the level of well-being. The increasing population upsurges the pressure on natural resources especially on land and water resources. It affects environmental pollution primarily through the use of natural resources and generates the bulk of waste, particularly in the sources of water. This situation raises the public expenditure on water supply and other mitigation programmes which adversely affects the health of the people.

Sources of drinking water are the major indicators of the state of the physical environment's health of an area, especially in high-income growth countries like India in this globalised era. Extensive exploitation of the surface and groundwater has reduced the availability of water and miserably affected the life of low-income groups, in which females and children are the main victims. Long continuation of poverty, poor management of freshwater sources also with the increasing pressure of population have risen the severity of water scarcity. In India, the intensity has further risen with climate change and has the least investment in water and sanitation sectors in the state. Reports published by Central Ground Water Board (CGWB, 2021) show that the majority of the Indian aquifers are in critical and semi-critical condition (Fig 4). Aquifers in states like Rajasthan, Tamil Nadu, Uttar Pradesh, West Bengal, Maharashtra, Karnataka, etc. are under high semi-critical to critical conditions (Fig 4). Fluctuating rainfall, increased exploitation for feeding the cultural landscape and reduced infiltration are causes for the declining level of surface aground water level and are well reflected in the figures (Fig 4d and 5). States/Union Territories (UT) like Tamil Nadu, Maharashtra, Rajasthan and Delhi are with low groundwater levels. Declining levels of groundwater cause high contamination of harmful minerals in the drinking water.

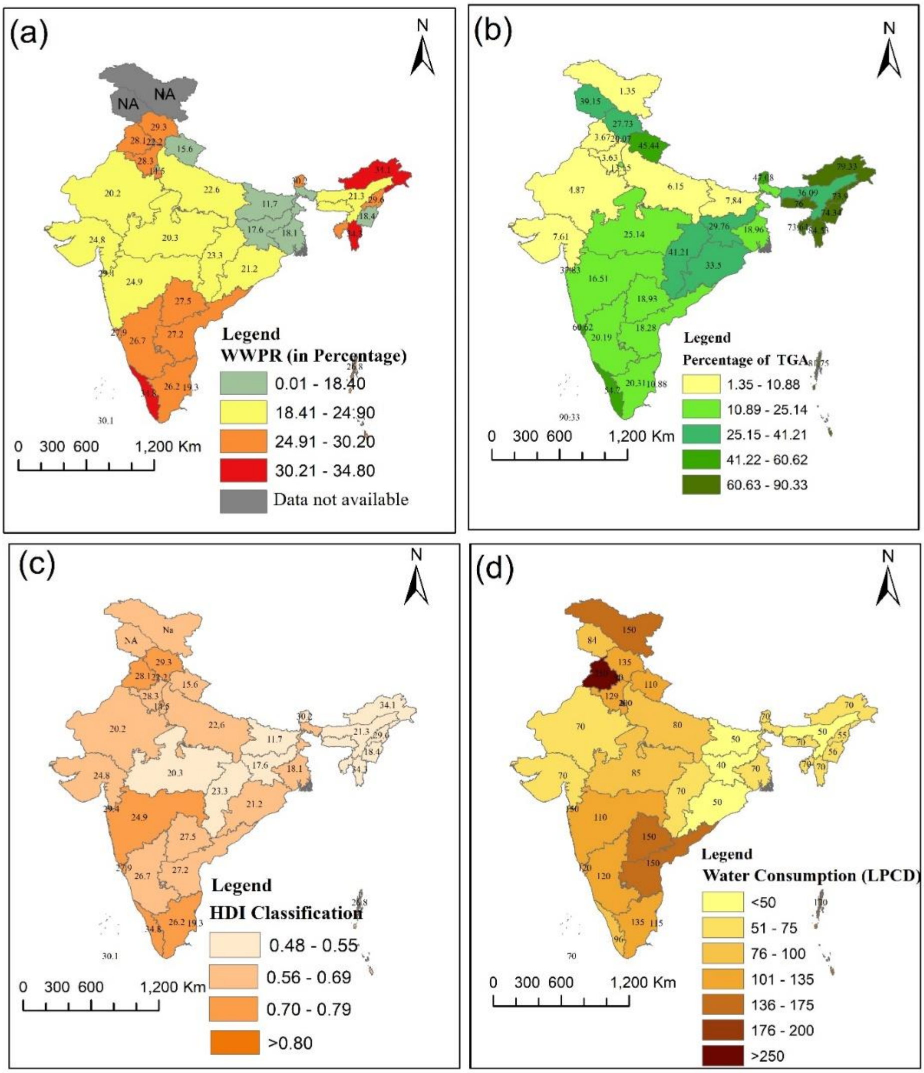

Figure. 4a. Women Workforce Participation in India, 2021(After World Bank, 2021) 4b. Forest Cover in India, 2019 (After FSI, 2019) 4c. Human Development Index- India, 2021 (After UNDP, 2022) 4d. Per capita Water Consumption in India, 2019 (After State and Union Government/s Documents of India, 2019, 2020, 2021)

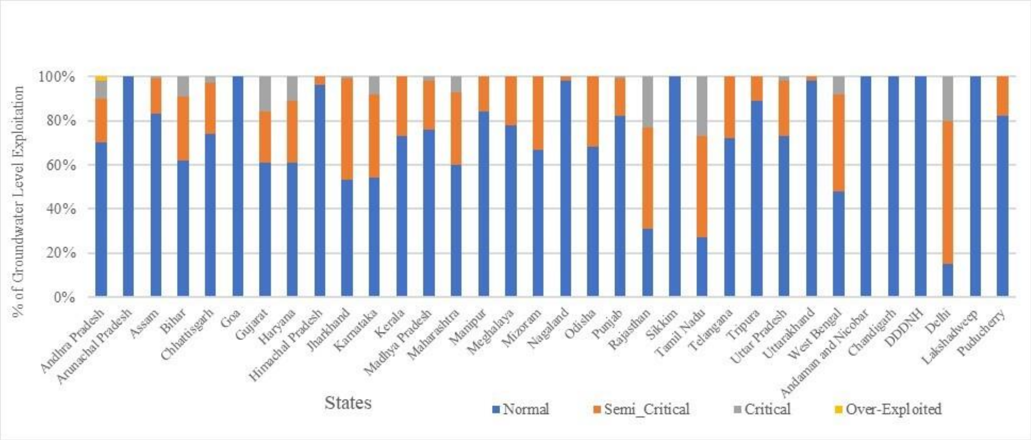

Figure 5. Level of Ground Water in Indian States, 2021 (After CGWB, 2021)

Agriculture production is reduced by the insufficient supply of fresh water, which also causes the rural population's animals to die off. The level of farmers' well-being will decline as a result of this. In India, a majority of the population depends on agriculture for their livelihood. Small and medium-scale manufacturing units and service centres cannot afford huge economic expenditures for accessing water. Shortage in natural availability causes over-exploitation, depletion and contamination of the natural resource.

The depth of groundwater and the nature of infiltration is important in deciding the quality as well as the availability of water. The increasing depth of the ground water table intensifies the effects of water scarcity and it impacts the local sources of livelihoods. Shortage in groundwater increases the concentration of chemical contaminants in the water, rendering it unsuitable for consumption purposes, (CGWB, 2014) and it may surge the health risk among the people (Table 1). Spending money for drinking water by the local population is a clear indication of the level of water scarcity and environmental vulnerabilities.

The quality of groundwater is directly related to the nature of the climate, in that the status of rainfall, geological configuration and anthropogenic activities are important (CGWB, 2014). Changes in the water level affect the physicochemical attributes of water. Extensive exploitation along with a low rate of infiltration has increased the contamination in groundwater. A majority of the South and Central Indian sub-surface is dominated by igneous and metamorphic rocks. These locations are facing the problems of geogenic contaminations along with large-scale anthropogenic inflexes to the groundwater (Fig. 4d and 5).

Increasing demand for freshwater has risen rapidly in the urban as well as in the rural areas. Per-capita share of fresh water is recorded as very poor in India in the year 2014. It was 5177 m^3/year in 1951 and in 2014 the availability had reached 1508 m^3/year (Ministry of Jal Shakti, 2020). Norway, a state with a Human Development Index (HDI) of

0.957 recorded a per-capita share of fresh water 71,914 m^3/year in 2018 (OECD, 2022). It is recorded that a decrease in more than fifty percent of freshwater resources in the last seven decades in India. The increasing size of the population and resultant exploitation of water resources for satisfying the needs have risen fresh water scarcity. Water scarcity always makes a negative correlation with the state of well-being.

Table 1. Impact of agro-chemicals on human health

Agro-chemicals	Maximum Contamination Levels	Health Effects	
		Established	Potential
Nitrates	10mg/NO_3^-N	Methaglominemia	Nitrate conversion to nitrite and N-Nitroso compounds affects the thyroid, and endocrine functions
Metals (Cd, As, Cr, Zn, Cu)	0.01 to 0.05 mg/L	Impact on kidney functions, skin disorder, tumour	Cancer risk
Pesticides (chlorinated hydrocarbons like DDT, organophosphate like Malathion, Carbamata like Carbaryl)		Affects the nervous system and reproduction, affects enzymes and muscles	Cancer risk

The situation of scarcity in the natural availability of water compels the state to arrange free and continuous availability of water in different parts of the country. As an essential commodity for human survival and growth, the utilisation of water has an important role in deciding the economic well-being of the people. There is a clear economic gap in the utilisation of water in India (OECD, 2014). The economically vulnerable section is unable to control the cost of fresh water for household consumption.

It is noticed that the levels of resource utilisation in a society reflect the political and economic freedom enjoyed by the people within the society. Economic empowerment has a reflection on the per-capita consumption and the quality of water. More than half of the states of India have recorded a per-capita fresh water consumption > 100 litre/ day limit (Fig 4d). As per the Bureau of Indian Standards (BIS), the minimum consumption status is 135 litres/ day in urban and 70 litres/ day in rural areas (Ministry of Jal Shakti, 2020). Based on the data available from state and the union governments, it is found that about 44 percent (in 2019) of the Indian rural population is unable to access the opportunity to enjoy quality water for an improved state of well-being (Fig. 4d). The states like Odisha, Chhattisgarh, Assam, Gujrat, Jharkhand, Rajasthan, Uttar Pradesh, and Madhya Pradesh are lagging in per-capita water consumption.

2. Land Resources

Land and water are the main supporters of almost every ecosystem on the earth, either natural or semi-natural, including the traditional land use system developed by human beings. The permanent utilisation of the land influences the environment at a large scale at the local and regional levels. Traditional agriculture was the major source of livelihood for the rural population. However, today rural traditional agriculture has changed due to mechanised, commercial agricultural practices. The dominance of modern agricultural practices has reduced the level of water and disturbs the ecological balance. Changing character of land use was largely determined by the economy and is reflected in the agricultural expansion, forest clearing, wetland drainage and irrigation, and expansion of human settlements (Bhattacharya, 2014). Agricultural activities that cause land degradation include shifting cultivation without an adequate fallow period, topsoil erosion (leaching) and the extensive use of chemical fertilisers which reduces the quality of the soil.

Commercialisation of agriculture in the modern period attracts the population towards cash crops which requires heavy irrigation and intensive care by fertilisers and pesticides. The insufficient rainfall forced the farmer to exploit the groundwater, which increases the intensity of drought and reduces the quality of products too. The modern industrial uses of agricultural land curtailed the size of agricultural land and increased water scarcity. This results in polluting land, water and air, which in turn affects human health and reduces the state of well-being of the people. The consequences of landuse change increase the tendencies of infectious diseases, especially because of the high presence of air pollutants in the atmosphere. Environmental degradation, to some extent, decides the levels of poverty in a region. It largely accounts for 9-10 percent of total deaths (WHO, 2002). The functions and services of a land-use pattern are the capacity of each land-use to provide, directly or indirectly, the goods and services that satisfy human needs. State policies (especially economic policies) have a greater influence on deciding the nature of land uses. Increasing agricultural practices after independence, along with urbanisation, has made a severe impact on the land quality in the country. It is noticed that nearly about 1. 2 lakh hectares of land in India are subjected to degraded and wasteland classes (Maji et al., 2010).

Forest cover in the country has reduced due to agriculture, industrial and urban expansions. The presence and absence of vegetation cover have a direct correlation with the state of well-being of the people. The presence of trees in the neighbourhood is an integral part of the subjective well-being of the people. According to Forest Survey Report 2021, forest cover in the country is limited to 24.62 percent of its geographical area (Fig 4b). Industrialised states like Gujrat, Maharashtra and Uttar Pradesh are losing their green spaces tremendously. Increasing urbanisation causes a disconnect between humans and nature, particularly in the countries like India where the urban share is above 30 percent according to the census 2011 (NCP, 2019). This has further reduced the density of forest land in India (Fig. 4b). It is identified that only 1.3 billion world population have clear access to green space. Availability of green space is associated with the livelihood of the farming communities (Bhandari, 2013). The least concentration forest cover is a clear threat to the overall well-being of the populous states of Gangetic plains. The poor concentration of green space is well correlated with the HDI among Indian states (Fig. 4b and 4c).

3. Socio-Economic Systems

The post-liberalisation period had given birth to a new form of economic, social and intellectual layers in society by increasing investment in human capital. The structure and pattern of society influence the state of well-being of the individual as well as the community. Households are not isolated units but are connected to others in patterns that create the fabric of social life. Social capital has been defined as "networks of social relations which are characterised by norms of trust and reciprocity which lead to outcomes of mutual benefits". Social capital includes several dimensions of relationships that are interrelated: trust, reciprocity, size, density and diversity. These dimensions can be used to measure the extent and impact of social capital at individual, community and institutional levels.

The earlier concept of cultural environment is the amalgamation of people from different sects, creeds, castes, religions, and languages. In modern society, economic status plays a pivotal role in cultural integration and unity. A society with less inequality will enhance the state of subjective well-being of the people and accelerate productivity. The neighbourhood's physical and economic environment influences the subjective perception of the individuals. Studies have mentioned that the relationship between the amount of greenery in the neighbourhood and the coping behaviour of the individuals has a role in the overall subjective well-being of the individuals (Van Kamp et al., 2003). The poor socio-economic environment as powerful social co-factors, including severe poverty, social practices and social taboos and poor governance, pushes the individual and society into a poor state of subjective well-being. Sovereign governments support social networking and community-based programs for the well-being of the people. Economic and social inequalities are the prime reasons for the occurrence of crimes and victimisation (Sharma, 2015).

The indicators such as women workforce participation and HDI provide a better picture of socio-ecnomic systems in India. The states better in women workforce participation are also better in HDI. Women make up 48 percent of the Indian population but have not benefitted equally from India's rapid economic growth. Participation of Indian women belonging to the productive age group in economic activities outside the home was less than forty percent. On the contrary, the high HDI countries like Norway and Sweden had a share of 68.2 and 72.5 percent respectively in 2021 (World Bank, 2021). This is an indication that females are still lagging behind the freedom of economic production in the country. It further indicates the absence of a conducive environment for the growth of females within the houses and at the societal level.

The share of women's participation in the workforce in India is highest in the high HDI states, except North East states (Fig. 4a). The central parts of India have the lowest female labour force participation rates (less than 25 percent). The empowerment and autonomy of women and the improvement of their political, social, economic and health status is highly important for social well-being. A proper partnership of both women and men is required for better health and well- being. Mahatma Gandhi Rural Employment Guarantee Act (MGREGA) is a great relief to the females from the poor and middle classes. MNREGA is an important programme which successfully ensures social security in rural areas, particularly in the states like Kerala, Tamil Nadu and Odisha. Women Self-Help Groups (WSHGs) are the platform for rural women to have active social and political participation in the rural cultural landscape. Workforce participation of Indian women is poor and it is worst in the low HDI states (Fig. 4a and 4c). WSHGs are continuing as channels for social integration, empowerment and freedom of the people from economic dependencies and domestic violence and social disorders. But the rate of workforce participation has increased in the states of Kerala, Tamil Nadu, Arunachal Pradesh and Himachal Pradesh (Fig. 4c).

Economic and social disorders disturb the subjective well-being of the individual as well as the households. Increasing educational status enhances the employability of the people and ensures economic security and individual identity in society (Conger et al., 2010). Data and reports of the National Crime Records Beuro (NCRB) 2021 (Chapter 2) show documented that the rate of suicides had increased from 9.9 to 12.0 per one lakh population from 2017 to 2021 (NCRB, 2021). States with better economic growth with high urbanisation are facing higher rates of suicide than other states with high rural population share (Fig. 6). Maharashtra, Tamil Nadu, Kerala, and Karnataka show alarming figures ever after high per-capita income. The rate of suicides is 12.3 in case of Sweden and 10.8 in Norway in 2019 (WHO, 2022). It is from the observations that the social fabric of rural India is largely responsible for healthy rural social cohesion, but there is an exemption with reference to farmers suicides. Isolation, economic distress, loss of hope and resultant poor levels of subjective well-being are considered the important reason for the increasing cases of suicides in India (NCRB, 2021). States having low HDI and poor living conditions are having the highest number of suicides (Fig. 6).

Conclusion

Natural resources are the renewable and non-renewable goods and services provided by the ecosystem. Moreover, it is the primary satisfier of subsistence by providing the necessities for human survival. From the above analysis, it is noticed that a sustainable environment is possible only with rational utilisation of natural resources. HDI values of the Indian states are well reflected in the various environmental indicators. The results show that poor performance in environmental well-being is observed all over India.

The plundering of the natural environment increases social distress and its accumulation leads to public outrage. The extensive environmental degradation is a major symptom of the government's failure to formulate an appropriate policy to ensure sustainable use of land and water resources. However, the cost of environmental

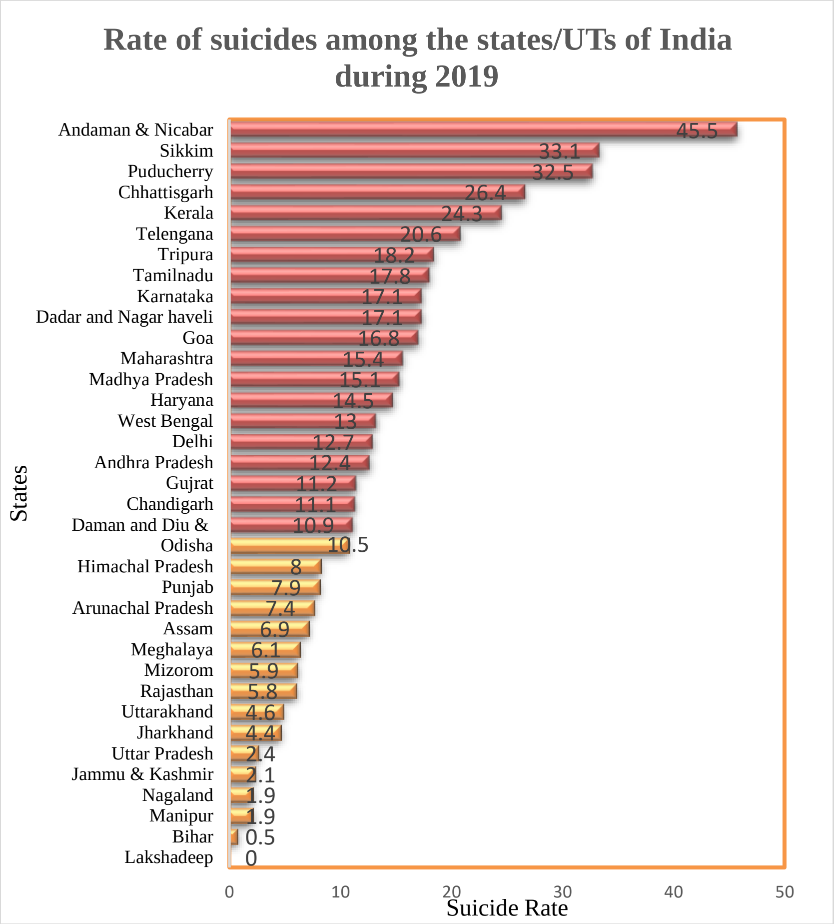

Figure 6. Suicides rates in India, 2019 (After NCRB, 2021)

degradation is always borne by the poor, which pushed them to further poverty. This has been well observed from the HDI of the states of India and the performance of Norway and Sweden. Low HDI states like Odisha, Jharkhand, Madhya Pradesh, Chhattisgarh and the Nort-Eastern states are performing badly in the environmental well-being. As Patnaik (2008) rightly observed that large-scale environmental degradation leads to poor agriculture production and shrinkage of per-capita food availability and food inflation. The absence of appropriate environmental well-being makes a negative impact on the basic foodstuff of the poor and the middle class because of the low purchasing power. Higher share of suicides in the high-income group of states are reflecting the low levels of well-being at the household and societal level raising many questions. In India, pressure of the population, beyond the thresholds of environmental limits causes the downfall of the levels of well-being. Productivity from individual and household levels to the economy as a whole will be possible only when environmental well-being is at its highest levels. Increasing expenditure for satisfying the necessities of human survival will push low-income households to the graves of poverty and a poor state of well-being.

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EMERGING TRENDS, PATTERNS AND CONCERNS OF URBANISATION IN PUNJAB

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Abstract

Punjab from largely an agriculture-based rural economy, now, has emerged as one of the most urbanised states of India. The state has been undergoing an unprecedented economic and social transformation including urbanisation over the past few decades. Urbanisation reflects growing economic development in the state. Overcoming a period of socio-political disturbances, the state has managed to sustain the pace of economic development and consequently higher urbanisation level. However, the level of urbanisation is variable across districts of the state. Data shows that the larger share of the urban population is confined to a handful of large urban agglomerations located in a few districts of the state. Cities of such districts have their shadows over medium and small urban centres. The role of in-migration in urbanisation has played a crucial part in the state. Thus, studying the nature and status of urbanisation in Punjab is relevant in contemporary times. The present study aims to analyse and explain the nature of urbanisation and its spatial patterns in the state, the role of industrialisation in the development and transformation of the regional economy, the impact of in-migration, and the emerging concerns. The study is largely based on secondary data and a mixed-method approach is applied.

Keywords**:** Cities, Economic Development, In-migration, Urban Agglomeration, Urbanisation, Urban Growth

Introduction

Urbanisation as a geographical process indicates the shift of population from rural to urban areas, the growth and the increase of urban settlements. Different measures are applied to understand the nature of urbanisation and provide an overview of such phenomenon in a country or region. Punjab is located in the north-western part of India. The state has witnessed various changes over the past few decades, which are influencing the process of urbanisation therein. The geological advantage of being situated in the fertile plain of rivers Sutlej and Beas has made it a natural region for rich agricultural practices. The green revolution promoted agricultural growth, economic development and made the state the 'Granary of India'. The process of industrialisation in the state started in a few important urban centres during the late 19th century. The establishment of industries especially the machine tools industries, hosiery industries, etc. had promoted the industrial growth in the state. During the post-independence period, the state's economy grew further and the share of the secondary and tertiary sectors increased significantly. The state now emerged as the sixth most urbanised state of India as per the Census of India 2011. Contemporary Punjab was formed after the separation of Haryana from the state in 1966. After the separation, the state witnessed many events which have huge impacts on the economic development and urbanisation of the state. However, the insurgency times adversely affected the process of development. The state re-emerged from insurgency and terrorism during post-economic reforms and gained momentum again in urbanisation and industrialisation. However, there are significant spatial variations in the level of urbanisation and degree of accretion of urbanisation. Much of urban growth is driven by agricultural produce which gets places in the urban market. Thus, most of the urban centres of the state perform as service centres. Only a few large cities dominate at the higher level in the urban landscape of the state. The paper addresses the following objectives: 1) to study trends, patterns and growth of urbanisation in the state of Punjab, 2) to discuss the nature of spatial variations in urbanisation across districts and the underlying drivers and 3) to explore emerging challenges of urbanisation and urban growth in Punjab.

Background of the Study

The United Nations (UN) data shows that "Between 1950 and 2018, the urban population of the world grew more than four-fold, from an estimated 0.8 billion to an estimated 4.2 billion" (World Urbanisation Prospects, 2019). Urbanisation may be seen as a function of natural increase in urban population, (de)classification of towns and rural-to-urban migration. The spatial process of urbanisation varies from one cluster to another. Singh and Singh (2014) noted that in the developed countries of the modern days, urbanisation is very much related to industrialisation. This trend is also followed differently in developing countries. The establishment of industries created a multiplier effect leading to the concentration of many small industrial units. It established a strong pull factor that attracted people from rural areas, where an agrarian crisis prevailed. Urbanisation in any region now is known as leading to better living conditions for the people since it offers better access to basic amenities and infrastructure. It creates ways of newer employment which helps in poverty reduction.

India as urbanising will be the new epicentre of urbanisation in the coming decades. India has a definite criterion for identifying places as urban. In India in 2011, the percentage of urban population was reported 31.20 percent. This has increased to 27.80 percent in 2001 from 25.7 percent in 1991 as reported by the Census of India. India's urban population recorded an annual growth rate of 2.76 percent during 2001-11, which is higher than that of the previous decade of 2.73 percent only in the second decimal point. Studies show that "the accelerated rate of urbanisation in the last decade, compared to the 1990s when the growth rate of Gross domestic product (GDP) rose to over 7 percent per annum, is widely applauded as a positive sign of development" (Chakraborty, 2017). This also signifies that higher economic growth is associated with an increasing level of urbanisation and the same can be examined in the context of any region and district.

Urbanisation in India may be broadly divided into two distinct phases. The first phase of India's urbanisation (1951-1991) has largely been propelled by an increasing share of rural-to-urban migration and (de)classification of towns apart from natural increase. The second phase (1991-till now) has witnessed the development of small towns and large cities leading to uneven urban structure. Rural-urban migration has begun to decline over the decades due to various reasons. Large cities are growing faster and at the same the rise of small towns, i.e. Census Towns has changed the conventional process of urbanisation in the country. Bhagat’s (2018) study elucidated that most parts of central, eastern and north-eastern India have a very low level of urbanisation. All southern states along with states in northern and western India such as Punjab (37.4 percent), Haryana (34.7 percent), Gujarat (42.5 percent), and Maharashtra (45.2 percent) have a higher level of urbanisation than the national average (31.1 percent). The way urban growth of large cites is taking place, this also shows growing squalor and various urban challenges.

The state of Punjab is traditionally known as an agricultural state. The fact is there are few districts of the state which are highly industrialised and attract people from many other neighbouring states for work and employment. For long, a few urban centres of the state remained known as industrial centres. Despite being a landlocked state, the growth of primary and secondary sectors of the economy has occurred simultaneously in modern Punjab. This process gave the state a unique identity that separates it from other states of the country in terms of a higher level of economic growth and urbanisation. Since the state’s formation, the state of Punjab has made strides towards commerce, manufacturing, transport and industrial expansion. A few cities significantly controlled urban landscape in the state. Over time, and with sectoral changes in the economy, a greater number of urban centres emerged. Still, there are two metro-cities- Ludhiana and Amritsar- which dominate the urban space of the state. Apart from these cities, several cities and towns are spread across the state. At present, Punjab is the fifth most urbanised state in India. Understanding the trend and pattern of growth of urbanisation in Punjab helps in better understanding the nature of the economic development and demographic shift in the state.

Methods and Data

The present study is based on both qualitative and quantitative approaches. The study interprets the role of determinants and processes that drive urbanisation in the region. For quantitative analysis, the data is collected from secondary sources. This includes data of is retrieved from existing studies, the Census of India reports of multiple years, the Economic Survey of Punjab, the National Family Health Survey reports, the Periodic Labour Force Survey, the Population Statistics of Punjab, the Smart Cities Mission, the Atal Mission for Rejuvenation and Urban Transformation, the Swachh Bharat Abhiyan etc. As the latest Census data is not available, an attempt has been made to project the data for the year 2021. The present paper analyses and explains the varied nature of urbanisation and its spatial pattern in the state.

The first section uses multiple statistical methods to measure the trend of growth, level, degree, and tempo of urbanisation in the state of Punjab. District-wise spatial analysis has been carried out to present an in-depth analysis of urbanisation in the state. The study adopts class-size classification which the Census of India has classified towns into various classes as per the population. The main statistical techniques used in this section are as follows:

- $CompoundAnnualGrowthRate\ (CAGR) = [\left(\frac{P_f}{Pi}\right)^{\frac{1}{n}} - 1\Big] \times 100$

  Where, P_f =Population of Final Year
  P_i =Population of Initial Year
  n= Number of Years

- $LevelofUrbanisation = \frac{UrbanPopulation}{TotalPopulation} \times 100$
- $Degree\ of\ Urbanisation = \frac{UrbanPopulation}{RuralPopulation} \times 100$
- $Tempo\ of\ Urbanisation = \frac{1}{n}(PU^{t+n} - PU^{t})$

  Where, PU^{t+n} = Percentage of Urban Population at the year t+n
  PU^{t}= Percentage of Urban Population at the year t
  n = Number of Years

- Population projection for 2021 (P_{2021}) = $P_{2011}\left(1 + \frac{K}{100}\right)^{n}$

Where P_{2021} is the projected population for 2021, P_{2011} is the population for 2011, n is the number of decades since the last census and K=$\sqrt[4]{K1 \times K2 \times K3 \times K4}$, where K1, K2, K3 and K4 are the population growth rate for 1981,1991,2001 and 2011 respectively.

- Projection of the number of towns/cities and population share in each city (T_{2021}) = T_{2011} + (A_o×T_{2011}/100)

Where, T_{2021} is the projection for 2021, T_{2011} is the number of towns/shares of the population in each town in 2011 and A_0 is the average growth rate of towns/population share in towns since 1981

The second section discusses trends of migration. It analyses it in the context of increasing urbanisation. It also attempts to establish the correlation between urbanisation and industrialisation in Punjab. In the third section, an analysis of the causes, impact and associated concerns of urbanisation in the state is discussed.

Results

Urbanisation in Punjab

Historically, urbanisation in Punjab can be traced back to Harrapan Period as many remains of such towns have been found in contemporary Punjab. Urbanisation in modern-day Punjab began with colonial establishments, canalization, agricultural and commercial developments. Much of urban phenomenon become a reality with the establishment of transport routes, i.e., railway lines and *mandi* towns in the state. It gave a boost to the urban spread in the state. The establishment of administrative bodies in districts also helped in the concentration of the Population in the state. Colonial Punjab had four distinct urban centres: (a) indigenous towns; (b) the Civil Lines, (c) the colony towns in the canal-irrigated areas, and (d) the hill stations.

The partition of the country did contribute to an increasing concentration of the majority of refugees in urban settlements in the state of Punjab. The share of the refugee population was significant, if not prominent in the overall composition of the urban population in India. Bose (1994) has estimated that the refugee migration accounted for 6.2 % points of the 41 percent increase in urban population during the 1941-1951 decade. A large number of refugees coming from West Pakistan settled in urban centres of partitioned eastern Punjab. The spatial pattern of urbanisation changed a lot in the state as driven by the increasing proportion of the refugee population in and around newly settled urban areas.

Punjab has witnessed rapid urbanisation in the past decades. Table 1 provides insight into trends and growth of urban and rural populations in the state. As per the Census of India 1971, the total population of Punjab was 13.55 million, of which 3.22 million were urban and 10.33 million were rural population. In the census year 1981, the total population of the state increased to 16.79 million. In the same year, the urban population increased to 4.65 million and the rural increased to 12.14 million. In 1991, the total population of Punjab grew to 20.28 million with 5.99 million urban and 14.29 million rural population. The decade of 1991-2001 witnessed a drastic population growth as the total population of the state grew to 24.36 million with 8.26 million urban and 16.10 million rural population. In the Census of 2011, the urban population grew to 10.33 million and the rural population grew to 17.32 million with a total population of 27.70 million in Punjab. However, the population projections made by *National Commission on Population* indicated that Punjab state had 30.33 million population in 2011. The population projection calculation suggests this figure to be at 29.55 million with 12.04 million urban and 17.51 million of the rural population by 2021.

Over these decades, the state of Punjab witnessed a differential trend of growth in urban and rural populations. The overall Compound Annual Growth Rate (CAGR) of Punjab showed a declining trend since 1971. During the decade 1971-1981, the CAGR of the population of Punjab was 2.17 percent, which declined to 1.91 percent and 1.85 percent during the decade 1981-1991 and 1991-2001 respectively. It further slumped to 1.29 percent during the decade 2001-2011. Comparatively, the CAGR of the rural population was very low and the CAGR of the urban population was high with respect to the total CAGR of the state. The CAGR of the rural population during the decade 1971-1981 was 1.63 percent, which remained almost static and just increased to 1.64 percent in the next decade 1981-1991. Further, it declined to 1.38 percent in the decade 1991-2001 and 0.73 percent in the decade 2001-2011. In contrast to this, the CAGR of the urban population witnessed a fluctuating trend. During the decade 1971-1981, the urban CAGR was 3.67

percent, which declined to 2.56 percent in the next decade of 1981-1991. This again jumped to 3.26 percent during the decade 1991-2001 and further declined to 2.23 percent in the decade 2001-2011. The trend is expected to further continue. The population projection indicates that the CAGR for urban will further decline to 1.54% in the decade 2011-2021.

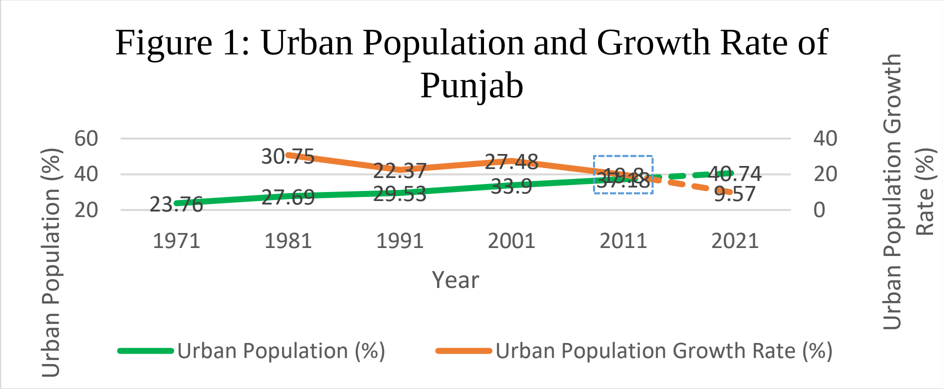
Table 1: Total Population and Compound Annual Growth Rate of Population of Punjab

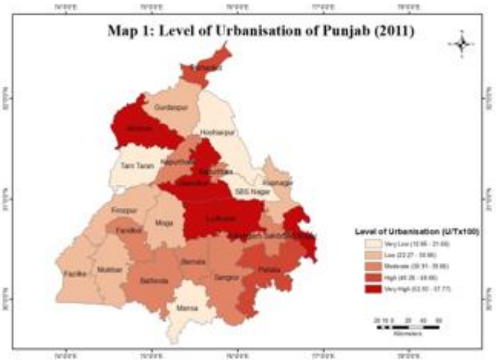
Year	Urban Population (in Million)	Urban CAGR (%)	Rural Population (in Million)	Rural CAGR (%)	Total Population (in Million)	Total CAGR (%)
1971	3.22	-	10.33	-	13.55	-
1981	4.65	3.67	12.14	1.63	16.79	2.17
1991	5.99	2.56	14.29	1.64	20.28	1.91
2001	8.26	3.26	16.10	1.38	24.36	1.85
2011	10.33	2.23	17.32	0.73	27.70	1.29
2021*	12.04	1.54	17.52	0.11	29.55	0.72

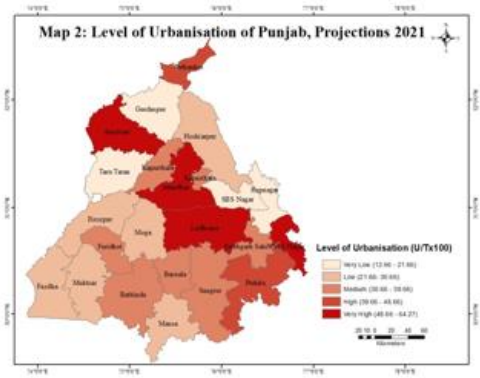
Source: Based on Census of India Reports (1971-2011) General Population Tables, Punjab Series 4 & Population Statistics of Punjab (1971-2011) *Projected Data

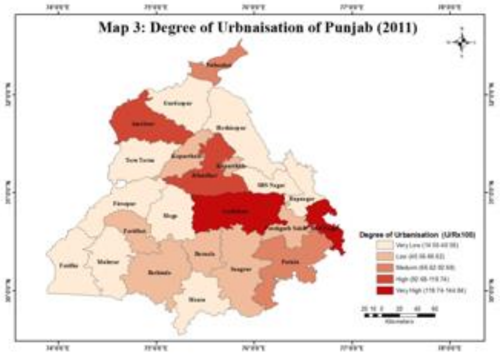
However, the net urban population of Punjab has been growing over the decades. The level of urbanisation in the state as shown in Figure 1, which is the percentage of urban population to the total population, was recorded at 23.76 percent in 1971. It increased to 27.69 percent in 1981. This further grew to 29.53 percent in 1991 and 33.90 percent in 2001. It ultimately grew to 37.18 percent in 2011. The level of urbanisation in the state is higher than the national average of 31.16 percent according to the Census of India 2011. The state recorded a jump of 56.48 percent in the urban population in the last five decades from 1971 to 2011. This growth rate has not remained uniform throughout these decades. The decade of 1971-1981 recorded the highest growth rate of the urban population in Punjab, which was 30.75 percent. It declined to 22.37 percent in the next decade. It further slightly increased to 27.48 percent in 2001. It again declined to 19.80 percent in 2011. The decade of 2001-2011 witnessed the lowest growth rate of the urban population in the state as reported in the last five decades.

Not just the temporal, there is also spatial variation of urbanisation in the state. Some districts of the state are highly urbanised, whereas the level of urbanisation in many districts is low. The urban to total population percentage is calculated to determine the level of urbanisation (Bose, 1973). Table 2 shows the district-wise level of urbanisation in Punjab since 1981. Ludhiana, Sahibzada Ajit Singh Nagar, Amritsar and Jalandhar have the highest level of urbanisation. These districts have more than 50 percent level of urbanisation. Ludhiana has had the highest level of urbanisation since the last three decades. The estimated figure for Ludhiana is 64.27 percent by the year 2021. The Punjab's districts continue to dominate urbanisation since they are more vibrant in the economic and commercial, communications and technology sectors in Punjab. Most of these top districts are home to the Special Economic Zones (SEZs) in Punjab. Other various activities such as production, processing and infrastructure and logistics are heavily located in these districts. Share of agriculture and food processing sector in manufacturing is 21 percent against India's 8.8 percent. Among the rest of the districts, most of them had more than a 25 percent level of urbanisation level in the last three decades. However, districts such as Moga, Gurdaspur, Mansa, Hoshiarpur, SBS Nagar and Tarn Taran have a very low level of urbanisation, i.e., less than 25 percent. This reflects that there is a gradual increase in the level of urbanisation in all the districts of the state. Map 1 and Map 2 show the spatial pattern of level of urbanisation in 2011 and 2021 in Punjab.









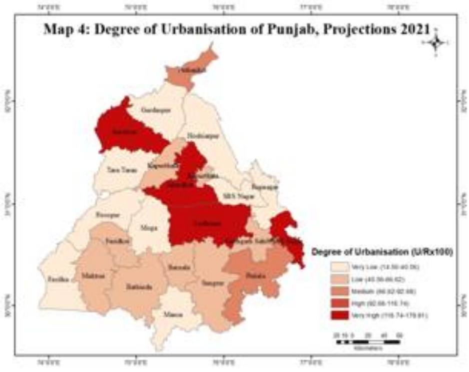


Table 2: District-wise Level and Degree of Urbanisation of Punjab

District	Level of Urbanisation (U/T*100)					Degree of Urbanisation (U/R×100)				
	1981	1991	2001	2011	2021*	1981	1991	2001	2011	2021*
Ludhiana	42.01	51.22	55.84	59.16	64.27	72.5	105	126.47	144.83	179.91
SAS Nagar	-	-	38.85	54.76	54.76	-	-	63.52	121.02	169.94
Amritsar	32.97	34.08	51.5	53.58	62.95	49.2	51.71	106.17	115.45	121.03
Jalandhar	35.32	40.65	47.48	52.93	58.16	54.6	68.48	90.42	112.47	139.02
Pathankot	-	-	-	44.07	44.07	-	-	-	78.79	78.79
Patiala	29.59	30.64	36.39	40.26	40.9	42	44.17	57.22	67.4	69.22
Bathinda	22.68	26.98	29.73	35.95	33.32	29.3	36.94	42.3	56.14	49.96
Faridkot	23.92	33.21	35.14	35.15	34.59	31.4	49.72	54.17	54.2	52.89
Kapurthala	29.97	25.76	32.67	34.65	35.08	42.8	34.71	48.53	53.02	54.04
Barnala	-	-	30.47	32.02	32.02	-	-	43.83	47.1	47.1
Sangrur	22.81	24.8	28.8	31.17	36.51	29.6	32.98	40.44	45.29	57.51
Fatehgarh Sahib	-	21.86	28.08	30.91	35.8	-	27.97	39.05	44.73	55.75
Firozpur	22.79	23.95	25.81	28.46	26.3	29.5	31.5	34.79	39.79	35.68
Shri Muktsar Sahib	-	23.4	25.54	27.96	30.45	-	30.54	34.3	38.82	43.78
Fazilka	-	-	-	26.03	26.03	-	-	-	35.18	35.18
Rupnagar	21.58	25.75	22.46	25.97	20.18	27.5	34.68	28.96	35.08	25.28
Moga	-	21.84	19.96	22.82	24.35	-	27.95	24.94	29.57	32.18
Gurdaspur	21.69	21.98	25.44	22.27	19.78	27.7	28.18	34.12	28.65	24.65
Mansa	-	14.85	20.68	21.25	24.18	-	17.44	26.07	26.99	31.9
Hoshiarpur	14.44	17.11	19.72	21.11	23.93	16.9	20.64	24.57	26.76	31.46
SBS Nagar	-	11	13.8	20.48	20.48	-	12.36	16.01	25.76	25.76
Tarn Taran	-	-	11.98	12.66	12.66	-	-	13.61	14.5	14.5
Punjab	26.64	26.41	30.07	33.34	34.58	37.8	38.52	47.47	56.43	62.52

Source: Based on Census of India Reports (1971-2011) General Population Tables, Punjab Series 4 & Population Statistics of Punjab (1971-2011)
Note: Dash (-) indicates that data is not available as district was not formed during the census year. *Projected Data

For a better understanding nature of urbanisation across districts in Punjab, the degree of urban accretion or degree of urbanisation is another useful technique. Conventionally, the percentage of urban population to the total population is often considered a better way to measure the level of urbanisation of region and place. Kundu assessed that Bose (1973 & 1994) did not find this method appropriate for the Indian scenario as *it fails to indicate the intensity of urban problems as it does not reveal the rapid growth of big cities and simultaneous stagnation of small towns* (Kundu, 1980). Therefore, Kundu (1980) introduced the percentage of urban to rural (U/R) index as a measure of the degree of urban accretion as it shows higher disparity over space since a higher incidence of urban accretion would be indicated in regions with a higher percentage of urban to total population. However, the higher degree of urbanisation is correlated with the higher level of urbanisation as well. Table 2 also shows degree of urbanisation in across districts of Punjab. Ludhiana has recorded the highest degree of urbanisation among all districts of Punjab. It was 72.45 percent in 1981, which increased to 105.00 percent in 1991 and further to 126.47 percent in 2001. District of Ludhiana had degree of urbanisation of 144.83 percent in 2011 and it is estimated to be 179.91 percent in 2021. The degree of urbanisation in Amritsar was 49.20 percent in 1981 which increased to 51.71 percent in 1991. It was recorded at 106.17 percent in 2001 which again increased to 115.45 percent and it is estimated to be 121.03 percent. The degree of urbanisation of SAS was 63.52 percent in 2001 which increased to 121.02 percent in 2011. It is estimated to be 169.94 percent in 2021 in Sahibzada Ajit Singh Nagar. The district of Jalandhar had degree of urbanisation of 54.60 percent in 1981, which increased to 68.48 percent in 1991. It was recorded at 90.47 percent in 2001 and increased to 112.47 percent in 2011. Its projection for 2021 is 139.02 percent in Jalandhar. These four districts have more than 100% degree of urbanisation, which means the urban population of these districts has surpassed the rural population. The remaining districts of Pathankot, Patiala, Bathinda, Faridkot and Kapurthala have had more than 50 percent degree of urbanisation during the last decade. The rest of the districts have less than 50 percent degree of urbanisation in the state. Tarn Taran ranked lowest with 14.50 degrees of urbanisation Map 3 presents the spatial variation of the degree of urbanisation in 2011 and 2021 in the state.

The tempo of urbanisation is an important technique to measure the process of urbanisation in a region. This enables us to sense the change in the level of urbanisation during the period. This is about the annual change of percentage points in urbanisation. When the level of urbanisation is measured in terms of percentage, the tempo can be measured either as the absolute change in percentage points or as the rate of change in the percent of urban population between two points. The tempo of urbanisation during 2001 and 2011 in India was 0.34 percent. Therefore, the trend of the tempo of urbanisation has been calculated to understand what has been the pace of change of urbanisation in the last several districts across the districts of Punjab. Table 3 presents the district-wise tempo of urbanisation in the last five decades. There is considerable variation in the tempo of urbanisation throughout all the districts. The overall tempo of the state of Punjab as recorded shows a fluctuating and declining trend. The tempo of urbanisation for the state was 0.43 percent in 1981, which dropped to 0.33 percent in 1991. It further increased to 0.42 percent in 2001 and declined to 0.26 percent in 2011. It is projected that the tempo of urbanisation in Punjab is 0.19 percent in 2021.

The tempo of urbanisation has been recorded as very high in Sahibzada Ajit Singh Nagar in 2011. Most of the districts of the state have shown a declining or erratic trend in the tempo of urbanisation. However, a higher tempo of urbanisation was recorded in Ludhiana at 0.72 percent in 1981, which increased to 0.92 percent in 1991. It declined to 0.46 percent in 2001 and further to 0.33 percent in 2011. The projection for 2021 in the tempo of urbanisation in Ludhiana is 0.51 percent which will be one of the highest values recorded in certain districts. The district of Kapurthala recorded 0.68 percent which was a high tempo of urbanisation in 1981. However, it declined to negative -0.42 percent in 1991 but a sudden jump was recorded in 2001 reaching 0.69 percent. However, it declined in 2011 coming down to 0.20 percent and the projection for 2021 is 0.001 percent for Kapurthala. Rupnagar district recorded a tempo of urbanisation at 0.65 percent in 1981 which declined to 0.42 percent in 1991. It further declined in negative coming down to -0.33 percent in 2001. With a sudden jump, it reached 0.35 percent in 2011 in Rupnagar, and the projection for 2021 is -0.58 percent. Bathinda had 0.49 percent of tempo of urbanisation in 1981 which came down to 0.43 percent in 1991. It further declined to 0.28 percent in 2001.

A sudden jump was recorded in 2011 and it reached at 0.62 percent. The projection for 2021 in Bathinda is -0.26 percent tempo of urbanisation. Jalandhar reported 0.52 percent of the tempo of urbanisation in 1981 and it slightly increased to 0.53 percent in 1991. It further enhanced to 0.68 percent in 2001 in Jalandhar. It recorded a decline in 2011 being at 0.54 percent in Jalandhar and the projection for 2021 is 0.52 percent. Faridkot recorded a 0.42 percent tempo of urbanisation in 1981 and it soared to 0.93 percent in 1991. It declined and came down to 0.19 percent in 2001 and further to 0.001 percent. The projection for 2021 in Faridkot is -0.06 percent tempo of urbanisation. Amritsar had 0.38 percent tempo of urbanisation in 1981. It declined to 0.11 in 1991. An unprecedented jump in the tempo of urbanisation in Amritsar was recorded in the next decade having reached at 1.74 percent in 2001. However, it declined to a historically low of 0.21 percent in 2011 in Amritsar. The projection for 2021 in Amritsar is a 0.94 percent tempo of urbanization.

Table 3: District-wise Tempo of Urbanisation of Punjab (1981-2021)

District	1981	1991	2001	2011	2021*
SAS Nagar	-	-	-	1.59	-
SBS Nagar	-	1.1	0.28	0.67	0.001
Bathinda	0.49	0.43	0.28	0.62	-0.26
Jalandhar	0.52	0.53	0.68	0.54	0.52
Patiala	0.35	0.10	0.58	0.39	0.06
Rupnagar	0.65	0.42	-0.33	0.35	-0.58
Ludhiana	0.72	0.92	0.46	0.33	0.51
Moga	-	-	-0.19	0.29	0.15
Fatehgarh Sahib	-	-	0.62	0.28	0.49
Firozpur	0.06	0.12	0.19	0.27	-0.22
Muktsar	-	-	0.21	0.24	0.25
Sangrur	0.25	0.20	0.40	0.24	0.53
Amritsar	0.38	0.11	1.74	0.21	0.94
Kapurthala	0.68	-0.42	0.69	0.20	0.001
Barnala	-	-	-	0.15	-
Hoshiarpur	0.23	0.27	0.26	0.14	0.28
Tarn Taran	-	-	-	0.07	-
Mansa	-	-	0.58	0.06	0.29
Faridkot	0.42	0.93	0.19	0.001	-0.06
Pathankot	-	-	-	-	-
Fazilka	-	-	-	-	-
Punjab	**0.43**	**0.33**	**0.42**	**0.26**	**0.19**

Source: Based on Census of India Reports (1971-2011) *General Population Tables, Punjab Series* 4 & Population Statistics of Punjab (1971-2011)

Note: Dash (-) indicates that sufficient data was not available for calculation as district was not formed.

*Based on projected data

Urban Size-Class Pattern

The Census of India has classified cities and towns based on population criterion into six size classes. The towns with a population of 1,00,000 and above have been classified as Class I cities. Class II cities have a population of 50,000-99,999, Class III has 20,000 to 49,999, Class IV has 10,000 to 19,999, Class V has 5,000 to 9,999 and Class VI has less than 5,000 population. Punjab has 217 cities/towns as per the Census of India, 2011. It had increased significantly to 108 in 1971, 134 cities/towns in 1981, 120 cities/towns in 1991 and 157 cities/towns in 2001 in Punjab. Table 4 depicts the growth of the number of cities/towns in the state. The number of Class I cities in Punjab was 4 in the year 1971, which increased to 7 in 1981, 10 in 1991, 14 in 2001 and 16 in 2011. The projection of towns reflects that the state has 23 Class I towns/cities, 32 Class II, 59 Class III, 69 Class IV, 68 Class V and 24 Class VI towns/cities, with the total number surging to 275.

Table 4: Numbers of Towns/Cities in Different Classes of Punjab

Year	Number of class I Towns/ Cities	Number of class II Towns/ Cities	Number of class III Towns/ Cities	Number of class IV Towns	Number of class V Towns	Number of class VI Towns	Total Towns
1971	4	8	22	32	30	12	108
1981	7	10	27	36	40	14	134
1991	10	18	25	46	14	7	120
2001	14	18	36	54	29	6	157
2011	16	24	49	61	49	18	217
2021*	23	32	59	69	68	24	275

Source: Based on Census of India Reports (1971-2011) *General Population Tables, Punjab Series* 4 & Population Statistics of Punjab (1971-2011)
*Projected figures

The urban population share in all class-size of towns/cities is highly variable. In 1971, the highest population was concentrated in Class I cities with 40.52 percent of the total urban population of the state. It was followed by Class III cities with a share of 22.53 percent population. In the same year, 15.83 percent of the urban population lived in Class II, followed by Class IV, Class V and VI with 13.32 percent, 6.53 percent and 1.28 percent respectively. In 1981, the trend remained somewhat constant with 46.38 percent in Class I, 20.46 percent in Class III, 14.39 percent in Class II, 11.06 percent in IV, 6.50 percent in Class V and 1.21 percent in Class VI towns. In 1991, the concentration of population increased in Class II towns/cities in comparison with Class III towns. In this Census, the Class I cities had a population of 54.16 percent, Class II had 19.91 percent, Class III had 13.12 percent, Class IV had 1.62 percent, Class V had 1.72 percent and Class VI had 0.47 percent of the total urban population. The share of the urban population in Class I town in 2001 was 58.32 percent. It was followed by Class II. Class III, Class IV, Class V and Class VI towns/cities with 15.91 percent, 13.10 percent, 9.81 percent, 2.58 percent and 0.28 percent respectively. The Census of India 2011 reported the concentration of the population in Class I cities in Punjab which was 57.17 percent. It was followed by Class II with a 17.07 percent population, Class III with 13.20, Class IV with 8.48, Class V with 3.35 percent and Class VI with 0.73 percent of the share of the urban population, as shown in Table 5. The population projection suggests that the percentage share of the urban population is 62.42% in class I towns/cities, 17.11% in Class II, 11.70% in Class III, 7.58% in Class IV, 3.39% in Class V and 0.82% in Class VI towns.

Table 5: Percentage share of Urban Population in different Classes of Towns/Cities of Punjab

Year	Class I	Class II	Class III	Class IV	Class V	Class VI
1971	40.52	15.83	22.52	13.32	6.53	1.28
1981	46.38	14.39	20.46	11.06	6.50	1.21
1991	54.16	19.91	13.12	10.62	1.72	0.47
2001	58.32	15.91	13.10	9.81	2.58	0.28
2011	57.17	17.07	13.20	8.48	3.35	0.73
2021*	62.42	17.11	11.7	7.58	3.39	0.82

Source: Based on Census of India Reports (1971-2011) *General Population Tables, Punjab Series* 4 & Population Statistics of Punjab (1971-2011)
*Projected percentage calculated on the basis of previous data.

Not only the share of the urban population in these classes of towns are changing, but there is also a drastic change in the growth rate of population in these towns/cities. Figure 2 shows the population growth rate in each Class of towns/cities in Punjab since 1981. During 1971-1981, the population growth rate of Class I cities of Punjab was 65.43 percent, which declined to 50.59 percent in 1981-1991, 48.45 percent in 1991-2001 and further to 23.37 percent in 2001-2011. This shows a trend of population saturation in Class I towns of Punjab. In Class II cities, the population growth rate was 31.29 percent during the decade 1971-1981, which increased to 78.41 percent in 1981-1991. It drastically declined further to 10.15 percent in the decade 1991-2001 but surged to 35.10 percent in the next decade of 2001-2011 was seen. The population growth rate in Class III towns was 31.3 percent during the decade 1971-1981. It showed negative growth in the decade 1981-1991 with a growth rate of -17.29 percent. It increased to 37.58 percent in 1991-2001 and declined to 26.83 percent in 2001-2011. In Class IV towns, the concentration of the urban population was 20 percent in 1981, which increased to 23.74 percent and 27.44 percent in 1981-1991 and 1991-2001 respectively. Later it declined to 8.8 percent from 2001-2011. The population growth rate in Class V towns during the decade 1971-1981 was 43.82 percent which slumped to -65.90 percent in the next decade 1981-1991. It again jumped to 107.30 percent during the decade 1991-2001 and again declined to 63.26 percent in the next decade 2001-2011. Class VI towns had 36.95 percent of the population in the decade 1971-1981. It declined to -49.97 percent in 1981-1991 and again dropped to -18.62 percent during the decade 1991-2001.

In the decade 2001-2011, it witnessed a drastic positive change and a growth rate of 228.89 percent was recorded. The projection of population for 2021 indicates a very low growth rate in all classes of towns/cities. Though there is saturation in population in higher classes of towns in the state, the Class VI towns have an increasing population growth rate as new Class VI towns have emerged in the state in large numbers. Most of these towns are census towns, which do not have any administrative body to regulate their growth and development at par with urban centres.

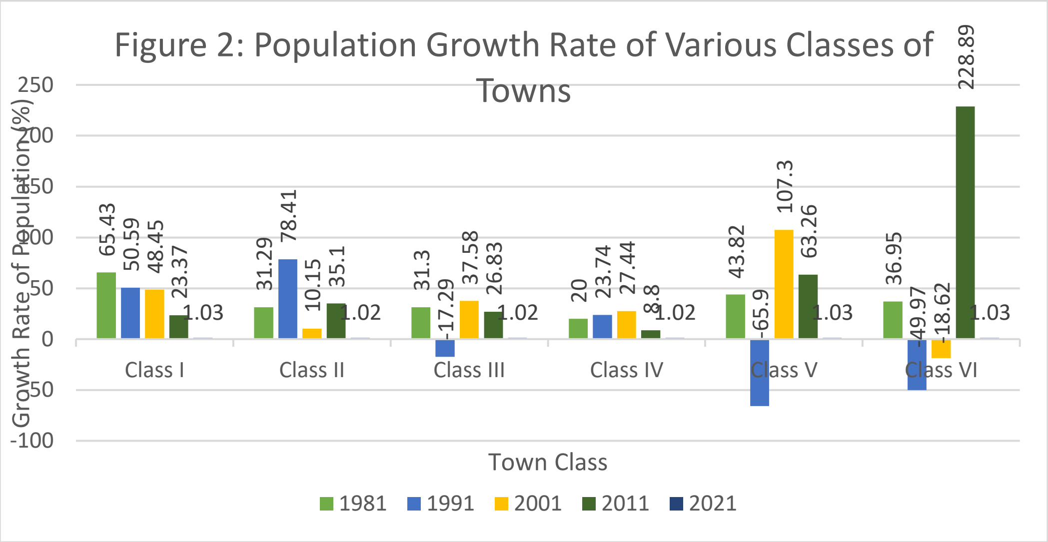


Figure 2: Population Growth Rate of Various Classes of Towns

Growth of Census Towns in Punjab

There were more than two hundred towns in 2011 in Punjab, out of which 163 were statutory towns and 74 census towns. The number of census towns has increased from 18 in 2001 to 74 in 2011. In this transition, as many as 55 census towns were transformed from village settlements to urban. There is a concern that this change is associated with the movement of people (particularly working people) from rural to the *place* they do business in and not to what are called towns. Working and business Punjabi people move to village service centres and engage in various economic activities of secondary and tertiary sectors. The people of Punjab with their movement to such places have created census towns that go unnoticed in the process of urbanisation. During the last decade, twenty lakh additional people from Punjab moved to urban areas, of which, perhaps 8 lakhs of them went to these towns due to economic reasons (see, The Ministry of Statistics and Programme Implementation). Generally, Census Towns are towns that are not statutory towns. i.e. they have not been notified as *urban areas* by the state government. In Punjab, a large number of census towns are located in certain districts such as Pathankot (12), Jalandhar (9), Ludhiana (9), Sahibzada Ajit Singh Nagar (7), Amritsar (7) and Gurdaspur (5). However, the majority of these towns are governed by the Panchayati Raj system and often they lack (a) basic infrastructure, and (b) robust governance structure and administrative capacity to deliver services. An interesting feature about census towns in the state indicates that most of such towns are located away from the large cities but closer to transport routes leading to large urban areas. However, much of the urban growth of cities and towns in Punjab appears like a *rurban* in the character. This refers to geographic landscapes which possess the economic characteristics and lifestyles of an urban area while retaining its essential rural features around. Rurban communities are the rural socio-geographic spaces, where styles of life and the standard of living have changed so much that they resemble those in urban localities. This phenomenon is perhaps due to either urban expansion or rural migration.

Industrialisation, Migration and Urban Punjab

The state of Punjab has a long tradition of being an agriculture-based economy. The *green revolution* started in the year 1960s promoted agriculture expansion in the state. The growth and prosperity primarily have been the result of Punjab's adoption of new technology in agriculture. The urbanisation in Punjab to a great extent is influenced by commercial activities, service providers and industrial establishments. In Punjab, much of agricultural prosperity has played an important role in shifting the population from rural to an urban economy driven by trade, commerce, service, manufacturing, and industries. The mechanisation of agriculture does lead to an increasing demand for the manufacturing of machine tools. This led to the establishment of machine tools industries meeting the requirement of the farm sector in the state. The demand from the agriculture sector pushed the industrial ecosystem in the state. Studies reveal that agriculture-induced industrialisation remains the main motive force for urbanisation in the state of Punjab (Maini, 2004). Major industries in the state include food processing, tractors and auto components, agro-based parts, bicycles and bicycle parts, sports goods, light engineering goods, metal and alloys, chemical products, textiles, information technology and pharmaceuticals. The contribution of urban areas to the State Gross Domestic Product is over 75 percent. This shows that urban areas are major drivers of the economy and promote the industry and service sectors. This means that the growth and development of the state are closely linked with the productivity, sustainability and operational efficiency of urban centres.

An attempt has been made to establish a correlation, as shown in Table 6, between the concentration of population and the concentration of industries in various districts of Punjab. At present, the most urbanised districts of Punjab are Ludhiana, Jalandhar, and Amritsar, which have the highest concentration of registered factories, firms and industries. A strong correlation between the concentration of the urban population and the concentration of factories has been found in the state. Ludhiana district has the highest share of the urban population which is 23.54 percent of the total urban population in the state. It also has the highest concentration of Industries with 29.78 percent of total registered factories in the state. Similarly, Amritsar has a 13.55 percent share of the urban population of the state and 8.76 percent of registered factories. Jalandhar has 11.65 percent of the urban population of the state and 10.92 percent of registered factories of the state. The Correlation Coefficient (r) between the district-wise share of the urban population and the share of registered factories is 0.945, which proves a very strong correlation between urbanisation and industrialisation.

Table 6: Correlation Between Urbanisation and Industrialization of Punjab

District	Percentage of Urban Population of district to total urban population of state (Projected for 2021)	Percentage of Registered Factories* (2020)
Ludhiana	23.54	29.78
Jalandhar	11.65	10.92
Amritsar	13.55	8.76
Sangrur	4.71	6.94
Patiala	6.76	5.01
Bathinda	3.15	4.81
SAS Nagar	6.01	4.02
Fatehgarh Sahib	2.06	3.90
Hoshiarpur	3.40	3.48
Gurdaspur	2.16	3.38
Firozpur	1.75	3.04
Kapurthala	2.61	2.86
Moga	2.43	2.53
Mansa	1.79	2.01
Faridkot	1.31	1.88
Shri Muktsar Sahib	2.69	1.47
Rupnagar	0.93	1.30
Fazilka	2.57	1.30
Barnala	1.79	0.95
Pathankot	2.67	0.74
SBS Nagar	1.08	0.62
Tarn Taran	1.40	0.30
Correlation Coefficient (R)= 0.945		

Source: Based on Census of India Reports (1971-2011) *General Population Tables, Punjab Series* 4 & Population Statistics of Punjab (1971-2011)
*Registered Factories under Section 85 and Section 2m (I and II) of Factories Act, 1948

The commercialisation of agriculture, urbanisation and industrial development played an important role in the rising trend of migration in the state. The migrants for employment purposes of all time have been considered in the Census of India from 1981 to 2011. Table 7 shows the trend of migration for employment within the state and outside the state. In the year 1981, there were 59.10 percent of total migrants moved within the state for the sake of employment. It declined to 57.70 percent in 1991. It drastically declined to 38.90% in 2001. It again increased to 51.36% in 2011. On the other hand, the migrants from outside the state were 40.90 percent in 1981, which increased to 42.29 percent in 1991. It further increased to 61.10 percent for the year 2001, but drastically declined to 48.64 percent in 2011. The projections indicate that the migration within the state is 51.29 and from outside the state is 48.71% in 2021. The projection is carried out on previous migration data and the impact of the COVID-19 pandemic and successive lockdowns on the migration has been partially accessed. It has been indicated that intra- state mobility for employment has increased, whereas the number of migrants coming from outside the state has declined.

Table 7: Migration for Employment in Punjab

	Nature of Origin	Nature of Destination	Total Migrants for Employment (%)				
			1981	**1991**	**2001**	**2011**	**2021***
Within State	Rural	Rural	20.8	18.49	9.57	11.33	11.31
	Urban	Rural	4.01	3.29	1.41	2.48	2.47
	Rural	Urban	20.71	22.05	17.69	18.86	18.84
	Urban	Urban	13.58	13.87	10.23	18.68	18.67
	All		**59.10**	**57.70**	**38.90**	**51.36**	**51.29**
Outside State	Rural	Rural	11.32	9.77	14.86	11.15	11.18
	Urban	Rural	3.08	2.87	1.56	1.58	1.57
	Rural	Urban	14.85	15.98	34.44	21.31	21.39
	Urban	Urban	11.65	13.67	10.24	14.61	14.57
	All		**40.9**	**42.29**	**61.10**	**48.64**	**48.71**

Source: Based on Census of India Reports (1981-2011) *Migration Tables* & Population Statistics of Punjab (1971-2011)
*Projected Data

Within the state of Punjab, the highest rate of migration for employment was from rural to urban 20.17 percent in 1981 and increased to 22.05 percent in 1991. It declined to 17.69 percent in 2001 but further increased to 18.68 percent in 2011. It is projected to be at 18.67% in 2021. It is projected at 18.84 percent in 2021. Urban to Urban migration within the state was 13.58 percent in 1981, which remained almost the same at 13.87 percent in 1991. Further, it declined to 10.23 percent in 2001 and again increased to 18.68 percent in 2011. In 1981 rural to rural migration within the state was 20.80 percent which declined to 18.49 percent in 1991. Urban to rural migration was 4.01 percent in 1981, which also declined to 3.29 percent in 1991. In the year 2021, it is expected to be witnessing the same pattern and reaching 11.32 percent and 2.47 percent in 2021.

Migration for employment purposes from outside the state has shown a declining trend in Punjab over the past decades. Several reasons emerge as the cause of this concern. Certain schemes of employment as being implemented in the States including the Mahatma Gandhi National Rural Employment Guarantee Act (MNREGA) have played a part in reducing the intensity of out-migration from the conventional states largely located in northern India. With this, the nature of the push factor has drastically changed and caused a weakening pattern of out-migration to Punjab state as well. For instance, in Bihar, 33.79 lakh individuals worked under the MNREGA schemes in 2018-19, which increased to 54.32 lakhs in 2021-22. Similarly, in Uttar Pradesh, this number has increased from 61.51 lakhs in 2018-19 to 95.54 lakhs in 2021-22. The major labour force comes to Punjab from such states. Traditionally, they send agricultural unskilled labours. They were absorbed in employment largely confining agriculture activities. Simultaneously, with increasing advances in mechanisation, the labour required for agriculture sectors also has witnessed a decline in prosperous states such as Punjab. All this has adversely influenced the migration flow to the state. According to the Economic Survey of Punjab (2020-21), the employment share of Agriculture and allied activities was 25.75% in Punjab as compared to 79.51% in 1971 and 64.11% in 1991. This was remarkably low as compared to national figures for employment in agricultural and allied activities which is 45.56% in India. It is evident that agriculture employment has declined. The unemployment rate in Punjab has also been increasing. According to the Centre for Monitoring Indian Economy, the unemployment rate in Punjab increased to 10.00 percent in 2019-20, which was 6.07% in 2016-17 (Vasdev, 2023). The perception of employment in the youth of Punjab is also poor. According to the Indian Youth: Aspiration and Vision for the Future survey by Centre for Study of Developing Societies, 78% of the respondent of the age group 18-24 felt that employment opportunity in Punjab is bad. Due to these reasons, there is a declining trend in the pull factor of Punjab. A further study can be done to understand the detailed cause of this decline. Migration from rural areas outside the state to the urban areas of Punjab was 14.85 percent in 1981, which increased to 15.98 percent in 1991. It reached its highest of 34.44 percent in 2001 but further declined to 21.31 percent in 2011. It is projected to be at 21.39 percent in 2021. The migration from rural areas outside the state towards the rural areas in the state was 11.32 percent in 1981. It reached 9.77 percent in 1981 but increased to 14.86 percent in 2001. During the next decade, it declined to 11.15 percent and is projected to further increase in 2021 to 11.8 percent. The urban-to-urban migration from outside the state was 11.65 percent in 1981 which increased to 13.67% in 1991. It declined to 10.24 percent in 2001 but again increased to 14.61 percent in 2011. Urban-to-rural migration from outside the state was 3.08 percent in 1981 and 2.87 in 1991. It declined to 1.56 percent in 2001 and 1.58 percent in 2011. It is expected to slightly decline in 2021 to 11.5 percent. Most of the migrants moving for employment were absorbed in the urban areas of Punjab.

Urban Development and Challenges in Punjab

Urbanisation in the state is associated with the development of urban areas and an improvement in access to basic amenities and infrastructure. Accessibility to potable water, electricity, sanitation facility, better housing, sewage, and roads is considered a major indication of the improved development status. The state of Punjab has relatively performed better in providing basic amenities to the urban population. According to the Economic Survey of Punjab 2020-21, 98.9 percent of households in the state had access to drinking water in the year 2011, which became 100 percent in 2018. During the year 2008-09, the households with electricity were 99.30 percent, which jumped to 100 percent in 2018. The urban population of Punjab also had witnessed good access to housing facilities. The Census of India classifies houses into three categories Good, Livable, and Dilapidated based on their living condition. In the state, around 57 percent of houses in urban Punjab are in “Good” condition. There was 37 percent of houses categorised as “Livable” and 5 percent were categorised as “Dilapidated” which lacked proper infrastructure as per the Census of India 2011. The percentage of dilapidated houses at the national level remained at 6.59 percent. As per Census of India 2011, in Punjab, 14.2 percent of urban households were living in slums. This means that out of about 143 towns, 71 had reportedly slums in 18 districts in Punjab.

According to the Economic Survey of Punjab, the percentage of slum dwellers is 5.3 percent of Punjab's total population (2021-22). Increasing slum population pressure in the urban area has created problems of unavailability of proper housing. The shortage of good living units is one of the major concerns in the urban centres of Punjab. According to National Building Organisation Report (2015), there are 1.46 million people in the state, which accounts for 14.01 percent of urban population of the state and 2.23 percent of the total slum population of India. Though various steps have been taken to counter this problem in the form of various schemes such as Pradhan Mantri Awas Yojna (Urban), Punjab Shehri Awas Yojana (PSAY), etc. An increasing population in urban centres and a higher absorption in the informal sector mostly have marked an increase in the need for many new dwelling spaces. The spatial pattern of inequality in terms of poverty is highly variable in Punjab. The urban poverty rate in Punjab is higher than its rural poverty rate (Chakraborty & Bhandari, 2015). The highest urbanised district of the state is Ludhiana which has almost double of urban poverty rate than the rural poverty rate. The unemployment rate among the youths in Punjab is also challenging. According to the Periodic Labour Force Survey (2020-21), the youth unemployment rate in Punjab remained at 19 percent, which is 12.9 percent at the national level in the same year. Thus, the high incidence of urban poverty and unemployment in urban Punjab is one of the major development concerns.

The National Family Health Survey (NFHS) indicates challenging characteristics of urban development in the state. Table 8 shows the status of access to basic amenities in urban areas of Punjab. The population living in households with an improved drinking water source was 95.5 percent in 1998-99 (NFHS, 1999), which increased to 100 percent in 2005-06 (NFHS, 2006). It fluctuated due to urban growth characterised by residential land use. Thus, the pressure of population and construction of new dwelling spaces led to its decline to 99.3 percent during NFHS round 4 (2015-16), which increased to 99.4 percent urban areas of Punjab in the fifth round of the National Family Health Survey (2019-21). However, the over-utilisation of groundwater has led to depletion in the condition of the water. Groundwater blocks of major urbanised districts such as Ludhiana, Amritsar, Jalandhar, etc. have been over-utilised (Ground Water Year Book, 2015). The study conducted by Chopra and Krishna discovered that 43% of Punjab's groundwater is unfit for use (2014). In urban Punjab, 82.7 percent of households had improved sanitation facilities in 2015-16 (NFHS, 2016), which improved to 87.8 percent in 2019-21 (NFHS, 2021) urban areas of Punjab. This has witnessed a drastic improvement from 51.4 percent in 1998-99 (NFHS, 1999) and 61.4 percent in 2005-06 (NFHS, 2006). It was higher than the national level of 81.5 percent in the same round of NFHS. The population living in households with electricity was 99.6 percent in urban Punjab in 2015-16 (NFHS, 2016), which improved to 99.8 percent in 2019-21 (NFHS, 2021). The composite level of urban development in the state is in much better condition compared to the national averages and many states of the country. However, the district-level and city-level variations in Punjab are the cause of concern and pose major challenges. The districts and the major cities of Amritsar and Ludhiana in Punjab demand efficient water supply and sanitation services. The much of population in these cities use groundwater from bore wells which are leading to water loss and wastage. This has health consequences as well since Amritsar district's groundwater is contaminated with arsenic and Ludhiana's groundwater with nitrates and other heavy metals (The World Bank, 2021).

Table 8: Access to Basic Amenities in Urban Punjab

	Improved Drinking Water	Improved Toilet/Sanitation	Electricity Facility
1998-1999*	95.5	51.4	95.5
2005-2006	100.0	61.4	98.2
2015-2016	99.3	85.0	99.6
2019-2021	99.4	87.8	99.8

Source: National Family and Health Survey Round 2 (1998-1999), Round 3 (2005-2006), Round 4 (2015-16) and Round 5 (2019-21)
*Indicates total figures for whole state

The Ease of Living Index is an attempt to assess the quality of life and the outcome of urban development policies and schemes implemented in the cities. The Ministry of Housing and Urban Affairs of the Government of India had come with reports about select cities in the recent past. The major factors taken into measurement include economic ability, sustainability, education, healthcare, culture, environment and infrastructure. Three cities of the state found a place in the Top Fifty Cities in the "Ease of Living Index, 2020". Ludhiana was ranked Fourteenth and Amritsar was ranked forty-fifth in the category of Million Plus cities in the "Ease of Living Index 2020", whereas Jalandhar was ranked 32nd most livable city under less than a million category cities. This reflects that large cities of Punjab provide better living conditions to their dwellers. However, the majority of the urban population living in small and medium towns and non-metro cities face challenges in terms of unauthorised and unplanned development; mushrooming of unauthorised colonies; growth of slums; lack of financial, technical and human resources with urban local bodies; and growth of the informal sector. Gupta reiterated that "Urban governance in Punjab is at crossroads. In the wake of growing urbanization, it has been facing serious challenges to meet the requirements of urban infrastructure, municipal services, environmental conservation, and urban poverty alleviation" (2006). Under the *Smart Cities Mission*, three cities are selected in Punjab- Ludhiana, Jalandhar and Amritsar through a nationwide selection process. These cities have been forerunners in the project design, selection and implementation process. Thus, 11 projects worth Rs 3385 crore in Amritsar, 19 projects worth Rs 1899 crore in Jalandhar and 19 projects worth Rs 1898 crore are at the Detailed Project Reports stage. Under *Atal Mission for Rejuvenation and Urban Transformation* (AMRUT), the State is focusing on universal coverage of water in the urban areas and proposes to provide 4.6 lakh new house connections. It has already provided 1.45 lakhs tap connections, 36% of the approved Action Plan is directed toward Water supply and 61% towards Sewerage. Under *Swachh Bharat Mission* in Punjab, so far only 61 urban local bodies (ULBs) out of 164 have been declared as Open Defecation Free.

Discussions

This study unfolds that the state of Punjab has moved forward from being an agriculture-based economy to a trio of commerce, industry and service-based economy. During the post-independence and particularly after the formation of a separate state, Punjab has seen an unprecedented increase in urban population. Earlier the *green revolution* played a major role in enhancing agri-production in the state and strengthened the economy. Its evaluative perspective shows that "The Green Revolution in the 1960s gave a boost to agro-processing activities in Punjab, resulting in modernization and commercialization of the agricultural sector. This led to a growth in the demand for agricultural implements and the consequent establishment of several engineering units" (Sivaramakrishnan, et. al., 2007). This gave a major push for the economic development of the state. It meant a boost to many industries specifically the machine tools industries. However, the post-partition and post-green revolution decades saw a major boost to urbanisation as well. It resulted from the demand for labour and the agglomeration of people in the major urban centres of the state. The decade of 1971-81 witnessed a high growth rate of the urban population and the tempo of urbanization also recorded higher in a few districts which have been the backbone of the state's economy. The studies revealed that "Market towns for agricultural products were developed in Punjab along the railway lines as mandi for purchasing agricultural produce and exporting outside the state" (Shekhar 2019). This decade can be termed the 'Decade of New Rise' for the state. The process of urbanisation along with industrial development marked an important distinction in the state's development journey.

The decade of 1981-1991 is termed a 'Decade of Disturbance' for the state. This decade witnessed lots of socio-political disturbances with the rise of insurgency in the state. During these years the economy started declining, and industrial expansion too came to a halt in the state. Instead, there was a financial drain from Punjab and the state's economic development was derailed for years to come. Maini's study revealed that there was a burden on the state government to restore law and order and to maintain the expenses of the Central Forces (Maini, 2004). This affected the process of urbanisation in the state by interrupting industrialisation, infrastructure, social security and welfare. This resulted in the decline of the urban growth rate in the state. It declined from 30.75 percent in the previous decade to 22.37 percent in this decade. The tempo of urbanisation also fluctuated in most of the districts of the state. It seems that this disturbance mainly impacted the small urban centres as the growth rate of population in Class V and Class VI towns declined and turned negative. This appeared as a result of the de-notification of Notified Area Committees by the state government in Punjab which led to a more prominent increase in large urban centres. This means that the areas of the state which were fast developing and fulfilled the conditions of municipality or municipal corporation were declassified from *notified areas* to Municipality or Municipal Corporation. This led to a decline in number of small towns and the addition to large urban centers.

People seemed to have moved towards major urban centres of the state. This decade is also termed as the "*Decade of missed opportunities for Punjab*" (Sivaramakrishnan, et. al., 2007). In the 1990s, the economy of the state came to revive with the introduction of a *new economic policy* in India and it gave new hope economy and urbanisation in the state of Punjab. The 1990s witnessed a major change in the economy with its restructuring and an increase in urban population in Punjab. The slumped growth rate again started rising and almost touched the pre-disturbances period. However, the major urban centres slowed the deceleration of urbanisation despite the tempo of urbanisation remained low in large urban districts. The tempo in less urbanised districts remained very high during the decade. This growth was accompanied by *Post-Reforms Growth* in Punjab.

With the dawn of the twenty-first century, the growth of urbanisation has again slowed down in Punjab. This is related to urban growth rate of the state which was19.80 percent. The absolute increase in the urban population remained high as compared to the rural population in four districts: Ludhiana, Sahibzada Ajit Singh Naga, Amritsar and Jalandhar. During the last decade, the growth rate of urban population in Class I cities had declined. However, their peripheral areas or fringe areas are still growing. The share and number of Class VI towns drastically increased. It indicates that many new small urban centres, i.e., Census Towns have emerged. The core of the large cities and their population tend to move towards saturation and small centres are now added to the urban population.

The trend of migration for employment towards the state also declined during this decade. It shows that the state of Punjab is grappling with agricultural expansion and rising commercial and industrial growth simultaneously. A few cities still dominate urban landscape of Punjab and have been for a long time, a dispersed pattern of small and medium towns is new reality of the state. However, the city of Ludhiana is well known for its hosiery, cycle and machine tools industries. Jalandhar is known for sports goods and Kapurthala for a rail coach factory. Bathinda is popular for its chemical and fabric industries and Amritsar for the tourism and textile industries. Central Punjab's urban concentration is in and around these big cities. The forward and backward linkages of these industrial towns gave rise to a strong industrial ecosystem, a *corridor*, which creates a major pull and attracted working population from outside and within the state. All this gives rise to *economies of urban agglomeration*. The urban-ward movement in the state indicates that urban Punjab is most preferred by people coming from the surrounding highly dense state and they move and settle here in search of business, employment, livelihood opportunities and living standard. The spill-over impact of these large towns and rural population growth has also caused an increase in small urban centres developed along the route to big states in the state. However, many small towns are more independent and autonomous and located away from big cities, which reflects a silent process of *subaltern urbanization* in the state. A strong correlation between the level of urbanisation and industrialisation exists in the state. A higher concentration of urban population in a few districts of Punjab is associated with the economic system as driven by key cities and towns. Thus, Shekhar's study noted that "the major reasons for the faster reason for growth of these towns are the concentration of manufacturing and industrial units within these districts" (Shekhar, 2019).

However, the study finds urban growth has been largely unplanned and organic growth of small and medium towns is not an uncommon phenomenon in Punjab. The informal sector of urban Punjab has been largely absorbing in-migrants.

The projection of population for 2021 for the state indicates that the state's urban stock is largely contributed by already highly urbanized districts, i.e. *central zone*. The middle-order districts, the level of urbanization, of the state will also register the higher level of and tempo of urbanization in Punjab. Many small and medium towns will come up in these districts in the coming times. Though the share of Class I and Class II in the total urban population of Punjab will maintain its usual importance, the share of Class V and Class VI has also registered unprecedented growth. Despite registering an overall slow growth of population in 2021, the growth of population will be recorded higher in small and medium urban centres. Migration for employment from outside and from within will slightly go up in the state. The slowing down of the tempo of urbanisation indicates that the cities are overburdened and growing very slowly. Other small centres are now providing new avenues for industrial growth and urbanisation. The urbanisation of Punjab can be understood as a result of three major factors: green revolution, industrial concentration and a well-developed transport network. The establishment of small industrial units after independence gave people employment opportunities. The green revolution boosted the industrial sector by giving an impetus to the machine tool industry. The development of the transport network in the state established a strong network with the nation's capital and other major economic centres of the country. Sivaramakrishnan et. al. noted that "the major factor behind the growth process is the emergence of urban industrial corridor along Ludhiana, Jalandhar and Amritsar Highway" (2007). These phenomena contributed to the process of urbanisation in the state of Punjab.

However, new schemes and policies such as the *Industrial and Business Policy of Punjab*, Atal Mission for Rejuvenation and Urban Transformation- *Amrut* (16 cities including Abohar, Barnala, Batala, Bathinda, Hoshiarpur, Khanna, Malerkotla and others), *Smart Cities Mission* (SCM-Ludhiana, Amritsar, Jalandhar), etc. are meant to contribute significantly to economic development and growth of urban centres in the state. The objective of SCM was to promote cities that provide core infrastructure and give a decent quality of life to its citizens. As the projection has been calculated on the previous decade's Census data, the impact of the COVID-19 pandemic on the population has not been accessed. The pandemic occurred in the last year of the decade, and its impact on the population can only be analysed by the actual census data. Therefore, the projection made is a reflection of trends based on the previous data and an actual Census is required for correct visualisation of the situation.

Conclusion

The urban population and level of urbanisation in Punjab have been growing rapidly over the last few decades. The State is now one of the most highly urbanised states in the country. The degree of urbanisation is spatially variable across the districts and it is highly confined to the central zone of the Punjab, where districts located have higher urban concentration. Apart from a few districts in the central zone, the rest of the districts are less urbanised than the state average. A higher concentration of population is found in Class I and Class II cities and towns of the state which altogether contribute significantly to the total urban population. The share of the population in small towns such as Class V and Class VI has been low over the past decades, however, their share now tends to increase to a new level. At present, there has been an unprecedented increase in the number of Census Towns which largely fall under the Class VI category. Large cities may depict that a declining pace of urbanisation also has an impact on the fluctuating trend of in-migration in Punjab. Though in-migration from other states for work and employment reasons has been higher in the past decades, it has shown signs of decline during the last decade or so. The study recognizes that new industrial units being developed in less urbanised districts will effectively diverge urban concentration and reduce the pressure of population on the existing large urban centres of the state. However, new schemes, for urban development and rejuvenation, are being implemented in cities of Punjab under the AMRUT and the SMART CITIES MISSION that are too early to comment on.

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MORBIDITY PATTERN AND THE HEALTH CARE SEEKING BEHAVIOUR AMONG THE ELDERLY WOMEN IN NALANDA DISTRICT OF BIHAR

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ABSTRACT

In India, seventy-one percent of the elderly population lives in rural areas whereas good medical facilities are mostly concentrated in urban areas. The state of Bihar records the highest population growth in the country, the lowest per capita income, nearly half of the population in the state are living below the poverty line, an unfavorable elderly sex ratio unlike other states and records low life expectancy at the age of sixty. All these parameters indicate the vulnerability and challenges of rural-aged women in the state. The study is based on the primary survey of the rural elderly women of the Nalanda district of Bihar. It analyses their health status in terms of morbidity patterns and healthcare-seeking behaviour. Ageing is associated with an increase in the prevalence of disease and an extra burden on the family's finance. Binary logistics regression analysis shows how health status and health-seeking behavior as dependent variable is linked with various socio-economic independent variables. This paper recommends formulating policies on accessible and affordable healthcare services mainly for elderly women who are mostly asset-less and are highly dependent on their families. To understand the triple jeopardy of being old, poor and female in Bihar, this work becomes essential in the context of understanding their health.

Keywords: Chronic Diseases, Elderly Women, Health-seeking Behaviour, Morbidity Pattern, Public Health Centres.

INTRODUCTION

India lives in her villages and three-fourths of the aged population are residing in the countryside. Bihar holds the second-highest rural population in the country with 88 percent of its population being mainly rural (Census, 2011). Rural areas provide a lack of resources and services when compared to urban areas. The rural poor and women are identified as the most vulnerable among the elderly (Sarkar, 2016). Elderly women are highly dependent on the males in their families in terms of financial need. Hence, they are poorer than their counterparts. Women, mainly in advancing ages are less displayed in medical trials and research (Davidson et al., 2011). This less reporting of women in clinical trials has stuck the progress of gender-based treatment and policy guidelines. The National Policy on Senior Citizens report shows that the majority of low-income families in rural areas can barely meet their daily subsistence and thus have no savings for their old age. About 3 percent of the aged males and 8 percent of aged females are living alone at the age when they need to be cared for most. Living arrangement impacts their care-receiving condition. Hence, elderly women who stay alone are considered ' at risk' by the World Health Organization. Consequently, there is no surety about their needs getting fulfilled. Elderly people who don't live with their families are more likely to suffer from chronic diseases and acute ailments (Agrawal and Keshari, 2014).

With globalizing economies rapidly changing technology and increasing migration, more nuclear families in India and the gradual decline of the joint family norm are witnessed. Due to this change in the very basic fabric of the community, the caregiving attitude of the society is also changed and they no longer protect the elderly as they used to do in the past. This makes the elderly women largely displaced in the community. They are more vulnerable to isolation. Deteriorating health leads to disability and psychological distress, elderly abuse and lower life satisfaction. Moreover, the concentration of elderly living alone is evident in rural areas rather than an urban phenomenon.

Rural people have a higher incidence of illness as compared to urban people. They have a higher incidence of low health-seeking attitudes, especially among elderly women. The shortage of trained medical staff and unaffordable medical expenditure creates an attitude of fear regarding seeking health services. The issue of disparities in terms of treatment-seeking behaviour among elderly women, disease prevalence and disability, expenditure on health care, mistreatment of elderly by their family members and overall life satisfaction among elderly women are the areas that need more attention as they can help in understanding the perspective of elderly living in a rural setup (Banjare, 2016). Inadequate health facilities in the rural areas force even poor people to visit private medical practitioners. Expensive costs of treatment force elderly women from low economic strata to delay treatment, thereby provoking health problems. More proportion of the elderly in the total population would give rise to a severe need for respect, care and support, mainly when joint family care is declining. With negligible pension and social security schemes changing household structures, understanding the rural elderly women, especially in terms of living arrangements, financial dependence, their overall satisfaction from life and its effect on health and hindrances in health-seeking behaviour becomes inevitable to look into (Agrawal and Arokiasamy, 2010).

Rural health care is one of the biggest challenges because 70 percent of the population lives in rural areas with low-level health facilities. Facts like the rising ageing population, higher concentration of aged persons engaged in the informal sector and the need to work beyond the age of sixties provide the need to understand the affordability, accessibility and quality of the available health services in rural areas of the state. The number of both public and private hospitals is disproportionately low in rural areas, even if available, for complicated health treatment, an individual has to migrate to the city for sound medical advice. Consequently, rural elderly women used to suffer from multiple diseases in terms of severity. They are also less likely to go for treatment since they often do not have transportation facilities and a person to accompany them to the health facilities. Their less exposure creates hindrances while meeting doctors, affecting their health-seeking behaviour.

The elderly sex ratio is abysmally low in Bihar, with 877 females per 1000 males compared to 1033 females per 1000 males for all India (census, 2011). State-wise life expectancy in India reveals that females have more life expectancy at the age of sixty than their counterparts except in a few states like Bihar, Haryana, Punjab and Uttar Pradesh. In Bihar, the unfavorable elderly sex ratio and low life expectancy at the age of sixty indicate many challenges for women. Bihar records the highest population growth in the country and along with this surge, the demand for various facilities comprising essential health services is on the rise. This condition turns out to be worse in Bihar because the state records the lowest per capita income and nearly half of the population in the state are living below the poverty line (Kumar and Raj, 2013).

The rural poor and women are identified as the most vulnerable among the elderly (Sarkar, 2016). Gender discrimination impacts elderly women. There are multiple instances of discrimination faced by rural elderly women regarding their healthcare needs beyond other necessities. To understand the triple jeopardy of being old, poor and female in Bihar, this work becomes essential in the context of their health status and health-seeking behaviour. Bihar faces several health challenges. Women's health has developed into a significant issue given their improved longevity and limited access to health care compared to men. Women, mainly in advancing ages are less displayed in medical trials and research (Davidson et al., 2011). This led to gender discrimination in treatment and policymaking because of dark figures. Women's improved length of life has noteworthy implications for women living alone, potentially with fewer resources and support.

Facts like the unfavourable elderly sex ratio and low life expectancy at the age of 60 in Bihar give another dimension to understanding elderly women's health and the impact of weak socio-economic background factors on their health-seeking behaviour. This work will consider health status because health is impacted by several factors that mirror socio-economic development regarding wealth possession of the family, standard of living, housing, sanitation, water supply, education, employment, health consciousness, and personal hygiene.

The present study examines the following objectives in the study area 1) to assess the health status of elderly women in terms of their morbidity pattern in the Nalanda district, Bihar, 2) to understand the impact of the social and economic status of rural elderly women on their health status and health-seeking behavior, and 3) to ascertain the role of availability, accessibility and affordability in utilising health care services by elderly women.

METHODOLOGY

The indicators used in the study to sample the representative study district in Bihar state are the rural sex ratio, rural elderly working women participation rate, the rural proportion of widows, the proportion of rural elderly females in the district's total population and the elderly female-headed households (Table-1). Based on the index score, Nalanda district which is performing average score and close to the state figure, is chosen (Table-2) as a study area. The district of Nalanda was constituted on 9th November 1972. Nalanda district has a population of almost three million. It recorded a growth rate of 21.2 percent in 2001-11. Almost 85 percent of the population of Nalanda is residing in rural areas (Census, 2011). Bihar Sharif is the leading town and also the head-quarter of the district. This district is surrounded by Patna district (the capital of Bihar) on its north and west (District Census Health Book, 2011). Two CD blocks that are Katrisarai and Bind Block and six villages in the Nalanda District of Bihar state with a better sex ratio have been taken. Villages with the highest population are the criteria for selecting villages with the assumption that a large number of elderly women will be from the total population.

Secondary sources of the study area do not provide data on many aspects of the elderly population in the study area. Therefore, a primary survey was conducted for further investigation. This work is mainly based on the primary data collected via asking questions to elderly women and recording the other members' responses. Elderly women of 60 and above age groups have been selected. A structured questionnaire schedule has been used to collect the data to get quantitative information.

The questionnaires design the queries based on the demographic and background profile of the elderly population which included demographic information on age groups, marital status and household size. Socio-economic variables included work status, financial dependence, literacy and level of education, caste, religion and elderly women. Other information is collected by the health infrastructure. These include the accessibility of health centres from home, transportation facilities, time taken to reach health centre, availability of health centres in the villages and availability of drugs and medicines at the health centre units.

A total of 450 samples have been chosen to take 75 from each village based on information from the voter's list from Gram Panchayat. From the list, target respondents have been selected by systematic random sampling method. Non-probability snowball sampling method is also used in the field because of the mismatch of elderly women in the voters' list and their actual presence. The survey is completed by reaching the next elderly woman with the help of one elderly household. Systematic random sampling is the random sampling method that select samples based on a system of intervals in a population.

The interview questions are focused on elderly women only including their family background, economic condition, health status and the problems faced by them after attaining the age of 60. The interview is carried out in Hindi as well as in the local language as per the convenience of the respondents. The reason for the study is described to the respondents and proper care was taken to maintain their response confidentially. In case of any difficulty in communicating with the women elderly, the help of other family members is taken. Morbidity is marked by self-reporting mainly. V1, V2, V3, V4, V5, V6 are village numbers for the survey.

Table-1 Districts of Bihar showing Various Indicators, Census -2011

DIstrIct	Rural Elderly Sex Ratlo	WPR of Elderly Rural	Percentage of Rural Elderly WIdow	Percentage of Rural Female of 60+	60+ Female Headed Household
Pasml Champaran	832.12	24.52	47.03	2.79	13.73
Purbl Champaran	812.73	15.80	45.53	2.85	13.81
Sheohar	857.39	13.63	44.83	3.79	18.08
SItamarhI	869.84	14.42	48.27	3.22	17.24
MadhubanI	920.18	18.49	47.26	3.49	16.99
Supaul	885.25	29.13	41.81	2.97	14.06
Ararla	826.81	27.91	47.04	2.54	16.68
KIsanganj	919.32	12.79	80.07	2.39	28.05
Purnla	832.52	25.66	25.89	2.35	19.50
KatIhar	898.49	25.92	47.06	2.50	23.10
Madhepura	834.75	34.02	73.32	2.75	13.37
Saharsa	899.23	25.64	42.50	2.88	14.46
Darbhanga	934.24	16.95	18.25	3.23	19.94
Muzzafarpur	875.40	15.22	37.60	3.54	15.97
Gopalganj	914.84	17.27	71.91	3.74	17.30
SIwan	930.31	16.29	29.95	4.13	18.35
Saran	913.24	13.13	35.33	3.88	18.82
VaIsalI	883.31	12.48	39.68	3.61	15.52
SamastIpur	894.33	16.29	45.77	3.39	16.49
Begusaral	891.09	17.20	44.26	2.71	17.96
Kagarla	865.70	22.01	43.37	2.82	14.90
Bagalpur	862.07	25.28	42.64	2.67	14.92
Banka	906.06	24.00	44.83	3.56	13.58
Munger	898.52	16.19	44.03	2.58	15.52
LakhIsaral	858.79	20.96	44.25	2.90	15.66
Shelkpura	876.91	23.87	39.38	3.03	13.89
Nalanda	898.75	29.79	38.13	3.31	13.06
Patna	875.44	18.58	37.64	2.07	15.25
Bhojpur	821.92	13.53	39.36	2.08	15.50
Buxar	844.17	11.55	37.19	3.61	16.53
Kalmur	875.79	20.00	35.54	3.59	13.54
Rohtas	842.98	14.45	38.53	1.98	13.02
Jahanabad	863.12	29.50	37.12	3.25	12.66
Aurangabad	840.98	20.94	36.00	2.77	11.92
Gaya	869.24	27.39	37.67	3.04	13.88
Nawada	868.82	24.97	39.50	3.02	13.80
Jamul	870.39	28.25	42.28	3.31	12.26
Arwal	862.02	18.19	39.02	3.51	13.60
BIhar	877	19.78	42.54	3.08	16.13
AVERAGE	874.40	20.58	42.89	3.05	15.87

Table-2 Composite Index of Districts of Bihar, Census -2011

District	Rural Elderly Sex Ratio	WPR of Elderly Rural	Percentage of Rural Elderly Widow	Percentage of Rural Female of 60+	60+ Female Headed Household	COMPOSITE INDEX
	Z Score	Z Score	Z Score	Z Score	Z Score	
Pasmi Champaran	-1.39	0.68	-0.50	-0.70	1.09	-0.82
Purbi Champaran	-2.02	-0.81	-0.39	-0.67	0.74	-3.15
Sheohar	-0.56	-1.19	1.41	0.72	0.58	0.96
Sitamarhi	-0.15	-1.05	0.33	0.45	1.38	0.96
Madhubani	1.50	-0.36	0.85	0.36	1.15	3.50
Supaul	0.35	1.47	-0.15	-0.59	-0.13	0.95
Araria	-1.56	1.26	-0.97	0.26	0.32	-0.70
Kisanganj	1.47	-1.33	-1.27	3.97	3.07	5.91
Purnia	-1.37	0.87	-1.34	1.18	0.82	0.16
Katihar	0.79	0.92	-1.05	2.36	1.82	4.82
Madhepura	-1.30	2.30	-0.57	-0.81	0.12	-0.27
Saharsa	0.81	0.87	-0.33	-0.46	0.42	1.32
Darbhanga	1.96	-0.62	0.35	1.33	0.65	3.66
Muzzafarpur	0.03	-0.91	0.95	0.03	0.47	0.57
Gopalganj	1.32	-0.56	1.32	0.46	-0.05	2.50
Siwan	1.83	-0.73	2.07	0.81	-0.48	3.50
Saran	1.27	-1.27	1.60	0.96	-0.76	1.79
Vaisali	0.29	-1.38	1.07	-0.11	-0.63	-0.77
Samastipur	0.65	-0.73	0.65	0.20	0.80	1.57
Begusarai	0.55	-0.57	-0.66	0.68	0.44	0.44
Kagaria	-0.29	0.25	-0.44	-0.32	0.23	-0.56
Bagalpur	-0.41	0.81	-0.73	-0.31	0.06	-0.58
Banka	1.04	0.59	0.98	-0.75	0.57	2.43
Munger	0.79	-0.75	-0.90	-0.11	0.39	-0.58
Lakhisarai	-0.51	0.07	-0.28	-0.07	0.44	-0.36
Sheikpura	0.08	0.56	-0.03	-0.64	-0.71	-0.74
Nalanda	**0.80**	**1.58**	**0.49**	**-0.92**	**-1.00**	**0.95**
Patna	0.03	-0.34	-1.88	-0.20	-1.11	-3.50
Bhojpur	-1.72	-1.20	-1.87	-0.12	-0.71	-5.62
Buxar	-0.99	-1.54	1.08	0.22	-1.22	-2.46
Kaimur	0.04	-0.10	1.03	-0.76	-1.61	-1.39
Rohtas	-1.03	-1.05	-2.05	-0.93	-0.90	-5.96
Jahanabad	-0.37	1.53	0.39	-1.04	-1.24	-0.74
Aurangabad	-1.10	0.06	-0.54	-1.29	-1.50	-4.36
Gaya	-0.17	1.17	-0.02	-0.65	-1.10	-0.78
Nawada	-0.18	0.75	-0.06	-0.68	-0.68	-0.84
Jamui	-0.13	1.31	0.50	-1.17	-0.02	0.49
Arwal	-0.41	-0.41	0.88	-0.74	-1.71	-2.38
Bihar	**0.62**	**0.13**	**0.17**	**0.11**	**0.34**	**0.74**

Table-3: Sample Household Distribution (Census-2011)

CD Block	Male Pop	Female Pop	Village Name	Total Pop	SampleHH
Bind	31714	30270	Bind rural	10478(V1)	225
			Lodipur	6699(V2)	
			Jamsari	3956(V3)	
Katrisarai	21528	20293	Katauna	9067(V4)	225
			Maira- Barith	7962(V5)	
			Katri	6583(V6)	

Data has been analysed with the help of suitable statistical techniques. The software used for the study includes SPSS 20 and Microsoft Excel. First, the data were recorded in the Excel spreadsheet and the analysis was done by SPSS version 20. A P-value of <0.05 is considered statistically significant. Composite index and Binary logistic regression statistical techniques are used. The composite index is made after calculating various indicators showing elderly women's situation in terms of sex ratio, household headed by them and their work participation rate, etc.

Results and Discussion

Morbidity Pattern (Chronic diseases) among Elderly Women

Age has been primarily seen as a major controlling factor in the prevalence of the disease among the elderly. Most studies show a high prevalence rate of chronic illness among the aged population in India. Table-4 shows the percent distribution of rural elderly women with chronic diseases in different age groups. It is observed from the table that almost half of the elderly women suffer from one of the other chronic diseases and disabilities. The most common chronic non-communicable diseases being osteoarthritis (41 percent), hypertension (17 percent), cataracts (16 percent), anaemia (10.6 percent), piles (10.2 percent), diabetes (7.1 percent), bronchial asthma (1.5 percent), gastric (10 percent), skin problems (6.6 percent), filarial (5.1 percent), urinary disorder mainly includes urinary incontinence which includes uncontrolled urination while sneezing, laughing, vomiting, coughing, etc. tuberculosis (0.8 percent), paralysis (2.4 percent). Most elderly persons are affected by one or more morbidities. Age group-wise distribution of chronic diseases presents that the 60-69 year age group in the study area are mainly suffering from joint pain/arthritis (29 percent), high/low blood pressure (18.3 percent) and cataract (6.8 percent). Compared to other age groups, this age group is suffering more from high/low blood pressure, followed by gastric (9.1 percent), anaemia (12 percent), piles (9.4 percent), goitre and thyroid (3.4 percent).

Residence-wise analysis shows that ailments are more common in rural areas than in urban.(Giridhar et al.,2017). A study by Chandwani et al. (2008) in urban areas of Gujarat noted that more than one ailment is common among the elderly. A study by Navaneetham (2009) on Kerala revealed that females outnumber males in the context of suffering due to morbidity. Sharma et al. (2013) in their study found that osteoarthritis was more in females (70.1 percent) than in males (41.6 percent). Purty et al. (2006) in rural areas of Pondicherry studied that the most commonly complained ailment among the elderly is joint pains/joint stiffness (43.4 percent) and cataract (32 percent). Other morbidities prevalent were hypertension in 25.9 populations and diabetes in 8.3 percent of the elderly. Hakmaosa et al. (2014) in rural areas of Assam found the majority of diabetes among rural elderly to be around 7 percent, similar to our rural finding. Mishra and Srivastava (2004) reported cataracts in 25.8 percent of the elderly in their study. Hypertension was found as the most common chronic complaint (41.4 percent) among the aged in their study (Mundada et al., 2013). Even though hypertension can happen at any age, the risk increases with advancing age. Besides these chronic ailments, many other irregularities in health like being underweight are also reported by elderly women. The reason may be the household custom of eating in the last after feeding all male members and children in the family degrades the health of elderly women. Lack of good food and safe drinking water, a gender-based division of domestic tasks, negatively impacts women's health as they age (Hiremath, 2012). So, females were two times more prone to these diseases than males.

Table-4 Pattern of Chronic Diseases of Elderly Women in the Study Area

	Chronic Diseases	**60-69**		**70-79**		**80+**		**Total**	
		N	**%**	**N**	**%**	**N**	**%**	**N**	**%**
1	**Arthritis/Joint Pain**	89	29	67	62	29	**80.5**	185	41
2	Abnormal B P	56	18.3	15	13.8	6	16.6	77	17
3	Anaemia	37	12	11	10.1	0	0	48	10.6
4	Gastric	28	9.1	19	17.5	8	22.2	55	10
5	Goitre/Thyroid	16	3.4	7	6.4	0	0	23	5.1
6	**Cataract**	21	6.8	39	36	17	**47.2**	72	16
7	Haemorrhoids	29	9.4	16	14.8	1	2.7	46	10.2
8	Diabetes	25	8.2	7	6.4	0	0	32	7.1
9	Filarial	9	3	6	5.5	2	5.5	17	3.7
10	Bronchial Asthma	3	0.6	4	3.7	0	0	7	1.5
11	Skin diseases	13	4.2	14	12.9	3	8.3	30	6.6
12	Tuberculosis	3	0.9	1	0.9	0	0	4	0.8
13	Paralysis	8	2.6	2	1.8	1	2.7	11	2.4
14	Heart Disease	2	0.6	3	2.7	1	2.7	6	1.3
15	Urinary disorder	7	2.2	5	4.6	2	5.5	14	3.1
16	Cancer	2	0	0	0	0	0	2	0.4

*Percent is calculated by considering each age group as the denominator/base

Impact of Health seeking behaviour on Chronic Illness among Elderly Women

Health-seeking behaviour is governed by the decision-making process which is based on individual and household behaviour and community acceptance. In addition to these, health facility availability, accessibility and affordability also come into the picture. Besides these factors, awareness level, demographic, socio-economic and cultural factors impact the seeking behaviour. Table 5 shows the results of several socio-economic and demographic variables on chronic illness. Compared to the women of age group 60-69, women of 70-79 and 80+ ages are less likely to be affected by chronic diseases. Although, the analysis reveals that the age- group does not seem to impact the prevalence of chronic illnesses among the aged women as they are not statistically significant.

Table-5: Impact of background characteristics on the prevalence of Chronic Illness

Independent Variable		B	S.E.	Sig.	Exp(B)
Age Groups	60-69®			.417	
	70-79	-.548	.431	.203	0.578
	80 and above+	-.554	.455	.223	0.575
Marital Status	Currently Married®				
	Widow	.197	.307	.522	1.217
Education	Literate				
	Illiterate	-.214	.395	.589	.807
Occupation	Paid Work				
	Unpaid Work	-506	.401	.207	.603
Living Arrangement	Living Alone			.431	
	Spouse, Children and Grandchildren	-461	.605	.446	.631
	Others	-.283	.244	.246	.753
Self-Rated Health	Good				
	Not Good	.584	.389	.133	1.793
Satisfaction Level	Dissatisfied®				
	Satisfied	-.121	.238	.612	.886
Accessibility to hospital	Inaccessible ®			.110	
	Moderately Accessible	-.582	.341	.088	.559*
	Completely Accessible	-.553	.282	.050	.575**
Transport Affordability	Can't afford®				
	Can afford	.563	.397	.157	1.756
Doctor's fees Affordability	Can't afford®				
	Can afford	.331	.303	.274	1.392
Social Participation	Never ®			.523	
	Whenever Required	.360	.463	.437	1.434
	Sometimes	-.214	.268	.423	.807
Decision making in Healthcare	Take final decision ®			.002	
	Decide equally withspouse and son	1.973	.591	.001	7.190***
	Can't decide on her own	2.323	.699	.001	10.202***
Financial dependency	Fully Dependent ®			.001	
	Partially Dependent	-1.953	.536	.000	.142***
	Fully Independent	-1.729	.579	.003	.177***
Constant		-1.001	.445	.025	.368

*p<0.10; **p< 0.05; ***p< 0.001; R=Reference

Source- Calculated from primary field survey, 2019

Women in rural areas are mostly homemakers and therefore are reliant upon their husbands' economic status. By being women, elderly women occupy a more unfavourable position than men. More pathetic financial concerns are for those elderly women who grow into widows. The widow is more likely to have chronic ailments than currently married aged women. The life of a widow in rural areas is extremely challenging and the problem worsens even more due to the age factor. Although, the analysis reveals that multiple factors like age group, education, occupation, living arrangement, self-rated health, affordability of transport and doctors' fees and social participation do not seem to impact the prevalence of chronic illnesses among aged women as they are not statistically significant. Elderly women who are engaged in unpaid forms of work like giving time in the kitchen or sanitation work or taking care of grandchildren, the likelihood of suffering from chronic illness is more among the aged women in this category than the women engaged in paid work. Elderly women who are dissatisfied with their lives are more likely to have chronic diseases than elderly women who are satisfied with their lives.

Accessibility of health centres is statistically significant and it does have an impact on the prevalence of chronic diseases among elderly women. The odds of occurrences of chronic illness among elderly women are less if the health centre is moderately accessible to them ($p<0.10$) and the likelihood is being affected by chronic illness becomes statistically significant at $p<0.05$ when the health centre is completely accessible to them. It is found that the likeliness is being affected by chronic diseases is more for those elderly who can't access health facilities compared to those women who can moderately or completely access health facilities whenever required. Those elderlies who can afford the transport facilities when required for their treatment are less likely to suffer from any other chronic ailments than those aged women who can't afford the cost of transport for their treatment of certain ailments.

Although, the ability to bear transport costs does not have a significant impact (statistically) on the prevalence of chronic disease among the elderly. Those elderly who can't afford doctor's fees are 1.3 times more likely to have a chronic illness than those aged women who can afford doctor's fees and can seek doctor's consultations when needed. Those elderly who can participate in social affairs anytime or whenever required is less likely to have chronic diseases than those elderly who have never participated in social activities. Social connectedness is found to positively impact the physical and mental health of aged persons (Tuohy and Cooney, 2019).

The likelihood of suffering from any chronic disease lessens when elderly women enjoy the autonomy to decide about their healthcare and participate equally in decision-making in healthcare-related matters. The impact of decision-making power in health matters has played a significant impact in the likelihood of prevalence of chronic illness among elderly women ($p< 0.001$), Elderly women who can't participate with their family in matters related to health care are 10 times more likely to suffer from chronic diseases than those who enjoy the autonomy to decide on their matters relating to their health care.

Table 6 tries to analyse the impact of socio-economic factors as the independent variable on the treatment-seeking behaviour during chronic illness as the dependent variable. Certain factors like age groups, treatment-seeking during acute ailment, social participation, the decision-making power on matters of health care, and accessibility to the health centre are statistically significant in terms of their impact on health-seeking behavior during chronic disease. However, no significant association is absorbed between marital status, education, occupation, self-rated health, living arrangement, satisfaction from life, and treatment-seeking behaviour of elderly women during chronic illnesses.

Table-6:Impact on Background Characteristics on Treatment Seeking Behaviour

Independent Variable		B	S.E.	Sig.	Exp(B)
Age Group	60-69®			.021	
	70-79	1.529	.560	.006	4.615***
	80 and above	1.000	.538	.063	2.720*
Marital Status	Currently Married®				
	Widow	-.165	.272	.544	.848
Education	Literate®				
	Illiterate	.220	.372	.555	1.246
Occupation	Paid Work®				
	Unpaid work	.281	.356	.431	1.324
Self-Rated health	Good health®				
	Not Good health	-.423	.313	.177	.655
Living Arrangement	Living Alone			.964	
	Spouse,Childrenand Grandchildren	-.026	.448	.954	.975
	Others	.049	.198	.803	1.051
SatisfactionLevel	Satisfied fromlife®				
	Dissatisfied from life	-.295	0.210	.159	.745
Treat taken inAcute illness	Yes®				
	No	.420	0.194	.030	1.522**
Accessibility of hospital	Inaccessible®			.006	
	Moderately Accessible	-.114	.301	.704	.892
	Completely accessible	.572	.251	.023	1.771**
Transport Affordability	Can't afford®				
	Can afford	-.162	.193	.401	1.176
Doctor's fees Affordability	Can't afford®				
	Can afford	.087	.201	.665	1.091
Social Participation	Never ®			.001	
	Whenever Required	1.377	0.441	.002	3.963***
	Sometimes	-1.039	0.596	.082	.354**
Decision Making in Health care	Take final decision ®			.000	
	Decide equally with spouse andchildren	-3.627	0.959	.000	.027***
	Can't decide themselves	-1.848	1.029	.073	.158**
Constant		-1.782	0.797	0.025	0.168

$*p<0.10$; $**p< 0.05$; $***p< 0.001$; R=Reference

In the survey, it is found that rural women of higher social categories are hardly allowed to go for their necessities without the permission of male members of the family. The process of sharing health issues with male members and the fear to cross their comfort zone for the approval of multiple family members results in low-seeking behaviour in the study area. The analysis found a significant association between social participation and the treatment-seeking behaviour of the aged women ($p<0.001$). The living arrangement is not found to have a significant impact on the health status of women. It is observed from the analysis that elderly women who stay with their spouse, children and grandchildren are less likely to take treatment during chronic diseases than those women who either reside with their other members or who stay alone.

Living alone is found to be associated with various health risks, health hazards, low ability to perform activities of daily living (ADL) and instrumental activities of daily living, morbidity, and high risk of diseases. A study by Dean et al (1992) found that the likelihood of getting depressed easily and the complaint of poor mental health increases with loneliness. The living arrangement affects eating patterns, sleep patterns, social life and many aspects of life. Mood swings and several day-to-day physical and mental health are found to be controlled by the living arrangement (Agrawal and Kesari, 2014). Staying with family members increases the likelihood of taking treatment for chronic illnesses almost two times compared to those women who stay alone. Therefore, living with family members has a considerable impact on treatment-seeking behaviour. Staying alone at an old age and tackling every situation of life alone degrades health and increases the chances of being a victim of chronic diseases.

Table-5 shows the results of several socio-economic and demographic variables on chronic illness. Compared to the women of age group 60-69, women of 70-79 and 80+ ages are less likely to be affected by chronic diseases. Although, the analysis reveals that the age- group does not seem to impact the prevalence of chronic illnesses among the aged women as they are not statistically significant. Moreover, in the marital status category, the widow is more likely to have chronic ailments than currently married aged women. The life of a widow in rural areas is extremely challenging and the problem worsens even more due to the age factor. Although, the analysis reveals that multiple factors like age group, education, occupation, living arrangement, self-rated health, affordability of transport, doctors' fees and social participation are not statistically significant. Nevertheless, in reality they do seem to impact the prevalence of chronic illnesses among the aged women.

A study by Agrawal (2012) indicates that the likelihood of suffering from chronic illness is more in those elderly who stay alone than those elderly who stays with their family. Elderly women who are dissatisfied with their lives are more likely to have chronic diseases than elderly women who are satisfied with their lives.

Accessibility of health centres is statistically significant and it does have an impact on the prevalence of chronic diseases among elderly women. The odds of occurrences of chronic illness among elderly women are less if the health centre is moderately accessible to them ($p<0.10$) and the likelihood is being affected by chronic illness becomes statistically significant at $p<0.05$ when the health centre is completely accessible to them. It is found that the likeliness of being affected by chronic diseases is more for those elderly who can't access health facilities compared to those women who can moderately or completely access health facilities whenever required. Those elderlies who can afford the transport facilities when required for their treatment are less likely to suffer from any of the chronic ailments than those aged women who can't afford the cost of transport for their treatment of certain ailments. Although, the ability to bear transport costs does not have a significant impact (statistically) on the prevalence of chronic disease among the elderly.

Table-7: Reasons for not receiving any treatment for Chronic Illness

Far from home/no medical facilities available	12.5
Transportation barrier	8.9
Can't go alone/nobody to accompany	17.8
No female doctors	16.1
Long wait for doctors/no doctors	16.9
Can't Afford	21.4
Ailment not considered serious	6.2
No treatment (chronic+) Total	100

Source- Calculated from Primary field Survey, 2019

Those elderly who can't afford doctor's fees are 1.3 times more likely to have a chronic illness than those aged women who can afford doctor's fees and can seek doctor's consultations when needed. Those elderly who can participate in social affairs anytime or 'whenever required' is less likely to have chronic diseases than those elderly who have 'never participated in social activities. Social connectedness is found to positively impact the aged persons' physical and mental health (Tuohy and Cooney, 2019). The likelihood of suffering from any chronic disease lessens when elderly women enjoy the autonomy to decide about their healthcare and participate equally in decision-making in healthcare-related matters. The impact of decision-making in health matters has played a significant effect on the prevalence of chronic diseases among elderly women ($p< 0.001$). Furthermore, it is observed that those women who have rated their health as bad/not good are more likely to be attacked by chronic disease than those women who have rated their health as good.

Accessibility, Availability and Affordability of Health Centres in the Study Area

Accessibility involves a manifold concept that requires geographical, financial and cultural inclusiveness and many more societal features. Accessibility is understood as the opportunity to reach and obtain healthcare services in times of need (Levesque et al., 2013). Access to healthcare facilities in the study areas is considerably underdeveloped. About half of the samples traveled more than 6-7 km to reach the health centres. The inaccessibility of hospitals and availability of required services has huge ramifications on the elderly's health and their health-seeking behaviour as the family members find visiting hospitals out of the village a tiring task. They believe that for the farmer community to run after doctors for an old family member is not possible for any family in their community. The reply is based on their perception of accessibility. Table 8 provides an overview of the extent of the accessibility of various health-related services.

Table-8 Accessibility of Health Centers for Rural Elderly Women

Blocks	Health Centers	Health Professional	Always available	Mostly available	Somewhat available	Rarely available
		Doctor	-	-	-	yes
		ANMs	yes	-	-	-
Katrisarai	PHSC	Male Health Worker	-	-	yes	-
		Pharmacist	-	yes	-	-
	PHC	Doctors	-	-	yes	-
		Nurses	yes	-	-	-
		Patho. professionals	-	yes	-	-
		Pharmacist	-	-	yes	-
Bind	PHSC	Doctor	-	-	-	yes
		ANMs	yes	-	-	-
		Male Health Worker	-	-	yes	-
		Pharmacist	-	-	yes	-
	PHC	Doctors	-	-	yes	-
		Nurses	yes	-	-	-
		Patho. professionals	-	-	yes	-
		Pharmacist	-	yes	-	-
Nalanda District Hospital		Doctors	yes		-	-
		Nurses	yes	-	-	-
		Patho. professionals	yes		-	-
		Pharmacist	yes	-	-	-

The connection of health centres with proper transport facilities increases the accessibility for rural residents. Ease of access is one of the prime reasons for availing any health services. Cost of services and quality of care are a few reasons which encourage patients to help themselves with benefits if accessible. The popular explanation for choosing the public health facility is free of cost or least cost services. The prime reason for preferring private practitioners is their availability and quality of care (Chauhan et al.,2015). Lack of education and no financial resources at their disposal give way to greater economic dependency and it is making them deprived on the socio-economic front. Due to old age and less exposure to doctors throughout life, many times, the elderly are unaware of health facilities available in health centres even if health facility is accessible.

Two types of expenditure are analysed for understanding the affordability of health services by the elderly women in the study area. The first one includes the direct expenditure related to health. They have spent more medical expenditure for treatment on the way of the fee paid to doctors, medicines costs, diagnostic/ test charges, bed charges and other expenses such as private medical uses and expenses on blood arrangement, oxygen cylinders, etc. The other includes indirect or non-medical expenditures like the transportation fare of the patient. Other non-medical expenditures incurred by the household for food, transportation for others, expenditure on the escort, lodging charges, hospitalisation charges and additional charges such as telephone charges made from PCO and spending on toiletries like soap, towels, toothpaste, etc. for the patients and attendants are included. The procurement prices of medicines in public pharmacies are free of cost or are cheaper than those in private pharmacies. Still, often the essential drugs are unavailable. One of the critical explanations for not seeking any treatment is the inability of the aged women to manage the amount required for treatment. Hence, their health care is dependent on the family's decision.

In Table 10 the various types of expenditure on health are given, including consultation fees, medicine costs, reports or scans (if done in private clinics that are not free) of any kind and transportation costs. Respondents who can't afford the expenditure of various bills mentioned above/fees are high among the aged women in the study area. In the survey, 64 percent of the elderly women admitted that they couldn't afford a private doctor fee which is around 200 to 400 rupees in the study area. Since most basic medicines are unavailable in government facilities women find it difficult to pay for their medication from private pharmacists. Most of them have replied that the high prices of allopathic medicines lead to discontinuing their dosage intake and shifting to homeopathy treatment. 69 percent of aged women admitted that they couldn't afford tests from private pathology. Almost half of the aged women considered transport cost a barrier to their poor seeking behaviour.

Table 9: Availability of Health Centers in the Study Area.

C D Block Bind	**Sub Centre**	**PHC**
Bind Village	No	Yes
Lodipur Village	No	No
Jamsari Village	No	No
C D Block Katrisarai		
Katuana	Yes	No
Maira-Barith	Yes	No
Katri	No	No

Source- Calculated from primary field survey, 2019

Socio-economic factors of treatment

Table-7 reveals the reasons for not seeking any treatment during chronic illness. Elderly women are the worst victims of poverty, poor nutrition and extreme male hegemony. One of the reasons for not receiving any treatment is that elderly women and their families do not consider the morbidity severe enough to be consulted by a doctor. If it remains unchecked for a long time, chronic disease may lead to severe organ failure and may result in loss of life. Due to the lack of health facilities in villages, elderly women cannot visit doctors outside their villages due to the cost involved in their treatment. Even in government hospitals with minimum registration fees, they fell prey to the unavailability of medicines in the health facilities. They can't afford to buy medicines or afford transport costs because of their poor economic situation. The lack of good doctors at government hospitals capable of curing them without multiple visits is also one reason for not availing governmenthospitals.

Table 10: Affordability of (Private) Health Check-ups by Rural Elderly Women

Expenditure on Health	Can't Afford Expenditure on Health	
	Frequency	In %
Doctor's consultation fees(private hospitals)	288	64
Medicines bill	333	73.7
Tests/ Report's bill (private hospitals)	311	69
Transportation costs	203	45.3
Total Samples	450	100

Source- Calculated from primary field survey, 2019

17 percent of the women admitted that their family members ignored the pain and didn't show interest to accompany them to hospitals even though the aged women wanted to get treatment. The PHC's lack of infrastructure facilities failed to diagnose of major ailments in the PHC. Though respondents and other village residents are not satisfied with the available facilities in the PHC, some residents agree that routine vaccination of children is done appropriately in PHC and prenatal and postnatal care. Moreover, PHC does not have the facility to look after the problems of the aged section of the population. The common complaints among many others are the absence of medical professionals without any information or public notice. Sometimes doctors are absent from the hospitals without prior notice of their leave, adding to the patient's problems. Patients are uncertain about the availability of doctors and wait for long hours in the hospital. Thus it creates a problem for elderly women who visit hospitals as OPD patients.

CONCLUSION

The elderly population is the most vulnerable segment of the population prone to various diseases due to lower immunity with an advancing age. Among all elderlies, arthritis, abnormal BP, anemia and hemorrhoids are the most common chronic diseases. The study reveals that the most commonly reported chronic disease in the sampled area is arthritis or joint pain. It is found that 29 percent of the elderly in the age group of 60-69, 62 percent of the elderly in the age group of 70-79 and 81 percent of the elderly of 80 years. The second commonly reported chronic illness in the age group of 60-69 is abnormal BP but is not the same for the other age groups. Gastric and hemorrhoids are reported to be the second and the third most commonly found chronic disease in the age group 70-79.

The survey found that the cost of treatment affects the health of elderly women more broadly. Elderly women suffering from any disease make them more vulnerable as the treatment-seeking behaviour of the affected women primarily depends upon their family members. Health status is to be great extent impacted by certain socio-economic factors. Though certain variable does have a significant impact on the health-seeking behaviour of elderly women in the study area, the result is not statistically significant. One primary variable that impacts the treatment-seeking behaviour of elderly women is the availability, accessibility, and affordability to utilise the facilities in the study area.

The real life of the women in the villages of Bihar is miserable and the life of the old women is exceptionally pathetic. The quantitative method is not always efficient enough to reveal an accurate picture of the qualitative life of the study population. The actual figure of the study population captures the empirical instances and the real facts that are not necessarily similar to the data facts because of the limitations of the sample size and many other factors. The disease becomes graver and the health of the elderly woman gets into danger when she is left untreated because of her poor financial condition and low importance in the family. One reason analysed with the health-seeking behaviour of elderly women is that much of the decision of seeking continuous treatment depends on the household expenditure and earning level. On the other side, if all the family members are earning and there is no burden of marriage or education of children, then in that case there are high chances that elderly women can get treatment because the demands to meet family responsibilities are low.

During the study that the inaccessibility of health centres along with the unavailability and irregularity of doctors, no ambulance service and medicine-giving staff, unavailability of costly medicines, and poor arrangement of various basic testing instruments in PHC and sub- centres demoralises health-seeking behaviour of elderly women. Besides this, immobility because of transport barriers, misconception and poverty leads to poor utilisation of healthcare services in the villages. The effects of ageing, low economic status and inadequate access to health care contributed to the elderly poor health status. The use of over-the-counter drugs is indicative of inadequate health facilities for the elderly.

The study points out the need to formulate policies that will target the health needs of the elderly. The under-utilization of health services in the public sector has been almost a universal phenomenon in all the surveyed villages. The availability of doctors in primary health centres becomes a determining factor for the villagers in the context of their decision-making about the selection of place of treatment (public or private health facilities) and nature of treatment which again depends on their financial prosperity. In sum, the state needs to admit its responsibility towards the elderly and work towards proper implementation of already made policies. The government and society should work towards improving the unmet needs for healthcare facilities and work towards providing a secure environment to elderlies.

Conflict of Interest: The author declares that she has no conflict of interest.

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ASSESSMENT OF LANDSCAPE EVOLUTION AND SPATIO-TEMPORAL VARIATIONS IN TECTONIC PULSES IN THE VAIGAI RIVER BASIN, SOUTHERN INDIA

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ABSTRACT

Earth's surface processes are active at variable scales resulting in spatial variations in topography that evolve under the primary controls of tectonics and climate, among others. On a river basin scale, these differences could be gauged through systematic documentation and analysis of morphometric metrics. The modern Vaigai River Basin is located in an antecedent valley or basin that owes its configuration and morphology to Precambrian-Recent tectonic-climatic-land use dynamics. This complexity and continuum of evolutionary history have hampered systematic documentation and comprehension of its evolution. We have investigated and studied the geomorphic aspects of this river with the help of ArcGIS 10.5 to understand the rock uplift, river incision and tectonics in the Vaigai River Basin by examining the longitudinal profiles, Asymmetric factor (Af), Transverse topographic symmetry factor (T). Thematic maps of geology and geomorphology were extracted from the Bhukosh website data and created. Vaigai River and its tributaries display uneven longitudinal profiles with numerous knick points along the profiles. Major breaks are observed only in the main channel where the river starts. River incision is not uniform in the Vaigai River. The streams become graded (absence of knickpoints) towards the river mouth, suggesting that the uplift and incision are in equilibrium. The Vaigai is highly elongated and it is easier to control floods in this basin. Upstream of Vaigai River and its tributaries have shown that a series of breaks and knickzones indicate active erosion and acute lithological control on the channel. The Asymmetry factor (Af) and the Transverse topographic symmetry factor (T) emphasize the tectonic control. Different lithological stages on knickpoint and channel incision substantiate the rejuvenation of Vaigai River in several phases during the geological past.

***Key Words*:** Longitudinal profiles; Knickzones; Lithology; Tectonics

1. INTRODUCTION

The river's course, channel geometry, and river valleys can all be affected by the rise and fall of the river's base profile which could be caused by tectonics or climate change. The rivers in India are typically divided into those that flow west and those that flow east. Several examples include the Narmada, Tapti, Sharavathi, Kali, Nethravathi, and Periyar rivers, which flow westward and have the Western Ghats as their source. The Mahanadi, Godavari, Krishna, Cauvery, Damodar, Brhamani, Palar, Pennar, Vaigai, and Thamirabarani are significant rivers that flow east in Southern India. The east-flowing rivers are mostly affected by tectonics, climate change, and the Indian plate movement, whereas climate change primarily controls the west-flowing rivers (Kale and Rajaguru, 1988). Endogenic and exogenic processes operate as highly coupled systems, indicating tectonic and climate feedback, particularly in active mountain ranges along convergent margins (Roe et al., 2008). However, in a natural landscape, the feedback of ridgelines and subsequent rain-shadowed topography is less understood. The longitudinal profile development also depends on the variability of lithology (Stock and Montgomery, 1999; Duvall et al., 2004), and river longitudinal profiles exhibit tectonic activity through their overall morphology and knickpoints in areas where the gradient of the river changes quickly.

The main goal of this research is to find out how rivers react to changes in the stability of the land and how the profiles of the Vaigai River and its tributaries have changed over time, utilizing quantitative analysis of longitudinal profiles. Additionally, this study aims to understand whether the knickpoints in the Vaigai River basin are controlled by lithology or by base-level changes resulting from active tectonism. To examine the control of tectonism, various metrics- the asymmetry factor, Transverse topographic symmetry factor (T), Circularity ratio (CR), Basin Elongation ratio (BE), and River Sinuosity (SS)- have also been used.

2. REGIONAL SETTING

The Vaigai River Basin, covering an area of 7380.60 Sq.km, is located in the Tamil Nadu state, encompassing five major districts: Theni, Dindigul, Madurai, Sivagangai, and Ramanathapuram. It is situated in the southern part of India, where the Western Ghats serve as the source of many east-flowing rivers. The basin (Figure 1) has an arcuate shape, stretching from the Western Ghats mountain range of Kerala in the west to the Bay of Bengal in the east, with a general gradient towards the northeast, up to Theni, and then in a south-eastern direction toward the sea. The river basin is bordered by the Western Ghats on the south and west, the southern slope of Palani hills (Kodaikanal hills), Sirumalai hills, Alagar hills, etc., on the north, and the Bay of Bengal on the east. Water is supplied to the Vaigai River's left bank via the large tributaries Suruliar and Manjalar. The Vaigai River is one of the east-flowing rivers originating from the Western Ghat in Varasanadu hill. Southern India is surrounded by the Indian Ocean, where all the east-flowing rivers drain into the Bay of Bengal (BOB), and the West-flowing Rivers drain into the Arabian Sea.

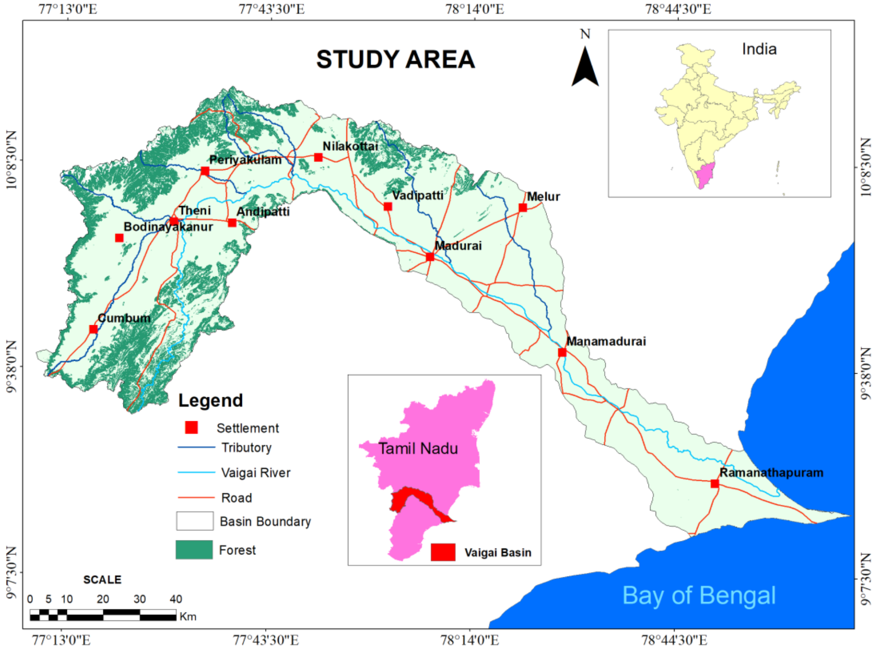


Fig1. Study area

The study by Richards et al. (2016) espoused that the evolution of the Western Ghats was attendant to the collision of the Indian Plate during the Early Cenozoic. The topographic rise commenced from the south and proceeded to the north, while an intensive tilt toward the east commenced around 25 Ma, continuing until today at a rate of 0.1 mm/year. The edge of the Western Ghats currently forms the main drainage divide of Peninsular India. Archean greenstone belt, charnockite, felsic orthogenesis, granite, khondalite, migmatite, and sedimentary cover are found in the peninsular region. The east coast of South India is draped with a sedimentary cover, and the drainage owes its origin to the Western Ghats, which drains the eastern part of the South Indian Plate with larger basins. The Vaigai river basin is covered by hard crystalline rock masses of Archaean age on the western portion, mostly covered with charnockite, migmatite, and gneiss (see Figure 2). Additionally, Archean greenstone belts, charnockite, felsic orthogneiss, granite, khondalite, migmatite, and sedimentary cover are found in the peninsular region, as reported by Ramkumar et al. (2019). From Manamadurai to the Bay of Bengal, rocks of upper Gondwana, tertiary alluvium, and coastal alluvium unconformably overlay the Archaean formations. Highland charnockite massifs make up the Southern Granulite Terrane (SGT), which is divided into three sections by a network of low-lying shear zones extending in different directions: NE-SW, E-W, and NW-SE (Mukhopadhyay, 1986). Vaigai River has a minor delta even though it is a perennial river originating from the Western Ghats. The selected major river Vaigai, which flows easterly and south-easterly, has deltaic platforms in its mouth (Ramkumar et al., 2016). Delta head starts from Manamadurai at 77 m above sea level. 270 km major drainage system along with other important tributaries:

Sirumalaiyar, Manjalar, Varahanadhi, Theniar, Varattar-Nagalar, Suruliar, Sathiyar and Uppar. (Alternative-From Manamadurai to the Bay of Bengal, rocks of upper Gondwana, tertiary alluvium, and coastal alluvium unconformably overlay the Archaean formations. The Southern Granulite Terrane (SGT) is primarily composed of highland charnockite massifs, divided into three sections by a network of low-lying shear zones extending in different directions: NE-SW, E-W, and NW-SE (Mukhopadhyay, 1986). Despite being perennial rivers originating from the Western Ghats, the Vaigai River and other selected major rivers have minor deltas at their mouths (Ramkumar et al., 2016). The delta head starts from Manamadurai at an elevation of 77m above sea level. The Vaigai River is part of a major drainage system spanning 270km and includes several important tributaries: Sirumalaiyar, Manjalar, Varahanadhi, Theniar, Varattar-Nagalar, Suruliar, Sathiyar, and Uppar.) Geomorphologically (Figure 3) the study area consists of a well-developed network of fluvial, fluvio-marine, Aeolian and marine geomorphic landforms. The upper portion of the basin is covered by structural hills and valleys, active flood plains, pediments and valley fills. In the prodelta part of the Vaigai river, an older deltaic plain and beach ridges are extensively developed. Dunes are often found to overlie the beach ridges in several places. The occurrence of numerous crescent-shaped tanks is a peculiar phenomenon associated with this delta. The delta predominantly consists of fluvial depositional landforms. The critical analyses of the morphology of the tanks have indicated that most of these tanks are human-made and further stand as evidence for the ingenuity of the inhabitants in this rain shadow region who converted the natural depressions of the oxbow lakes, paleochannels, interlobal depressions, paleo swales, etc into the structures (tanks) for storing the excess runoff of the Vaigai river during the rainy seasons.

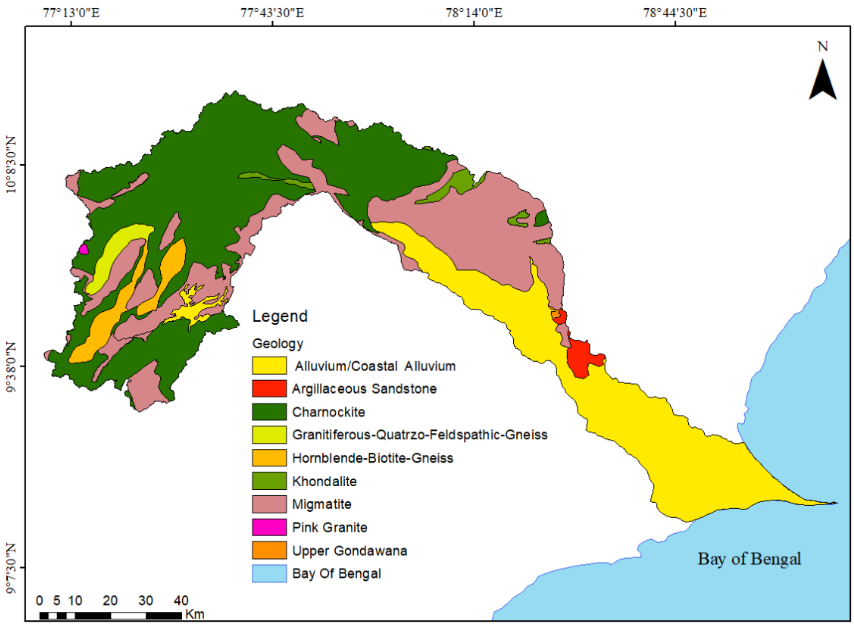


Fig 2. Geology of the study area

Geological map of the Vaigai River basin; Vaigai river basin is covered by hard crystalline rock masses of Archaean age on the western portion; mostly covered with charnockite-Migmatite-gneiss. From Manamadurai to the Bay of Bengal, rocks of upper Gondwana, teritiary alluvium and coastal alluvium are spread over the Archaean formations unconformably.

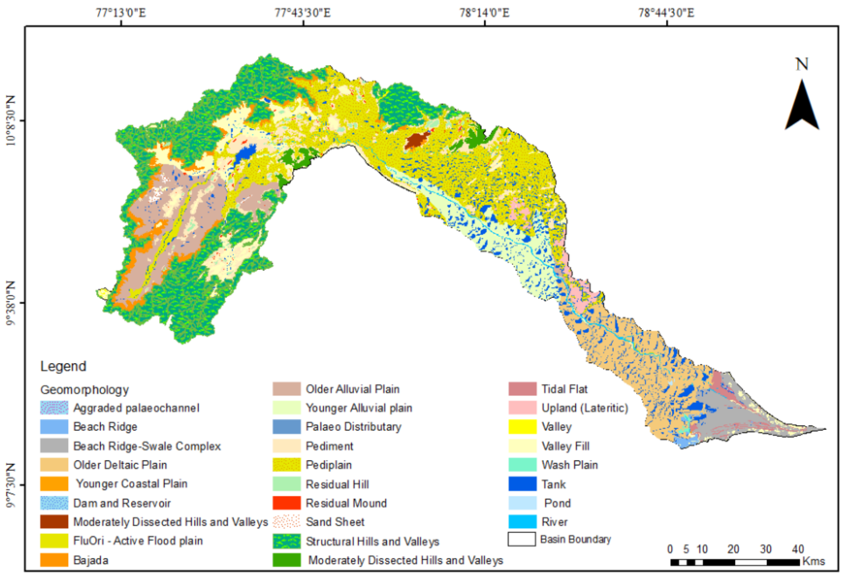


Fig3- geomorphology of the study area

3. METHODS AND MATERIALS

The study utilized synchronized data collected from published literature. This data was employed to create and interpret longitudinal profiles and to identify significant knick points. Additionally, the collection and compilation of secondary data sources, including thematic maps on geology and geomorphology, were accomplished using ArcGIS 10.5. It was followed by other geomorphic indices of active tectonism and spatial analysis. These were supplemented with limited field checks wherever found necessary. Comprehensive analyses of the data were conducted to investigate spatial variations of tectonically active and quiescent regions. The study aimed to elucidate the relative controls on these variations, including factors such as structure, climate, lithology, and more (Source: https://bhuvan.nrsc.gov.in).

3.1 Longitudinal Profile

The longitudinal profile (Lp) is a cross-sectional representation of the channel reach and is measured in a linear direction downstream. It refers to the elevation of the river's surface in relation to the distance from its source to the mouth. Analysing the longitudinal profile provides valuable insights into historical climate patterns, river flow rates, sediment transportation, and the influence of tectonic activity on a particular region (Leopold et al., 1964; Das et al., 2018). Vaigai and its tributaries, such as Sirumalaiyar, Manjalar, Varahanadhi, Theniar, Varattar-Nagalar, Suruliar, and Sathiyar, were manually digitized using GoogleEarth Pro software to create a digital elevation profile. To generate the longitudinal profile of the river, data points at intervals of 1 km and their corresponding elevations were collected. The data were then exported to Excel software, and the longitudinal profiles were plotted for the main channel and its major tributaries. Knickzones, identified through longitudinal profiles, were documented and recorded. The sub-basins of Vaigai such as Suruliar (SRL), Varahanadhi (VRN), Theniar (TNR), Upper Vaigai (UVR), Manjalar (MJR), Varattar-Nagalar (VNR), Sirumaliar (SMR), Uppar (UPR), Satiyar (STR), and Lower Vaigai (LRV) were delineated from the Toposheets (Figure 4).

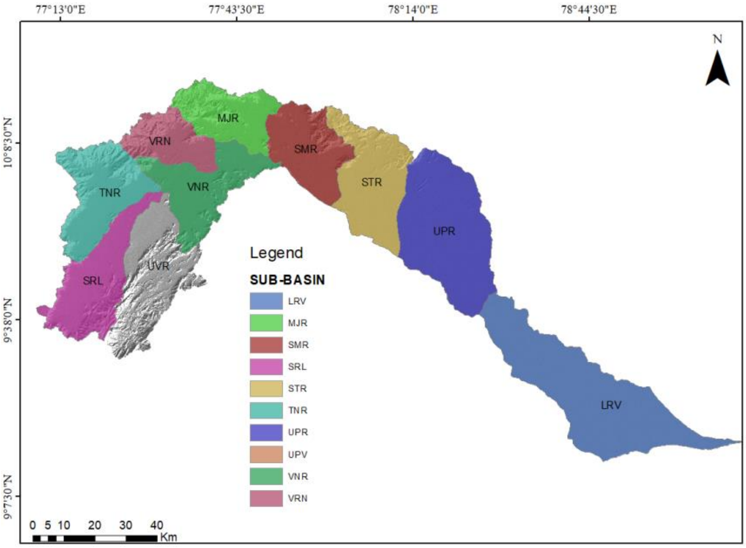


Figure 4. Sub-basins of Vaigai River Basin

3.2 Asymmetric Factor (Af)

The asymmetry factor (Af), which is sensitive to tilting perpendicular to the downstream direction of a stream, can be used to determine the tectonic tilting of a catchment (Hare and Gardner, 1985; Flores-Prieto et al., 2015; Das S, 2020). An asymmetry factor value close to 50 indicates the absence of tilting, whereas deviations of Af values (above or below 50) indicate the extent of tilting caused by lithological or tectonic influences. The asymmetry factor can be interpreted as a measure of basin asymmetry (Keller and Pinter, 2002, Das S, 2020). It is calculated by using the equation (1)

$$Af = (Ar / At) \times 100 \qquad (1)$$

The Ar is the area of the basin on the right side of the main trunk stream and is the total area of the basin (Cox, 1994).

3.3 Transverse topographic symmetry factor (T)

The T factor analyses the symmetry of the basin. It is the ratio between Da (distance from the midline of the meander belt to the midline of the river basin) and Dd (distance from the basin divide to the basin midline). The T factor helps to investigate the lateral tilting of a river basin for its mainstream. Tectonically inactive zones create a perfect symmetric basin with a *T* value of 0. The tectonically active zones, dependent on tectonic intensity, create asymmetric basins with *T* value more than 0.0 and up to 1.0 (Cox, 1994). The values close to 1.0 indicate the river is flowing nearly to the basin boundary, possibly formed by severe and recent tectonic activities. Such breaks on the longitudinal profiles are generally associated with uplift or geological or structural control.

Basin midline, Da and Dd, were digitized by using Arc GIS tools and calculated by the equation (2) herein:

$$T = Da / Dd \qquad (2)$$

3.4 Basin elongation ratio (BE)

The basin elongation ratio is an important geomorphic index that confirms a drainage basin's neotectonic activity. It is a dimensionless quantity calculated as the ratio of the greatest basin to a circle with a diameter equal to the area of the basin under consideration (Bull and McFadden, 1977, Gupta et.al., 2022). The value of BE is calculated by the equation (3)

$$BE = 2(A/\pi)\ 0.5/\ Bl \qquad (3)$$

Where A and Bl are the area and maximum length of the basin, respectively.

3.5 Stream sinuosity (SS)

Stream sinuosity can be regarded as a significant indication of tectonic activity in a region. The curvilinear ratio of a stream's length, or the index of stream sinuosity, can be used to determine the length of the straight line connecting the two ends of the chosen channel reach, and the path. Calculated by equation (4) herein:

$$SS = CL/ L \qquad (4)$$

Where *CL* is the length of the stream channel and *L* is the straight line joining the two ends of the channel (Mueller, 1968).

3.6 Circularity ratio (CR)

The circularity ratio (CR), is assessed to determine the drainage basin's shape. The circularity ratio (CR) of the basin was calculated by equation (5) herein:

$$CR = 4\pi A / p2 \qquad (5)$$

Where A and P are the basin's area and perimeter respectively.

3.7 Field logging and primary data collection

The latitude and longitude of the knick points have been collected and recorded in an Excel sheet. Systematic fieldwork was conducted from the catchment area to the confluence of the trunk stream and all its tributaries. Field photographs of selected knickpoints were taken and verified on-site. Drainage basins and stream networks are delineated with the help of Toposheets and Google Earth data using ArcGIS 10.5. An examination of river channels and basins using the above-mentioned methodologies is performed in this paper to demonstrate the general geomorphic characteristics and structural control over the basin.

4. RESULTS

Figure 5 presents the spatial distribution of the knickpoints in the trunk river, as well as in the major tributaries of the Vaigai River, with lineaments overlaid by the geology. Knickzones, identified from longitudinal profiles and confirmed by field observations, have been methodically recorded with reference to their altitude above base level and the lithology gradient.

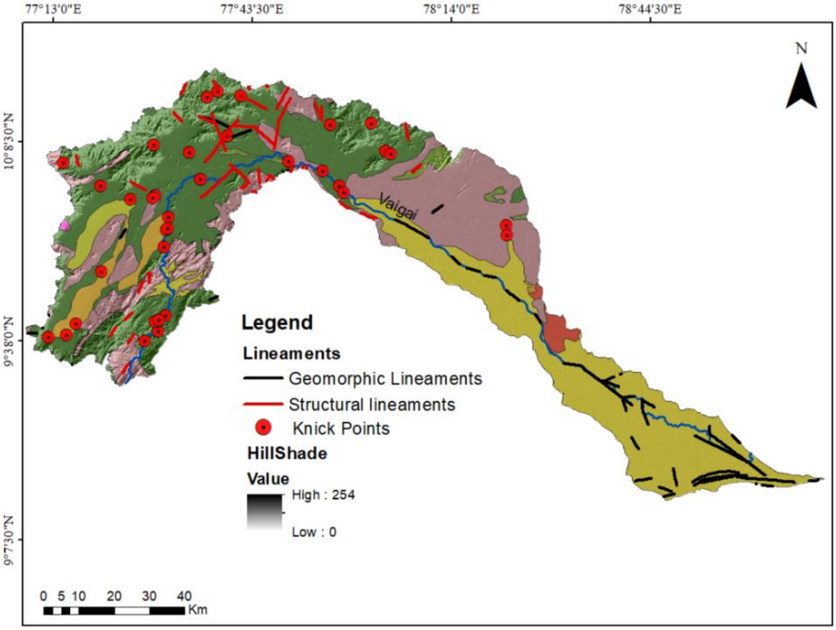
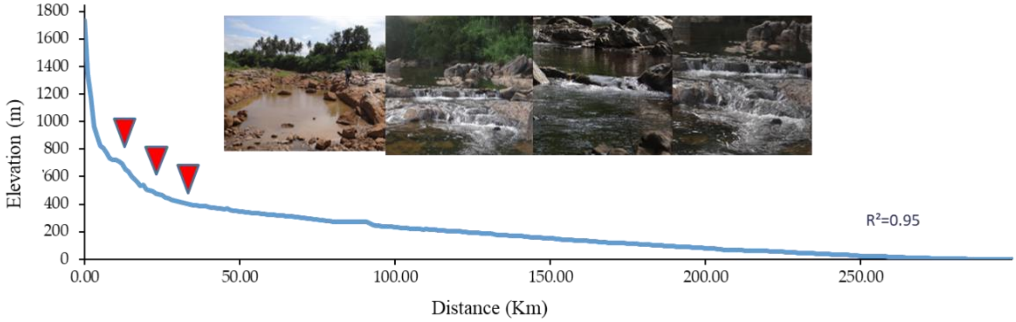


Figure 5. Location of knick points

A small part of the catchment region shows several continuous knick points, while most of the trunk river exhibits no topographic change. The river forms in former valleys and experiences an initial fall, followed by a monotonous flow for its entire length. The Vaigai River and its tributaries display uneven longitudinal profiles with numerous knickpoints along them. All the tributaries and the trunk channel show a linear fit towards the downstream (Figure 5a, 5b, 5c, 5d, 5e, 5f, 5g). The profile of Varahanadhi exhibits significant disruption, as indicated by the high R^2 value of 0.99 (Figure 5d). Similarly, the tributaries, namely Marudhanadhi, which is a major tributary of Manjalar stream within the Manjalar sub-basin (MJR) and Satiyar (STR) also demonstrate the incision with R^2 values of 0.98 (Figure 5f and 5c). Field verification confirms that the Vaigai River also exhibits incision (R^2 = 0.95) at various locations (Figure 6a). The Suruliar falls, and Thalaiyar falls (Figure 6b) are the major knick points in the Vaigai River Basin. Thalaiyar waterfall is the steepest and highest waterfall, nearly 820-meter elevation in the Manjalar stream. The calculated asymmetry factor (Af) of the entire Vaigai River Basin is 45, resulting from drainage basin tilting, either due to tectonic activity or to lithological control. The T factor for the Vaigai River Basin is calculated at different segments of stream channels (Figure 7). The computed value of the transverse topographic symmetry factor ranges from 0.18 to 0.87 but most of the computed values lies within the range of 0.53 to 0.59 (Table 1). The mean value of the entire basin is 0.55. The mean values of the asymmetry factor for sub-basins are 48.06. The ‘T’ factor values of the sub-basins vary from 0.17 (LRV) to 0.79 (SRL). The maximum Af for SMR (53.34), UVR (51.83) and LRV (51.38) shows an asymmetry value of more than 50, with all others having a value less than 50 (Table 2).



Vaigai (Fig5 a)

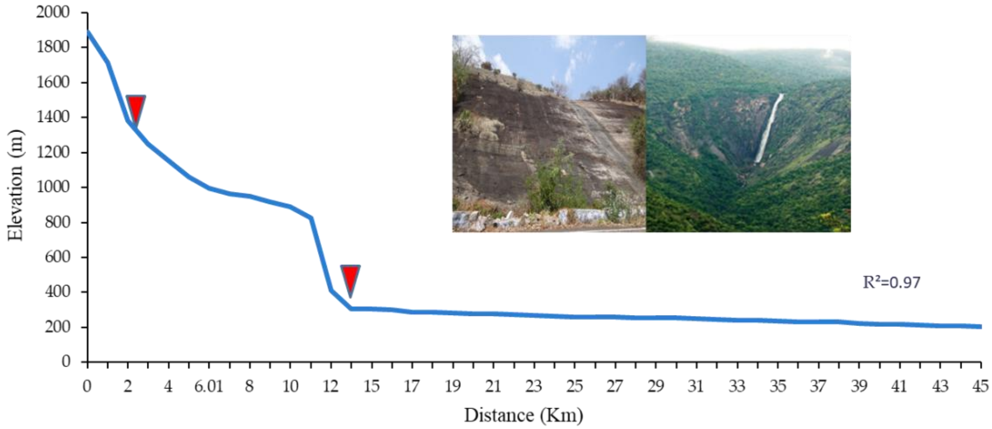


Fig 5b. Manjalar

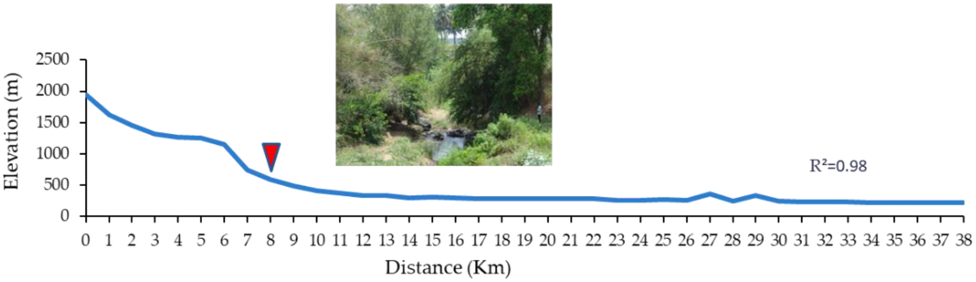


Fig 5c Marudhanadhi

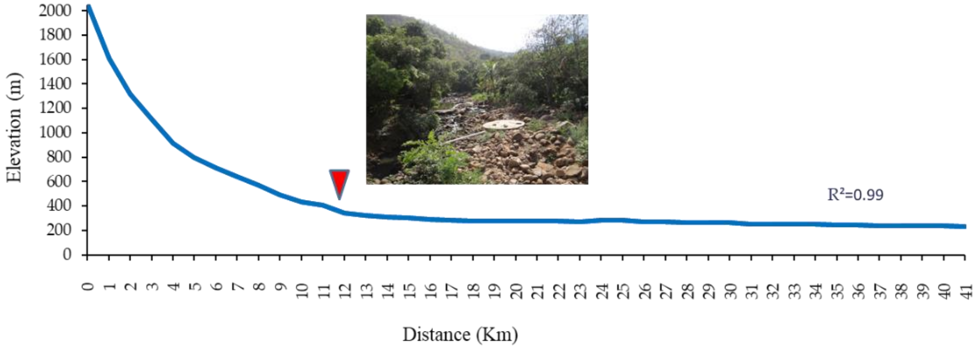


Fig 5d. Varahanadhi

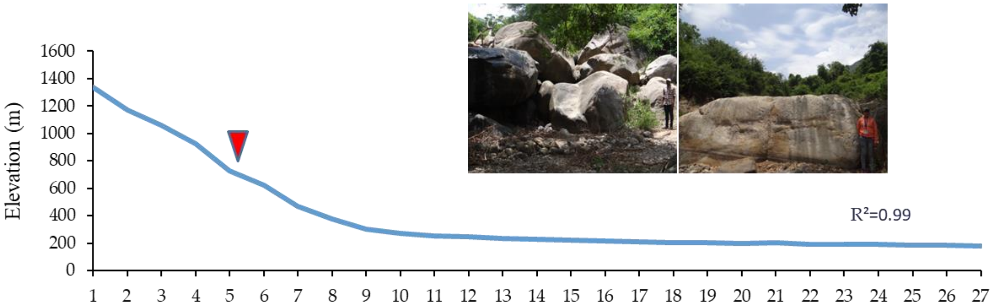


Fig 5e.Sirumalaiyar

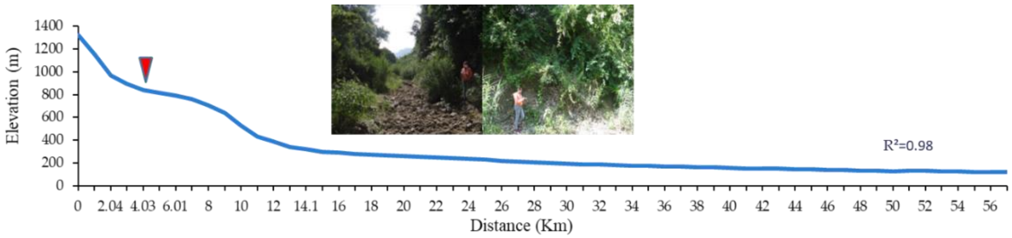


Fig 5f. Sathiyar

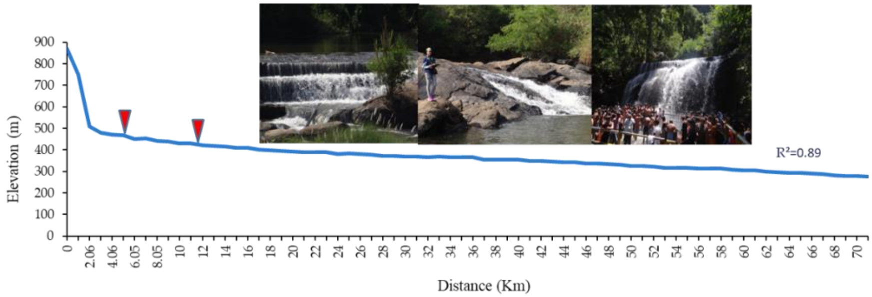


Fig.5g Suruliar

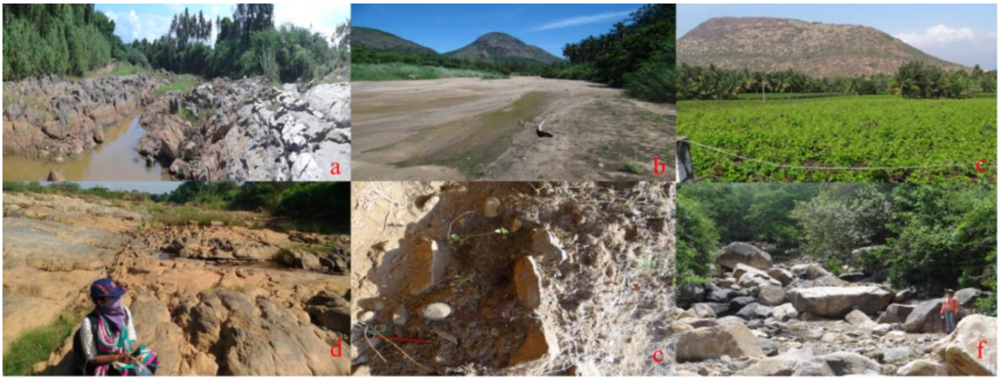


Figure 6a. Field Photographs showing Incision and tectonic characteristics, a)&d) Bedrock channel with riffle-chute structure, suggestive of intensive erosion as a result of tectonic and fluvial activity b) Meandering of stream in a high altitude region as a result of tectonic activism and channel course shift c) "L"-shaped landscape morphology evidencing inheritance of palaeolandscape, continuation and recent activism d) Bedrock channel with riffle-chute structure, suggestive of intense erosion as a result of tectonic and fluvial activity e) Alluvial Fan f) (Sirumalaiyar) Its bed rock channel having boulder to pebble sized sediments.

In the present study, the BE value for the sub-basins is ranging from 0.34 to 0.53. Basins SRL, UVR, LRV, MJR and STR have the BE values 0.35, 0.40, 0.34, 0.50, 0.41 respectively and the rest of the basins such as VRN, SMR, TNR, VNR, and UPR, obtained BE values of 0.52,0.51, 0.53,0.53,0.53 respectively. The sinuosity of the Varattar-Nagalar River corresponds to a low SS value (1.14). The SS index has a minimum value for stream UVR of (0.80) and a maximum value for basin Manjalar of 1.66. The circulatory ratio (*CR*) calculated in this study lies from 0.27 (Basin VNR) to 0.67 (Basin UPR). The CR calculated the whole basin is 0.14. The sub-basins such as VRN, TNR, SRL, UVR, MJR, SMR, LRV, and STR show values 0.52, 0.41, 0.29, 0.33, 0.45, 0.54, 0.32, 0.39 respectively (Table 2). The spatial distribution map (Figure 8) for indices clearly says that sub-basins fall under the low to moderately active class. SMR almost shows a high value of geomorphic indices. The sub-basin LRV has low values of geomorphic indices. The T factor for sub-basin UPR, VNR, SRL, SMR, UVR, MJR, STR, and VRN, ranges from 0.37-0.79 except TNR, LRV. The

SS value is <1.05 for the sub-basin LRV and UVR. MJR has an SS value >1.50, while all other sub-basins range from 1.05-1.50. TNR, MJR, UPR, and VNR sub-basins have the BE value ranging from 0.51-0.53 and others fall in the range of 0.34-0.50. Most of the sub-basins have the CR value <0.4 while the VRN and SMR range >0.5. The Af factor obtained for UVR, SMR, and LRV is >50.

Figure 6b. Major Knick points, a) Knick point in Suruliar tributary b) Location Uthamapalayam c) Suruli falls near Cumbum d) Thalaiyar falls

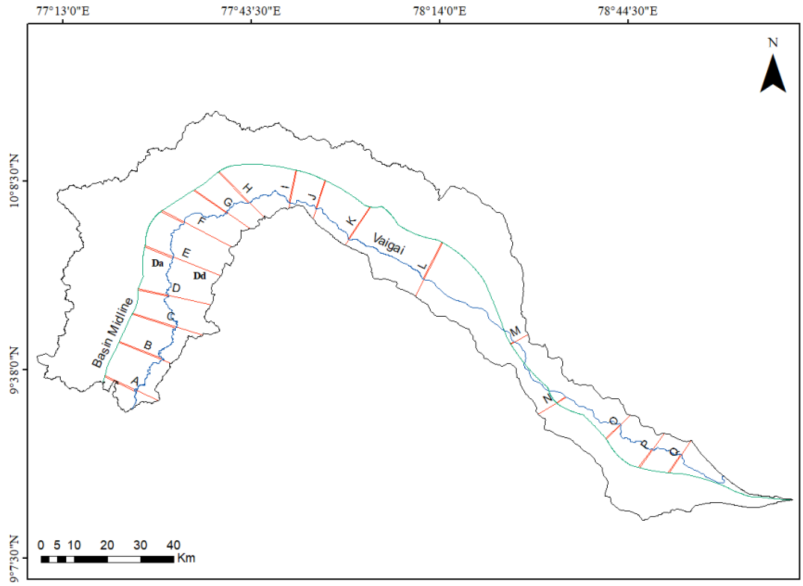


Figure 7. Transverse topographic asymmetry (T) of Vaigai River Basin.

Table 1: Transverse topographic asymmetry (T) of Vaigai basin, Da = Distance between active channel and basin midline; Dd = Distance between basin divide to basin midline

	T=Da/Dd
A	0.55
B	0.87
C	0.42
D	0.42
E	0.36
F	0.32
G	0.59
H	0.67
I	0.85
J	0.73
K	0.84
L	0.68
M	0.18
N	0.34
O	0.59
P	0.53
Q	0.57
Mean	0.559412

Table 2: Basin Elongation ratio (BE), Sinuosity Index (SS), Circularity Ratio (CR), Asymmetry factor (Af), Transverse topographic symmetry (T)

Sub-basin	BE	SS	CR	Af	T
VRN	0.52	1.37	0.48	48.13	0.77
TNR	0.53	1.36	0.41	43.95	0.27
SRL	0.35	1.3	0.29	46.58	0.79
UVR	0.4	0.8	0.33	51.83	0.52
MJR	0.5	1.66	0.45	45.87	0.45
VNR	0.53	1.14	0.27	48.91	0.77
SMR	0.51	1.25	0.54	53.34	0.73
LRV	0.34	0.91	0.32	51.38	0.17
UPR	0.53	1.2	0.67	47.19	0.47
STR	0.41	1.33	0.39	47.99	0.37

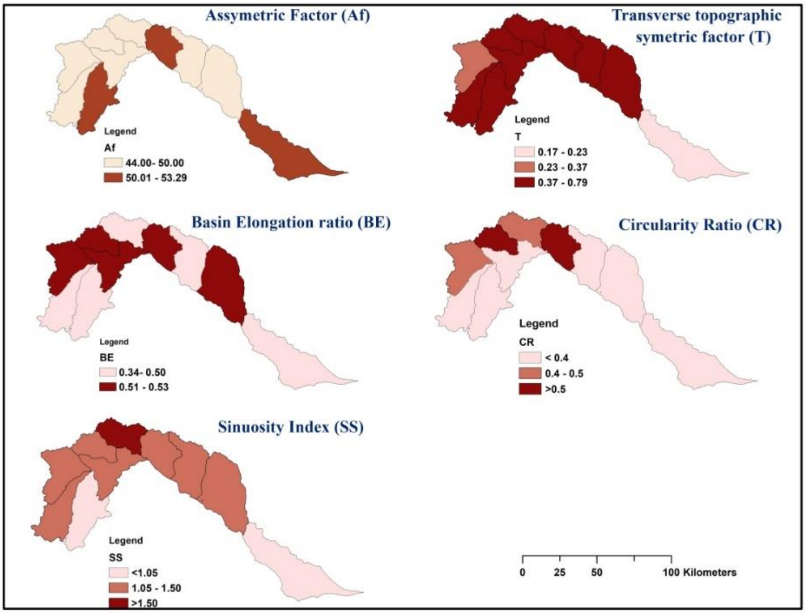


Figure 8. Asymmetric factor (*Af*), Transverse topographic symmetry (*T*), Basin elongation ratio (*BE*), Circularity Ratio (CR), Stream sinuosity (*SS*)

5. DISCUSSION

A comprehensive theory of coupled tectonic deformation and river incision would provide a method for converting between uplift rates, incision rates, and the geometry of river profiles. This would reveal details about local and regional uplift histories and, consequently, the underlying tectonic history (Royden and Perron, 2013). The longitudinal profile analysis of the tributaries of the Vaigai River Basin sheds light on the effect of tectonism in shaping the river profile, and similar studies have been attempted by many researchers (Bishop et al., 2005; Ambili and Narayana, 2014; Reddy, 2021). The tributaries of the Vaigai River drainage basin do not show much variation in the longitudinal profile, and the variation in lithology is limited in the basin. Hence, the differences in base level and tectonics may be the causative factors for the sudden change in the slope gradient. In the upper reaches of the stream profile, major knickpoints are evident, and tectonics plays an important role in their formation. According to Ramkumar et al. (2019), a stream in equilibrium has a concave-up longitudinal profile, but a knickpoint is a break in the gentle curve often identified by a convex reach. Similarly, the longitudinal profiles of both the trunk stream and tributaries show a linear fit and gentle slope towards the downstream, while the upstream exhibits numerous knickpoints. The Vaigai River flows on a former valley, and its distinctive direction was brought about by periodic tectono-morphological events influenced by an inherited Proterozoic structure (Ramkumar et al., 2016, 2019).

According to Ramkumar et al. (2019), the 270-km long Vaigai River has a more concave shape, with an R^2 value of 0.76. There are two knickpoints at the upper reaches of the stream, causing a convex shape in the longitudinal profile (Lp), while it shows a linear fit towards the downstream. The "Goodness of Fit" (R^2) serves as an indicator of the maturity of a drainage basin. During the equilibrium stage of a stream, its slope demonstrates a linear relationship and exhibits a high R^2 value, aligning with the concave longitudinal profile of the basin's mainstream. The interplay between intrinsic and extrinsic factors influences the migration of the knickpoints along the longitudinal profile, temporarily disrupting the linear fit in the slope-area profile. To comprehend the rock uplift and river incision, we have investigated the longitudinal profiles of both the trunk stream and its tributaries. Field verification confirms the incision of tributaries such as the Satiyar and Marudhanadhi, as evidenced by their high R^2 values of 0.98 (Figure 5f & 5c). Similarly, the Vaigai also exhibits incision (R^2= 0.95) at various locations (Figure 6a). Knickpoints frequently occur in tectonically active areas at similar elevations along with the incision wave, as supported by (Das et al., 2020). Although the Thalaiyar waterfall is the steepest knickzone, its nearly 820-meter elevation is situated in the Manjalar stream. This waterfall shows evidence of a palaeo-terrace, typical faulting of the palaeo-valley, and recent incision, forming terraced and waterfall morphology. The synergized results of geomorphic indices and field evidence show that the basin is tectonically active. The transverse topography symmetry also reflects the basin has been affected by the tectonic forces while changing its course from almost northwest–southeast direction. Knick points, deeply incised valleys, are the common features of the basin that point out the neotectonic activity in this region. AF values significantly above or below 50 result from drainage basin tilting, either due to tectonic activity or lithological control (El Hamdouni et al., 2008). Here, the T factor indicates the asymmetric nature of the basin, with tectonic tilt in the upper part of the basin indicating a more asymmetric pattern than the lower end, having T values of 0.84, 0.85, and 0.87 approaching 1. Bravard et al. (1997) found that river incision, a common occurrence in regulated rivers downstream of dams, can decrease habitat heterogeneity. Both tank and river irrigation in the Vaigai Basin are mentioned in the Sangam literature when referring to paddy agriculture. Initial dam constructions involved temporary structures. Inscriptions from the period of the Madurai Pandyas and Chola Kings (A.D. 750–A.D. 1300) provide evidence that the expansion of tanks, as well as the improvement of the dam and channel system, led to the significant advancement of irrigated agriculture during their reign (Ludden, 1979). Similarly, many dams have been constructed along the streams, such as the Vaigai dam, Marudhanadhi dam, Satiyar dam, Manjalar dam, Sothuparai dam, etc., and check dams are also present. The construction of dams and tanks may affect and disturb river flow regimes, resulting in changes in sediment transport processes and differences in geological settings (Charoenlerkthawin et al., 2021). The tectonically active zones are basins with BE values below 0.50, slightly active zones between 0.50 and 0.75 and active zones above 0.75 (Bull and McFadden, 1977, Gupta et.al., 2022). The values of BE obtained in the present study were divided into three classes (Mahmood and Gloaguen, 2012) high, moderate, and low tectonic activity as Class 1 (0.477–0.502), Class 2 (0.503–0.664), and Class 3 (0.665–0.684), respectively. Here, the basins underwent high to moderate tectonic effects. In the present study, sub-basins fall under the active to slightly active class, with values ranging from 0.34 to 0.53. Basins SRL, UVR, LRV, MJR, and STR are represented as high tectonic active areas, covering an area of approximately 4055.46 sq.km. The basins VRN, SMR, TNR, VNR, and UPR fall under the category of moderate tectonic areas, with a total area of 3325.14 Sq.km. Very high transverse topographic symmetry factor values were obtained for sub-basins SRL (0.79), VNR (0.77), and SMR (0.73), indicating that they are tectonically and structurally controlled. In contrast, the least value was observed for sub-basin LVR (0.17) as indicated in Table 2. On the contrary, higher values indicate the asymmetry of the river due to a significant shift away from the basin midline. According to Taesiri et al. (2020), the SS values were dispersed spatially and divided into three classes: Class 1 (1.114–1.171), Class 2 (1.172-1.450), and Class 3 (1.451-2.102). While a low value of SS suggests that the basin region is dynamic, a high value of SS indicates that the river is tectonically stable and closer to equilibrium (Mueller, 1968). The sinuosity of the Varattar-Nagalar River corresponds to a low SS value (1.14) and therefore falls under Class 1 (1.11–1.17). Sub basins such as VRN, TNR, SRL, SMR, STR, and UPR have SS values of 1.37, 1.36, 1.30, 1.25, 1.33, and 1.20, respectively, indicating that these streams fall under Class 2 (1.18–1.45) with moderate tectonics. Class 3 (1.46–2.10) comprises the stream Manjalar, showing a value of 1.66, revealing a low active zone. According to Anand and Pradhan (2019), the values of CR were divided into three separate active tectonic classes: Class 1 (0.122-0.207), Class 2 (0.208-0.264), and Class 3 (0.265-0.301), which stand for high, low, and moderate CR values, respectively. A circular basin with a high value of CR tends to become stretched over time. The LRV, UVR, STR, TNR, MJR, SMR, VRN, and UPR basins have CR values of 0.32, 0.33, 0.39, 0.41, 0.45, 0.48, 0.54, and 0.67, respectively, indicating that they tend to become stretched over time, while the SRL and VNR fall under Class 1, showing values of 0.29 and 0.27, respectively. Moderate values of CR for both basins indicate mature topography, and the SRL basin is comparatively elongated compared to VNR. The entire Vaigai basin shows a CR value of 0.14.

6. CONCLUSIONS

The Vaigai River Basin possesses an unusual configuration at basin scale, with the present-day river channel running on an antecedent basin/valley and interrupted by major crustal-scale structures that are active since the Precambrian era. Superimposed on this are the episodic activeness of tectono-climatic pulses, within which historic-modern land-use dynamics impart differential rates and scales of landscape evolution. By utilizing geomorphic indices, particularly basin asymmetry, T index, longitudinal profile, and SS, one can enhance the detection of tectonic disturbances that have taken place in a particular region. These indices serve as valuable tools for identifying active tectonic zones and evaluating anomalies in drainage patterns, thus aiding in reconnaissance efforts. In the present study, the longitudinal profile and geomorphic indices, together with field data, are calculated using spatial analysis and statistical tools. The concavity of a river profile remains unaffected by lithology, indicating that river morphology is primarily influenced by the rate of uplift over spatial and temporal scales. Longitudinal profile analysis of the tributaries of the Vaigai River suggests that base-level changes may influence the evolution of channel profiles. As most of the streams flow through uniform lithology along their profiles, we can infer that these knickpoints are structurally controlled. Each index is classified into three classes, ranging from high, moderate, and low, and analysed for the active tectonics of the study area. Also, each of the sub-basins shows low to moderate tectonic effects with respect to various geomorphic indices. The circularity ratio indicates a low to moderate level of structural control in the study area, while the basin elongation ratio indicates a high to moderate level of structural control over the basin in the study area. The value of Af indicates the presence of tectonic activity in some of the sub-basins. The transverse symmetric factor (T) suggests a tectonically and structurally controlled environment.

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DELINEATION OF GROUNDWATER POTENTIAL ZONES USING FUZZY ANALYTIC HIERARCHY PROCESS IN CHEYYAR WATERSHED, TAMIL NADU

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Abstract

The present study is conducted in the Cheyyar watershed part of the Palar basin, where 45% of the groundwater resources were overexploited. Three broad factors have been selected to carry out the study: topographic factors (slope, roughness, curvature, drainage density, Topographic Wetness Index (TWI) and Topographic Position Index (TPI)), geological factors (geology, geomorphology, soil type and lineament density), land use and climatic factors (land use/land cover, rainfall, temperature and Normalised Difference Moisture Index (NDMI)). All the thematic layers are reclassified with fuzzy triangular membership function and integrated with the global weightage for mapping groundwater potential zones. The ROC curve is used to estimate the accuracy, which is 86.15%. This study showed that 37% (~805 sq. km) of the study area has high to very high groundwater potential. The potential zones identified in the study would be helpful to the policymakers in implementing the recharge structures to manage and conserve groundwater resources in this overexploited region.

Key Words: Fuzzy Analytic Hierarchy Process, Groundwater potential zones, Cheyyar watershed, GIS.

Introduction

Water plays an influential role in human life on the planet. The development of the human race primarily depends on water resources. About 70% of the earth's surface is covered by water. Oceans and seas cover 97% of the global water as saline water; only 3% is freshwater. Glaciers and ice sheets contain about 70% of the total freshwater; the rest is primarily in the subsurface as groundwater. Hence, groundwater in confined and unconfined aquifers is one of the most precious resources in the earth's sub-surface for all water needs of humankind (Naghibi, 2015).

All over the globe, there is significant pressure on freshwater resources, notably in developing and overpopulated countries. Over the past decade, the need for freshwater has been increasing continuously all over the globe due to population and industrial growth (Masilamani et al., 2023; Killivalavan et al., 2022). Most of the earth's population depends on groundwater resources for various purposes, and groundwater extraction is an easy and cost-effective method. Therefore, regular assessment of the quality and quantity of groundwater resources is essential for sustainable development. In general, the groundwater table recovers itself by infiltration of rainwater, but the infiltration rate cannot meet the exploitation rate if it is over-exploited. If the recharge process is insufficient compared to the extraction rate, drying unconfined aquifers and subsequent drought-like situations are common in most parts of the country (Biswajit et al., 2019).

Groundwater potential zone identification is the most significant step in optimising and preserving the water resource (Balasubramani et al., 2020). There are many techniques have been used to demarcate the groundwater potential zones; those techniques are mainly based on field surveys that are usually time-consuming and not cost-effective (Arulbalaji et al., 2019). There are enormous cost and time-effective methods and models are used such as multicriteria decision-making techniques (Chowdhury et al., 2008), logit regression (Pourghasemi and Beheshtirad, 2015), frequency ratio (Razandi et al., 2015), decision tree (Chenini and Ben Mammou, 2010), Artificial neural network (ANN) (Lee et al., 2012), Shannon's entropy (Naghibi et al., 2015), Machine learning techniques (Rahmati et al., 2016) and Certainty factor (Razandi et al., 2015) in the recent past. Remote sensing (RS) and Geographical Information System (GIS) techniques play a significant role in these techniques as they provide valuable tools for mapping water resources. Many researchers have used RS and GIS techniques to demarcate the groundwater potential zones, especially in hard rock terrains. Since many physical-climatic-environmental factors control groundwater, the application of the Analytical Hierarchical Process (AHP), multicriteria decision-making (MCDM) technique is extensively considered for mapping and managing water resources (Rahaman et al., 2015). In recent years, AHP has been combined with fuzzy logic that can set up an outline to get reliable outcomes using fuzzy triangular membership functions. The Fuzzy Analytical Hierarchical Process (FAHP) has a flexible membership function that makes the way to increase the accuracy and reliability of the results. The Receiver Operating Characteristic (ROC) curve is used to examine the overall validity of the groundwater potential zones with the help of the locations of the existing groundwater wells.

The study examines potential groundwater zones by integrating RS, GIS and FAHP techniques in the Cheyyar watershed in Tamil Nadu with the help of topographic, geological and land use and climatic factors. The study used characteristics of groundwater wells to validate the results and suggested remedial measures to attain sustainability in groundwater management.

Study Area

Cheyyar watershed is a region drained by river Cheyyar which originates in Jawadhu hills in Tiruvannamalai and Tirupattur districts. It fully drains in Tiruvannamalai district, mainly in the Taluks of Cheyyar, Chengam, Vandavasi and Polur, before it opens in River Palar (Fig. 1). It is one of the essential seasonal rivers flow in Northern Tamil Nadu.

Cheyyar is the main source of water in Tiruvannamalai district. The watershed covers an area of around 2,072 sq. km in Tiruvannamalai and Tirupattur District and it extends 12^{0}14'5" N to 12^{0}38'49" N latitude and 78^{0}39'46" E to 79^{0}24'12" E longitude. The study area covers the hilly regions of Tirupattur district and eleven blocks in Tiruvannamalai district, namely, Chengam, Peranamallur, Thurinjapuram, Tiruvannamalai, Chetpet, Vandavasi, Polur, Cheyyar, Jawadi, Kalasapakkam and Pudupalayam. The entire watershed covers 296 villages (1,317 sq. km) and 23 Reserve forests, which cover 755 sq. km. The pediment pediplain complex is the predominant geomorphological feature, occupying 1,244 sq. km of the study area. Charnockite is the major dominating geological structure found in the study area. The largest towns in the study area are Polur, Chengam, Cheyyar, Chetpet and Vandavasi, and the rest are agricultural villages. Agriculture is the backbone of the Cheyyar watershed. Paddy and Groundnut are the most prevalent crops in the region. Irrigation is mainly done through tube wells, canals and open wells. Since groundwater is a significant source of fresh water for various purposes, identifying groundwater potential zones is essential research to be done in the study area.

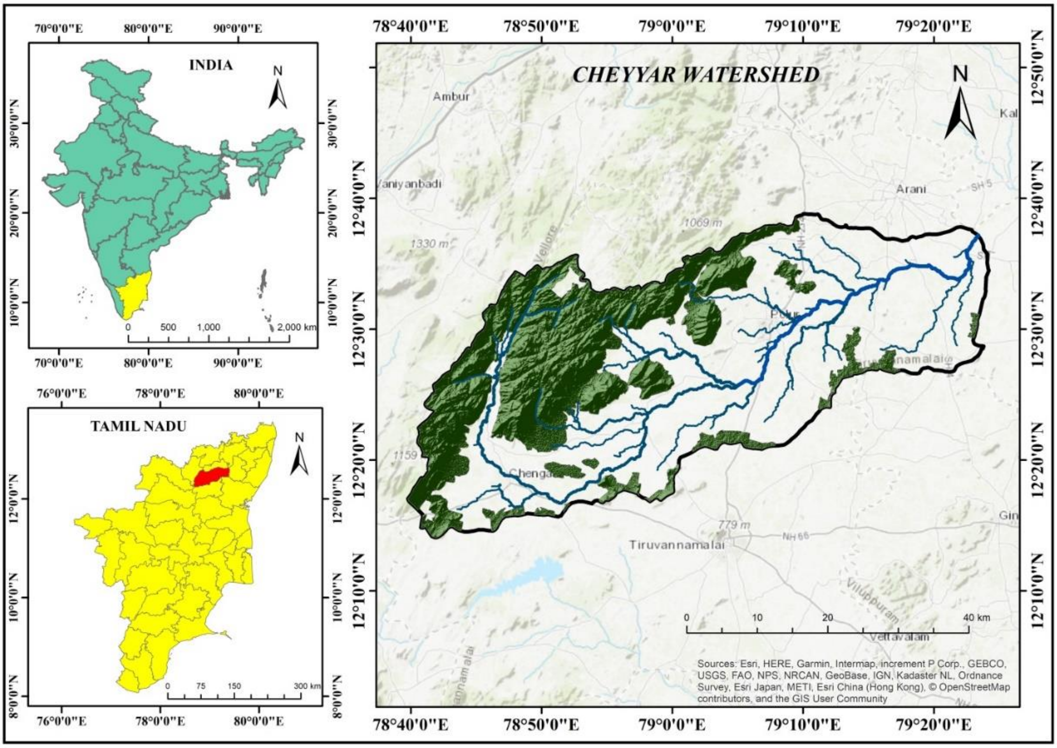

Figure 1: Location of the Study area

Data and Methods

Data

The mapping of the groundwater potential zone for the Cheyyar watershed is attempted through multiple remote sensing data products. All the topographical factors like slope, roughness, curvature, drainage density, Topographic Wetness Index (TWI) and Topographic Position Index (TPI) are computed from high-resolution ALOS PALSAR DEM data which has 12.5 m spatial resolution. The Geological Survey of India (GSI) provides region-wise geology maps from which the geological feature of the watershed is mapped, and the general soil types are mapped from the National Bureau of Soil Survey and Land Use Planning (NBSS & LUP), Tamil Nadu Soil Map (Table 1). Then factors like geomorphology and lineament density are extracted (e.g., clipped) according to the study area from the Bhuvan web portal and mapped. The daily recorded rainfall data for 1991 - 2021 is collected from the Statistical Department of Tamil Nadu. Further, the Landsat 8 OLI data is utilised to map the land use/land cover through the visual interpretation, land surface temperature (temperature) extracted through the split window algorithm and NDMI extracted with a per-defined algorithm (Ravichandran et al., 2022).

Table 1. Variables of the study and their data sources

Factors	Data Source
Slope Roughness Curvature Drainage Density Topographic Wetness Index (TWI) Topographic Position Index (TPI)	ALOS PALSAR DEM
Geology	Geological survey of India (GSI) Map
Soil	National Bureau of Soil Survey of India sheet
Geomorphology Lineament Density	Bhuvan web portal
Rainfall	Statistical Department of Tamil Nadu
Land Use/Land Cover Land Surface Temperature Normalised Difference Moisture Index (NDMI)	Landsat 8 OLI

Analysing Method

Around 14 significant factors are adopted and grouped into three sections namely, Topographic factors (slope, roughness, curvature, drainage density, Topographic Wetness Index (TWI) and Topographic Position Index (TPI)), Geological factors (Geology, Geomorphology, general soil type and Lineament density), Land use and climatic factors (land use/land cover, rainfall, temperature and Normalised Difference Moisture Index (NDMI)). The weightage of the 14 factors is calculated by utilising the Fuzzy Analytical Hierarchical Process (FAHP) and these factors are integrated into three main factors to construct a groundwater potential zone. Table 2 represents the pairwise comparison matrix constructed using FAHP techniques and its weight is assigned for each factor (Fig. 2).

Finally, the ROC curve has been made by using existing groundwater well locations collected from the field to validate the results.

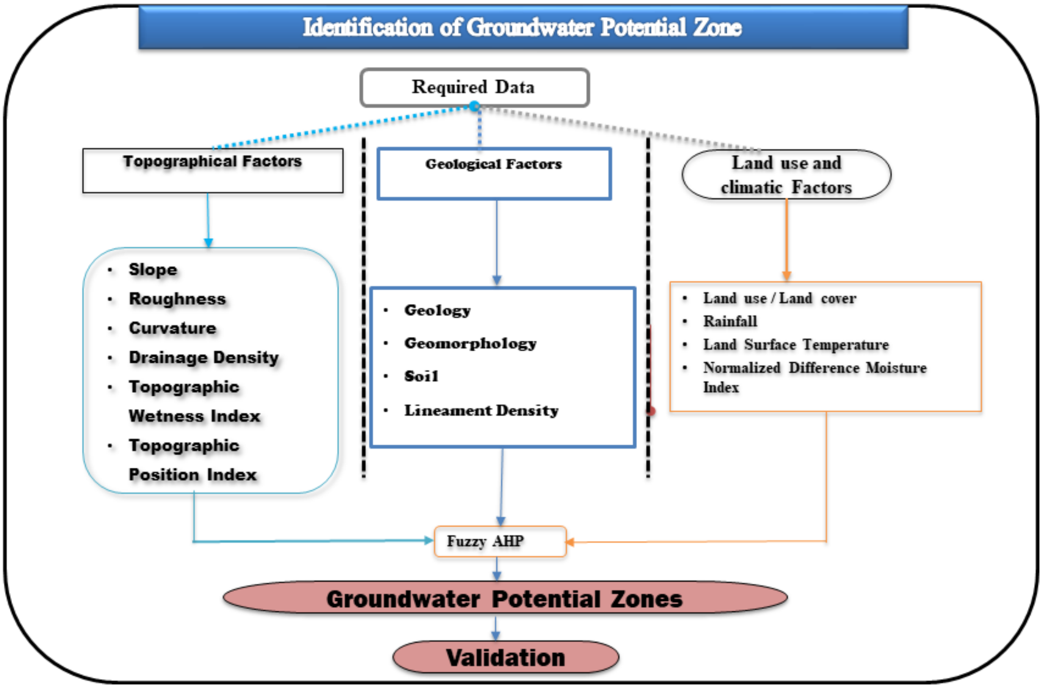

Figure 2: Methodological Flow chart of the Study

Fuzzy Analytical Hierarchical Process (FAHP)

The FAHP is one of the best techniques in the multicriteria decision-making process (Saaty, 1980; Rahaman et al., 2015). Thus, the study utilised the efficiency of FAHP to assign criterion weights and rank for the factors of groundwater potential zone. The procedure and steps mentioned below have achieved it. Initially, the pairwise comparison matrix for each factor is computed with the fuzzy triangular elements (Eq. 1). Based on the relative scale of importance, the decision maker assigns the value ranges from 1 to 9, reflecting the relationship between each criterion.

$$\tilde{A}_{ij} = (\tilde{a}_{ij})n \times n = \begin{pmatrix} (1,1,1) & (l_{12}, m_{12}, n_{12}) & (l_{1n}, m_{1n}, n_{1n}) \\ (l_{12}, m_{12}, n_{12})^{-1} & (1,1,1) & (l_{in}, m_{in}, n_{in}) \\ (l_{1n}, m_{1n}, n_{1n})^{-1} & (l_{in}, m_{in}, n_{in})^{-1} & (1,1,1) \end{pmatrix} \quad (1)$$

The initial value is transformed into a fuzzy value through the eq (2)

$$\tilde{a}_{ij} = (l_{ij}, m_{ij}, n_{ij}) = \tilde{a}_{ij}^{-1} = \left(\frac{1}{n_{ij}}, \frac{1}{m_{ij}}, \frac{1}{l_{ij}} \right) \text{ where i, j=1, 2,…n and i} \neq \text{j} \quad (2)$$

Through equation 3, the fuzzy geometric mean value for every criterion (a_{ij}) is calculated

$$\tilde{r}_i = \left(\prod_{j=1}^{n} a_{ij} \right)^{1/n} \text{ Where, i= 1, 2,…..n} \quad (3)$$

Each criterion (a_{ij}) fuzzy weightage ($\tilde{w}_i$) are assessed through eq (4)

$$\tilde{w}_i = \tilde{r}_i \times \left(\tilde{r}_1 + \tilde{r}_2 + ...\tilde{r}_n \right)^{-1} \quad (4)$$

De-fuzzification of fuzzified value into a numerical value (w_i) through eq (5)

$$w_i = \left(\frac{l\tilde{w}_i + m\tilde{w}_i + n\tilde{w}_i}{3} \right) \quad (5)$$

Finally, numerical value (w_i) is normalised through eq (6)

$$N_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \quad (6)$$

Results

Topographic Factors

The slope is divided into four classes based on the slope in degrees that are flat (less than 2), gentle (2–7), moderate (7–12), and steep (more than 12) (Showmitra et al., 2022). The maximum portion of the study area is flat terrain and highly steep slopes in the upper part (Fig. 3). roughness is classified by four as less than 0.3, 0.3–0.5, 0.5–0.7 and more than 0.7 (Showmitra et al., 2022). Moderate roughness values (0.3 – 0.5) dominated the study area about 900 sq. km fell under this category. Curvature values are classified as very low (less than -0.3), low (-0.3–0.1), moderate (0.1–0.7) and high (more than 0.7). The low curvature is the dominant distribution and all the other classes are found only in trace amounts.

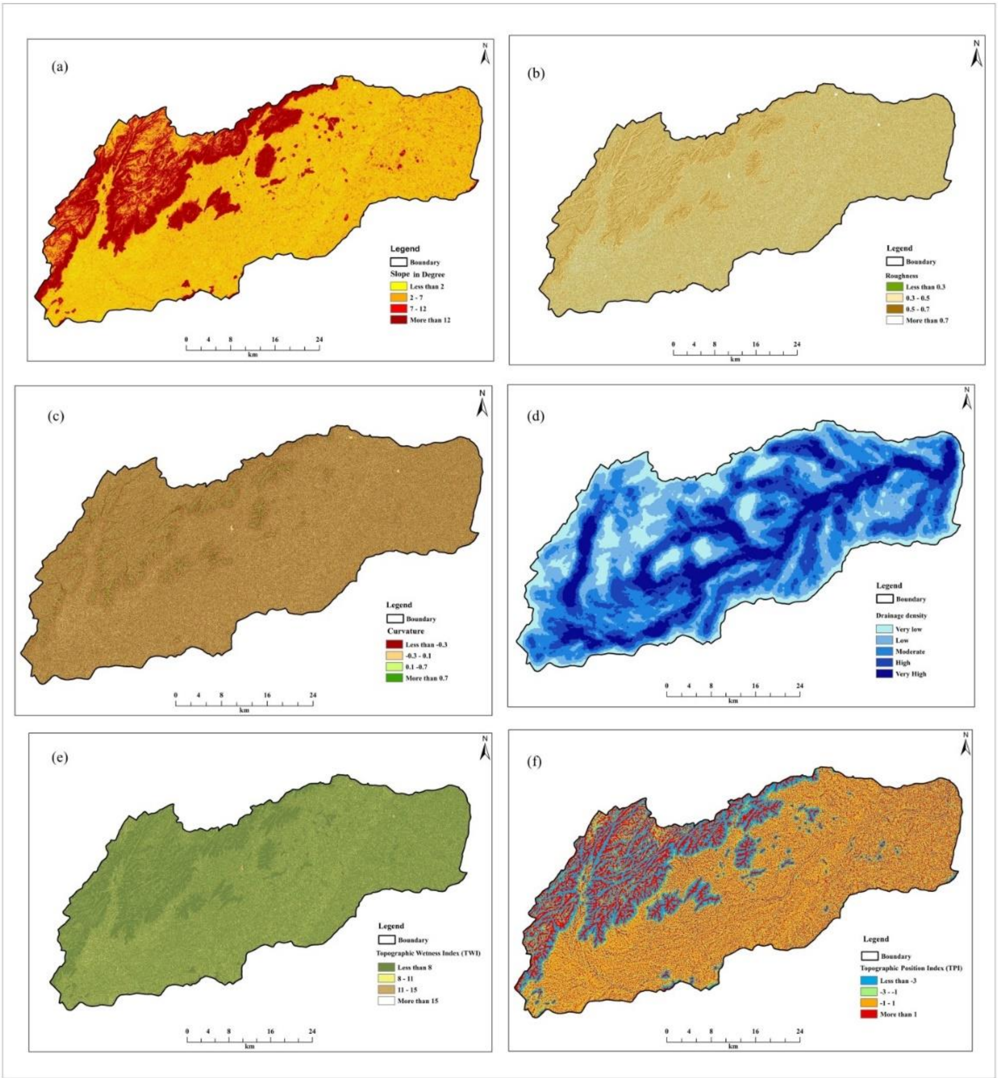

Figure 3: Spatial distribution of topographical factors (a) Slope, (b) Roughness, (c) Curvature, (d) Drainage Density, (e) TWI and (f) TPI.

The drainage density is characterised by five classes: very low (sparse), low, moderate, high and very high (dense). The centre portion, along with the main river channel in the study area, is the high drainage density area with a high potential of water infiltration and less dense areas with less groundwater potential. The TWI has been categorised into four classes: less than 8, 8–11, 11–15 and more than 15. Most of the study area is occupied by less than 8 and 8-11, representing low groundwater potential (52%), especially in the northwestern part (Jawadhu Hills). The infiltration is high in the foothills parts of the study area and sparse over the other parts of the study area. TPI less than -3 refers to a flat surface, and more than one refers to an elevated region. The northwestern part of the studyarea is highly elevated and sparsely in the central portion. Low elevation values highly influence the groundwater potential. Notably, the foothills of Jawadhu Hills have a high potential for groundwater recharge.

Geological Factors

Charnockite is the primary dominating geological structure in the Cheyyar watershed; it consists of metamorphic rocks with variable chemical composition. It occupies an area of 1526 sq. km (74%). Hornblende-biotite genesis covers 416 sq.km (20%). The other geological features are found in the study, such as Pyroxene Granulite, Pink Migmatite, Epidote, Granite, Ultramafic rocks and Magnetite quartzite, which covers 6% of the study area. High weightage is given to Magnetite Quartzite, and the lowest weightage is given to Pink Mignatite, which has less infiltration (Fig. 4). The geomorphological structure of the Cheyyar watershed shows well-matured Pediplain complex; it also has the Dissected Hills of Jawadhu Hills in which the mainstream of Cheyyar rises. The pediment pediplain complex occupies around 1244 sq. km (60%) of the study area. Dissected Hills and valleys are found mainly in the northwestern portion of the Cheyyar watershed region; it covers an area of 462 sq. km (22%).

The waterbody includes the main Cheyyar stream along with lakes and ponds covering an area of 153 sq. km (7%). The dissected upper plateau found in Jawadhu Hills covers an area of 96 sq. km (4.6%). Bajada is like an alluvial fan occupying 92 sq. km (4.4%) of the study area. The piedmont slope covers 17 sq. km. Active flood plain forms at the confluence of river Cheyyar with Palar in the Northeastern direction of the study area and covers 8 sq. km. Active floodplains, water bodies, and plain land are more effective in infiltration rate than hills and valleys.

Clayey type of soil is the most dominant in the Cheyyar watershed. Gravelly clay soil, cracking clay soil and clayey soil are subtypes that cover almost 90 per cent of the total study area; loamy soil covers 196 sq. km, and it has three subtypes: loamy soil, stratified loamy soil and gravelly loam soil. The combination of clay soil and rock outcrop has the lowest infiltration rate. Similarly, loam soil and fine soil are greatly benefitting groundwater rejuvenation. Lineament density has been divided into four classes such as < 0.4, 0.4 – 0.8, 0.8 – 1.2 and > 1.2. High weightage is given to high lineament density and contrariwise. Lineament density is low all over the study area except the hilly region.

Land Use and Climatic Factors

The study area is ultimately covered with agricultural area and vegetation. The barren land is sparsely spread throughout the study region (Fig. 5). Water bodies and agricultural land have a high groundwater potential. Barren and rocky land has less potential since the infiltration is low. The rainfall Is classified into five classes: very low, low, moderate, high and very high. So, intense rainfall with stagnant surface water increases the groundwater potential. The high rainfall found in the central and eastern parts of the study area has a high possibility of water infiltration into the subsurface due to low runoff. Low rain in the northwestern part of the Cheyyar watershed has lead to a less infiltration.

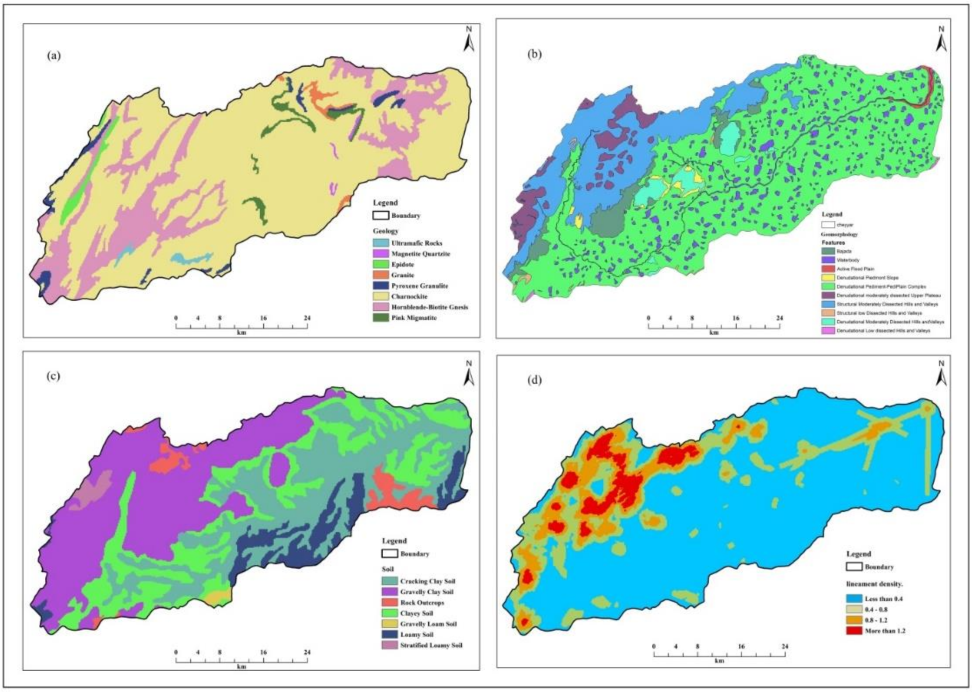

Figure 4: Spatial distribution of geological factors (a) Geology (b) Geomorphology (c) Soil and (d) Lineament Density.

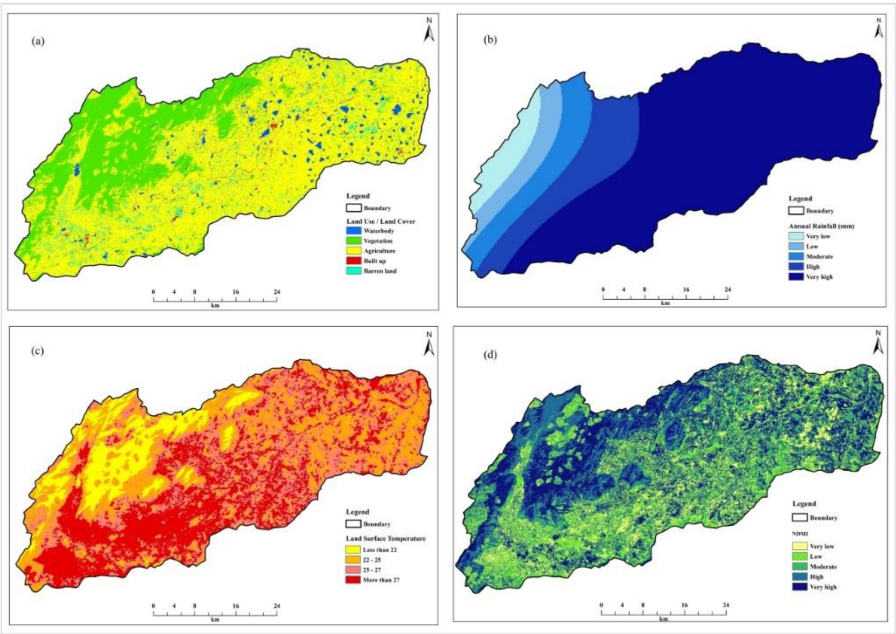

Figure 5: Spatial distribution of land use and climatic factors (a) Land use / Land cover (b) Rainfall, (c) LST and (d) NDMI.

The highest temperature in the study area is 37^0 C found in the part of Chengam, and the lowest is 17^0 C in the higher altitude part of Jawadhu Hills. About half of the study area experienced more than 27^0 C temperature. In the plain region, the infiltration rate is very high, and the potential is higher on flat surfaces. NDMI describes the water stress level of the area, and the moisture value is between -1 to 1. The northern portion of the study area is highly moist. The high and very high moisture levels are dominant in the study area.

Groundwater Potential Zones and Validation

The groundwater potential zones have been examined by using FAHP and proper weightage given to each sub-factor and class (Table 2). After executing the FAHP with proper weightage of factors, sub-factors and each class, the groundwater potential zones can be mapped by using the final weightage values. Low to high potential for groundwater dominantly prevails over the study area (Table 3.). However, the study area was dominated (63%) by moderate and high groundwater potential zones. Figure 7. shows the ROC curve of the study area. The Area Under Curve (AUC) in the ROC was about 86.15%., which denotes a reasonable accuracy.

Table 2. Representing the weight of each factor and sub-factor

Factors	Criteria Weight	Sub Factors	Sub - Criteria Weight
Topography Factors	0.41	Slope	0.1
		Roughness	0.05
		Curvature	0.04
		Drainage density	0.09
		TWI	0.07
		TPI	0.06
Geological Factors	0.32	Geology	0.06
		Geomorphology	0.14
		General soil type	0.09
		Lineament density	0.03
Land use and Climatic Factors	0.27	Land use/Land cover	0.08
		Rainfall	0.13
		LST	0.04
		NDMI	0.02

Discussion

The groundwater potential depends on many factors. Amongst, the slope is the most crucial topographic feature that determines the infiltration of precipitation (Yeh et al., 2009; Singh et al., 2013; Arulbalaji et al., 2019). The plain surface tends to have a high infiltration rate, and the high slope indicates steep terrain with a significantly lower infiltration ratio. Areas with steep slope with faster-flowing water do not get enough groundwater recharge, notably in the short seasonal (monsoonal) rainfall regions (Yeh et al., 2009). The roughness indicates the degree of undulation on the surface. The area with a flat surface, i.e. low roughness and value has the potential for a high infiltration rate and vice versa for highly undulating surfaces. The slope curvature also constrains the erosion and runoff process (Rejith et al., 2019): the convex and concave helps to accumulate the groundwater. Therefore, roughness and curvature significantly impact groundwater potential. These parameters can also be understood indirectly by analysing the drainage patterns of the region (Singh et al., 2013). The higher the density, higher the infiltration; low the density, the lower the accumulation (Yeh et al., 2006). The higher density of streams was found in the central part of the study area, where the groundwater potential is high. In addition, TWI can be used to strengthen the analyses as infiltration is also affected by the hydrological process (Mokarram et al., 2015; Arulbalaji et al., 2019). The greater value represents the more significant the groundwater potential. Higher wetness is found in the parts of Jawahu Hills; however, there is less infiltration due to its topographical setup. An area's soil profile also substantially determines the infiltration and percolation rates of water entering aquifers, and it is essential for agriculture.

Table 3. Representing groundwater potential zone categories and their respective area and percentage of area.

Sl.No	Groundwater Potential Categories	Area in Sq.km	Percentage
1.	Very low	142.06	6.85
2.	Low	389.21	18.78
3.	Moderate	735.69	35.50
4.	High	565.96	27.32
5.	Very high	239.36	11.55

The geological structure of a watershed is the most important for analysing the morphology of the study area. The Magnetite Quartzite has the highest infiltration rate as reflected in the final potential map (Fig. 6). Combined with geomorphology, geological structures provide essential information about the infiltration process, groundwater variation, surface runoff and geochemical changes. (Raja Veni et al., 2017). Faulting and fracturing zones represented by lineaments are responsible for secondary porosity and permeability of the ground surface (Yeh et al., 2006). The high density of lineaments has a high potential for groundwater and vice versa. Still, in the case of the Cheyyar watershed, the plain region has less lineament density, which does not favour secondary porosity and permeability. The land use /land cover pattern in the study area gives an idea about the utilisation of groundwater. The increase in the build-up area with increased agriculture practices leads to decreased water quality and groundwater recharge (Elmahdy et al., 2020). Notably, in Chengam, there is minimal infiltration because it has highly dense built-ups. Rainfall also significantly affects groundwater recharge and water availability (Showmitra et al., 2022). Exceptionally, high rain with low runoff and high infiltration rates leads to high groundwater potential. The final result reveals that rainfall, land use and drainage density are the highly influencing factors in delineating the groundwater potential zones in the study area.

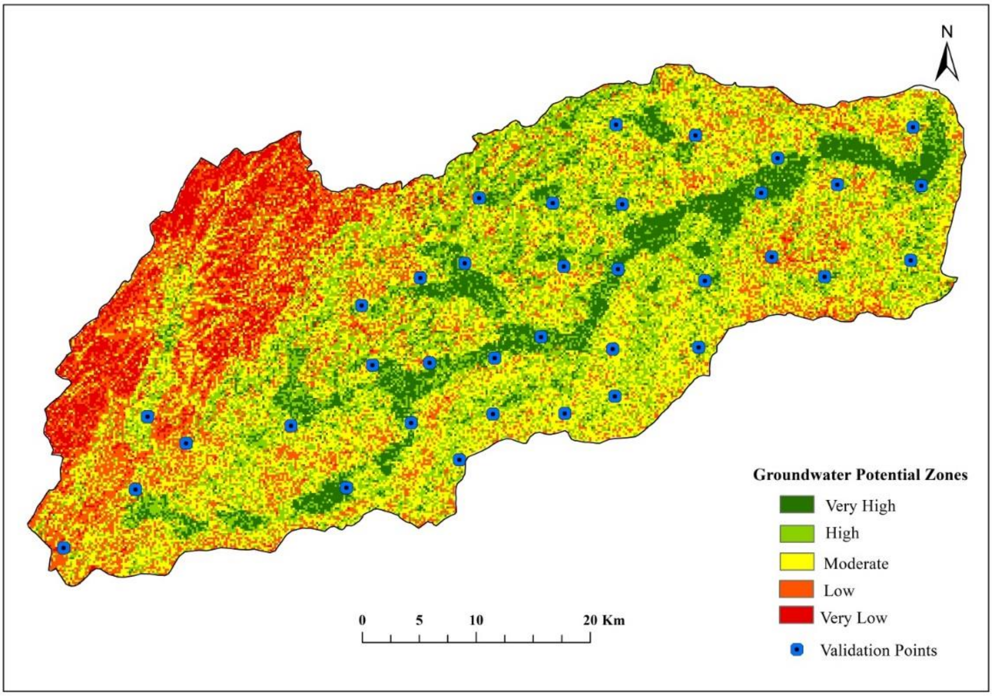

Figure 6: Spatial distribution of groundwater potential zone by integrating RS, GIS techniques and FAHP

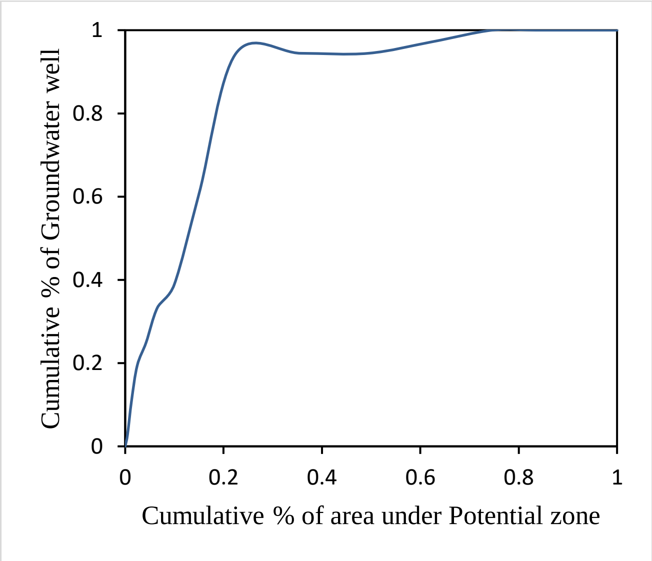

Figure 7: ROC curve for validation of groundwater potential.

Conclusion

The study used three major factors and 14 sub-factors to assess the groundwater potential zones by integrating RS, GIS and FAHP. Based on the FAHP values, the study area has been divided into five classes: very low, low, moderate, high and high potential zones. However, about 37% (~ 805 sq. km) of the study area has high to very high groundwater potential, especially along the river banks and the foothills of Jawadhu hills, indicating that the construction of small check dams can subsequently increase the groundwater level. The accuracy of the study has been quantified using the ROC curve, and it was found that the accuracy of the final result is 86.15%, which is reasonable. Notably, most agricultural areas have moderate to high groundwater potential; therefore, implementing percolation ponds is recommended to increase the infiltration in these areas. The study results could help policymakers implement strategies for managing the groundwater resources, especially for irrigation and drinking purposes of the study area, and to attain a sustainable future.

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Archives - 1

NEWS AND NOTES

from The Indian Geographical Journal Formerly Known as The Journal of The Madras Geographical Association

(Volume XVII, 1942, pp.75-77)

News and Notes

We are glad to acknowledge with thanks the fresh support that we have received for the journal during the last year. That is due largely to its becoming an All-India journal. Continued and increased support of this kind will enable us to improve further the size and quality of the journal, with the return of normal times. Under the stress of war conditions we have regretfully to cut down the number of pages and illustrations.

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The conversion of the Journal as an All-India one is but the first step in a comprehensive plan of forming an Indian Geographical Society, from out of the nucleus of the Madras Geographical Association, which has been fully functioning for the last sixteen years.

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It may not be out of place to recall in this connection certain relevant facts, detailed from time to time in the back issues of the Journal during the last five years. It was the Indian Science Congress that first provided a common platform for the Geographer in India to come together by expanding its Geology Section into the Indore and Hyderabad Sessions in1936 and 1937. But the response was rather poor on the part of the Geographers, due probably to insufficient notice.

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Next year (1938) at the Silver Jubilee Session of the Congress at Calcutta, Geography was separated from Geology, temporarily for that year, as a distinct Section. And in a business meeting of the new Geography Section, at the instance of British Geographers - Professors Fleure, Fawcett, Stamp and others who attended the Session - the need was discussed for an All-India Geographical Organisation to co-ordinate the geographers and geographical work done in the several Provinces and States. A committee of five members was appointed with Mr. N. Subrahmanyam as Convener to carry on correspondence with geographers and geographical associations and societies in India, and going into the question fully to work out a scheme for adoption at the time of the next Congress Session at Lahore in January 1939.

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Accordingly, a circular letter enclosing a Questionnaire was sent widely to persons known to be interested in the cause of geography in the several Provinces and States to elicit and gather information. But the response was most disappointing. When the matter was actually discussed at Lahore Session, there was little enthusiasm or support for starting an All-India Geographical Organization. The chief reason for this appears to be the lack of general interest in Geography even among educated people and the indifference of Universities to geographical Studies.

* * * * *

Under circumstances detailed at P. 105 of Vol. XVI No.1 of the Journal, the Journal of the Madras Geographical Association was converted into the Indian Geographical Journal, as a first and preparatory step in the formation and development of an Indian Geographical Society; and seeing that this step has justified itself by results, it has now been decided to make alteration in the title and scope of the Association itself so as to suit the coming into being of an All-India Geographical Institution. This step had to be hastened as a result of the practical scrapping of the Geography Section of the Indian Science Congress from next year by reamalgamating it with the Geology Section. After long deliberation and discussion, the tittle of new All-India Organization has been settled as the Indian Geographical Society, with membership thrown open to all interested in Geography.

* * * * *

A Committee of the Council prepared draft Rules by adapting the existing Rules to suit the requirements of an All-India Society; and the Council and the General Body adopted them in their last meeting. The Rules concerning the formation and working of the branches have been carefully revised; and it is hoped that several of these would be formed in different localities in India, where there are no Geography Societies or Associations.

* * * * *

It will now be possible for an Indian Geographical Conference to meet annually in the several branch centres in turn, as a common platform for discussion of paper on geographical studies carried out by geographers in the country. If conditions and circumstances are favourable, it may even be possible to start with the first Indian Geographical Conference in Madras during the ensuing Christmas holidays, along with All-India Educational Conference which is expected to take place at the time.

* * * * *

The 12th Madras Geographical Conference will be held at Vellore (North Arcot District) about the middle of May next, when paper on various aspects of Geography of

North Arcot District will be read and discussed. Mr. A. Swaminatha Ayyar, Retired Deputy Collector and former Editor, "Rural India" has been elected President of the Conference.

* * * * *

Owing to the present war conditions, the Summer School of Geography, usually conducted by the Madras Geographical Association at the Teachers' College, Saidapet in April, has been postponed to May and will be conducted in a mofussil centre. The exact time, place and other details will be duly notified as soon as they are settled.

* * * * *

Three meetings were held during the current quarter. On 24-1-42, Mr. N. Subrahmanyam read a paper on "*Seasonal Control of Rural Life and Activities in the Conjeeveram Region*". On 2-2-42 Mr. N. Sundarama Sastry spoke on "*localization of crops in India*.". On 14-3-42 Mr. M. P. Rajagopal read a paper on "*The Environment of the Tanjore Ryot in relation to Agriculture in Tanjore District.*'

* * * * *

The Sixteenth Annual Meeting of the Madras Geographical Association was held at the Meston Training College, Royapettah, at 5 P.M. on Saturday the 7th March 1942 with Mr. M. Subrahmanya Ayyar, B.A., B.L., in the Chair. The 16th Annual Report was presented by Secretary on behalf of the Council, and was approved. The result of the Elections of 1942 were next announced. The change in the title of the Associations to the Indian Geographical Society and the draft Rules as proposed by the Council were then accepted; and it was resolved that they come into force forthwith.

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Archives - 2

NEWS AND NOTES

from The Indian Geographical Journal Formerly Known as The Journal of The Madras Geographical Association

(Volume XVII (2), 1942, pp.149-150)

News and Notes

Owing to the war emergency, our difficulties have increased in all ways. In particular, we have to mention the difficulty of procuring paper and getting blocks made, both of which have told on the size of the Journal and the number of maps etc., that could be included. We ask for the indulgence of our subscribers.

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Owing to enemy action, it is possible that our foreign subscribers and exchanges may not have received some issues. In such cases we shall be glad to supply the missing copies on intimation.

* * * * *

The Summer School of Geography, which used to be held every year in April-May, had to be given up this year for want of proper response, owing partly to scare and partly to anticipated difficulties of transport.

* * * * *

The 12th Madras Geographical Conference, planned to be held in Vellore in May 1942, had to be postponed along with the Provincial Educational Conference, to September-October, owing to difficulty of getting accommodation. It is hoped that there will be no need for further postponement.

* * * * *

The All India Educational Conference, which was proposed to be held at Madras in December next, has been arranged be held at Indore, as the South Indian Teachers' Union expressed its inability to run the same under present conditions.

* * * * *

Against all this tale of negative record, it is heartening to find the determination everywhere to concentrate all efforts on the war and carry on the struggle for freedom to success, and the record of war production in India published in the pages of the Indian Information is simply astounding.

* * * * *

Qualified young Indian geographers, along with others, are undergoing military training in the Officers' Training School at Mhow and elsewhere, to take their place presumably as Lecturers in Geography in recruit schools.

* * * * *

We congratulate Prof. M. B. Pithawalla, who has been awarded the Moos Gold Medal by the University of Bombay for the best thesis of scientific research for the year 1940-41.

The Moos Medal is an endowment of Rs. 10,000; and the Medal is a coveted prize offered annually to the best amongst the recipients of the highest degree in the Faculty of Science.

* * * * *

Archives - 3

NEWS AND NOTES

from The Indian Geographical Journal Formerly Known as The Journal of The Madras Geographical Association

(Volume XVII(3), 1942, pp.227-228)

News and Notes

The difficulty of procuring paper in time has caused considerable delay in bringing out this issue within the quarter. Members and subscribers, it is hoped, will appreciate our war time difficulties and not mind the delay.

* * * * *

Two meetings were held during the quarter. In the first one Mr. George Kuriyan read a paper on *India-a Study in Space Relations*. In the second one Mr. N. Subrahmanyam spoke on *The Geography of Hill Fortresses in South India*.

* * * * *

We are glad to note that the University of Mysore which introduced Geography for the Intermediate course two years ago has this year carried it on the B.A. course also.

* * * * *

The Indian Science Congress will meet at Lucknow in the first week of January 1943. As the Geography Section of it has lost its place as a separate section having been tacked on to the Geology Section in spite of all the efforts of the Geographers to prevent this amalgamation, a desire has been expressed by several of them to have a separate Conference of their own as a clearing house of Geographical thought and research in this country like the Political science, Economic, Historical and Oriental Conferences. It has been urged that such a Conference can also tackle important questions, such as preparation of Land Utilization Maps, A National Indian Atlas, A Standard Regional Geography of India etc. Co-operation of the work of several Governmental departments such as the Geological and the Meteorological, and the Survey of India has to be done as preliminary to and part of a National Regional Planning. An Indian Geographical Conference held annually in the different University centres may be found to be extremely helpful in carrying out such work. Opinion is invited on this idea.

* * * * *

Owing to the emergency conditions prevailing in south India during last summer, the Provincial Educational and Geographical Conferences could not be held at Vellore in May 1942 as was originally planned. It is now understood that the two postponed Conferences will be held in May, 1943.

* * * * *

During the quarter a Refresher course in Geography was conducted at Madanapalle by Mr. N. Subrahmanyam, which was attended by 20 teachers of Geography from the several schools in the locality. A number of excursions were also conducted as part of the programme of the course, the most important of which was that to Horsley Konda.

* * * * *

The All-India Educational conference will be held at Indore, from 27th to 30th December, 1942. The New Education Fellowship and the Indian Adult Education Conference will also meet there at the same time.

* * * * *

We are glad to welcome the publication of the Punjab Geographical Journal, Volume I. In the vast sub-continent of India, there is great need for the promotion and diffusion of a good deal of Geographical knowledge; and one more journal, at present, means some more useful work carried out in that direction.

* * * * *

It is interesting to note that the newly started University of Ceylon has a full-fledges Department of Geography from the very beginning, instead of having to wait for tardy recognition and slow development as in several of the Indian Universities.

* * * * *

We are glad to state that the Ceylon Geographical Society, which is closely associated with the University Department of Geography, has been giving a series of popular lectures by specialists, illustrated with slides and views, for the benefit of the Military Officers and soldiers now staying at Colombo.

* * * * *

The Indian Geographical Journal
Volume 97 (1) June - 2022, pp 100-100
ISSN 0019-4824

THE INDIAN GEOGRAPHICAL SOCIETY

Department of Geography, University of Madras, Chennai - 600 025

12th IGS Online Talent Test – 2022

Date: 11.05.2022 Time: 11.00 a.m. - 12.00 Noon

WINNERS

Young Geographer (Under Graduate Programme)

The IGS Founder Prof. N. Subrahmanyam Award

Name of the Student	Name of the Institution	Total Score	Marks Scored	Rank
R.R. Harini	Department of Geography, Nirmala College for Women (Autonomous), Coimbatore 641 018.	75	69	I
R. Mouliya	Department of Geography, Nirmala College for Women (Autonomous), Coimbatore 641 018.	75	69	I
Navneet Sharma	Department of Geography, Tourism and Travel Management, Madras Christian College (Autonomous), Tambaram, Chennai - 600 059.	75	69	I
Janet kethsiyal I	Department of Geography, Nirmala College for Women (Autonomous), Coimbatore 641 018.	75	68	II
Aakash R	Department of Geography, Bharathidasan University, Tiruchirappalli - 620 024.	75	65	III
Mohammed Noorul Hasan	Department of Geography, Tourism and Travel Management, Madras Christian College (Autonomous), Tambaram, Chennai - 600 059.	75	65	III

Young Geographer (Post Graduate Programme)

Prof. A. Ramesh Award

Name of the Student	Name of the Institution	Total Score	Marks Scored	Rank
Chithra Nair Rajendran	Department of Geography, University of Madras, Guindy Campus, Chennai - 600 025.	75	60	I
Gayathri Devi. U	Department of Geography, Madurai Kamaraj University, Madurai - 625 021.	75	60	I
Anjana Anie Thomas	Department of Geography, Central University of Tamil Nadu, Thiruvarur - 610 005	75	57	II
Akshaya Gireesh M P	Department of Geography, Madurai Kamaraj University, Madurai - 625 021.	75	56	III

The Indian Geographical Journal
Volume 97 (2) December - 2022, pp 101-120
ISSN 0019-4824

MUNICIPAL SOLID WASTE MANAGEMENT IN THE DEVELOPING WORLD: AN EVIDENCE OF ALIPURDUAR TOWN, WEST BENGAL, INDIA

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Abstract

Alipurduar is one of the growing towns in Northern Bengal in India. The population of the town has increased by 162.24 percent from 1951 to 2011. Therefore, the generation of solid waste has also been increasing. The town generates around 22 tons of solid waste per day at a rate of 269.19 gm per capita per day, which is almost 150.12 gm/day higher than the national average, i.e. 119.07 gm/day. The study aims to highlight the status of solid waste management and to examine the satisfaction level of the residents with the solid waste collection services provided by the Alipurduar municipality. Primary data was collected with the help of a structured questionnaire from 384 sample households distributed in 8 (40 percent) sample wards, and 368 samples were used for data analysis. The results revealed that the existing solid waste management system in Alipurduar municipality is inadequate in terms of solid waste transport vehicles, primary waste collection centres, and dumping grounds. The research also indicated that the appropriate door-to-door solid waste collection is accessible to only 30 percent of the municipality's wards, and 61 percent of respondents are dissatisfied with the existing door-to-door solid waste collection system. The study found that 77 percent of respondents disposed of their garbage in an unscientific way. One-way ANOVA results show that there is a significant difference in mean between the levels of satisfaction except for solid waste collection, environmental change, and burning of solid waste among different income groups. The study suggests that the residents are not satisfied with the service provided by the municipality. Nevertheless, 48 percent of residents are satisfied with the decision to pay money for waste disposal. The study results would help policymakers and bureaucrats devise optimal plans for solid waste management in the city.

Keywords: Urban, Solid Waste Management, Waste Collection, Satisfaction, Environmental Degradation

Introduction

Essentially, "solid waste" refers to waste that has not naturally decomposed over a period of time. Solid waste has been produced since the beginning of civilisation (Chattopadhyay et al., 2009). It is now a global concern as the generation and mismanagement of waste pose significant environmental and public health challenges (Kaza et al., 2018). Developing countries, in particular, face inadequate solid waste management practices, resulting in environmental pollution, land degradation, and health risks for local communities. The process of rapid industrialisation and population growth in the global south has led to extensive urbanisation, attracting substantial migration from villages to cities. The rate of urbanisation is very high in the developing countries compared to the developed and less developed countries, and people move towards the city for different purposes. Consequently, this influx contributes a significant amount of solid waste to the urban environment and indiscriminate disposal of solid waste. Kaza et al. (2018) underscored the rapid growth of municipal solid waste generation, outpacing the pace of urbanisation. World Bank indicated that by 2025, approximately 4.3 billion urban inhabitants could potentially produce an estimated 1.42 kg/capita/day of municipal solid waste, totalling a staggering 2.2 billion tonnes per day. Due to insufficient financial assistance and infrastructure, many growing cities will fail to manage their solid waste properly. The unmanaged waste creates major health and environmental issues for urban residents (Katusiimeh et al., 2012). Thus, solid waste management has become a critical issue in today’s world, especially in developing countries like India (Chattopadhyay et al., 2009; Haque & Talukder, 2021)

As per the UN (World Urbanization Prospectus 2018), India ranks 196 among the world’s countries in terms of percentage of urban population. Thus, India can be considered one of the least urbanised countries in the world, with an urban population of only 31.16%. In 2011, the urban population grew to 377 million, which is quite large in absolute number. The United Nations-Habitat’s World Cities Report 2022 indicated that India’s urban population will reach 675 million in 2035, the second highest behind China’s one billion. Keeping pace with the country, the state of West Bengal has also experienced a gradual increase in urbanisation since 1951. In 1951, the percentage of urbanisation in West Bengal was only 23.90, which increased to 31.89 percent in 2011.

In the Himalayan foothill region (Jalpaiguri et al.) of the northern portion of West Bengal, the total population increased by four times, while the total urban population increased by ten times, and the number of urban centres increased by seven times from 1951 to 2011 which is higher than the national level. The urbanisation in the Himalayan foothill region is mainly concentrated in the district headquarters. Alipurduar town is one of the oldest towns in northern West Bengal. It came up along the domestic and international borders (Bhutan and Bangladesh) and the mainland route (rail and road) towards Assam. It belongs to the Class II town category as per the India census. The town's significance has increased after it was designated as a district headquarters on 25th June 2014. Many people from adjacent villages came to Alipurduar town for jobs, medical facilities, and other purposes (Haque & Talukder, 2021).

Joardar (2000) highlighted the challenges arising from India's substantial population burden, indicating that efficient management of solid waste remains a significant hurdle. (2024) also stressed that the amount of rubbish produced in the Class II towns in West Bengal, like Rampurhat municipality, rises dramatically each year along with its population. This issue is further exacerbated in India's tier three or four cities, where municipal financial constraints hinder providing effective waste management services to residents (Roy, 2023). Kumar and Pandit (2013) delved into the reasons behind India's inadequate solid waste management performance. They identified factors such as insufficient financial resources, ineffective institutional structures, inappropriate technological approaches, weak legislative frameworks, and a lack of public awareness as culprits contributing to waste management services' unsatisfactory and inefficient state. Mohanty et al. (2014) reported that the city's primary and secondary waste collection points, as well as its dumping sites, operate in an unscientific manner, exacerbating the challenges associated with waste management.

Solid waste generation has always been related to the socioeconomic status of households. These include monthly income, family size, occupation types, age and education level (Kala et al., 2020). On the other hand, the people in Indian towns like Allahabad, Bilaspur, Raiganj, Bolpur, and Dum Dum are dissatisfied with the municipality's waste management services (Akaateba & Yakubu, 2013; Fetene, 2018; Roy, 2023; Sharholy et al., 2007). Various studies reveal that most households were willing to pay for the safe disposal of the generated solid waste for the betterment of their life (Balasubramanian, 2019; Dhanalakshmi, 2015; Roy & Deb, 2013). It is noted that the income of households, education, size of the household, waste generation quantity and environmental consciousness are the major factors affecting their willingness to pay (WTP) (Hazra et al., 2015; Kala et al., 2020)

The waste management landscape in West Bengal, India, closely resembles other regions in the country. Bhattacharyya (2019) found that the ordinary people of Panihati municipality, North 24 Pargana, of West Bengal, are unaware of how to handle solid waste properly. In the cities of Siliguri and Raiganj, for instance, waste management efforts are hindered by a shortage of both financial resources and technological advancements (Chowdhury, 2018; Haque & Talukder, 2021; Roy, 2023). Haque and Talukder (2021) found a similar tale of mismanagement unfolding in Cooch Bihar, where inadequate solid waste management practices led to evident environmental degradation. They opined that the population of Cooch Behar bears the brunt of this mismanagement, grappling with adverse consequences due to a lack of essential technologies and resources required for effective waste management within the city. Haque and Talukder (2021) sought for the pressing need for improved waste management practices in Cooch Behar to alleviate the hardships endured by its residents and mitigate environmental degradation.

India's per capita solid waste generation (national average) for the last six years has been decreasing (CPCB, 2020-21). As per (2020-21), the national per capita solid waste generation rate is 119.07 gm/day. As per the estimation of the Alipurduar Municipality, the town generates around 22 tons of solid waste per day (WBPCB, 2020) at a rate of 269.19 gm per capita per day. This indicates that the amount of solid waste generated by each individual in the Alipurduar municipality is almost 150.12 gm/day, higher than the national average, i.e. 119.07 gm/day. As a local urban body, the municipality is primarily accountable for solid waste management in Alipurduar. The population load in the town increased, leading to an increase in solid waste generation.

The absence of proper waste management impacts the environment, poses public health risks, and diminishes the overall quality of life in these cities. Urgent attention is required to address these challenges to ensure sustainable and efficient waste management practices for improving life satisfaction and quality of life of vulnerable people from a policy-making perspective. The predominant focus of existing research in the field of municipal solid waste management and planning primarily revolves around three key areas: the characterisation and quantification of solid waste, the identification of appropriate disposal sites, and the optimisation of garbage collection routes, the majority of which have been conducted in metro areas or municipal corporations. In contrast, cities categorised as Class II in India, with populations ranging from 50,000 to 99,999, have received much less attention (Mondal & Mandal, 2024). Therefore, it is essential to know whether the existing infrastructure facilities of small towns like Alipurduar are adequate to serve the residents. Since the residents are the major generators and vulnerable to solid waste, it is also essential to investigate their level of satisfaction with the existing solid waste management system provided by the local urban bodies like municipalities and whether there is a difference in satisfaction about their level of income.

Most of the prior studies, like Chattopadhyay et al. (2009) and Chowdhury & Chowdhury (2020), focused on assessing the status of solid waste management in urban areas. Different studies like Chowdhury, 2018; and Mohanty et al., 2014 used more or less similar criteria to determine the municipality's solid waste management infrastructure. However, the current study aims to expand on these findings by considering the satisfaction level of the municipality's residents regarding the available waste collection services they receive. The present study aims to explore two research inquiries: firstly, it investigates the status of solid waste management within Alipurduar Municipality, and secondly, it assesses the satisfaction level of the municipality's residents with respect to solid waste collection service provided by the Alipurduar Municipality.

Settings of the Study Area

Alipurduar Municipality came into existence under the provision of the Bengal Municipal Act, 1932, on 7 February 1957. Earlier, Alipurduar town was a sub-divisional headquarters in the undivided Jalpaiguri district. On 25th June 2014, the Govt. of West Bengal declared Alipurduar as the 20th district of West Bengal and Alipurduar town was designated as the headquarters of Alipurduar district. Alipurduar Municipality is on the east bank of the river Kaljani, which flows from the northwest to the southeast. The Nonai River bound the eastern side of this town. Geographically, this municipality lies between 26°28'15" N to 26°30'30"N and 89° 31'06" E to 89° 33'14" E (Fig. 1).

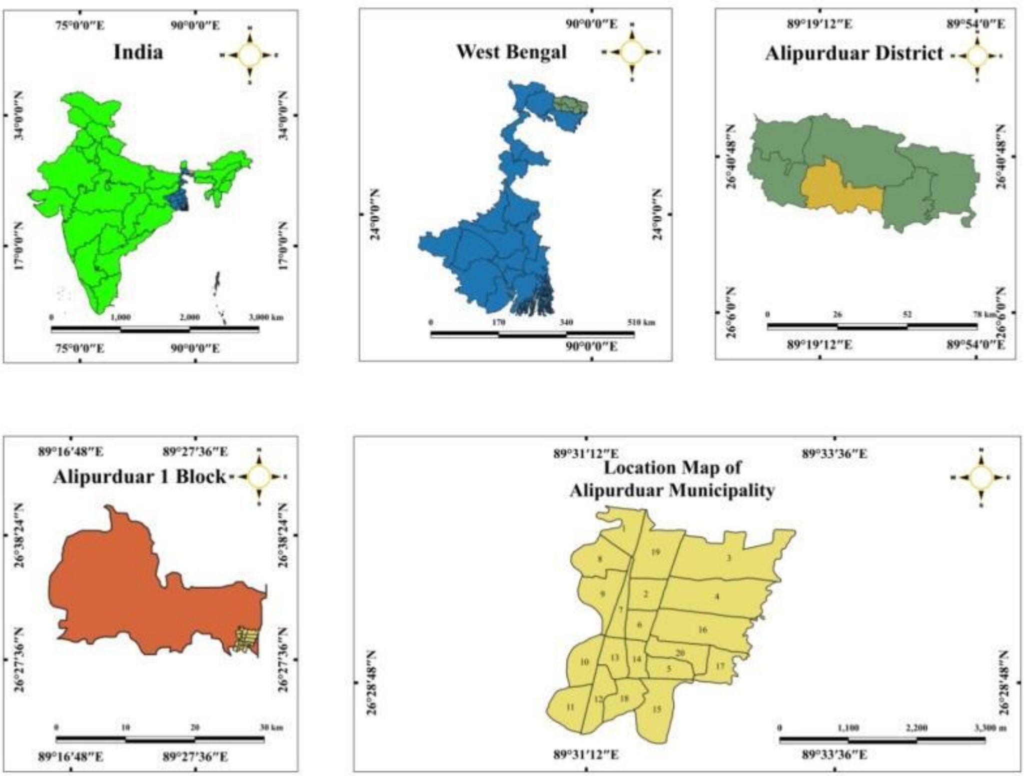

Fig. 1: Location Map of the Alipurduar Municipality

Currently, the municipality is divided into 20 wards covering an area of 8.98 sq. km. with 65232 populations, of which 33137 are male and 32095 are female. The sex ratio is 969 females per thousand males against the state average of 950 females per thousand males. The literacy rate of Alipurduar municipality is 91.03 percent which is higher than the state average of 76.26 percent. The male literacy rate is around 93.34 percent while the female literacy rate is 88.65 percent (Census, 2011). As per the census of India 2011, the population density of Alipurduar municipality is 6071 people per sq. km. The population of Alipurduar Municipality have been increasing since 1951. In 1951, the total population of Alipurduar town was 24886, which increased to 65262 in 2011.

Database

Both secondary and primary data sources were used for the study. The secondary data were collected from the office of the District Magistrate, Alipurduar, Census of India, Alipurduar municipality office and the Ministry of Urban Development of India. On the other hand, a household survey was conducted in March 2023 in Alipurduar municipality with a structured questionnaire from 384 randomly sampled households to collect the primary data. Heads of the households were interviewed face to face as they are the primary decision-makers of the family and have extensive information on various aspects of their households, including demographics, financial standing, and living arrangements. This position is critical in enabling accurate and consistent data-gathering procedures. In the absence of the head of the household, successive senior members available in the household were interviewed.

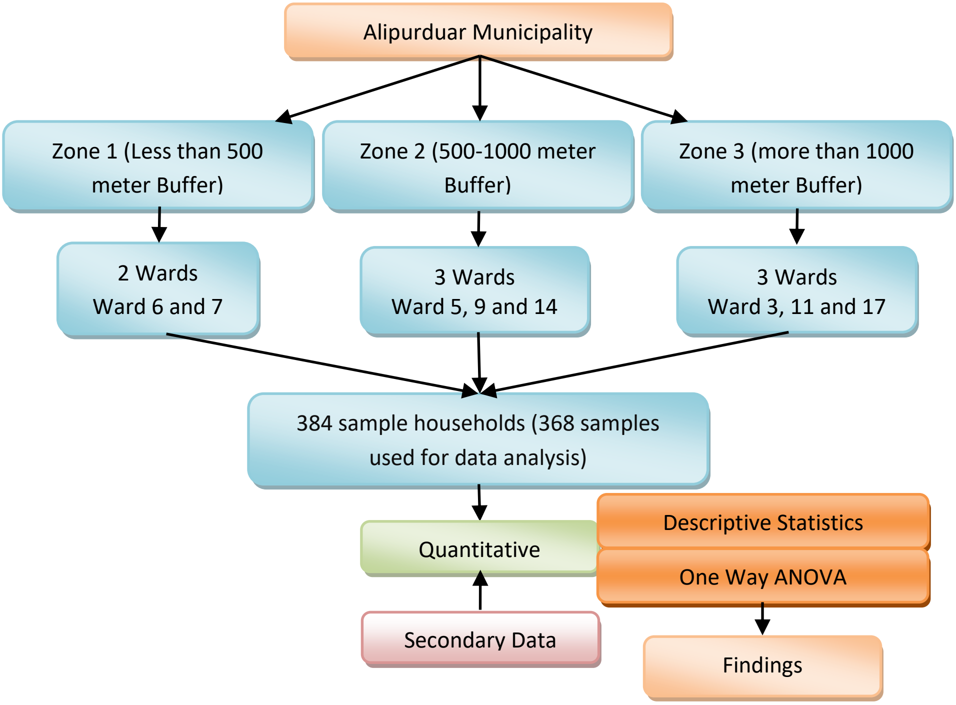

Fig. 2: Flow Diagram of the Study

Sample Design

Alipurduar municipality is formed of 20 municipality wards. As per the pilot study only 7 (30 percent) wards have municipality solid waste management systems in the form of door-to-door solid waste collection. Altogether, eight wards (40 percent) of the Alipurduar were selected for the study, out of which two wards belong to the category having door-to-door municipal solid waste collection system (Fig. 3). To identify the sample wards, a centroid was drawn on the municipality ward map of Alipurduar in QGIS environment as a geographical centre of the town. From the centroid of the Alipurduar Municipality, 500-metre and 1000-metre buffers were created. Sample wards were selected purposively based on the following conditions. Firstly, the number of wards will be proportionate to the percentage of wards having and without having door-to-door solid waste collection services. Secondly, the maximum covered wards within each buffer zone will be selected, maintaining the maximum possible cardinal direction. Within the 500-metre buffer, two wards, namely wards 6 and 7, were selected as most of the wards are covered by the zone. Within the 1000 metre buffer, most of the wards 20, 5, 14, 13 and 9 were covered. Fifty percent of wards within this zone (Ward 5, 14 and 9) following the cardinal direction were selected. On the other hand, 11 wards, namely 1, 3, 8, 19, 4, 17, 18, 15, 12, 11 and 10, have most of the area beyond the 1000-metre buffer zone. The remaining three wards (Ward 3, 17 and 11) from each cardinal direction of this zone were selected for the study (Fig. 2 and Fig. 3).

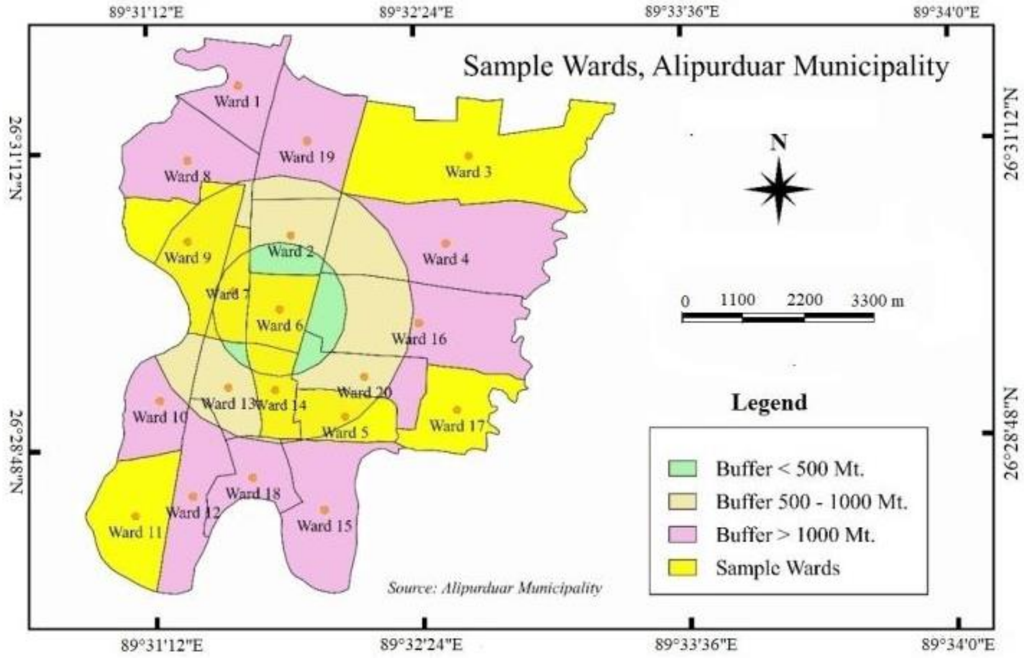

Fig. 3: Distribution of Sample Wards of Alipurduar Municipality

A sample size of 384 households was determined using the Cochran formula (1977) with a confidence level of 95 percent and 5 percent plus or minus precision. The sample households were distributed equally among all people wards and executed randomly.

$$\text{Sample size calculation} \quad n_o = \frac{Z^2(pq)}{e^2}$$

Where,
n= Sample Size
Z= Standard Error associated with the chosen level of confidence
P= Variability/Standard Deviation
q= 1-p
e= Acceptable sample error

Statistical Analysis

A modified version of the structured questionnaire was adopted from Akaateba and Yakubu (2013) to measure the respondent's satisfaction level with the waste collection services provided by the municipality. A set of 12 questions related to the aspects of the solid waste management services provided by local urban bodies has been prepared based on the literature review and insights acquired from the field visits (Table 1). Respondents were asked to assess the extent to which they were satisfied with the services given by the municipality of Alipurduar. The responses for each statement in the questionnaire were scored on a five-point Likert scale ranging from 'very satisfied' to 'very dissatisfied'. The values were entered as 5 = very satisfied to 1= very dissatisfied. In addition, the questionnaire included a part that collected data on socio-demographic and economic data, as well as garbage collection and disposal techniques. Age, gender, educational level, marital status, income level, garbage collection bin condition, and waste collection frequency were included as explanatory variables based on a literature review.

Initially, the questionnaire was pre-tested to determine its reliability using Cronbach's alpha in IBM SPSS Statistics 22. The internal consistency of the questionnaire was demonstrated by Chronbach's alpha value of reliability 0.753 (>0.7 is considered satisfactory). Due to the lack of a complete dataset, 16 questionnaires have been removed, and 368 samples have been used for the data analysis. Descriptive statistical techniques have been applied to analyse the data. The higher mean indicates a higher degree of satisfaction, and the variables are ranked accordingly. A mean score of less than 3 indicates a higher degree of dissatisfaction, a mean of 3 to 3.50 shows a moderate level of satisfaction, and a mean of more than 3.50 indicates a high level of satisfaction (Akaateba & Yakubu, 2013). Lower values in the rank indicate a higher level of satisfaction. As a significant controlling factor, the average monthly income of any household may be considered a proxy measure of socio-economic status and standard of living, resulting in variations in the generation and disposal of solid waste. Higher-income households have a more significant contribution to solid waste production. Furthermore, these higher-income households can manage their solid waste privately by being willing to pay for solid waste management. Consequently, the level of satisfaction with different aspects of municipal solid waste management will be different among various income groups. A one-way ANOVA was employed in this study to evaluate any differences in mean household satisfaction and income level. The P value of 0.05 is considered statistically significant.

Results

Socio-Economic and Demographic Characteristics of Respondents

There are 55.40 percent males and 44.30 percent females among the 368 total respondents. Most respondents (36.10 percent) are between the ages of 30 and 45. On the other hand, 32.10 percent of respondents are between the ages of 45 and 60. 15.5 percent of respondents are between the ages of 15 and 30, while 16 percent are between the ages of 60 and above. The survey reveals that the majority of respondents in this survey are graduates (28.8 percent). Respondents with secondary and higher secondary levels of education account for 16.6 percent in each category. 13.3 percent of respondents completed their education to the upper primary level and 11.4 percent completed their education to the elementary level. Only 9.2 percent of respondents in the studied population have a postgraduate degree, while 3.8 percent of respondents are illiterate.

Table 1: Questions for Satisfaction Survey*

Question No	Statement: To what extent are you satisfied with the following Statement	Reference
1	Are you satisfied with the Alipurduar Municipal Council's waste collection vehicles?	(Shriwas et al., 2018)
2	Are you satisfied with the behaviour of the waste collection crew towards your residence?	(Shriwas et al., 2018)
3	Are you satisfied with the waste collection containers supplied by the Alipurduar Municipal Council?	(Fetene, 2018)
4	Are you satisfied with the availability of dustbins provided by the Alipurduar Municipality Council's Waste Collection?	(Fetene, 2018)
5	Are you satisfied with the Alipurduar Municipal Council's dumping collected solid waste procedure?	(Shriwas et al., 2018)
6	Are you satisfied with the door-to-door solid waste collection status in your neighbourhood?	(Chowdhury & Chowdhury, 2020)
7	Are you happy with your neighbourhood's garbage disposal system?	(Shriwas et al., 2018)
8	To what extent are you satisfied with the quality of the environment in Alipurduar compared to the environment five years ago?	(Rajkumar, 2015)
9	Are you pleased with the public garbage dumpsters' condition near your residence?	(Akaateba & Yakubu, 2013)
10	Are you satisfied with the frequency of public waste bin cleaning in your locality?	(Fetene, 2018; Sharholy et al., 2007; Shriwas et al., 2018)
11	How satisfied are you with the solid waste burning in your area?	(Nikhanj & Mishra, 2014)
12	Are you satisfied with the decision to pay for solid waste disposal?	(Afroz et al., 2009)

**Each question was coded as 5 = Very Satisfied; 4 = Satisfied; 3 = Neutral; 2 = Dissatisfied; 1= Very Dissatisfied*

Table 2 highlights that a large number of respondents in the study area collect their waste materials in the 'old bucket' (49.2 percent) whereas 27.2 percent use cardboard containers. Only 8.7 percent of respondents utilise municipally provided garbage collection containers to gather waste, and 6.8 percent use tins or cans. Furthermore, 8.2 percent of respondents did not have a waste container and hence dropped it in the open field.

Table 2: Description of Study Participants about the Garbage Collecting Bins and Disposal of Solid Waste
(N= 368)

Variables	Categories	Frequency	Percent
Type of container used to collect waste materials	Cardboard Container	100	27.2
	Old Bucket	181	49.20
	Tin/Can	25	6.8
	Municipality Bins	32	8.7
	Open Detach in the household premises	30	8.2
Place to put away collected wastes	In the Public Bin	42	11.40
	By the Road or street side	185	50.30
	On an Open Space	94	25.5
	Municipality Vans	42	11.4
	By the River	5	1.4

Source: Field Survey, 2023

To answer the question" Where do you usually put your collected waste?" half of the respondents (50.30 percent) admitted that they dump their collected waste materials on the road and street sides. Only 11.4 percent of respondents said they take their trash to municipal vehicles. 25.5 percent of the population disposed of their garbage in open space. 11.4 percent of respondents dispose of their domestic garbage in public containers, while 1.4 percent disposes of their generated waste in river water. Altogether 77.2 percent respondents disposed off their garbage in an unscientific way (Table 2).

Solid Waste Management Infrastructure in the Alipurduar Municipality

In Alipurduar municipality, only seven wards (out of 20) have door-to-door waste collection facilities (Table 3), and the residents of the remaining wards are disposed of openly by roads or river water. Only 58 primary and one secondary waste collection point are in operation to serve the municipality. Moreover, there is no permanent landfill site in the study area for the proper disposition of solid waste. Out of 20 municipal wards, only seven households were provided solid waste collection bins. The municipality has only 33 trolleys and 12 battery-powered trippers, insufficient to cover all 20 wards (Table 3).

Satisfaction Level of the Residence of the Alipurduar Municipality

Considering the current state of solid waste management in the developing world, it is essential to investigate the quality of solid waste management in the municipality (Akaateba & Yakubu, 2013). Table 4 depicts the quality of waste collection services provided by the Alipurduar municipality by examining the level of satisfaction of the households with the service provided by municipalities.

Table 3: Present Solid Waste Management Infrastructure in the Alipurduar Municipality

Criteria	Availability
Door-to-Door Waste Collection	7 Wards
Waste Collection	7 wards with 33 trolleys, 12 battery-operated trippers, and available PPEs is 50
Waste Transport Point	58 primary waste transfer points and 1 secondary waste transfer point.
Waste Transport Vehicles	Tricycle Van: 33, Trucks: 02, Mini Truck: 01, Tractor: 06, Mini Dumper: 02, Dumper Placer: 01, Battery Operated Tripper: 14
Landfill Site	Not Available
Segregation and Recycle/ Reuse	MRF facility exists and is working where segregation of all types of dry waste is done. The segregated dry wastes are regularly handed over to a vendor against the highest market price. Set-up for energy
Source Alipurduar Municipality, 2023	

The study shows that the majority of the respondents are 'very dissatisfied' in case of their satisfaction level with the waste collection vehicles (35.3 percent), the behaviour of the waste collection crews (31 percent), waste collection containers (37.8 percent), dustbins provided (39.7 percent), the procedure for dumping (37.5 percent), quality of the public dumpers (33.4 percent), frequency of the waste bins cleaning (28.8 percent) and burning of solid waste in the localities (32.3 percent). It was found that the highest percentage of respondents (39.4 percent) is dissatisfied with the status of the municipality's door-to-door solid waste collection procedure. The highest percentage of respondents (40.5 percent) is basically 'neither satisfied nor dissatisfied' to the extent of the quality of the environment in Alipurduar as compared to the environment five years ago. Altogether, 48.7 percent of households are satisfied with their neighbourhoods' garbage disposal system. Besides, it is interesting to note that 48.1 percent of households are 'satisfied' with the decision to pay nominal charges for solid waste disposal.

Respondent's Satisfaction by Income Level

Table 5 depicts the effect of householder's income level on satisfaction with various waste management services of Alipurduar municipality. The analysis (p-value less than

0.05 considered as significant) indicates that there was a statistically significant difference in mean household income and satisfaction with service component regarding waste collection vehicles (F= 3.11, P= 0.015), behaviour of the trash collection crew (F= 3.86, P=0.004), waste collection container supplied by the municipality (F= 3.84, P= 0.005) dustbins provided by the municipality (F= 5.52, P= 0.000) waste dumping process (F=5.019, P= 0.001), neighbourhood garbage disposal system (F=2.15, p=0.074), quality of public bins (F=6.685, P=0.000), frequency of public waste bin cleaning (F=3.24, P=0.012) and satisfied with the decision to pay for the disposal of solid waste (F=3.001, P=0.019). On the other hand, in case of satisfaction with door-to-door waste collection (F= 1.055, P= 0.379), quality of the environment in Alipurduar as compared to the environment five years ago (F=3.27, p=0.12), and solid waste burning issue in the area (F=1.61, p=0.154) we do not have sufficient evidence to conclude that there is a statistically significant difference between the means of the income and household satisfaction.

Discussion

In Alipurduar town, solid waste management is primarily the responsibility of the municipality as it is the local urban body. Most municipal wards have yet to install door-to-door solid waste collection systems. Besides, the study reveals that the infrastructural facilities required for a healthy and efficient solid waste management system in a class II town like Alipurduar are inadequate. The findings of the studies conducted in the context of class II towns of Northern Bengal like Cooch Behar, Jalpaiguri (Chowdhury & Chowdhury, 2020), and Raiganj (Roy, 2023) also highlights similar results. Shriwas et al. (2018) also found the inadequacy in solid waste management infrastructural facilities in class I towns like Bilaspur and Raipur in Chattisgarh. Thus, a Class I town may have a larger population and potentially more resources; it does not automatically mean that its waste management practices are better than those in a Class II town.

Inadequate infrastructural facilities and shortage of manpower in the towns of developing countries like India caused a heavy workload on the municipality's trash collectors, impacting their behavioural instability. This is probably why the respondents expressed extreme dissatisfaction with the driver's (trash collector's) behaviours. Infrequent and irregular door-to-door solid waste collection schedules may be another reason for dissatisfaction. Due to insufficient dustbins, the residents collect their waste materials in old buckets without segregation. The absence of door-to-door solid waste collection services in most wards compelled the residents to put away their waste materials along the roads or street sides, in open spaces and on the river. Notably, the results of this study indicate a prevailing sense of discontent among the municipality's inhabitants, with many expressing significant dissatisfaction with the services provided by the Alipurduar municipality as a local authority. Interestingly, many residents are happy and neutral with the neighbourhood's garbage disposal system. It is also reflected in their neutrality and satisfaction with the environmental changes in Alipurduar town.

Table 4: Measures of Satisfaction Level of the Respondents in Alipurduar Municipality

Statement: To what extent are you satisfied with the following Statement	Very Satisfied n (%)	Satisfied n (%)	Neither satisfied nor dissatisfied n (%)	Dissatisfied n (%)	Very dissatisfied n (%)
Are you satisfied with the Alipurduar Municipal Council's waste collection vehicles?	45 (12.2)	71 (19.3)	53 (14.4)	69 (18.8)	130 (35.3)
Are you satisfied with the behaviour of the waste collection crew towards your residence?	32 (8.7)	67 (18.2)	108 (29.3)	47 (12.8)	114 (31.0)
Are you satisfied with the waste collection containers supplied by the Alipurduar Municipal Council?	23 (6.3)	41 (11.1)	94 (25.5)	70 (19.0)	139 (37.8)
Are you satisfied with the availability of dustbins provided by the Alipurduar Municipality Council's Waste Collection	23 (6.3)	67 (18.2)	48 (13.0)	84 (22.8)	146 (39.7)
Are you satisfied with the Alipurduar Municipal Council's procedure for dumping collected solid waste?	31 (8.4)	63 (17.1)	72 (19.6)	63 (17.1)	138 (37.5)
Are you satisfied with the status of door-to-door solid waste collection in your neighbourhood?	19 (5.2)	68 (18.5)	56 (15.2)	145 (39.4)	80 (21.7)
Are you happy with your neighbourhood's garbage disposal system?	68 (18.5)	111 (30.2)	122 (33.2)	30 (8.2)	37 (10.1)
To what extent are you satisfied with the quality of the environment in Alipurduar as compared to the environment five years ago?	25 (6.8)	84 (22.8)	149 (40.5)	58 (15.8)	52 (14.1)
Are you pleased with the condition of the public garbage dumpers near your place of residence?	10 (2.7)	65 (17.7)	49 (13.3)	121 (32.9)	123 (33.4)
Are you satisfied with the frequency of public waste bin cleaning in your locality?	43 (11.7)	60 (16.3)	76 (20.7)	83 (22.6)	106 (28.8)
How satisfied are you with the solid waste burning in your area?	43 (11.7)	63 (17.1)	58 (15.8)	85 (23.1)	119 (32.3)
Are you satisfied with the decision to pay for solid waste disposal?	58 (15.8)	119 (32.3)	90 (24.5)	82 (22.3)	19 (5.2)

Source: Field Survey, 2023

Table 5 Results of One-Way ANOVA Analysis between Income Level and Household Satisfaction

Statement	Average Monthly Income level in Thousand Indian Rupees					F
	>5	**5 -10**	**10 -15**	**15 -20**	**<20**	
Are you satisfied with the Alipurduar Municipal Council's waste collection vehicles?	3.04	2.91	2.58	2.40	2.41	3.11*
Are you satisfied with the behaviour of the waste collection crew towards your residence?	2.99	2.64	2.74	2.58	2.27	3.86**
Are you satisfied with the waste collection containers supplied by the Alipurduar Municipal Council?	3.01	2.69	2.45	2.73	2.17	3.84**
Are you satisfied with the availability of dustbins provided by the Alipurduar Municipality Council's Waste Collection	3.00	2.75	2.75	2.31	1.96	5.52**
Are you satisfied with the Alipurduar Municipal Council's procedure for dumping collected solid waste?	2.96	2.92	2.71	2.33	1.63	5.01**
Are you satisfied with the status of door-to-door solid waste collection in your neighbourhood?	3.00	2.93	2.75	2.57	2.66	1.05
Are you happy with your neighbourhood's garbage disposal system?	3.02	2.78	2.77	2.58	2.16	2.15**
To what extent are you satisfied with the quality of the environment in Alipurduar as compared to the environment five years ago?	2.84	2.72	3.08	2.28	2.40	3.27
Are you pleased with the condition of the public garbage dumpsters near your place of residence?	3.07	2.65	2.66	2.87	1.91	6.68**
Are you satisfied with the frequency of public waste bin cleaning in your locality?	2.07	2.79	2.72	2.87	2.83	3.24*
How satisfied are you with the solid waste burning in your area?	2.76	2.64	2.89	2.55	3.29	1.61
Are you satisfied with the decision to pay for solid waste disposal?	2.53	2.33	2.74	2.87	2.98	3.00**

*p-value less than 0.05 consider as significant; *p<0.05; **p<0.01*

Source: Field Survey, 2023

The findings of the present study are contrasting with the findings of the study where Katusiimeh et al. (2012) reported that the respondents are satisfied with the frequency of services provided by the municipality. However, this study found that most respondents are very dissatisfied with the frequency of services, the quality of garbage collection bins and the number of bins provided by the municipality. One of the primary sources of discontent is with the primary waste collection stations, where wastes are piled for several weeks without being removed. The rubbish mounds generate a foul odour, which is hazardous to one's health and the environment (Mohanty et al., 2014). The respondents are extremely dissatisfied with the municipality's garbage disposal techniques, as no suitable disposal site exists. Overall, respondents were mostly dissatisfied with the municipality's expected role with the existing door-to-door solid waste collection system in the town. This reflects on the level of satisfaction of the residents with the solid waste management services provided by the local urban body in Indian towns like Shilchar (Roy, 2023) and Allahabad (Sharholy et al. (2007), Chinese towns like Harbin, and African towns like Ghana (Akaateba & Yakubu, 2013), Jimma city of South East Ethiopia (Fetene, 2018).

Studies conducted in Indian towns like Shilchar (Roy & Deb, 2013), Kolkata (Hazra et al., 2015), Madurai (Balasubramanian, 2019), Alappuzha (Dhanalakshmi, 2015) and African towns like Ghana (Akaateba & Yakubu, 2013) have highlighted the fact that residents in municipalities often contribute financially to ensure smooth waste disposal within the city. Our study highlights noteworthy findings wherein respondents express satisfaction with the decision to pay for door-to-door waste collection services. This also suggests an intense desire among the people in Alipurduar municipality to promptly address their waste disposal concerns, which is influenced by their economic strength.

Jha et al. (2011) found that solid waste management practices vary significantly across different income groups. In this study, we found that the residents of various income groups share a similar level of satisfaction on the issues of door-to-door solid waste collection, environmental change in the town, and burning of solid waste. Perhaps this results from the nature of the issues, as the household’s financial investment does not influence these general problems. Furthermore, these issues consistently impact households across various income groups. On the other hand, specific issues like the quality of waste collection vehicles, behaviour of the trash collection crew, waste collection containers provided by the municipality, dust bins provided, waste dumping process, neighbourhood’s garbage disposal system, quality of public bins, and the frequency of cleaning public waste bins are perceived differently by respondents of various income groups due to their differential economic strength and standard of living. This is also evident in the respondents' decisions to pay for solid waste disposal.

Conclusion

The primary goal of this article is to examine the degree of satisfaction of the residents with the available municipality solid waste management system. In Alipurduar town, the infrastructure or services related to solid waste management have not kept pace with the population growth, creating a potential issue or challenge. Besides, the available services could not reach to the citizens of the municipality adequately due to a lack of technological and muscular strength. The research also indicated that the appropriate door-to-door solid waste collection is inaccessible to the municipality's wards. The lack of required services compelled the residents to put their collected solid waste material away in open spaces, roadsides and rivers. Overall, the findings of this investigation indicate that the respondents are "very dissatisfied" with the available municipal solid waste management systems in the town.

As a local urban body, the Municipality should implement the door-to-door solid waste collection system in all wards. The municipality should establish an appropriate waste disposal ground. Besides, the number of human resources and collector vehicles involved in door-to-door collection should be increased proportionately to the number of wards. Waste collection frequencies and primary waste collection points should be increased, keeping parity with the demand. Every household should provide two waste collection bins to segregate the generated waste materials primarily. Nevertheless, the municipality has to take serious initiatives to spread awareness among the residents about segregation and effectively dispose of the created garbage. The study revealed a strong desire among the people in Alipurduar municipality to promptly address their waste disposal concerns, with satisfaction in the decision to pay money for waste disposal. The taxation for improving the proper solid waste management services may be implemented considering the layers in the income groups. Residents of Alipurduar municipality may be more satisfied if the municipality's waste management system is improved with the improved infrastructural facilities covering all the municipal wards.

Competing Interests and Funding

The authors have no conflicts of interest to disclose. No funding was received for this study.

Availability of Data and Materials

The data that supports the findings of this study is mainly primary data obtained from the household survey using face-to-face interview techniques. The data is related to the satisfaction of the residents of Alipurduar Municipality with municipal solid waste management. The data also includes the socio-economic and demographic status of households. The data were collected from the respondents, assuring them that the privacy of their data would be maintained in strict confidence. The collected data and other information will be used for purely academic purposes. However, the data is available from the authors upon reasonable request and with the permission of the respondents from whom the data was collected.

Author’s contributions

BK collected data, undertook statistical analyses, prepared and edited the manuscript; DS designed the study, and edited the manuscript.

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UNVEILING URBAN DEVELOPMENT DEPRIVATION: A WARD-LEVEL STUDY IN MUNICIPAL CORPORATIONS OF UTTAR PRADESH, INDIA

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Abstract

This paper examines and compares the deprivation of development across the Municipal Corporations of Uttar Pradesh, India. We attempted to consider an area-based approach to explore the socio-spatial differences in quality of life. The principal components analysis is used to develop a composite index for 1063 wards from 13 Municipal Corporations based on 2011 census data. This index is constructed based on 22 selected variables and categorised into three domains, i.e., the House Quality Index, the Basic Amenities Index, and the Physical Assets Index. The study used descriptive statistics and ANOVA analyses to understand Municipal Corporations' development trajectories. The result shows that the variation in development is highest in Saharanpur Municipal Corporation (Mean -0.40; SD = 2.09) and lowest in the wards of Agra Municipal Corporation (Mean = 0.14; SD = 1.03), and the ANOVA analysis reflects that there is a significant difference in the House Quality Index, the Basic Amenities Index, and Physical Assets Index across the Municipal Corporations. The study suggests that providing essential amenities and services to deprived wards can improve living and working conditions, ultimately leading to an enhanced standard of living for inhabitants.

Key Words: Urban development, development deprivation, multivariate analysis, Municipal Corporation, Ward, Uttar Pradesh

Introduction

Urban development deprivation can significantly impact the social and material outcomes of city dwellers. This is because socially valued resources are not evenly distributed across urban areas (Bhan & Jana, 2015). Development deprivation does not affect society as a whole uniformly; instead, it shows a specific concentration within particular segments of the population. The term "deprivation" refers to a state where individuals or groups experience a standard of living that falls below that of the majority within a given society, resulting in hardships and limited access to necessary resources (Herbert, 1975). In the discourse surrounding spatial inequalities and urban deprivations, concepts with some degree of overlap, including quality of life, living quality, and liveability, are frequently used synonymously (Lelo et al., 2019).

Urban deprivation is not easily empirically distinguishable within an urban setting. It can be detected by the census and census type data variable, which can provide information on geographical clusters of intra-urban development deprivation (Kirby, 1981). Scholars explore such data across geographical scales to analyse the distributional patterns of resources and answer the questions of "who gets what, where, and how" (Smith, 1979) as people's life prospects are influenced by their area of residence, which includes their access to clean drinking water, energy, healthcare, excellent education, decent jobs, and other goals included in the 2030 Agenda for Sustainable Development.

According to the insights gained from economic agglomeration effects, researchers have concluded that households in larger cities enjoy higher economic prosperity than those in smaller towns and rural areas (Mills & Mitra, 1997). However, it is essential to note that significant levels of material deprivation continue to exist, and it is evident when the living conditions at the ward level are examined. Numerous studies have consistently indicated that concerning household inequality, urban populations show more significant heterogeneity in terms of income, expenditure patterns, housing, and access to services, both within and across different regions. In their focus on Bangalore city in India, Balakrishnan and Anand (2015) discovered that peripheral wards display enhanced heterogeneity in multiple attributes compared to central regions, marked by a more significant proportion of scheduled caste population and lower levels of assets, housing quality, and female literacy. In his study, Kumar (2015) concluded a substantial annual decline rate in deprivation, prominently for electricity, followed by toilet facilities, drinking water, and drainage arrangements in urban India; however, an observed increase in disparity of access to basic amenities emerges between poor and non-poor households. Haque et al. (2020) observed that housing amenities and assets had diverse geographical dimensions, indicating a considerable variance in developmental factors.

Pacione (2003) argues that identifying the multiple deprivations makes identifying the quality of life in any area possible. Townsend (1993) defines deprivation as different from poverty as it encompasses physical, environmental, and social conditions rather than solely focusing on resources. He manifested two forms of deprivation: material and social. Material deprivation denotes the absence of commodities and amenities intrinsic to the contemporary quality of life. In contrast, social deprivation signifies the precariousness of interpersonal connections extending from the familial realm to broader communal networks.

The objective of this research paper is to investigate the many aspects of material deprivation at the ward level in all Uttar Pradesh Municipal Corporations, with an emphasis on housing quality, access to basic services, and asset ownership. It seeks to reveal and explain existing patterns of deprivation inside and across Uttar Pradesh's Municipal Corporations. This holds considerable importance as an insightful examination of these deprivation areas will lead to a comprehensive understanding, enabling the formulation of inclusive development strategies and targeted plans.

Materials and Methods

Data Sources

For this study, we used data from India's 2011 Census as the source for valuable information on specific key indicators disaggregated at the ward level. We gathered this comprehensive data from the Primary Census Abstract and the Household Amenities and Assets datasets. These datasets, in addition to basic demography, contain an array of key metrics such as the percentage of habitable households, deteriorated households, households without rooms, rented accommodations, water and lighting sources, cooking fuel types, toilet facilities, the prevalence of open defecation, and the lack of waste-water drainage system (Census, 2011). Additionally, the dataset provides ownership statistics for nine assets in each household, specifically computers, computers with internet, cars/Jeeps, bicycles, motorcycles, telephones, mobile phones, televisions, and radios. In this study, we focused on wards within Municipal Corporations as a core unit of analysis. We identified and examined 1065 wards from all Municipal Corporations in Uttar Pradesh.

Study variables

We conducted a comprehensive analysis of 22 variables to assess the extent of development deprivation within and across the wards of Municipal Corporations. We categorised these variables into three domains: House Quality Index, Basic Amenities Index, and Physical Asset Index. The House Quality Index is used to estimate the relative level of housing access, considering specific characteristics. The Basic Amenities Index is created to assess the extent of access to essential household amenities. At the same time, the Physical Asset Index is used to approximate the relative purchasing power of households. All the selected domains are explained in Table 1.

Study area

Indian Constitution, Article 243Q, provides an inclusive classification of urban local bodies, differentiating them into three specific types: Nagar Panchayats, responsible for coordinating the development and governance of areas transitioning from rural to urban; Municipal Councils, liable for the administration of relatively smaller urban areas; and Municipal Corporations which are responsible for the management of larger urban areas (Mohanty et al., 2007). According to the research done by the Praja organisation's Urban Governance Index 2020 report, Uttar Pradesh lags in the execution of tasks given to the Municipal Corporations.

As per the 2011 Census, the state of Uttar Pradesh is the most populous, accounting for 16.5 per cent of India's total population. The 2011 Census data reveals that the urban population in Uttar Pradesh accounted for 22.28 per cent of the total population, representing a significant increase from the 20.7 per cent recorded in 2001. As per the 2011 Census in India, Uttar Pradesh has the most extensive urban system in India, with 904 urban centres. These include 13 Municipal Corporations (Figure 1), 13 Cantonment boards, 193 Municipal Councils, 423 Nagar Panchayats, and 262 Census Towns. However, Its level of urbanisation lags behind that of other states. The Municipal Corporation comprises 38 per cent of the total urban population in Uttar Pradesh. Among the 13 Municipal Corporations in Uttar Pradesh, seven are found in the western region, two in the central region, three in the eastern region, and only one in the Bundelkhand region. Seven Municipal Corporations, namely, Agra, Ghaziabad, Kanpur, Lucknow, Meerut, Prayagraj, and Varanasi, have a population exceeding one million. Additionally, ten Municipal Corporations (Agra, Aligarh, Prayagraj, Bareilly, Jhansi, Kanpur, Lucknow, Moradabad, Saharanpur, and Varanasi) are part of the government's ambitious smart city mission program. The fundamental aim of this mission is to enhance the quality of life in urban areas by implementing sustainable and innovative solutions, known as "Smart" initiatives.

Figure 1 Location Map of Municipal Corporations of Uttar Pradesh, India

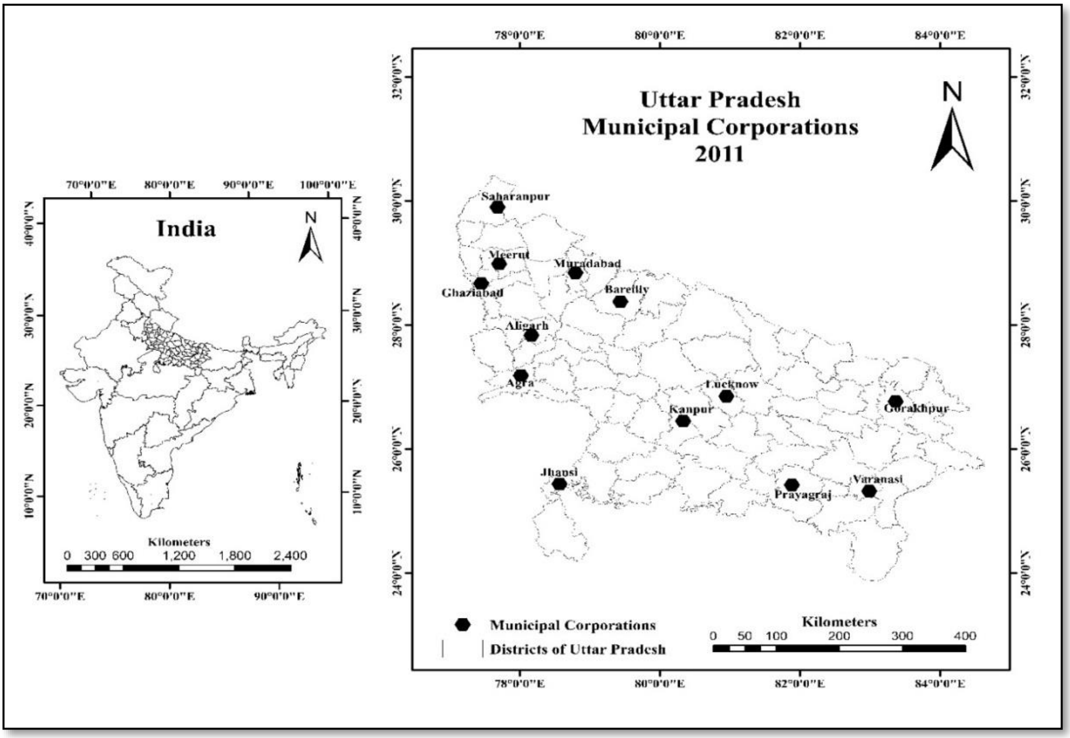

Table 2 presents the demographic profiles of the Municipal Corporations. Among Municipal Corporations, Lucknow stands out for having the largest population, whereas Aligarh demonstrates the highest population density, with around 21.6 thousand persons residing per square kilometre. Conversely, within the Prayagraj Municipal Corporation, there was a notable distortion in the sex ratio, with 852 females per 1000 males, indicating that the city accommodates a comparatively large number of male migrants.

Among the cities under consideration, Ghaziabad, part of the National Capital Region, shows the highest percentage share of inter-census migrants in its total population.

This percentage is twice as high as the second highest observed in Lucknow, indicating that these cities serve as intermediate destinations for migrants.

Table 1 Selection of major domains and indicators

Domains	Variable ID	Name of the Variable	Variables Explanation	#Component Score Coefficient
House Quality Index	GCH	Good Condition of Census House	% of HHs having good condition	0.062
	PH	Permanent House	% of HHs living in a permanent house	0.801
	OH	Own House	% of HHs living in their own house	-0.438
	DR	Dwelling Room	% of HHs have at least two dwelling room	0.642
	RM	Roof Material	% of House having material with burnt bricks or cemented	0.335
	WM	Wall Material	% of House having wall material with burnt brick or cemented block	0.81
	FM	Floor Material	% of House having floor material with cemented	0.982
	GCCHOU	Good Condition of Census House cum other use	% of HHs having a good condition of residence cum other use	0.138
Basic Amenities Index	HK	Having Kitchen	% of HHs have a kitchen	0.407
	DWF	Drinking water facility	% of HHs have drinking facilities within the premises	0.294
	ISW	Improved source of water	% of HHs having improved sources of water	0.293
	EC	Electricity	% of HHs have electricity	0.362
	LF	Latrine	% of HHs having latrines within premises	0.353
	BF	Bathroom	% of HHs have a bathroom facility	0.423
	CDS	Close Drainage System	% of close drainage system	0.274
	CF	Clean source of fuel	% of HHs having LPG/PNG facility	0.39
Physical Assets Index	BS	Banking Service	% of HHs using banking service	0.395
	TV	Television	% of HHs have television	0.372
	TM	Telephone/Mobile	% of HHs have telephone or mobile	0.412
	CL	Computer/Laptop	% of HHs have a computer or laptop	0.419
	MC	Motorcycle	% of HHs have a motorcycle	0.422
	CJV	Car/Jeep/Van	% of HHs have a car/jeep/van	0.427

Source: Computed from Census of India 2011 data

#The component score coefficient has been derived from principal component analysis (PCA).

Agra Municipal Corporation has the highest percentage share of the scheduled caste population. In contrast, Varanasi Municipal Corporation, traditionally regarded as a site for inclusion and exclusion (Choudhary et al., 2020), possesses the lowest percentage share of the scheduled caste population. However, the share of the slum population in Meerut Municipal Corporation was the highest, implying a concentrated manifestation of urban poverty within the city (Bhan & Jana, 2015). The overall literacy rate in Municipal Corporations was higher than the average in Uttar Pradesh, indicating that these cities have a comparatively better-educated workforce than their counterparts.

Table 2 Demographics setting of the Municipal Corporations

Municipal Corporation	Population	Population Growth Rate (2001-20011)	Area (sq. km.)	Population Density (Census, 2011)	Sex Ratio	Literacy Rate	Schedule Caste Population (%)	Percentage of Inter-Census (2001-2011) Migrants to Total Population	Percentage of Slum Population to Total Population
Agra	1585704 (4)*	24.35 (7)*	120.57 (7)*	13151 (5)*	874 (11)*	73.10 (10)*	23.36 (1)*	6.90 (13)*	33.64 (2)*
Aligarh	874408 (10)	30.68 (4)	40.43 (13)	21628 (1)	893 (8)	68.51(12)	15.80 (4)	11.53 (4)	29.60 (3)
Bareilly	904797 (8)	25.61 (6)	106.43 (8)	8501 (9)	894 (7)	68.27(13)	7.87 (12)	7.21 (12)	15.92 (7)
Ghaziabad	1648643 (3)	70.26 (1)	220 (3)	7494 (11)	885 (10)	84.78(1)	13.67 (6)	29.96 (1)	20.25 (5)
Gorakhpur	673446 (12)	8.14 (13)	141.016 (6)	4775 (12)	902 (4)	83.91(3)	9.31 (11)	8.25 (9)	7.31 (13)
Jhansi	505693 (13)	18.65 (9)	150 (4)	3371 (13)	905 (3)	83.02(4)	21.81 (2)	8.09 (10)	19.67 (6)
Kanpur	2768057 (2)	8.30 (12)	266.74 (2)	10377 (7)	857 (12)	82.42(6)	12.33 (8)	8.26 (8)	15.35 (8)
Lucknow	2817105 (1)	28.87 (5)	348.8 (1)	8076 (10)	928 (1)	82.49(5)	10.75 (9)	15.35 (2)	12.95 (10)
Meerut	1305429 (5)	22.14 (8)	141.94 (5)	9197 (8)	897 (6)	75.65(9)	16.21 (3)	13.78 (3)	41.73 (1)
Moradabad	887871 (9)	38.38 (3)	75 (10)	11838 (6)	911 (2)	68.75(11)	10.44 (10)	7.74 (11)	13.48 (9)
Prayagraj	1168385 (7)	14.76 (10)	70.05 (11)	16679 (2)	852 (13)	84.66(2)	12.73 (7)	9.19 (6)	7.84 (12)
Saharanpur	705478 (11)	54.79 (2)	46.74 (12)	15093 (3)	897 (5)	76.32(8)	14.19 (5)	10.40 (5)	9.54 (11)
Varanasi	1198491 (6)	8.56 (11)	82.1 (9)	14597 (4)	886 (9)	79.27(7)	6.85 (13)	8.40 (7)	25.20 (4)

Source: Census of India 2011 *Rank of the Municipal Corporation

Methods

Descriptive statistics are applied to determine the magnitude of heterogeneity across all Municipal Corporations. Key statistical indicators such as the mean, standard deviation, minimum and maximum values, and rank are used to highlight the distinct evidence among Municipal Corporations.

We have constructed the area-based indices using the principal components approach. The data is first converted into a set of z-scores of 22 variables, achieved through the formula: Z= (x - mean) / standard deviation (Krishnan, 2010). The z-scores are free of measurement since they are ratios. The z-scores are also standardised scores since they all have zero means and one standard deviation. The Principal Component Analysis (PCA) technique is employed to diminish a substantial set of variables into a more concise and manageable dimensions. The principal components, which are derived from linear combinations of the standardised variables, are characterised by factor loadings that represent their respective weights.

In the current research, the Kaiser-Meyer-Olkintest (KMO), a measure of sample adequacy, was employed to discover multicollinearity in the data, allowing the suitability of factor analysis to be determined. KMO also compares the correlations and partial correlations of variables (Krishnan, 2010). The data's value is displayed in Table 3, indicating that principal component analysis can proceed. Another examination of the strength of the association between variables was performed using Bartlett's sphericity test.

Bartlett's sphericity test evaluates the null hypothesis that the variables in the population correlation matrix are uncorrelated. The result of our analysis (Table 3) showed a significance level of 0.00, a value that is small enough to reject the hypothesis (Krishnan, 2010). These diagnostics indicate that Principal components analysis is appropriate for data.

Table 3 KMO and Bartlett's test for house quality basic amenities and physical assets indices

KMO and Bartlett's Test for House Quality Index		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.693
Bartlett's Test of Sphericity	Approx. Chi-Square	1203.834
	df	28
	Sig.	0.00
KMO and Bartlett's Test for Basic Amenities Index		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.849
Bartlett's Test of Sphericity	Approx. Chi-Square	6824.415
	df	28
	Sig.	0.00
KMO and Bartlett's Test for Physical Assets Index		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.841
Bartlett's Test of Sphericity	Approx. Chi-Square	7329.069
	df	15
	Sig.	0.00

Kaiser's Latent Root Criteria, often known as the 'eigenvalue larger than one' criterion, was used to extract the number of components. This criterion is ideal for principal component analysis. Furthermore, the most often utilised rotation technique, the Varimax method, was applied. The weights assigned to each principal component are determined by the eigenvectors obtained from the correlation matrix. The value of the component score coefficient is shown in Table 1. In this manner, Principal Component P_1 is determined as

$$P_1 = a_1.Z_1 + a_2.Z_2 + \ldots\ldots\ldots\ldots + a_n.Z_n$$

Where,

P_1 = The first principal component

a_{ji} = Factor loading or weight of the first principal component vector relating to jth indicator and ith ward

Z_i = z-score of the observed variable

The calculation follows separately for three indices, namely the House quality index, the Basic amenities index, and the Physical assets index, and an average of these provides the Development Deprivation Index. The result of the principal component analysis is shown in Table 4. The data for each index is categorised into three equal groups for mapping purposes based on the mean of the indices.

Table 4 PCA analysis for house quality basic amenities and physical assets indices

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
House Quality Index-total variance explained						
1	1.938	24.223	24.223	1.938	24.223	24.223
2	1.524	19.045	43.268	1.524	19.045	43.268
3	1.238	15.48	58.748	1.238	15.48	58.748
4	0.963	12.038	70.786			
5	0.737	9.215	80.001			
6	0.691	8.635	88.636			
7	0.62	7.751	96.387			
8	0.289	3.613	100			
Basic Amenities Index- total variance explained						
1	5	62.496	62.496	5	62.496	62.496
2	0.945	11.807	74.303			
3	0.664	8.306	82.609			
4	0.518	6.471	89.08			
5	0.343	4.291	93.37			
6	0.308	3.849	97.219			
7	0.166	2.078	99.297			
8	0.056	0.703	100			
Physical Assets Index-total variance explained						
1	4.5	74.996	74.996	4.5	74.996	74.996
2	0.923	15.382	90.378			
3	0.231	3.858	94.236			
4	0.157	2.609	96.845			
5	0.143	2.378	99.223			
6	0.047	0.777	100			

In the present study, One-way analysis of variance (ANOVA) is applied to compare the selected indices across different wards within the Municipal Corporations of Uttar Pradesh. By analysing the variability within and between the wards, this statistical method helps to determine if there are significant variations in the indices under consideration. It allows for determining whether the observed differences are statistically significant or merely due to random variation. All the statistical analyses conducted in this study are carried out using SPSS software version 22. Additionally, for spatial mapping, ArcMap GIS software version 10.8 is used.

Result and Discussions

Deprivation in House Quality Index

Within the realm of improving the overall welfare of individuals, housing assumes a critical function as it fulfils the basic need for shelter, supports skill acquisition, facilitates social integration, and enables diverse engagement in educational and leisure activities (Perera & Mensah, 2019). Apart from this, housing conditions greatly impact a wide range of outcomes. As housing expenses comprise a substantial segment of household budgets, individuals, particularly those with constrained incomes, encounter limitations on essential expenditures, such as healthcare, education, and nutrition (OECD, 2011). In this context, urban centres become particularly crucial, where the escalation of housing costs presents a substantial obstacle for low-income households. Moreover, Municipal Corporations function as gravitational canters, drawing a large population in pursuit of enhanced living standards.

According to the 2011 census, 62.3 per cent of households within the Municipal Corporation wards of Uttar Pradesh are categorised as residing in good-condition census houses. However, there are persisting disparities across the wards, with the lowest percentage of 13.2 per cent of individuals residing in good-condition census houses in a ward of Moradabad Municipal Corporation. The census classified households according to the type of structure of the census house, namely permanent, semi-permanent, and temporary, considering the primary materials used for roofs and walls (Das & Mistri, 2013; Mondal, 2020). The data reveals that the majority of households, 89.2 per cent, live in permanent houses, while the lowest proportion, 54.9 per cent, is recorded in a ward of Kanpur Municipal Corporation, where the rental accommodation is comparatively high. The ownership status indicates that, on average, 79.6 percent of households in the Municipal Corporation own their own houses.

Interestingly, within the Municipal Corporation of Uttar Pradesh, 30.6 percent of households have at least two dwelling rooms, indicative of relatively better living conditions. Conversely, in a ward of the Saharanpur Municipal Corporation, the percentage of households with at least two dwelling rooms is the lowest, referring to comparatively poor living conditions. The number of dwelling rooms is inversely proportional to the congestion level, i.e., an increase in dwelling rooms is associated with decreased congestion (Kundu, 2006). As per the Census of India (2011), a census house is categorised as a 'pucca' if its roof and the wall material predominantly consist of stones, machine-made tiles, cement tiles, burnt bricks, cement bricks, stones, slate, G.I./metal/asbestos sheets, or concrete. For this study, our analysis focused exclusively on census houses with burnt bricks and cemented materials, as other types categorised as 'Pucca' exhibit a relatively minor representation within the Municipal Corporation of Uttar Pradesh. On average, approximately 69.7 percent of houses exhibit a predominant roof material composed of burnt bricks or cemented materials. In contrast, about 85.3 percent of houses possess walls made from burnt or cemented blocks.

Furthermore, cement is the most common floor material in around 62.8 percent of dwellings. Many homes in metropolitan areas serve as residence-cum-other use businesses, such as stores, factories, hotels, and other commercial operations as well as residences (Kundu, 2012). Around 3.5% of dwellings in Uttar Pradesh Municipal Corporations have this multipurpose feature with decent conditions.

Surprisingly, 30.6 per cent of households in the Municipal Corporation of Uttar Pradesh have at least two dwelling rooms, indicating relatively better living conditions. In contrast, the percentage of households with at least two dwelling rooms is the lowest in a Saharanpur Municipal Corporation ward, indicating comparatively poor living conditions. The number of dwelling rooms is inversely proportional to the level of congestion, implying that an increase in dwelling rooms is associated with less congestion.

Figure 2 shows that the Housing Quality Index rank is high in the Municipal Corporations of Moradabad, Bareilly, and Lucknow, whereas the Municipal Corporations of Jhansi, Varanasi, Saharanpur, and Gorakhpur demonstrate the lowest rank of housing quality. However, there is persistent heterogeneity across the wards of Municipal Corporations. The highest variation is seen in the Kanpur Municipal Corporations, while the lowest is in the Lucknow Municipal Corporations. The results of our investigation demonstrate discernible variations in house quality encompassing diverse levels of intra and inter-city disparities.

Deprivation in Basic Amenities Index

Providing basic amenities, including drinking water, sanitation, electricity, and drainage, is pivotal in promoting well-being and establishing a reasonable quality of life for individuals. Nonetheless, accessing these facilities empowers households by freeing up the time that would otherwise be spent on procuring these indispensable resources (Kumar, 2015). In India, the accelerated pace of population growth and inadequate investment in urban development have led to a critical dearth of essential amenities within towns and cities (Kundu et al., 1999). However, considerable progress has been achieved in enhancing housing conditions and ensuring access to drinking water, sanitation, electricity, and similar resources in urban areas. The promotion of privatisation, partnership arrangements, and community-based initiatives as alternative solutions has not effectively addressed the shortfall caused by the state’s reduced involvement under the new system of governance (Kumar, 2015).

Moreover, within Municipal Corporations, inequalities remain intact, which may exacerbate deprivation in some wards of the city, as the descriptive statistics provide evidence of notable variations in household amenities within Municipal Corporations. The analysis reveals that, on average, approximately 84.4 per cent of households enjoy access to drinking water facilities within their premises. This percentage highlights significant disparities, varying from 100 per cent to 16.7 per cent across different wards. Concerning improved water sources, an average of 58.9 per cent of households benefited, yet a 42.61 per cent coefficient of variation indicates diverse levels of access across wards.

Additionally, while electricity availability is nearly universal in some wards, there exists an 8.62 per cent coefficient of variation within Municipal Corporations. Considering sanitation, a critical determinant of community health and hygiene, two vital parameters are assessed: the availability of toilets within household premises and the connection of household wastewater outlets to closed drainage systems (Mondal, 2020). An average of 91.4 per cent of households possess latrines; however, concerns arise regarding the condition of closed drainage systems, with the highest coefficient of variation (64.01 percent) recorded within Uttar Pradesh's Municipal Corporations. On average, 75.3 per cent of households use clean energy fuel in Municipal Corporations, and this proportion may have experienced enhancement following the implementation of the Pradhan Mantri Ujjwala Yojana. The National Family Health Survey (NFHS) 2019-20 reported that 88.6 per cent of urban households employ LPG or piped natural gas (PNG) as their primary cooking fuel. Furthermore, the presence of bathroom facilities within households indicates a safe, secure, and hygienic environment, and the data reveals that an average of 81.6 percent of households in Municipal Corporations possess this facility.

Figure 2: Spatial distribution of house quality, basic amenities, physical assets and development deprivation indices in Municipal Corporations of Uttar Pradesh

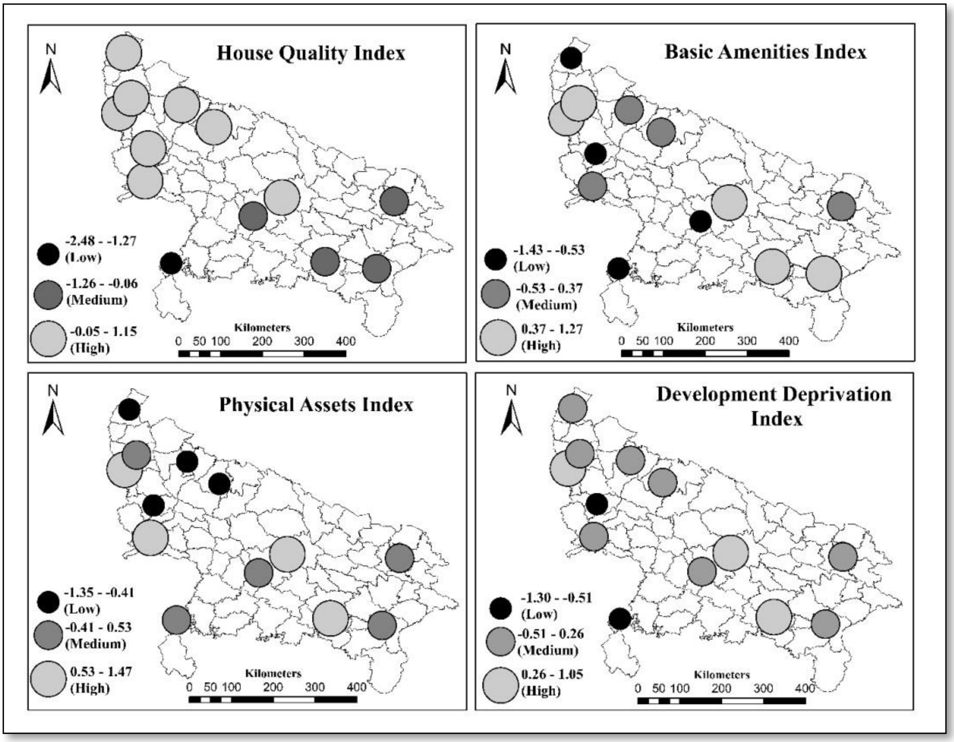

Table 5 elucidates the hierarchy of the availability of basic amenities, ranking Prayagraj, Ghaziabad, Varanasi, and Lucknow Municipal corporations as the top performers. At the same time, Aligarh and Jhansi reveal a significantly deprived status across all amenities. Notably, Jhansi's wards show the highest range in the Basic Amenities Index. The comparison of variation in the Basic Amenities Index across Municipal Corporation wards reveals that the Municipal Corporations of Prayagraj, Agra, Ghaziabad, Varanasi, and Lucknow have the highest levels of heterogeneity. In contrast, the Municipal Corporations of Saharanpur, Jhansi, Aligarh, and Moradabad have the lowest levels of variation in the availability of basic amenities. The results emphasise the fairer distribution of basic facilities in Prayagraj wards while also highlighting the need to create infrastructure to address deprivation identified in Saharanpur, Jhansi, and Aligarh Municipal Corporation's wards.

Table 5: House quality, basic amenities and physical assets indices of Municipal Corporations of Uttar Pradesh

Municipal Corporations	Number of Wards	House Quality Index		Basic Amenities Index		Physical Assets Index	
		Mean	Rank	Mean	Rank	Mean	Rank
Agra	90	0.01	8	-0.118	7	0.56	4
Aligarh	70	0.09	7	-1.439	13	-1.018	11
Bareilly	70	0.99	2	0.181	6	-0.783	10
Ghaziabad	80	0.55	4	1.142	2	1.474	1
Gorakhpur	70	-0.61	11	-0.498	9	0.378	5
Jhansi	60	-2.48	13	-1.299	12	-0.126	7
Kanpur	110	-0.27	10	-0.813	11	-0.251	8
Lucknow	110	0.56	3	0.552	4	1.009	3
Meerut	80	0.15	6	0.417	5	-0.114	6
Moradabad	70	1.15	1	-0.461	8	-1.357	13
Prayagraj	80	-0.16	9	1.277	1	1.013	2
Saharanpur	85	0.46	5	-0.611	10	-1.049	12
Varanasi	90	-0.87	12	1.083	3	-0.359	9

Deprivation in Physical Assets Index

Filmer and Scott (2008) assert that asset availability offers a perspective on a household's economic status, reflecting their material living conditions. Conversely, the other two indicators, household income and consumption, often experience fluctuations influenced by seasonality (Mondal, 2020), and it fails to capture the multiple economic deprivations. Thus, the ownership of assets by households emerges as a viable alternative, offering a reliable proxy for assessing relative wealth levels and impoverishment within the wards of Municipal Corporations in Uttar Pradesh.

The census data 2011 reveals that, on average, 70.9 per cent of households within the wards of Municipal Corporations in Uttar Pradesh have access to banking facilities. This significant proportion suggests a willingness to save and reflects a level of financial awareness prevalent in the urban areas of the state. However, a significant disparity becomes apparent in the Aligarh Municipal Corporation, where the lowest proportion (7.9 percent) reported in a ward highlighted a greater degree of marginalisation, limited savings opportunities, and diminished financial awareness.

Modern communication and transportation amenities in households also provide insights into media exposure and comparatively better connectivity and awareness of the surrounding world. On average, 79.8 percent of individuals possess televisions, indicating widespread media exposure. Moreover, 45.4 percent of individuals utilise motorcycles as a mode of transport, with the highest percentage (90.2 percent) recorded in a ward of Agra Municipal Corporation. Ownership of cars, jeeps, or vans indicates a relatively affluent position in society, and an average of 11.2 percent of households possess such vehicles across Municipal Corporations—the highest value for this indicator is found in a ward of Ghaziabad Municipal Corporation. This shows that access to inner-city jobs has been facilitated by vehicle ownership as a result of the construction of highways and new mass transit systems in the periphery of the city.

The insights derived from Figure 2 reveal the relative positions of Municipal Corporations based on the Assets Index, with Ghaziabad, Prayagraj, and Lucknow securing the top rank. In contrast, Moradabad, Saharanpur, and Aligarh Municipal Corporations rank lowest in terms of asset ownership. Notably, Ghaziabad Municipal Corporation shows the highest variation in asset ownership, indicating an unequal level of asset availability. The outcomes of the study elucidate the manner in which assets are distributed, bringing attention to the varying levels of wealth disparity evident across and within the Municipal Corporations of Uttar Pradesh.

Composite Development Deprivation Index

Table 6 uncovers that Jhansi, Aligarh, and Kanpur Municipal Corporations show the highest levels of deprivation, while Ghaziabad, Prayagraj, and Lucknow Municipal Corporations demonstrate comparatively more favourable development positions. Specifically, Kanpur's wards display the most extensive range of development, illustrating a nuanced combination of better-developed and highly deprived wards. In addition, the variation in developmental conditions is most pronounced in the wards of Saharanpur, Meerut, Jhansi, and Aligarh Municipal Corporations, indicating a relatively higher degree of heterogeneity in the overall developmental trajectories. The research findings underscore significant divergences in the level of development across Municipal Corporations in Uttar Pradesh, with some embracing more inclusive development. In contrast, others tend to have a more exclusionary nature. The ANOVA test (Table 7) shows meaningful results, showing a considerable difference in house quality, basic amenities, and asset ownership among the Uttar Pradesh Municipal Corporations.

Moreover, a noticeable disparity in development deprivation was evident across these corporations. The statistical test was performed at a significance level of 0.05, with the calculated P-value being less than 0.0001. The results reveal that the F-statistic is the greater the variation between sample means relative to the variation within the samples and, thus, a significant difference in the developmental dynamics among Uttar Pradesh's Municipal Corporations.

Conclusion

The present study used a composite index to assess the developmental trajectory across Municipal Corporations in Uttar Pradesh. The results revealed noteworthy deprivation in development among the Municipal Corporations. The level of development deprivation is related to the historical and spatial setting of the Municipal Corporations. Ghaziabad Municipal Corporation, situated within the national capital region, shows relatively higher levels of development despite experiencing relatively higher inter-ward variations. The current study also uncovers that certain wards demonstrate more pronounced development across Municipal Corporations, although a substantial developmental gap persists. This gap represents a pathological situation where city stakeholders are unable to maintain public services due to persistent urban population growth and financial constraints at the ward level. The private investors in the city's infrastructural development are largely free to determine the investment location. It leads to disproportionate development across the city. Thus, the question of spatial justice in the planning and development of local areas is crucial. Providing essential amenities and services to underdeveloped wards can foster better living and working conditions, contributing to an enhanced standard of living for inhabitants.

Table 6 Descriptive Statistics of the Development Deprivation Index for Municipal Corporations

Municipal Corporations	Number of Wards	Mean	Rank	Range	Standard Deviation	Variance
Agra	90	0.149195	5	5.429855	1.03723	1.07585
Aligarh	70	-0.78923	12	9.145167	1.839135	3.38242
Bareilly	70	0.128605	6	8.269903	1.727934	2.98576
Ghaziabad	80	1.05498	1	6.073745	1.471475	2.16524
Gorakhpur	70	-0.24379	9	8.067373	1.56321	2.44363
Jhansi	60	-1.30293	13	9.603123	1.870053	3.4971
Kanpur	110	-0.44575	11	10.13424	1.660418	2.75699
Lucknow	110	0.705566	3	7.221994	1.341187	1.79878
Meerut	80	0.149785	4	7.805332	1.903401	3.62294
Moradabad	70	-0.22209	8	7.432603	1.836892	3.37417
Prayagraj	80	0.71105	2	6.139095	1.044935	1.09189
Saharanpur	85	-0.40016	10	9.566605	2.090887	4.37181
Varanasi	90	-0.04699	7	6.053482	1.310049	1.71623

Table 7 ANOVA tests for house quality, basic amenities, physical assets and development deprivation indices in Municipal Corporations of Uttar Pradesh

Domains		Sum of Squares	df	Mean Square	F	*P* value
HQI	Between Groups	79.276	12	6.606	14.567	<0.0001
	Within Groups	477.11	1052	0.454		
	Total	556.386	1064			
BAI	Between Groups	774.358	12	64.53	14.925	<0.0001
	Within Groups	4548.29	1052	4.323		
	Total	5322.64	1064			
PAI	Between Groups	764.726	12	63.727	16.65	<0.0001
	Within Groups	4026.55	1052	3.828		
	Total	4791.28	1064			
DDI	Between Groups	291.222	12	24.268	13.733	<0.0001
	Within Groups	1859.02	1052	1.767		
	Total	2150.24	1064			

To summarise, urban development deprivation is highly concentrated locally and varies significantly throughout urban spaces, and understanding its occurrence necessitates a micro-geographical analysis. However, as the Constitution states, strengthening local urban bodies at the ward level might promote better planning decisions and resource distribution. Area-based economic policies of social regeneration revival may help the underdevelopment wards. Moreover, there is a need to reinforce central and state initiatives through targeted intervention in the most disadvantaged wards, which could further reduce the development deprivation within the city.

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COMPARATIVE ANALYSIS IN GIS-BASED LANDSLIDE SUSCEPTIBILITY MAPPING USING FREQUENCY RATIO, ANALYTICAL HIERARCHY PROCESS AND WEIGHTED OVERLAY ANALYSIS METHODS: A CASE STUDY IN MAHABALESHWAR TEHSIL OF SATARA DISTRICT, MAHARASHTRA, INDIA

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Abstract

Landslide is a natural disaster that causes many casualties and economic losses worldwide. As per report of GSI, Western Ghat, Eastern Ghat, Himalaya are more landslide susceptible areas and suffer numerous fatalities and financial damages. Therefore, the mapping of landslide vulnerable areas is essential for mitigation and preparedness. The purpose of this study is to evaluate the landslide susceptibility using Frequency Ratio, Analytical Hierarchy Process, Weighted overlay analysis methods in Mahabaleshwar tehsil of Satara district, Maharashtra, India. Sixteen landslide causing factors including slope, rainfall, relief, lithology, soil depth, soil erosion, soil texture, land use / land cover, road distance, drainage distance, drainage density, lineament distance, lineament density, aspect, temperature and seismology are analyzed. The weight and score assigned to each factor as per their importance and triggering intensity. All factors are merged into a single raster layer and the GIS multi-criteria model in ArcGIS 10.5 software used for the mapping of landslide susceptible zones. The landslide susceptibility map is classified into five classes: very high, high, moderate, low, very low. The final LSM shows that the relatively high susceptible (unsafe) area is 68.31%, moderately susceptible (slightly safe) area is 17.78 % and low to very low susceptible (safe) area is 13.91 %. 47 villages out of 113 and an important road of the study area is under high to very high risk. The developed landslide susceptibility map is very important for decision makers, planners, and engineers to prevent and mitigation measurements for reducing losses of life and properties.

Keywords: Remote Sensing and GIS, Landslide susceptibility, Weighted overlay analysis, Analytic hierarchy process, Frequency ratio

Introduction

Landslide is a very destructive and fatal natural disasters among geological disasters (Tariq & Gomes, 2017). Landslides occur when the land slope is unstable due to natural or anthropogenic activities. The landslide causative factors are adverse climatic conditions, earthquakes, weathering, erosion, volcanoes, forest fires, relief, soil, gravity, agriculture, construction, mining, slope modification, overgrazing, drainage pattern, land-use/land cover etc. As per the report of Geological Survey of India (GSI), 12.6 % area of India comes under landslide susceptible zone and every year Himalayan region (Darjeeling, Sikkim, Himachal Pradesh, Uttarakhand, Jammu and Kashmir, Ladakh) Western Ghat, Eastern Ghat, suffers heavy losses in terms of life and property (https://www.gsi.gov.in). Major landslide data in the last fifty years available on the website Geological Survey of India (https://www.gsi.gov.in) is presented in table 1.

Table 1: Major Landslides in India

Date / Year	District / State	Effect
July 1975	North of West Bengal	45,000 people homeless in the areas of Teesta, Jaldhaka, and Diana.
October 1990	The Nilgiris, Tamil Nadu	36 people were killed and several injured. Several buildings and roads were damaged, and communications disrupted.
July 1991	Assam	300 people were killed, roads and buildings worth lakhs of rupees damaged.
August 1993	Kalimpong, West Bengal	40 people were killed, heavy loss of property.
August 1993	Kohima, Nagaland	200 houses were destroyed, 500 people killed, a 5 km stretch of road was damaged.
October 1993	Marapplam, the Nilgiris, T.N.	40 people were killed, property worth several lakhs of rupees damaged.
18 August 1998	Malpa, Kali river, Uttarakhand	210 people were killed. The village was wiped out in the event.
5 July 2004	Badrinath, Chamoli District, Uttarakhand	16 persons killed, 200 odd pilgrims stranded, 800 shopkeepers and 2,300 villagers trapped as cloudburst triggered massive landslides washed away nearly 200 metre of road on the Joshimath-Badrinath road cutting off Badrinath area.
16-20 February 2005	Anantnag, Doda, Poonch, Pulwama, and Udhampur Districts, Jammu & Kashmir	Over 300 people lost their lives.
July 2005	Raigad, Maharashtra	Places affected by landslides were at Dasgaon (36 deaths), Rohan (15 deaths), Jui (96 deaths), and Kondivate (34 deaths). Also, damage was caused to roads and other structures.
25 February 2010	Chimakurthi, Prakasam District, Andhra Pradesh	20 workers were feared killed
18 May 2010	Ladakh, Jammu & Kashmir	2 persons were killed and The Indian Army rescued 73 other persons
16 June 2013	Uttarakhand	Approximately 5700 peoples death in flood and landslide
30 July 2014	Malin Village, Pune	Around 151 peoples died and approximately 100 peoples were missing
1 July 2015	Mirik area of Darjeeling	Over 40 people had died

Source - https://www.gsi.gov.in.

The demarcation of the landslide-susceptible region is essential for reducing its intensity and saving lives and property. Various methods are used for the mapping of landslide susceptibility i.e., heuristic, qualitative, quantitative, semi-quantitative, probabilistic, geotechnical process model, on-ground monitoring, geomorphologic approach, factors overlay, remote sensing data etc. (Zink et al., 2001). Geospatial technology is a powerful tool to analyse landslide-susceptibility (Karimi et al., 2010). In the recent decade Geographical Information System (GIS), Remote Sensing (RS) and Global Positioning System (GPS) based geospatial technology play a crucial role in the prediction and mapping of landslide-susceptible zones. It is a versatile time and cost saving technology handling a large and multiple data set. It is helpful in remote, mountain and forest areas for hazard mitigation and monitoring. The accuracy and efficiency of geospatial technology has led to much research and studies worldwide. This tool is used for the demarcation of landslide susceptibility. The main objective of this study is to prepare a landslide susceptibility map of Mahabaleshwar tehsil of Satara district based on the combination GIS and Analytical Hierarchical Process (AHP), Frequency ratio (FR) and Weighted overlay Method (WoM). Three different landslide mapping methods are used to create landslide susceptibility map in this study.

Study Area

The research area is located in the Mahabaleshwar tehsil of Satara district, Maharashtra. It lies between north latitude $17^0$42’2” - $17^0$58’55” and east longitude of 73^o32’14” - $73^0$51’34”, with an area of 518 Km^2. According to the population census of 2011 the total population of tehsil was 72,830 persons (Census of India, 2011). The elevation of the tehsil is varied from 600 to 1440 m and average elevation is 1050 m, above mean sea level and 45 % area of the tehsil is dominated by the mountain range of Sahyadri. The climate of the tehsil is humid subtropical. The average amount of rainfall in the study area is 5805 mm, whereas 96 % rainfall is received only during the southwest monsoon. The mean temperature ranges between 16 ^{0}C and 26 ^{0}C (www.imd.gov.in, www.maharain.maharashtra.gov.in). Mahabaleshwar tehsil has 113 villages. Mahabaleshwar tehsil is an important tourist destination in India, millions of tourists visit various places in this tehsil every year. The important tourist places are Mahabaleshwar, Tapola, Panchagani, Pratapgad etc. According to the civilians the landslide has become more common in the last few years in the tehsil. The landslide disrupted the life of tehsil and it also affected tourism on a large scale. The study is covered with basaltic lava and also called as a Deccan trap. The thickness of these layers is from 4 to 66 m. Geologically this is most stable region but some natural and manmade reasons occur the instances of landslides in this area. Bhilar, Kaswand, Mahabaleshwar (Hotel Gautam), Panchgani, Metgulad, Gadalwadi, Tapola to Mahabaleshwar road landslide in 2005, Panchgani and Bhekawli landslide in 2015 and Umbari landslide in 2017 were major past landslide in the study area (www.satara.gov.in). In the year 2021, 1517 landslides[1] occurred during the monsoon season in the tehsil. Many villages were out of contact for a month. More than 100 landslides occurred on Ambenali ghat (Mahabaleshwar - Poladpur road) and it was closed for 45 days to all types' transportation. Location map of the study area is shown in Fig. 1.

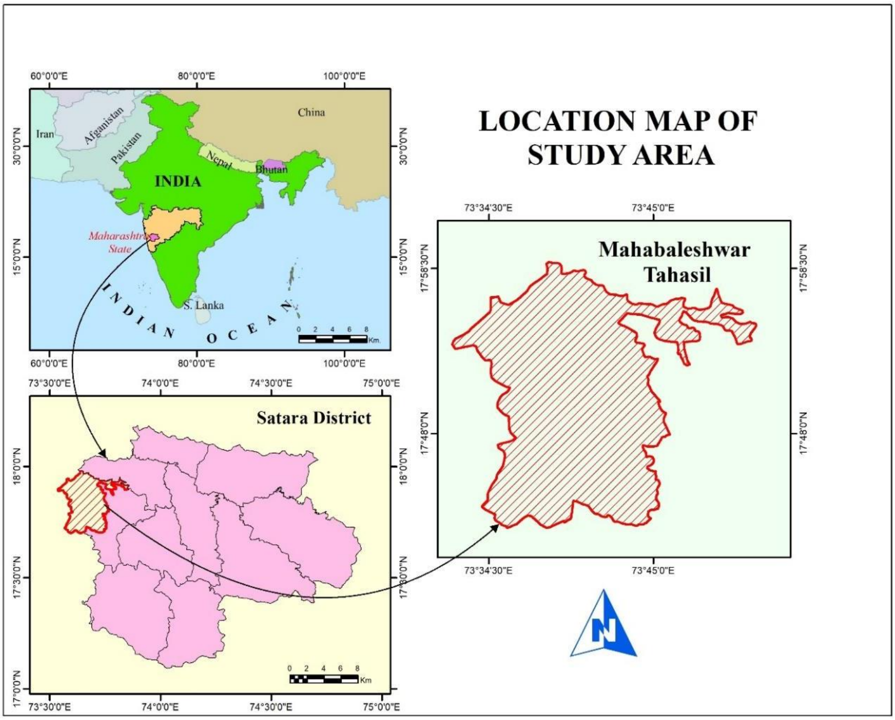


Fig. 1: Study Area

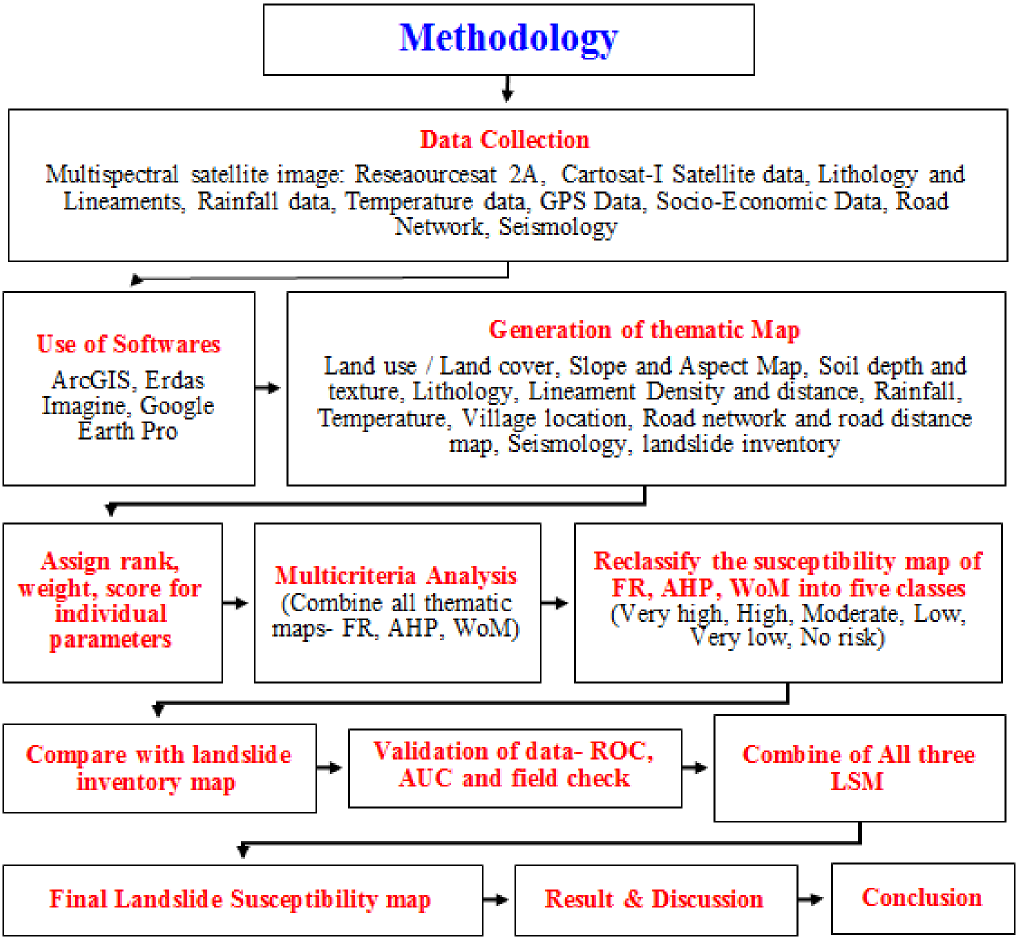
Material and Methods

For the present study, the methodology is involved in five steps: 1) selection of causative factors 2) database creation and generation 3) assign rank, weight and score for each causative factor 4) preparation of landslide susceptibility map 5) data validation and accuracy assessment. The workflow diagram of methodology adopted for this study is shown in Fig. 2.

Landslide inventory

Landslide inventory of the study area is developed based on the field visit and visual interpretation of high-resolution Google earth images. Total 1517 landslide locations are identified in the study area (Fig. 3).

[1] The data of the landslide were collected from the news in print and digital media, interaction with civilians, journalists, and administrative officers, Google earth image and during field visits.



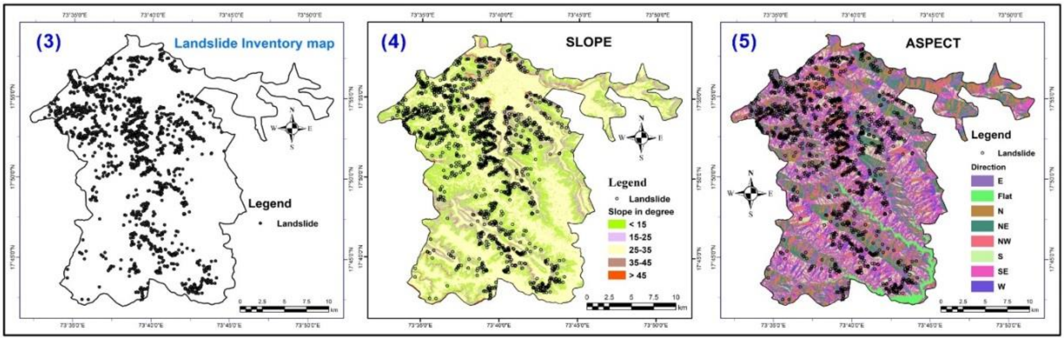


Fig. (3) Landslide Inventory Map, (4) Slope map, (5) Aspect map

Landslide causative factors

Sixteen causative factors of landslide (slope, rainfall, relief, lithology, soil depth, soil erosion, soil texture, land use/land cover, road distance, drainage distance, drainage density, lineament distance, lineament density, aspect, temperature, seismology) are selected for LSM based on literature review, field visit, and characteristics of study area. This database is collected from various sources and its specific use is presented in Table 2. Thematic layers of all these factors are prepared using ArcGIS 10.5 and ERDAS IMAGINE software.

Landslide susceptibility mapping (LSM)

Landslide susceptibility mapping is essential for identifying the spatial probability and intensity of landslides. Three methods (FR, AHP, WoM) are used to produce the LSM of the study area. The qualitative heuristic approach is used in this study and the weight and score for each thematic layer are assigned based on their relative contribution to landslide occurrence (Awawdeh et al., 2018), expert's opinion, literature review and field visit. The process adopted for LSM of all three methods is discussed below.

FR: The frequency ratio is a quantitative model used for landslides susceptibility mapping based on GIS techniques and spatial data (Lee and Talib; 2005). This model expresses the relationship between landslides inventory and landslide causative factors (Mandal et al., 2018). Frequency ratio of each class of the causative factors is calculated by using following formula (Mondal and Maiti, 2013):

$$Fr = \frac{b}{a} \qquad (1)$$

Where,

$$a = \frac{NPix}{\sum NPix} X\ 100$$

Npix is the number of pixels in individual class of each factor and ∑ *NPix* is the total number of pixels of each class in the whole area

$$b = \frac{NPil}{\sum NPil} X\ 100$$

Npil is the number of landslides in individual class of each factor and ∑ *NPil* is the total number of landslides of each class in the whole area

Normalization frequency Index (FRn) = FRxi/Ln (2)

Where, FRxi is a frequency ratio of individual classes of each factor and Ln is a highest frequency ratio of each factor.

FRn values are assigned for individual classes of each thematic layer and landslide susceptibility is computed from the summing of the FRn of each thematic layer using the following formula in the ArcGIS 10.5 software (Lee and Talib, 2005).

$$LSI = \sum Fr_n \qquad (3)$$

Where Frn is a normalized frequency Index and LSI is a landslide susceptibility index. Table 3 shows the Frequency ratio calculation of landslide influencing factors.

Table 2: Data sources and specific use

Sr. No.	Data Types	Source	Data/Layer Extracted
1	Multispectral LISS-IV satellite image: ResourceSat-2A Date: 31/01/2021 & 24/02/2021 Path: 95, Scene: 60 Spatial resolution - 5.8 M	NRSA, Hyderabad (https://bhoonidhi.nrsc.gov.in)	Land use / Land cover
2	DEM Satellite data: Cartosat-I Spatial resolution- 2.5 M	Bhuvan (*https://bhuvan-app3.nrsc.gov.in/data/download/index.php*)	Slope and Aspect Map
3	Soil Data Scale -1: 500000	European Soil Data Center (*https://esdac.jrc.ec.europa.eu/*)	Soil depth and texture map
4	Lithology and Lineaments Scale - 1:50000	Bhukosh website (*http://bhukosh.gsi.gov.in/Bhukosh/MapViewer.aspx*)	Lithology map, Lineament Density and distance
5	Climatic data Rainfall data	India Meteorological Department of Pune (*https://imd.gov.in/*) and Maharashtra agriculture websites (*http://mahaagri.gov.in/*)	Rainfall and Temperature Map
6	Road Network	Google Earth Image and Satellite image	Road network and road distance map
7	Seismology	Bhukosh website (*http://bhukosh.gsi.gov.in/Bhukosh/MapViewer.aspx*)	Seismology Map
8	Landslide location	GPS survey and Google earth satellite image	Landslide inventory map

Table 3: Frequency ratio calculation of landslide influencing factors

Factor	Class	Num. of Pixel in Class	Class Area % (a)	Num. of Landslide	Landslide % (b)	FR b/a	FRn
Slope (°)	< 150	160578	27.86	667	43.97	1.58	0.65
	16 to 250	81901	14.21	473	31.18	2.19	0.90
	25 to 350	309121	53.64	230	15.16	0.28	0.12
	35 to 450	20313	3.52	130	8.57	2.43	1.00
	> 450	4422	0.77	17	1.12	1.46	0.60
Aspect	Flat	14742	2.58	7	0.46	0.18	0.12
	N	35962	6.30	61	4.02	0.64	0.43
	NE	78519	13.75	157	10.35	0.75	0.51
	E	64633	11.32	174	11.47	1.01	0.68
	SE	70846	12.41	258	17.01	1.37	0.92
	S	78819	13.80	311	20.50	1.49	1.00
	SW	76935	13.47	221	14.57	1.08	0.73
	W	59705	10.46	133	8.77	0.84	0.56
	NW	60502	10.60	146	9.62	0.91	0.61
	N	30309	5.31	49	3.23	0.61	0.41
Relief (m)	0 to 600	72924	12.65	10	0.66	0.05	0.03
	600 to 800	238582	41.40	635	41.86	1.01	0.60
	800 to 1000	135750	23.55	598	39.42	1.67	1.00
	1000 to 1200	79571	13.81	253	16.68	1.21	0.72
	Above 1200	49508	8.59	21	1.38	0.16	0.10
Lithology	Laterite	39755	7.01	17	1.12	0.16	0.15
	Basalt	527169	92.99	1500	98.88	1.06	1.00
Lineament distance (m)	< 50	6949	1.21	21	1.38	1.15	0.62
	50 - 100	7790	1.35	23	1.52	1.12	0.61
	100- 150	7856	1.36	38	2.50	1.84	1.00
	150-200	6142	1.07	27	1.78	1.67	0.91
	>200	547588	95.01	1408	92.81	0.98	0.53
Lineament density (m/km^2)	Below 50	2833	0.49	34	2.24	4.56	1.00
	50 to 100	14142	2.45	88	5.80	2.36	0.52
	100 to 150	49653	8.62	266	17.53	2.04	0.45
	150 to 200	86623	15.03	259	17.07	1.14	0.25
	Above 200	423064	73.41	870	57.35	0.78	0.17

Drainage distance (m)	<50	184253	31.97	364	23.99	0.75	0.54
	50-100	153690	26.67	393	25.91	0.97	0.70
	100-150	109118	18.93	380	25.05	1.32	0.96
	150-200	57202	9.93	208	13.71	1.38	1.00
	> 200	72061	12.50	172	11.34	0.91	0.66
Drainage density in sq. km	Very low (< 2)	77306	13.41	73	4.81	0.36	0.25
	Low (2 to 3)	123860	21.49	300	19.78	0.92	0.65
	Medium (3-4)	255033	44.25	699	46.08	1.04	0.74
	High (> 4)	120124	20.84	445	29.33	1.41	1.00
Soil depth	Very shallow	274525	47.69	618	40.74	0.85	0.42
	Shallow	54334	9.44	45	2.97	0.31	0.16
	Moderately deep to Deep	61936	10.76	47	3.10	0.29	0.14
	Very Deep	148781	25.85	789	52.01	2.01	1.00
	Water	36026	6.26	18	1.19	0.19	0.09
Soil texture	Clayey	253216	43.99	567	37.38	0.85	0.57
	Fine Loamy	210756	36.61	835	55.04	1.50	1.00
	Loamy	75603	13.13	95	6.26	0.48	0.32
	Water Body	36029	6.26	20	1.32	0.21	0.14
Soil erosion	Very Low	499105	86.71	1301	85.76	0.99	0.51
	Low	22668	3.94	116	7.65	1.94	1.00
	Medium	1632	0.28	5	0.33	1.16	0.60
	High	113	0.02	0	0.00	0.00	0.00
	Very High	15988	2.78	77	5.08	1.83	0.94
	Water	36103	6.27	18	1.19	0.19	0.10
Land use / Land cover	Agriculture	63392	11.00	6	0.40	0.04	0.02
	Dense Forest	200084	34.72	873	57.55	1.66	1.00
	Fallow land	71408	12.39	68	4.48	0.36	0.22
	Medium forest	141715	24.59	426	28.08	1.14	0.69
	Road	5195	0.90	9	0.59	0.66	0.40
	Settlement	1734	0.30	0	0.00	0.00	0.00
	Scrubland	65249	11.32	135	8.90	0.79	0.47
	Waterbody	27545	4.78	0	0.00	0.00	0.00

Rainfall (mm)	<2000	21221	3.68	0	0.00	0.00	0.00
	2000-3000	90635	15.73	34	2.24	0.14	0.10
	3000-4000	96787	16.79	215	14.17	0.84	0.62
	4000-5000	197317	34.24	657	43.31	1.26	0.93
	>5000	170363	29.56	611	40.28	1.36	1.00
Temperature ℃	<21.5	165137	28.65	605	39.88	1.39	1.00
	21.5-22.5	257613	44.70	813	53.59	1.20	0.86
	22.5-23.5	127383	22.10	99	6.53	0.30	0.21
	>23.5	26190	4.54	0	0.00	0.00	0.00
Road distance (m)	<100	102658	17.81	160	10.55	0.59	0.47
	100 - 200	72384	12.56	132	8.70	0.69	0.54
	200 - 300	65577	11.38	143	9.43	0.83	0.65
	300 - 400	50648	8.79	149	9.82	1.12	0.88
	400 - 500	46901	8.14	135	8.90	1.09	0.86
	> 500	238157	41.32	798	52.60	1.27	1.00
Seismology	Zone II	477111	82.79	1420	93.61	1.13	1.00
	Zone III	99212	17.21	97	6.39	0.37	0.33

AHP: The Analytic hierarchy process (AHP) is a multi-criteria assessment decision-making tool developed by Saaty (Saaty, 2001). It is an effective tool to deal with complex and multi-attribute problems and widely used by the different scholars (Potekar et al., 2023; Bachri and Shresta, 2010). In this study, the score of each causative factor is assigned based on the expert's opinion and individual experience. The LSM based on the AHP method has been prepared in the following order.

1) Generation of the pairwise comparison matrix: The degree of the importance (1 to 9) of each causative factor for generation of pairwise comparison matrix is assigned based on the Table 4 (Saaty, 2008). Table 5 shows the Pairwise Comparison Matrix of AHP weightage.
2) Computation of the criterion weights: The weight of each causative factor is divided by the sum of the column of the same causative factor and prepared by the normalized pairwise comparison matrix (Npcm). The row wise sum of each causative factor in the normalized pairwise comparison matrix is divided by the total number of the factors and prepared by the criteria weight. The criteria weight is multiplied with 100 and prepared the percentage of criteria weight (Table 6).
3) Estimation of the consistency ratio: Column wise original pairwise comparison matrix value of each class multiplies with criteria weight of same class and then row wise sum of each class and prepare the weighted sum value of consistency vector. Weighted sum value of the consistency vector of each class is multiplied with the criterion weight of the same class and prepared for the average value of the consistency vector. Consistency index is calculated using the following formula

Table 4: Degree of Importance in AHP

Numerical scale	Intensity of Importance
1	Equal importance - Two factors contribute equally
3	Moderate importance - slightly importance of one over another
5	High prevalence - Essential or strong importance
7	Very high prevalence - Demonstrated importance
9	Extremely high prevalence - Absolute importance
2, 4, 6, 8	Intermediate values - used when comprises is needed

Table 5: Pair-wise Comparison Matrix of AHP

F	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1	2	2	3	3	4	4	5	5	5	6	6	4	4	7	7
2	1/2	1	2	7	2	2	4	5	3	3	7	7	3	2	7	3
3	1/2	1	1	2	3	3	4	4	4	4	5	5	5	6	7	7
4	1/3	1/7	1/2	1	2	2	3	3	3	3	4	4	4	5	6	6
5	1/3	1/2	1/3	1/2	1	2	3	3	3	3	4	4	4	5	6	7
6	1/4	1/2	1/3	1/2	1/2	1	2	2	3	3	4	4	4	5	7	7
7	1/4	1/4	1/4	1/3	1/3	1/2	1	2	2	2	3	3	3	4	5	5
8	1/5	0	1/4	1/3	1/3	1/2	1	1	2	2	3	3	3	4	5	5
9	1/5	1/3	1/4	1/3	1/3	1/3	1/2	1/2	1	2	3	3	3	4	5	5
10	1/5	1/3	1/4	1/3	1/3	1/3	1/2	1/2	1/2	1	2	2	2	3	5	5
11	1/6	1/7	1/5	1/4	1/4	1/4	1/3	1/3	1/3	1/2	1	2	2	3	5	5
12	1/6	0	1/5	1/4	1/4	1/4	0	0	0	1	1	1	2	3	5	5
13	1/4	1/3	1/5	1/4	1/4	1/4	1/3	1/3	1/3	1/2	1/2	1	1	2	5	5
14	1/4	1/2	1/6	1/5	1/5	1/5	1/4	1/4	1/4	1/3	1/3	1/3	1/2	1	3	3
15	1/7	1/7	1/7	1/6	1/6	1/7	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/3	1	3
16	1/7	1/3	1/7	1/6	1/7	1/7	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/3	1/3	1
Sum	4.89	7.35	8.22	16.62	14.09	16.90	24.15	27.65	28.15	30.23	43.73	45.23	40.90	51.67	79.33	79

1- Slope, 2- Rainfall, 3- Relief, 4- Lithology, 5- Soil Depth, 6- LULC, 7- Soil Texture, 8- Road Distance, 9- Drainage Distance, 10- Drainage Density, 11- Lineament Distance, 12- Lineament Density, 13- Soil Erosion, 14- Aspect, 15- Seismicity, 16- Temperature

Table 6: Relative Weight of Criteria of AHP

Factors	NPCM Sum	Weighted sum value (WSV)	Criteria Weight (CW)	WSV/CW	Weights
Slope	2.66	3.11	0.17	18.68	17
Rainfall	2.27	2.78	0.14	19.62	14
Relief	2.03	2.40	0.13	18.95	13
Lithology	1.43	1.69	0.09	18.91	9
Soil Depth	1.37	1.60	0.09	18.69	9
LULC	1.20	1.38	0.07	18.50	7
Soil Texture	0.85	0.98	0.05	18.42	5
Road Distance	0.78	0.89	0.05	18.30	5
Drainage Distance	0.73	0.83	0.05	18.05	5
Drainage Density	0.59	0.66	0.04	17.81	4
Lineament Distance	0.48	0.53	0.03	17.57	3
Lineament Density	0.45	0.47	0.03	16.72	3
Soil Erosion	0.43	0.45	0.03	16.39	3
Aspect	0.34	0.35	0.02	16.30	2
Seismicity	0.20	0.20	0.01	16.26	1
Temperature	0.19	0.21	0.01	18.13	1
	Total- 16		**Total- 1**	**λ - 17.96**	**100**

$$CI = \frac{\lambda - n}{n-1} = 0.13 \quad (4)$$

Where, λ = average value of consistency vector and n=number of causative factors

$$CR = \frac{CI}{RI} = 0.08 \quad (5)$$

where CI = consistency index, RI= random index

The ideal CR values for a large matrix is 0.1, if it is more than 0.1 the pairwise matrix should be revised. For the generation of LSM, the weight for each causative factor and their subclasses is assigned and all thematic layers combined using an overlay analysis tool in the ArcGIS 10.5 environment. The final landslide susceptibility map is classified into five classes including very low, low, moderate, high, and very high.

Weighted Overlay Method (WoM): Weighted overlay method is also used in this study for landslide susceptibility mapping. Each causative factor classified into subclasses and heuristic technique based on the local information, prior knowledge of past landslide and their importance in causing or triggering landslide are used for the assign the scale (0 to 9) and weight (Gawali et al., 2017; Dai et al., 2002; Sarkar and Kanungo 2004). A detailed weightages is assigned to individual causative parameters as shown in Table 7.

Final LSM: LSM prepared using the all three methods are superimposed to each other and final LSM of the study area are prepared by addition of all the three classes (FR + AHP + WoM). The village and landslide inventory has been superimposed over the LSM and identifies landslide potential maps of villages.

Accuracy: After the landslide susceptibility mapping (LSM) of all three methods, the accuracy of LSM is evaluated by using the receiver operating characteristic (ROC) and area under curve (AUC) in ArcGIS software. The AUC is a graphical representation of binary operating classes and it is a good method for the validation of models.

Result

Slope: The slope is an important parameter for stability assessment (Kannan et al., 2015), the slope angle controls the slope stability and driving force intensity of unstable moving material. According to Dai & Lee (2002), the highest landslide occurs when the slope angle is between 25° to 35° degree and it decreases when slope is above 35°. The slope map of the study area is derived from DEM data of Cartosat-1 using spatial analyst tool in ArcGIS (Fig. 4). On the basis of angle, slope data classified into five classes as per Bureau of Indian Standards (BIS) such as <15^0 (Very gentle slope), 15 - 25^0 (Gentle slope), 25 - 35^0 (Moderate slope), 35 - 45^0 (Steep slope) and above 45^0 (Very steep slope) (Fig. 4). Most of the landslide (1370) was reported in areas where slope is between 5° to 35°. These classes are rated with the highest weight. About 43.97% of landslide events occurred in class I (< 15°), whereas the least landslide events (1.12 %) occurred in class V (> 45° %).

Table 7: Rating and Weightage to landslide responsible layers

Parameter	Class	Rating	Weightage
Slope	0-15	5	20
	15-25	4	
	25-35	3	
	35-45	2	
	Above 45	1	
Rainfall	<2000	1	15
	2000-3000	2	
	3000-4000	3	
	4000-5000	5	
	>5000	4	
Relief	0 to 600 m	1	12
	600 to 800	5	
	800 to 1000	4	
	1000 to 1200	3	
	Above 1200	2	
Lithology	Laterite	1	12
	Basalt	2	
Soil depth	Very shallow	4	5
	Shallow	2	
	Moderately deep to Deep	3	
	Very Deep	5	
	Water	1	
Land use / Land cover	Agriculture	3	5
	Dense Forest	8	
	Fallow land	5	
	Medium forest	7	
	Road	4	
	Settlement	1	
	Scrub land	6	
	Waterbody	2	
Soil texture	Clayey	3	4
	Fine Loamy	4	
	Loamy	2	
	Water Body	1	
Road Distance	<100 m	5	4
	100 - 200	1	
	200 - 300	3	
	300 - 400	4	
	400 - 500	2	
	> 500	6	
Drainage distance	<50	4	4
	50-100	6	
	100-150	5	
	150-200	3	
	200-250	2	
	>250	1	

Drainage density	Very low (below 2 Km)	1	4
	Low (2 to 3 sq km)	2	
	Medium (3 - 4 sq km)	4	
	High (above 4 sq km)	3	
Lineament distance	< 50	1	3
	50 - 100	2	
	100- 150	4	
	150-200	3	
	>200	5	
Lineament density	Below 50 m/Km2	1	3
	50 to 100 m/Km2	2	
	100 to 150 m/Km2	4	
	150 to 200 m/Km2	3	
	Above 200 m/Km2	5	
Soil erosion	Very Low	6	3
	Low	5	
	Medium	2	
	High	1	
	Very High	4	
	Water	3	
Aspect	Flat	1	2
	N	2	
	NE	5	
	E	6	
	SE	8	
	S	9	
	SW	7	
	W	3	
	NW	4	
Seismology	Zone II	2	2
	Zone III	1	
Temperature	<21.5	3	2
	21.5-22.5	4	2
	22.5-23.5	2	2
	>23.5	1	

Aspect: Aspect map shows the directions of the ground slope, it is one of the most important predisposing factors of landslides. Mostly the aspects control the microclimatic factors such as rainfall intensity, soil moisture, sunlight exposure, wind intensity, intensity of evapotranspiration and ground temperature etc. (Dai et al., 2002; Cevik and Topal, 2003). Aspect map of the study region is generated from DEM data Cartosat - 1 using spatial analyst tool in ArcGIS 10.5. The aspect map of the study area is divided into nine classes on the basis of slope directions viz., north, northeast, east, southeast, south, southwest, west, northwest and flat (Fig. 5). The last ninth class represented the flat area and remaining eights are representing the slope angle. Most of the landslide (790) was reported in S, SW and SE direction, whereas it is monsoon facing.

Relief: Relief is related to the elevation of the terrain. Fig. 6 shows the relief map of the study area which is derived from DEM data of Cartosat-1 using spatial analyst tool in ArcGIS 10.5. It is divided into five relief zones such as a very low relief zone (< 600 m), low relief zone (600 - 800 m), medium relief zone (700 - 1000 m), high relief zone (1000 - 1200 m) and very high relief zone (> 1200 m). Highest landslide was observed in 600 to 800 (635) and 800 to 1000 (598) classes. Highest rating allotted to these classes.

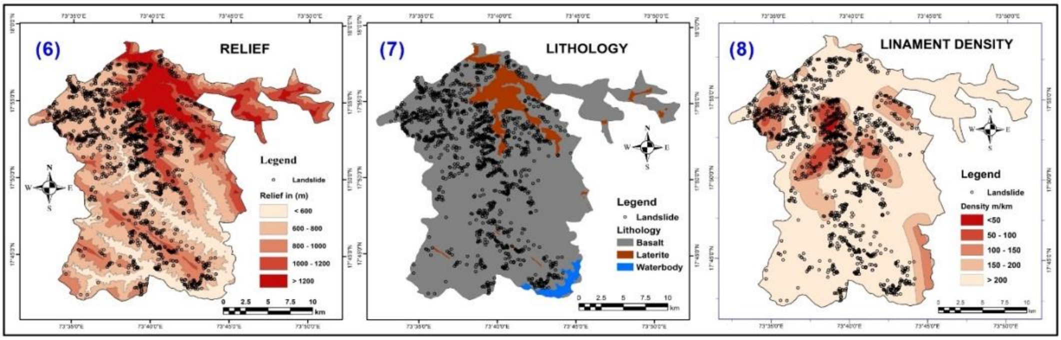


Fig. (6) Relief map, (7) Lithology map, (8) Lineament Density

Lithology: Lithology refers to all physical characteristics of a rock and it controls slope stability. (Sarkar and Kanungo, 2004). The lithological map of the area has been prepared by using the data of "Bhukosh GeoPortal" of Geological Survey of India. Major lithological characters of the study area are divided into two classes viz. Basalt and Laterite (Fig. 7). The most dominant lithology class is Basalt and they cover 93 % of the study area and the highest 1500 landslide incidence was observed in this class. Therefore, the highest rating value is assigned to this class.

Lineament Density and Lineament Distance: Active faults are more susceptible to the landslide (Mehmood et al., 2022). Lineament data is downloaded from "Bhukosh GeoPortal" of Geological Survey of India. Lineament density and distance map generated from this lineament data in spatial analyst tools of ArcGIS software. The lineament density map is divided in five classes viz., very low (< 50 m/km^2), low (50 to 100 m/km^2), medium (100 to 150 m/km^2), high (150 to 200 m/km^2) and very high (more than 200 m/km^2) density zone (Fig. 8). The highest landslide (870) event is observed in the lineament density above 200 m/km^2. Therefore, the highest rating value is assigned to this class. The distance from lineament is generated using the Euclidean distance tool of ArcGIS 10.5. The lineament distance map is classified into eight classes viz. <20 m, 20 to 40 m, 40 to 60 m, 60 to 80 m, 80 to 100 m, 100 to 120 m and >120 m (Fig. 9). The highest landslide (1408) event is observed in the lineament distance above 200 m. Therefore, there is no correlation of the lineament distance with landslide incidence.

Soil: The different characteristics of soil and its parameters play an important role in the study of soil stability and landslide susceptibility mapping. On the basis of observational study different soil characteristics affected slope stability (Sidle et al., 2006). The soil data is prepared from the map published by the European Soil Data Center on the website. It is georeferenced and digitized in the ArcGIS 10.5 software and used for preparation of soil depth, soil texture and soil erosion map. Field check is carried out to verify the characteristics of soil data. The study area is dominated by three soil types: clayey (43.99%), fine loamy (36.61 %) and loamy (13.13 %) (Fig. 10). The majority of landslide events (835) happened in the fine loamy soil and shallow black soil (567). Therefore, the highest rating values are assigned to these classes. The soil depth map is classified in four classes: very shallow, shallow, moderately deep to deep, and very deep (Fig. 11). Most of the landslide was observed in very shallow (618) and very deep soil depth (789). Therefore, the highest rating values are assigned to these classes. The soil erosion map is generated using a RUSLE model (Renard et al., 1997). The soil erosion map is divided into five classes which are Very low, Low, Medium, High, very high (Fig. 12). The highest landslide (1301) event is observed in the area of very low soil erosion and very low were observed in the High (0) and medium (05) soil erosion area. Therefore, there is no correlation of the soil erosion with landslide incidence.

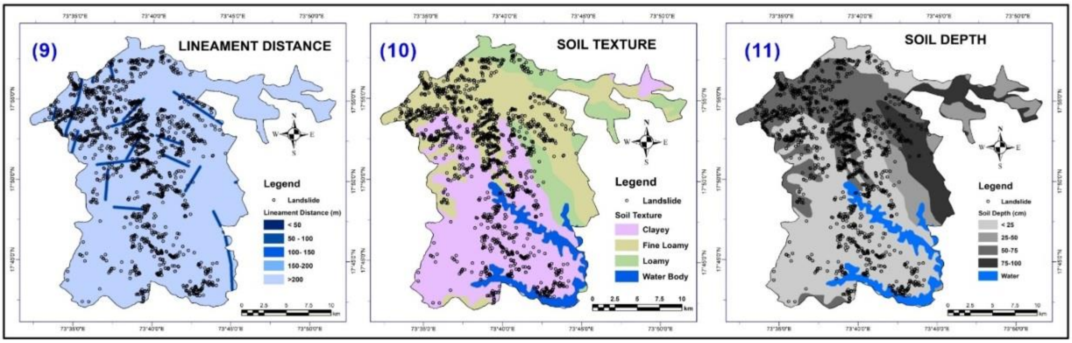


Fig. (9) Lineament Distance map, (10) Soil Texture, (11) Soil Depth map

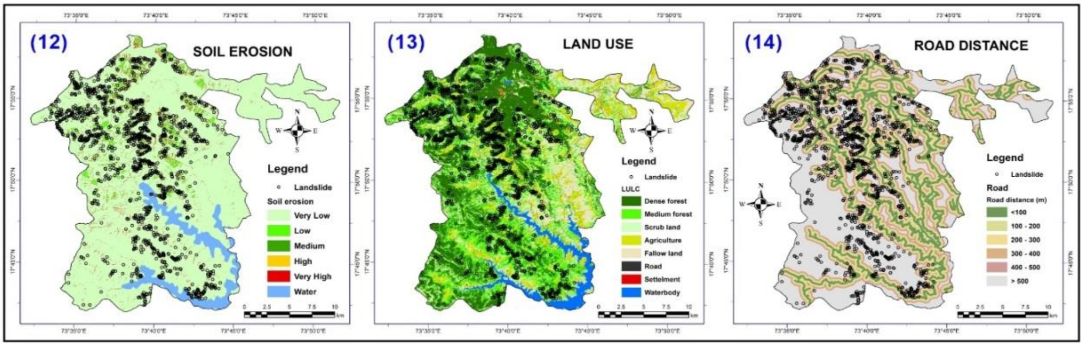


Fig. (12) Soil erosion map, (13) Land Use / Land Cover map, (14) Road Distance map

Land use and Land cover: Land use and land cover map of the study area generated from multispectral ResourceSat-2A (LISS-IV) satellite image with 5.8 m spatial resolution acquired on 31/01/2021 & 24/02/2021 after digital image processing in ERDAS imagine software (Fig. 13). It is classified into 8 classes: Dense Forest (34.72 %), Medium Forest (24.59 %), Fallow land (12.39 %), Scrubland (11.32 %), Agriculture (11 %), Waterbody (4.78 %), Road (0.9 %) and Settlement (0.3 %). The roots of the trees hold the soil firmly in place and slope more stable and less prone to slipping (Nohani et al., 2019). However, in this study area the highest (1299) landslide is observed in the forest area.

Distance from road: The road network in the mountainous area poses a threat to slope stability (Nohani et al., 2019). The road network in the area is digitized from ResourceSat-2A (LISS-IV) satellite image and Google earth satellite data. The distance from the road map is prepared by using the Euclidean distance tool in ArcGIS 10.5 and it is classified into six classes viz. <100 m, 100 – 200 m, 200 – 300 m,300 – 400 m,400 – 500 m and > 500 m. In the area under study, 10.55 % landslide events occurred within 100 m distance from any given road and the highest (72 %) landslide was observed away from the road (Fig. 14). This may be because most of the part of the study area is mountain and occupied with dense vegetation cover, however the road network is not dense.

Drainage distance and Drainage density: Drainage is an important aspect to determine the landslide probability. Drainage density and drainage distance influencing the occurrence of the landslide. Pham et al. (2018) stated that 65% of landslides occurred within 50 meter distance from drainage. The drainage network is generated from DEM data of Cartosat-I using the spatial analyst tool of ArcGIS 10.5 software. Using the drainage network two thematic maps are prepared viz., drainage density and drainage distance. The distance from drainage is prepared from the drainage network by using the Euclidean distance tool of spatial analyst in ArcGIS. The map is categorized into five classes as follows below: 50 m, 50 - 100 m, 100 - 150 m, 150 - 200 m and above 200 m. (Fig. 15). In the study area, distanced 0-100 m from the stream is a high potential of landslide (757) occurrence. The drainage density is prepared for using the density tool of Spatial Analyst in ArcGIS 10.5. The density is calculated as the length of streams in Km^2 (Fig. 16). These are classified into three classes' viz., very low (below 2 km^2), low (2 to 3 km^2), medium (3 to 4 km^2) and high (> 4 km^2). The highest landslide occurred in the medium to high drainage density area.

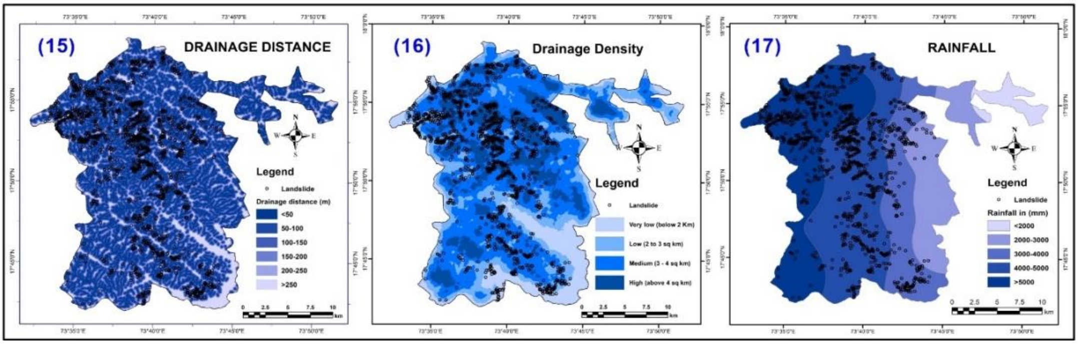


Fig. (15) Drainage distance map, (16) Drainage density map, (17) Rainfall map

Rainfall: Rainfall is the most landslide triggering factor (Tesic et al., 2020). The study area experiences heavy rainfall during monsoon season and most of the landslides have occurred in this season. The heavy rainfall in the year 2021 initiated more than 1500 landslides in the study area. The rainfall map (Fig. 17) is generated in the IDW interpolation method of Arc GIS and the entire study area is divided into five classes: <2000 mm, 2000 to 3000 mm, 3000 to 4000 mm, 4000 to 5000 mm and >5000 mm. The highest rainfall values are observed in the western part of the study area and the lowest values in the eastern part (Fig. 17). The rainfall data showed that the frequency of landslide events increases with increased rainfall intensity. The highest weightage is assigned to these classes.

Temperature: Temperature is a passive cause of landslides. It regulates the amount of runoff and evaporation and the increase in air temperature can have contrasting consequences on slope stability. A higher air temperature will expand evapotranspiration on vegetated slopes (Gariano and Guzzetti, 2016). The temperature map is generated in the IDW interpolation method of ArcGIS 10.5 with the help of temperature data (Fig. 18).

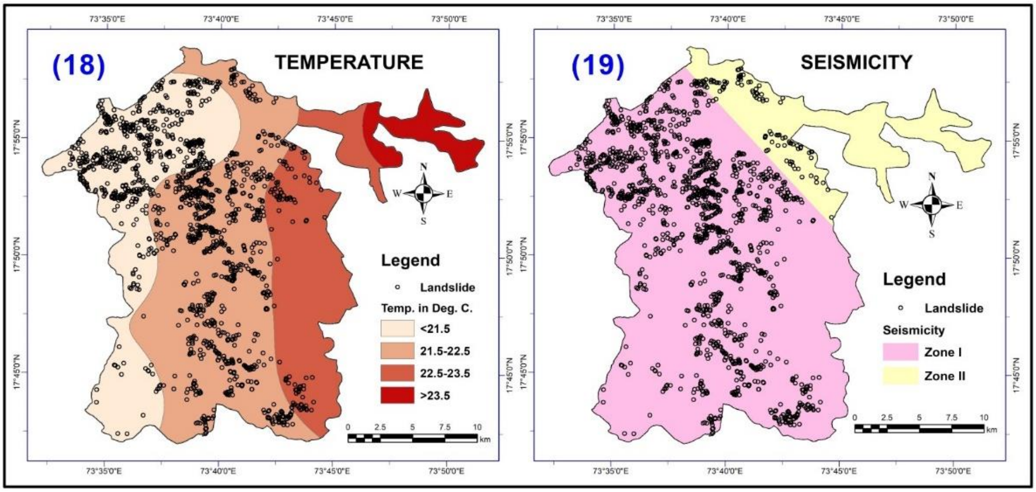


Fig. (18) Temperature map, (19) Seismology map

Seismology: Earthquake data is downloaded from "Bhukosh GeoPortal" of Geological Survey of India. Seismology map generated from earthquake data. The study area is distributed in two seismic zones (Fig. 19). Highest landslide occurred in the seismic zone –I.

Discussion

In this study, sixteen causative factors are used for preparation of potential landslide susceptibility in Mahabaleshwar tehsil using FR, AHP and WoM methods. The details of each method have been illustrated below.

Landslide susceptibility map using FR

The landslide susceptibility map (LSM) prepared using the frequency ratio (FR). The FR values between 0.0 to 4.56 (equation 1) and FRn values between 0.00 to 1 (equation 2). The LSI values vary from 0.10 to 15 (equation 3). The larger LSI values indicate a higher landslide susceptibility. For the visual interpretation equal interval methods are applied to classify the LSI maps into five classes (very low, low, moderate, high, and very high). Fig. 20a shows the LSM using FR and Table 8 shows the class wise landslide susceptibility. The results indicate that 34.80% area falls in the very high class followed by high susceptibility class 24.40% while 16.70% area is recognized as moderate class, 13.41 is under very low and low susceptibility class is 10.69 %. The mean of this model is 9.2852, median 9.66 and standard deviation 3.1786. The landslide inventory indicates that 1122 (73%) landslides are under the very high susceptibility class, 315 landslides under the high susceptibility class, 66 landslides are under the moderate susceptibility class and only 14 landslides are under the low and very low susceptibility class.

Table 8: Landslide susceptibility based on FR

Sr. No.	Susceptibility Class	Area (km^2)	% of Area	Landslide	% of landslide
1	Very high	180.28	34.80	1122	73.96
2	High	126.39	24.40	315	20.76
3	Moderate	86.48	16.70	66	4.35
4	Low	55.40	10.69	11	0.73
5	Very low	69.45	13.41	3	0.20
Total		**518**	**100**	**1517**	**100**

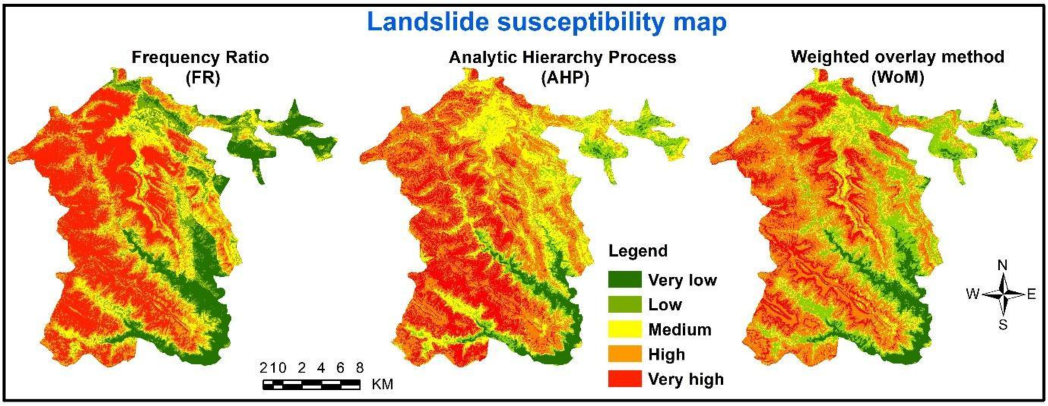


Fig. 20: (a) Landslide susceptibility map of FR, (b) Landslide susceptibility map of AHP and (c) Landslide susceptibility map of WoM

Landslide susceptibility map using AHP

The CR values of this study is 0.08 (equation 5) which is lower than 0.1, then AHP pairwise comparison matrix is acceptable. The Landslide susceptibility map generated by the AHP methods is shown in Fig. 20b and Table 9 shows the class wise landslide susceptibility. The mean of this model is 256.42, median 261.5 and standard deviation 137.7. The results shows that 61.76 % of the study area was categorized as high (39.96) to very high (21.80) landslide susceptibility class and 24.43% falls on moderate susceptibility class, while the rest 13.81 % is categorized as low to very low susceptibility class. The landslide inventory indicates that 637 landslides are under the very high susceptibility class, 745 landslides under the high susceptibility class, 128 landslides are under the moderate susceptibility class and only 7 landslides are under the low susceptibility class.

Table 9: Landslide susceptibility based on AHP

Sr. No.	Susceptibility Class	Area (km^2)	% of Area	Landslide	% of landslide
1	Very high	112.94	21.80	637	41.99
2	High	206.98	39.96	745	49.11
3	Moderate	126.57	24.43	128	8.44
4	Low	43.49	8.40	7	0.46
5	Very low	28.02	5.41	0	0.00
Total		**518**	**100**	**1517**	**100**

Landslide susceptibility map using Weighted Overlay Method

For the generation of LSM, each causative factor is evaluated independently and assigned weight based on their importance. The highest weight assigned to slope (20), rainfall (15), relief (12) and lithology (12) based on their highest influence on slope instability. All raster layers of the causative factors combined using an overlay analysis tool in the ArcGIS 10.5 environment and final landslide susceptibility map is classify into five classes (very low, low, moderate, high, and very high). Final LSM is prepared using a weighted overlay method in ArcGIS 10.5 environment and it is classified into five classes including very low, low, moderate, high, and very high. The Landslide susceptibility map generated by the WoM is shown in Fig. 20c and Table 10 shows the class wise landslide susceptibility. The mean of this model is 224.2168, median 224.5 and standard deviation 126.921. It can be concluded that a total of 24.28 % of the area is not susceptible (low and very low susceptibility), 18.10 % area is moderate susceptible and 57.62 % of the area is susceptible (high and very high susceptibility) to a landslide occurrence (Fig. 20c). About 1431 landslides are observed in high (796) and very high (635) susceptible areas.

Table 10: Landslide susceptibility based on WoM.

Sr. No.	Susceptibility Class	Area (km^2)	% of Area	Landslide	% of landslide
1	Very high	71.22	13.75	635	41.86
2	High	227.23	43.87	796	52.47
3	Moderate	93.76	18.10	74	4.88
4	Low	89.29	17.24	12	0.79
5	Very low	36.50	7.05	0	0.00
Total		**518**	**100**	**1517**	**100**

Data validation

The classified landslide susceptibility map of three methods is validated using the ROC and AUC. The AUC values and test quality of the model as shown in Table 11 (Metz, 1978). The accuracy is evaluated by comparing 1517 the landslide locations with the LSM in the ROC tool of Arc- SDM in ArcGIS 10.5. (Fig. 21)

Table 11: AUC values and Test Quality

AUC Values	Test quality
0.9 - 1.0	Excellent
0.8 - 0.9	Very Good
0.7 - 0.8	Good
0.6 - 0.7	Satisfactory
0.5 - 0.6	Unsatisfactory

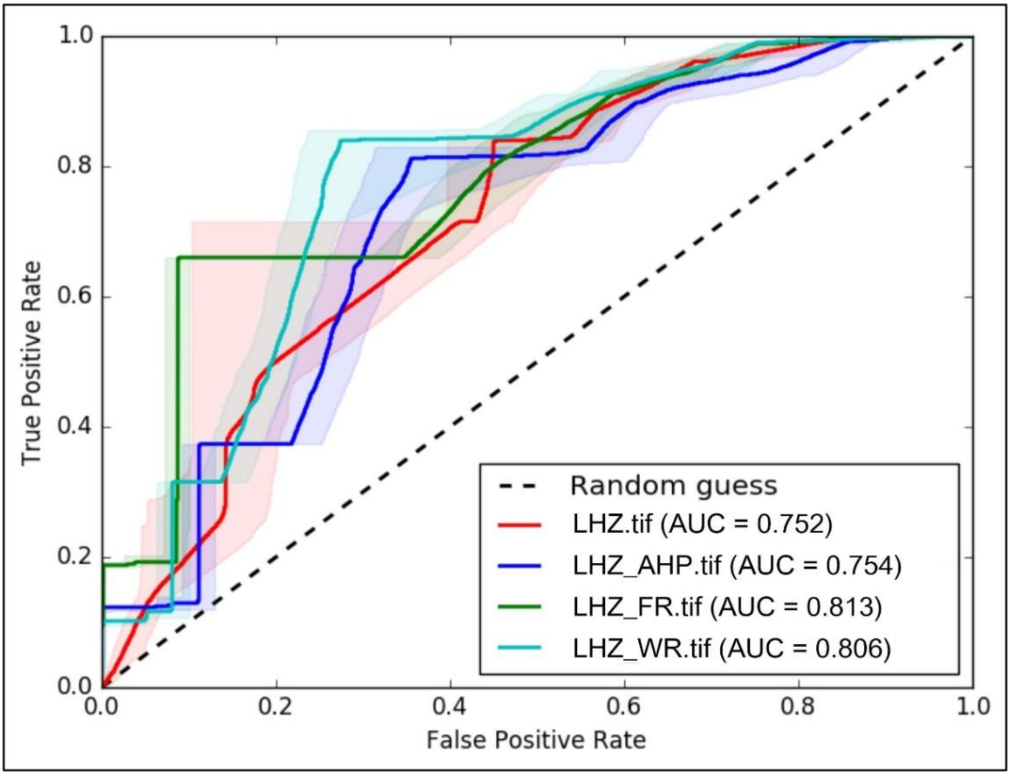


Fig. 21: ROC and AUC Curve of Landslide susceptibility map of FR, AHP, WoM and final LSM

The area under the curve of FR and WOM shows the accuracy value of 0.813 (81.3%) and 0.806 (80.6 %) respectively; it is above 0.8 and shows very good test quality of the model. The area under the curve of AHP and final LSM shows the accuracy value of 0.754 (75.4 %) and 0.752 (75.2%) respectively, it is above 0.7 and shows good test quality of the model. The validation results showed that all three models are correctly classified and test quality good and acceptable.

Final Landslide Susceptibility Map

All three methods are combined in the ArcGIS 10.5 and final LSM of the study area (Fig. 22) has been prepared and classified in five classes (Table 12). T he landslide susceptibility map shows, very high susceptibility zone occupies about 224.15 km^2 (43.27 %) of the total area. 1190 landslides (78.44 %) landslide and 13 villages are followed in this class. High susceptibility zone covered 129.71 km^2 (25.04 %) area and about 286 landslides and 34 villages are under this class. Moderate susceptibility zones covered 92.1 km^2 (17.7 %) area and 37 landslides and 45 villages are under this category. Low and very low susceptibility zone covered 72.03 km^2 area and only 4 landslides and 21 villages are under this category. It is notable that most of the high and very high potential zones are located in the central and western part of this study area due to the presence of lower slope, high drainage distance, shallow soil density, and heavy rainfall. The medium potential zone is found in the surroundings of high and very high potential zones. The low and very low potential zones are found in alluvial plains and along the Koyna dam.

Table 12: LSM based on the combination of three methods

Sr. No.	Class	Landslides	% of Landslides	Villages	% of Villages	Area
1	**Very low**	0	0.00	10	8.85	35.40
2	**Low**	4	0.26	11	9.73	36.63
3	**Moderate**	37	2.44	45	39.82	92.10
4	**High**	286	18.85	34	30.09	129.71
5	**Very high**	1190	78.44	13	11.50	224.15
Total		**1517**	**100**	**113**	**100**	**518**

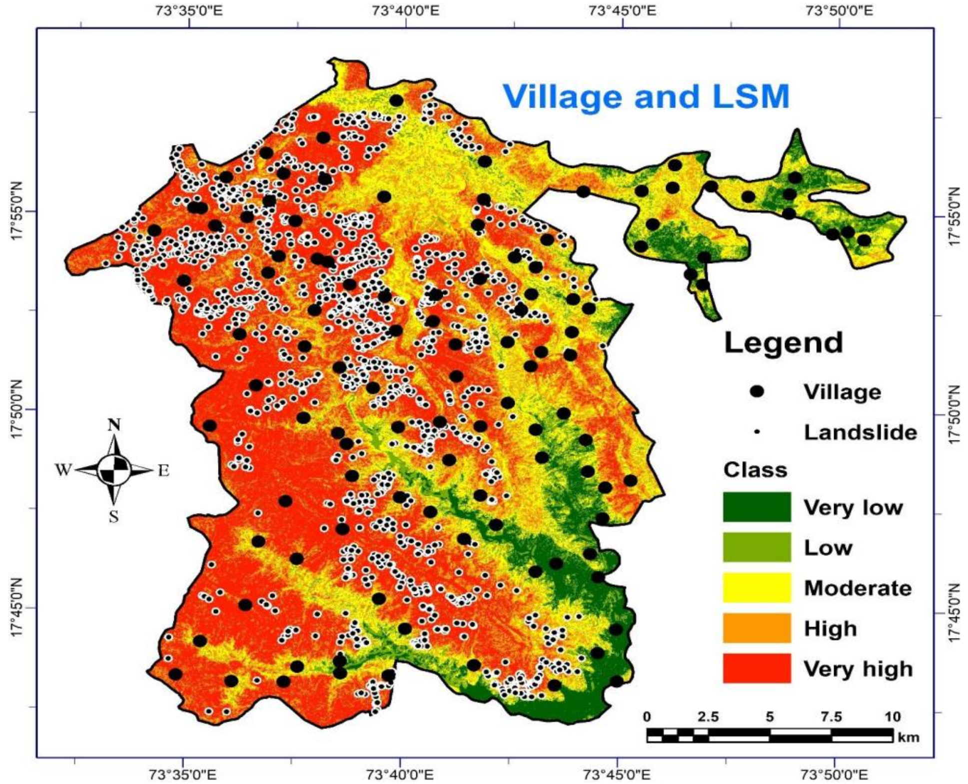


Fig. 22: Village and Landslide susceptibility map

Conclusion

Geospatial technology (RS, GIS and GPS) is an effective tool for landslide susceptibility mapping. In this study, a landslide susceptibility map has been prepared using the FR, AHP and WoM in the GIS environment. Sixteen causative factors, including slope, rainfall, relief, lithology, soil depth, soil erosion, soil texture, land use, road distance, drainage distance, drainage density, lineament distance, lineament density, aspect, temperature, seismology are selected for LSM. The weight and score are assigned to each causative factor and their subclass based on the expert's opinion, literature review and field visit. The LSM prepared based on three methods are classified into five classes: very low, low, moderate, high, and very high. The result is validated using the AUC and ROC curves. The AUC graph shows the map obtained with FR, AHP and WoM methods gives an accuracy value of 0.813, 0.754 and 0.806 respectively. This means all three models are correctly classified and test quality good and acceptable in predicting the landslide susceptibility of the study area. The derived landslide susceptibility map through FR, shows that 59.2 % of the study area is identified as high to very high susceptible, 16.7 % area is moderate and 24.1 % area is low to very susceptible. The final results of the LSM by the AHP methods indicate 61.76 % of the overall area is under high to very high susceptibility zone, 24.43 % is under moderate, and 13.81 % is under low to very low susceptibility. Whereas the LSM generated with the WoM shows that 57.62 % of the total area is under high to very high susceptibility, 18.10 % moderate, and 24.2 % is under low to very low landslide susceptibility. The final LSM shows that the relatively high susceptible (unsafe) area is 68.31%, moderately susceptible (slightly safe) area is 17.78 % and safe (low to very low) area is 13.91 %. 47 villages along with Ambenali ghat, Pasarni ghat, Kelghar ghat and Mahabaleshwar-Tapola road are identified to be in high to very high landslide susceptible zones and more than 3000 populations of these areas under the threat of landslides.

The comparison of the landslide inventory with the landslide causative factors shows that the physiographic condition (slope, relief, aspect, soil, drainage and lithology) and certain anthropogenic activities like, cutting of mountain for road network, construction work on the slope side, agriculture, and deforestation are the most influential and controlling factors of the landslide. It is noticed that, most of the landslides occurred during the monsoon rainfall and heavy rainfall is the triggering factor of the occurrence of landslides. It showed that FR (Frequency Ratio) methods are considerably better to predict the landslide susceptibility as compared to the AHP and WoM. The comparative study of all these methods are ideal for the correct mapping of the landslide susceptibility. Every year millions of tourists visit the different places in the Mahabaleshwar tehsil. Hence, the developed landslide susceptibility map is very important for decision makers, planners, and engineers to prevent and mitigation measurements for reducing losses of life and properties. It is recommended that partial or complete rehabilitation is required of some villages, to avoid all types of future development in the high to very high susceptible zones. The retaining wall and proper drainage control along the roadside will be helpful in reducing the landslide intensity. In addition, awareness of landslide causes and effects among the residents is required.

Acknowledgement

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Declaration

"I declare that the manuscript has not been published in any journal/book or proceedings or in any other publication, or offered for publication elsewhere in substantially the same or abbreviated form, either in print or electronically.

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A SPATIAL ANALYSIS OF THE DETERMINANTS OF PNEUMONIA DISEASE IN NORTH BASTAR KANKER DISTRICT, CHHATTISGARH, INDIA

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Abstract

Pneumonia is a leading cause of morbidity and mortality among the major diseases in the tribal areas of Chhattisgarh, including the North Bastar Kanker district. Pneumonia contributes about 20 per cent of infant deaths and it is the 2nd highest cause of infant mortality (after prematurity and low birth weight)in the district. This disease has been chosen to investigate at the ground level because the factors behind its origin are both physical and socio-cultural.This paper attempts to investigate the causal relationship between the natural environment and the socio-cultural environment in instances of outbreak of pneumonia disease. It also tries to find out the spatial distribution of pneumonia cases in the North Bastar Kanker district. The study is based on both primary and secondary sources of data. Primary data on pneumonia cases and their socio-cultural determinants have been collected from sample households. The elevation map prepared using a 30-metre SRTM DEM (Satellite data), and drainage and vegetation maps prepared from Landsat-8 images were used as environmental indicators. Pearson's product-moment correlation coefficient has been used to find out the relationship between socio-cultural determinants and pneumonia disease.The Odds Ratio (OR) has been measured to understand the prevalence of risk and strengths of the relationship between exposure and non-exposure groups. The prevalence of pneumonia has a notable association with physical conditions and the socio-cultural determinants such asscheduled tribes population, illiterate people, unclean household environment, low family income, not maintaining personal hygiene and nature of housing condition.

Keywords: Spatial analysis, Determinants ofPneumonia, Natural environment, Public health

Introduction

Pnuemonia is defined as a change in living tissues that endangers the survival in an environment. It is intimately related to the natural and socio-economic environment. Spatial epidemiology deals with the geographical distribution of diseases and it is a holistic approach that involves the interactions and associations between the elements of physical and socio-cultural environments.Pneumonia is one of the leading public health issues worldwide and the World Health Organization (2021) defines Pneumonia as a 'form of acute respiratory infection that affects the lungs'.Pneumonia is an acute illness that usually occurs from an infection that causes the lungs to expand and inflam, decreasing oxygen exchange and producing a cough and shortness of breath. It can be caused by a large variety of microorganisms, including bacteria, respiratory viruses, and fungi. The prevalence of these microorganisms varies widely across different geographic regions.Most severe cases of pneumonia are caused by bacteria, of which the most important are Streptococcus pneumoniae (pneumococcus) and Haemophilusinfluenza. In addition, about half of all pneumoniais caused by either *H. influenzae* or *S. pneumoniae* (Scott et al., 2008). Severe pneumonia is more common in children between two and 12 months of age compared with children between 13 and 60 months of age. The global prevalence of pneumonia is highest in the age group of 1–4 years(Kasundriya et al., 2020).Banstola and Banstola (2013) claimed that children residing in rural areas were more affected by severe pneumonia compared with children living in urban areas.Children under the age of five and older adults with a history of chronic diseases are particularly sensitive groups who are affected by pneumonia more frequently than other people. It is transmitted through direct contact with respiratory droplets of carriers. Moreover, the bacteria often spread within households and in crowded conditions. Naturally, the pneumonia mortality rate of children in rural areas is 1.6 times higher than their urban counterparts due to limited healthcare services at the community and facility levels. In terms of gender, more girls die due to Pneumonia than boys (Wahl et al., 2020).Meade and Emch, (2010) said how human behaviour interacts with environmental conditions *for preventing disease in the cultural and socio-economic contexts.Infections of pneumonia are more prevalent in the winter and early spring seasons.

Socio-cultural factors significantly impact health and well-being, making health inequalities a severe public health concern worldwide. The socio-cultural circumstance of the study area has a significant degree of inequities, influencing the well-being of people.Poor parental educational status is significantly associated with acute respiratory infection. (Ujunwa, &Ezeonu, 2014).Undernutrition, crowding, lack of exclusive breastfeeding, low degree of maternal education, limited access to secondary care and passive care–seeking behaviour are the characteristics, of poor households found by many studies, which are the common risk factors for the occurrence of acute respiratory infection (Rudanet al. 2013).Socio-cultural determinants include social group, literacy, nature of the house, food habits, personal hygiene, sanitation addiction, family size per room, family annual income, and occupation are also studied in association with acute respiratory infections.

North Bastar Kanker district, where the tribal population is highly concentrated, is one such area in the state of Chhattisgarh state. The tribes dwell in hilly forested areas where their widely dispersed rural hamlets are in such inhospitable terrain and environs wherein access to health and medical care services is challenging because of inadequate availability of transport facilities, hilly terrain, and inadequate health infrastructure.Basedon the available data on diseases from various government sources in North Bastar Kanker district, it is found that the district has poor health conditions. However, diseases that are very prevalent in the district, like malaria, pneumonia, typhoid, tuberculosis, cough, fever, diabetes mellitus, gastric ulcer, hypertension, and sickle cell anemia, Pneumonia is a life-threatening disease to children and old age groups in the district. It is also observed that there is a wide variation in the epidemiology of Pneumonia in the district in terms of prevalence rate, dominance power, and intensity of diseases. The specific environmental conditions and socio-economic factors closely associated with this disease's occurrence, in the district, are not explored much. Further, many people are affected by this disease due to lack of health awareness. Therefore, this study focuses on spatial distribution of pneumonia cases in North Bastar Kanker District and investigates the relationship between the physical and the socio-cultural environments where pneumonia is prevalent. The findings of the study have important implications for public health and also provide guidelines for health management plans for pneumonia in the tribal region.

Study Area

North Bastar Kanker district is located in the southern part of Chhattisgarh state, which shares a 5.3 per cent area of the state. It is the part of Bastar Plateau covered by the Kanker and Kotri basins. Kotri is a tributary of the IndrwatiRiver, while the Mahanadi River and its tributaries drain the Kanker basin. The total geographical area of the district is 6432.68 km^2 in which rural areas is 73 per cent area (4698.35 km2). The location of the study area extends from 19°42′ N to 20 °31 ′ N latitude and 80 °23′ Eto 81° 49 ′ E longitude. As per the forest report 2019, the district has covered 3396.01 sq. km of forest area. It is surrounded by Rajnandgaon district in the northwest, Narayanpur district in the south, Durg district in the north, Bastar district in the southeast and Dhamtari district in the northeast. It shares a boundary with Maharashtra in the west. Administratively, the district includes seven tehsils and equal numbers of CD blocks namely, Koyalibeda, Antagarh, Durgkondal, Bhanupratappur, Kanker, Charama, and Naraharpur **(Fig.1)**. It consists of 1083 villages which includes 1058 inhabitant and 25 un-inhabitant villages. As per the Census of India (2011) the total population of North Bastar Kanker district is 748941, and the decadal growth rate was 15.1 per cent during 2001-2011. The density of the population is 105 persons / km^2. The sex ratio is 1006, which is more than the state’s sex ratio of 991 females per thousand males. The literacy rate of the North Bastar Kanker district is 70.3 per cent. Most of the people in the study area are Schedule Tribe (55.3 %) and the least number of people live in urban areas (10.3%).

Sources of Data and Methodology

The present research work is based on both primary and secondary data. Primary data, on pneumonia cases and its socio-cultural determinants, have been collected from sample households surveys.Here, pneumonia risk factors have been chosen based on the previous studies.In general, the outbreak of pneumonia disease is influenced by various sociocultural factors like social groups, household environment, personal hygiene, education, income, housing condition, family size, and smoking addiction.hHence, this information have been collected from the surveys. From the literature such as Braveman and Gottlieb (2014), Alves and Oliveira (2018), Chelogo et al. (2020), Coyne et al. (2006), Mankar and Shaikh, (2021), and Nayak et al. (2012) the study assumed that the occurrence of pneumonia disease in the North Bastar Kanker district is directly or indirectly influenced by various physical determinants like elevation, natural drainage, vegetation cover, temperature and rainfall. Therefore, the elevation, drainage, and vegetation maps have been prepared using 30-metre SRTM DEM and Landsat-8 images. The data generated was used tostudy the relationship between physical and sociocultural determinates of pneumonia disease and their spatial distribution patterns in the North Bastar Kanker District.

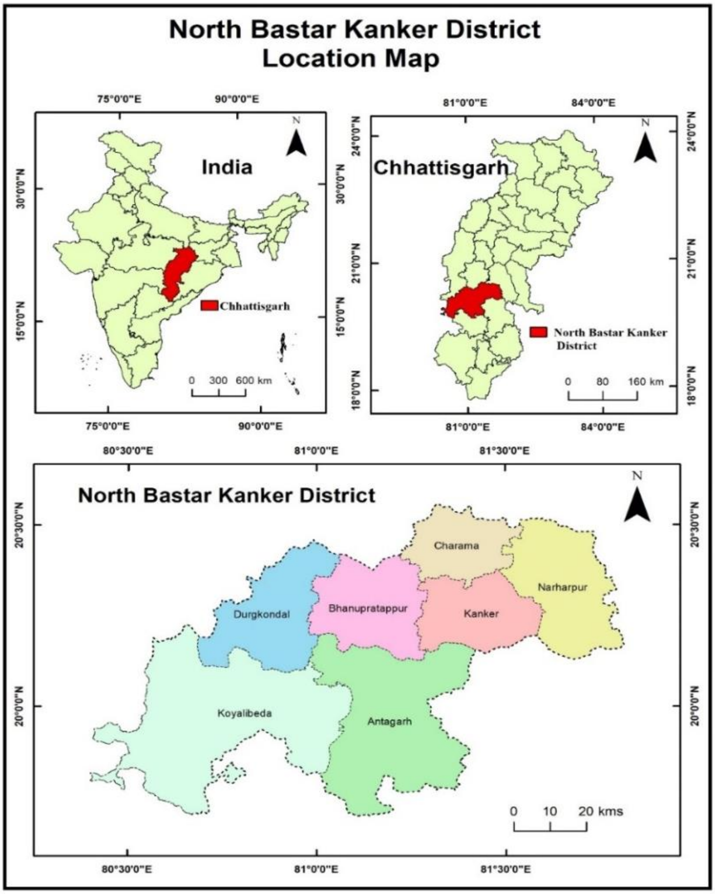


Fig. 1

The North Bastar Kanker district has seven CD blocks and 1083 villages where pneumonia is the most common disease.To investigate the factors that caused pneumonia, 21 villages, or 2 per cent of the total, were chosen randomly from each of the seven CD blocks in the North Bastar Kanker district. A random sampling method was used to select 50 per cent of the households from each sample village. A total of 4,706 samples were chosen from 983 sample households (**Figs. 2 and 3)**. A questionnaire was prepared to collect information on pneumonia cases and their contributing factors. The responses of respondents provided data of pneumonia cases and their determinants from each sampled household.In this case, reporting of pneumonia cases by the respondents related to their households during the survey is based on diagnosis and treatment by the doctors at the health centres or clinics.The patients' medical prescriptions were referred forconfirmation ofthe pneumonia.Proper consent was obtained before data collection by highlighting the district's geo-medical importance, high morbidity, and mortality.

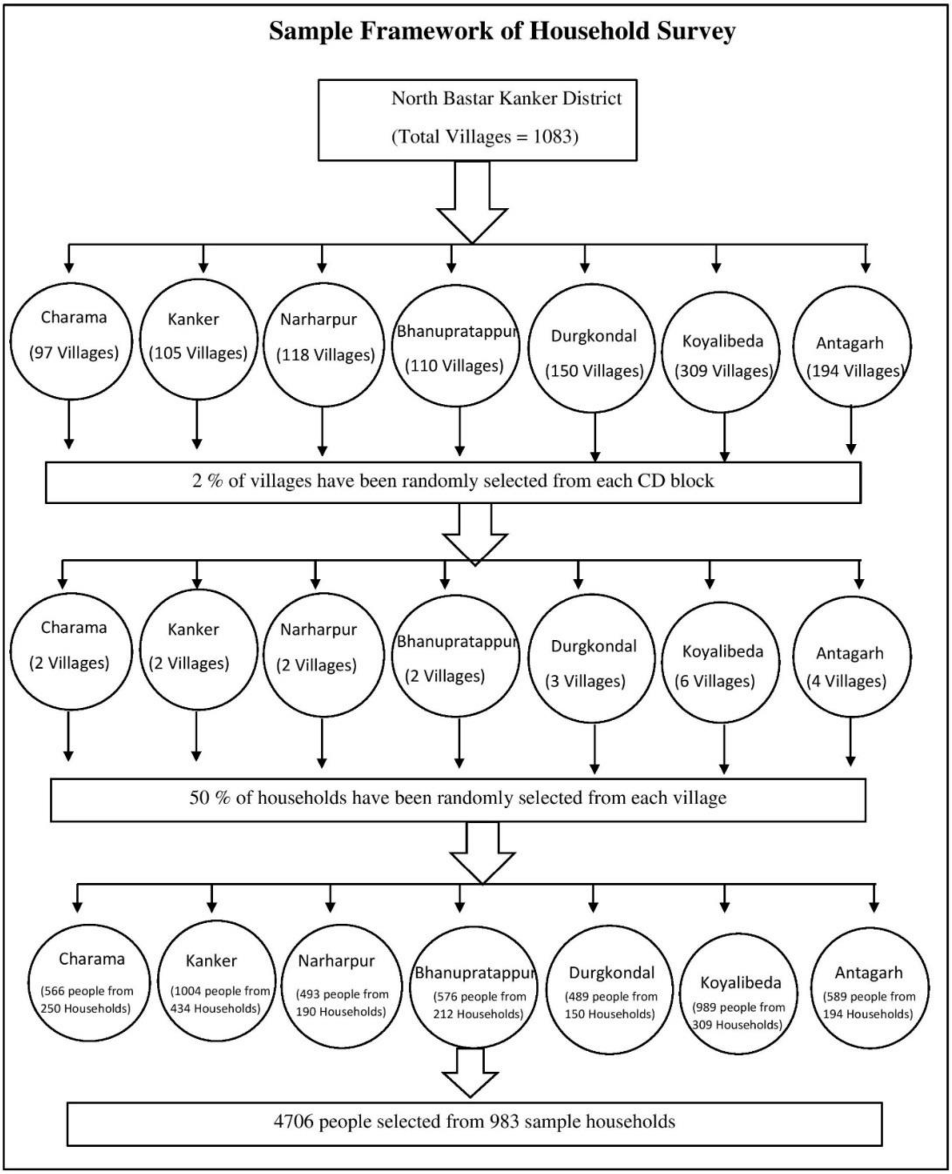
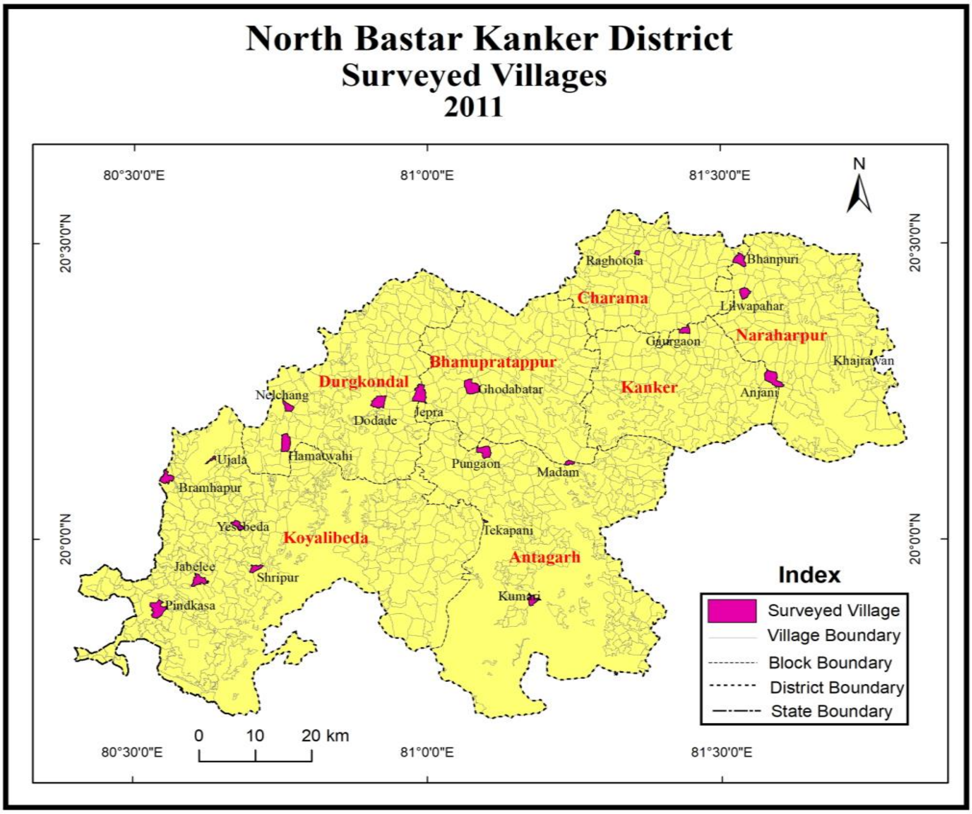


Fig. 2



Source: District Census Handbook: Uttar Bastar Kanker,2011

Fig. 3

Pearson's product-moment correlation coefficient has been used to determine the correlation between socio-economic variables and diseases. In the present study, the absolute and casual relationship between sociocultural determinates and pneumonia disease has been worked out using e linear regression model. The formula of the linear regression model is given below:

$$\mathrm{Y} = bX + a$$

Where,

Y = Dependent Variable

a = Intercept (Constant)

b = Slope of the line

X = Independent Variable

Student's t-distribution has been calculated to find the significant difference between variables. In the case-control studies, the Odds Ratio (OR) has been measured to understand the prevalence of risk and strengths of association between exposure and non-exposure groups. It is also called the '*gross product ratio'*.The Odds Ratio (OR), its standard error and 95% confidence interval, Z statistics, and significance level are calculated. It is computed using MedCalc-20.110 software. Theodds range from 0 to infinity while the Odds Ratio of 1 (OR = 1) is associated with the prevalence in the exposed group which is same as the prevalence of the unexposed group. It means there is a high degree of association between exposed and unexposed groups. However, an odds ratio is more than 1 (OR>1) indicates the prevalence of the exposed group is greater than the prevalence of the unexposed group. This shows a positive strength of association between exposed and unexposed groups and increased risk levels. On the other hand, odds ratio of less than 1 (OR<1) refers to the prevalence of disease in the exposed group which is lower than the prevalence of disease in the unexposed group. It reflects the negative strength of the association and decreases the risk. The Odds Ratio (OR) has been calculated from the following formula:

$$\text{Oddsatio (OR)} = \frac{\text{Odds that a case was exposed } (A * D)}{\text{Odds that a control was exposed } (B * C)}$$

Groups	Disease (Case)	No Disease (Control)	Total
Exposed	A	B	A + B
Unexposed	C	D	A + B
Total	A + C	B + D	A + B + C + D

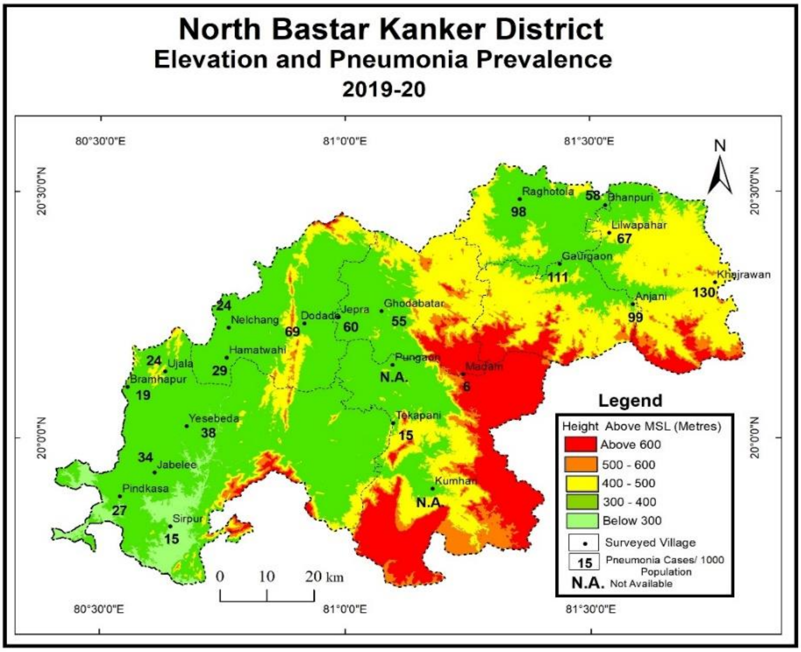
Results and Discussion

Pneumonia is a serious inflammation of the lung tissue (alveoli) caused by a wide variety of microorganisms such as viruses, fungi, bacteria, chemical exposure, or physical damage to the lungs, as well as the indirect effects of other diseases (Solehati et al., 2017). Pneumonia is a major cause of death in children all over the world, and it is one of the most common infectious diseases in the district. The caseswere prevalent in all age groups, but 31.6 per cent of pneumonia cases were only found in the below 10 years of age group. It also affectsthe old age population. Most of the children and old age groups are infected by the disease and it is also a major cause of death in this age group.Pneumonia sickness is most common in the under-5 age group (147 per thousand children) and 75–79 age group

(210 per thousand persons). Due to low immunity power, these age groups are more vulnerable to pneumonia disease.

The disease is associated with different physical factors like elevation, temperature, rainfall, soil, water bodies, and vegetation cover. In this study, the topographical features of the district influence pneumonia cases. The temperature and rainfall are closely associated with pneumonia cases. The study reveals that average monthly temperature and pneumonia cases are inversely related (r= -0.523) while the monthly amount of rainfall is positively correlated (r=0.258) with pneumonia cases. Vegetation cover is negatively correlated (r= -0.653) with the prevalence rate of pneumonia disease in the district.The northern parts of the district have a high prevalence rate of pneumonia as compared to the southern parts of the district. The existence of water bodies and water logging areas of Kanker, Narharpur and Charama blockshave a high concentration of pneumonia cases.

The maximum prevalence of pneumonia cases has been reported in the surveyed households of Anjani village (64 /1000 population), which is located 395 m above mean sea level. However, the western parts of the district arefound with low prevalence of pneumonia, and low elevation (below 340 m) whereas the eastern parts of the district are found with c higher prevalence of pneumonia and high elevation. Moreover, pneumonia patients are absent in Kumari and Pungaon villages where the elevation are 396 and 360 respectively **(Fig. 4)**. Pneumonia cases between Anjani village of Kanker block and Kumari and Pungaon sample villages of Antagarh block located at 395 metres, 396 metres and 360 metres respectively from sea level are due to their distinct location.

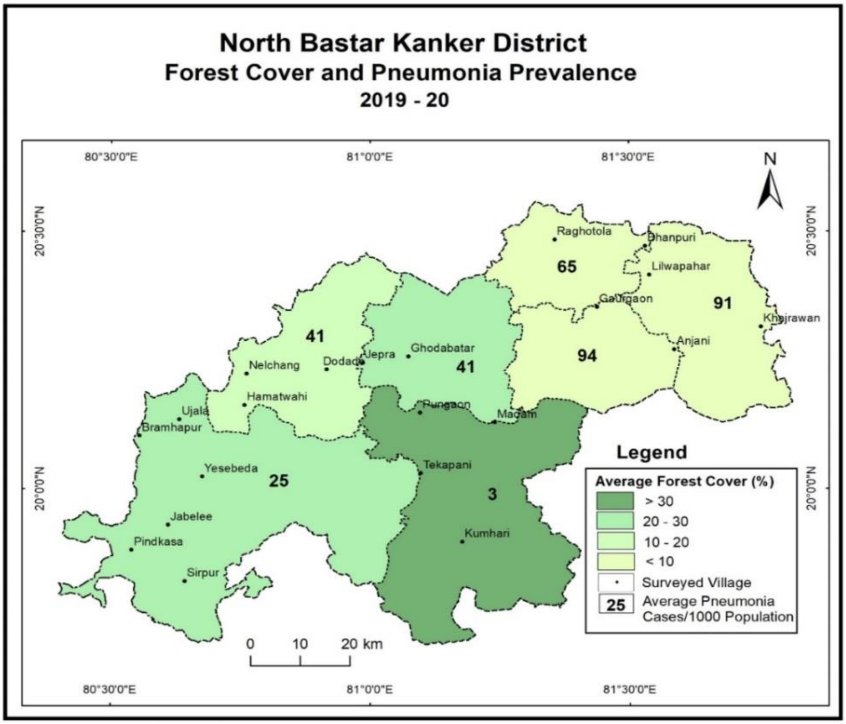


Sources:SRTM Digital Elevation Model (Satellite Data), Field Survey, 2019-20

Fig. 4

Anjani village is close to the urban area, where people are more aware of their diseases and treatment. They used to contact the primary health centre, sub-healthcentre, and private doctors, whenever they get sick. Their disease is diagnosed and made known to the patient and then treated. On the other hand, Kumari and Pungaonvillages are located in the interior, where people are least aware of their health; whenever they get sick, they go to the Baiga /Traditional healers for treatment. So they do not come to know about the reality of the disease. For this reason, they might have not reported pneumonia cases during the household survey.

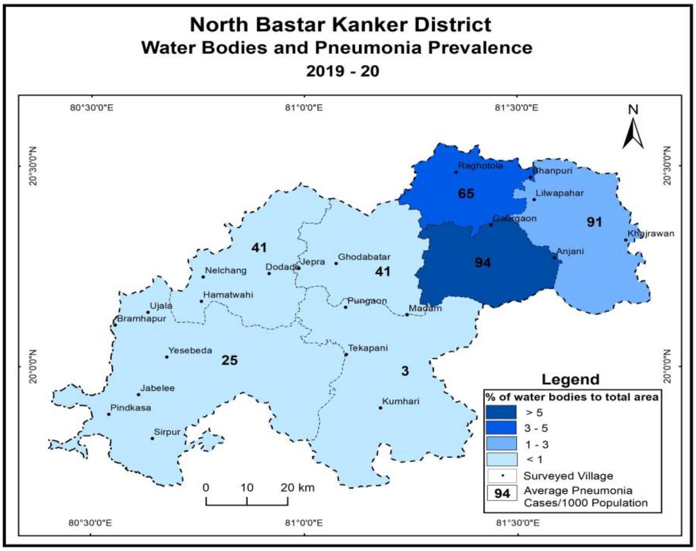
Vegetation cover is inversely related to the prevalence rate of pneumonia disease in the district. Vegetation cover can have both direct and indirect effects on pneumonia cases. It plays a crucial role in improving air quality by absorbing pollutants, thus reducing the risk of respiratory infections like pneumonia. Moreover, it can regulate the microclimate by providing shade, reducing temperature extremes, and maintaining humidity levels. This modulation of temperature and humidity can impact the survival and transmission of respiratory pathogens, potentially decreasing the likelihood of pneumonia cases.The data reveal that the lowest prevalence of pneumonia cases have been recorded in the surveyed households of Antagarh block, which has the highest percentage of vegetation cover (58.5 %). On the other hand, the northern parts of the district have a high prevalence rate of pneumonia with low vegetation cover **(Fig. 5)**.



Sources: Village Panchayat, Field Survey, 2019-20

Fig. 5

The existence of water bodies and water logging areas is one of the major influencing variables for the development of pneumonia. The existence of water bodies in tribal areas can have both positive and negative effects on the incidence of pneumonia cases. Water bodies such as rivers, and ponds can contribute to humidity and moisture in the surrounding air. High humidity levels can potentially increase the risk of respiratory infections which includes pneumonia as humidity creates an environment conducive to the growth of bacteria and viruses. Moreover, tribal areas could lack in basic sanitation practices would lead to an increased risk of vector-borne diseases like malaria, and dengue. While these diseases are not directly related to pneumonia, their presence can weaken the immune system and make individuals more susceptible to secondary respiratory infections, including pneumonia. If the water bodies are not adequately maintained, it may generate an environment that is favourable to the occurrence of various infectious diseases, such as pneumonia. It is noticeable thatthe higher concentrations of pneumonia cases are only found in the areas with a large concentration of water bodies. Moreover, tribes mainly use small water bodies, which are, in most cases, contaminated due to regular bathing, washing of dirty clothes with detergents, cleaning of animals, etc. This contaminated water causes waterborne pathogens, notably Legionella, Shigella spp., Pseudomonas aeruginosa, and Nontuberculous mycrobacteria which are responsible for pneumonia. The study finds that Kanker, Narharpur and Charama blocks have a higher concentration of pneumonia cases found, and the proportion of water bodies is high **(Fig. 6).**



Sources: Landsat - 8, Field Survey 2019-20

Fig. 6

Temperature and rainfall in the study area are closely associated with pneumonia cases. The winter months (Dec-Feb) comprise 46.5 per cent of pneumonia cases followed by the rainy months (June to August) with 36.7 per cent. On the other hand, a low number of pneumonia cases have been reported in the summer months when the temperature is maximum and rainfall is scanty. The monthly amount of rainfall is positively correlated (r=0.258) with pneumonia cases. People are more exposed to cold environments in winter and rainy months than in summer. Due to these reasons, people were more infected with pneumonia disease **(Fig. 7)**.

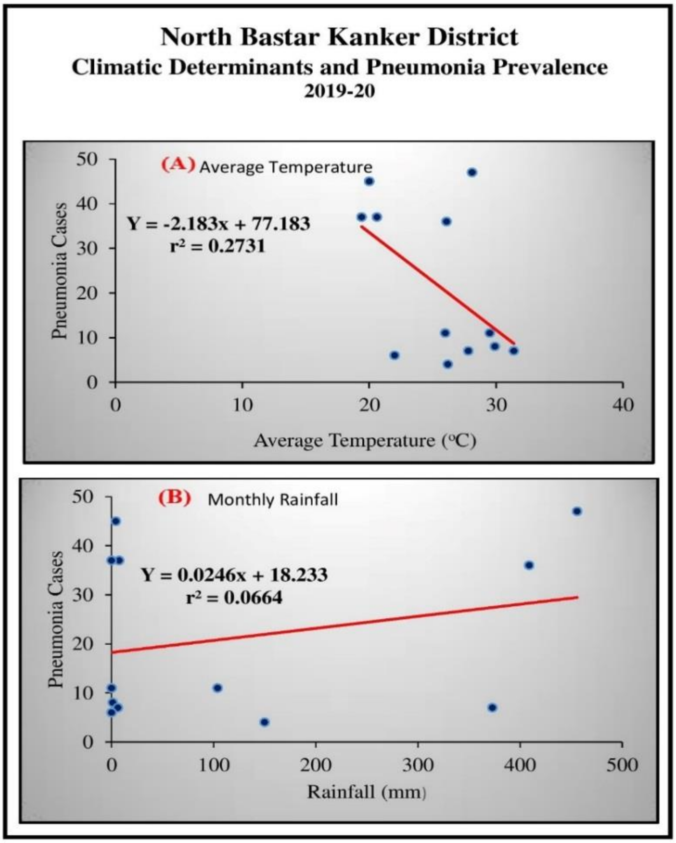


Fig. 7

Air pollution is a significant environmental variable of pneumonia outbreaks. It increases the risk of pulmonary infections. However, exposure to ambient air pollutants is associated with an increased rate of respiratory diseases such as pneumonia, especially in younger children (Brunekreef and Holgate, 2002). Poor ambient air quality can adversely affect the respiratory system and damage the human body's natural defences against bacteria and viruses. As a result, pneumonia disease is more prevalent where the air quality is poor. However, in the current study, North Bastar Kanker is a tribal district of Chhattisgarh that covers 47.42 per cent of forested area. High forest coverage areas have shown good air quality. Due to high forest coverage, the North Bastar Kanker district is the most convenient place for health. The ambient air quality (AAQ) values are below 50 and consistent throughout the year. It displays good air quality that is suitable for respiratory health. The study reveals that the ambient air quality of the district is not at risk of an outbreak of pneumonia disease.

The outbreak of pneumonia disease is also influenced by socio-cultural factors like social groups, household environment, personal hygiene, education, income, housing condition, family size, and smoking addiction. In the study area, the scheduled tribe population is largely affected by pneumonia disease compared to other social groups.Due to a lack of knowledge, high levels of illiteracy, low family income, and an unhealthy lifestyle, the scheduled tribe population is more vulnerable than other social groups in the district. The regression Coefficient (b) value shows that one unit increase in the scheduled tribe population has resulted in 0.664 unit increase in pneumonia cases **(Table 1)**. However, the coefficient (r^2) value indicates that 41 per cent of the change in disease occurrence can be explained by the scheduled tribe population **(Fig. 8.A)**. The Odds Ratio (OR = 0.688 point) shows that the prevalence rate of pneumonia cases in the scheduled tribe population is lower than that of other social groups in the district **(Table 2)**.

Table 1 North Bastar Kanker District: Relationship between Socio-cultural Determinants and Pneumonia Cases, 2019-20

Product Moment Correlation Coefficient			Student's t-Distribution					Regression Analysis		
X	Y	r	Calculated t value	Tabulated 't' Value		Sig / Insig	H_o / H_1	a	b	r^2
				0.05	0.01					
Scheduled Tribes Population (%)	Pneumonia Cases (%)	0.640	3.727	2.093	2.861	Sig	H_1	10.178	0.664	0.41
Unclean Household Envt. (%)		0.239	1.100			Insig	H_o	3.519	0.911	0.057
People maintain Personal hygiene (%)		0.326	1.542			Insig	H_o	30.808	0.704	0.107
Illiterate People (%)		0.307	1.443			Insig	H_o	9.877	1.102	0.095
Low HouseholdIncome (%)		0.572	3.119			Sig	H_1	4.31	0.894	0.328
Kutcha Houses (%)		0.554	2.976			Sig	H_1	-32.24	1.289	0.307
Households living More than 4 Persons per Room (%)		0.297	1.391			Insig	H_o	25.425	0.911	0.088
People Consumed Tobacco (%)		0.458	2.306			Sig	H_1	0.842	1.282	0.210

Source: Based on Field Survey, 2019-20

An unclean household environment can have a significant impact on the occurrence and severity of pneumonia cases. Unclean environments can harbour a higher number of bacteria, viruses, and other microorganisms. Exposure to these pathogens, especially in crowded or poorly ventilated spaces, increases the chances of respiratory infections such as pneumonia. Here, the unclean household environment is positively related to pneumonia cases. The surveyed North Bastar Kanker district households have found 9.4 per cent of pneumonia cases in 31.6 percent of unclean households. The coefficient determination (r^2) shows that a weak relationship was found between these two variables **(Fig. 8.B)**. The odds ratio (OR= 1.462 point) also explains that an unclean household environment is not a risk for pneumonia cases in the district. On the other hand, an unhealthy lifestyle, and not maintaining personal hygiene are the risk factors for outbreaks of pneumonia disease in this tribal district. The regression coefficient (b) value also shows that per unit change in the population which does not maintain personal hygiene has caused rise in pneumonia cases (30.8 point). However, coefficient determination (r^2) shows a weak relationship between these variables **(Fig. 8.C)**. The Odds Ratio (OR= 2.835 point) reveals that people who do not maintain personal hygiene have a 2.88 times greater chance of risk of pneumonia than those who maintain personal hygiene.

Table 2 North Bastar Kanker District: Socio-cultural Determinants of Pneumonia and Odds Ratio, 2019-20

Socio-cultural variables	Disease (Case)	No Disease (Control)	Odds Ratio (OR)	95 % confidence interval		Z Value	Level of Significance (P value)
				Lower Limit	Upper Limit		
Social Group							
Scheduled Tribes	142	2867	0.688	0.534	0.887	2.888	0.0039
Other Social Groups	114	1583					
Total	256	4450					
Household Environment							
Unclean	24	287	1.462	0.946	2.26	1.708	0.0876
Clean	232	4163					
Total	256	4450					
Personal Hygiene							
Not Maintain	158	1548	2.835	2.188	3.673	7.888	<0.0001
Maintain	98	2902					
Total	256	4450					
Education							
Illiterate	78	1095	1.736	1.296	2.324	3.701	0.0002
Literate	123	2997					
Total	201	4092					
Household Income (Rs.)							
< 20000 / Year	41	652	1.111	0.787	1.577	0.599	0.549
> 20000 / year	215	3798					
Total	256	4450					
Nature of House							
Kutcha	212	3520	1.273	0.913	1.775	1.422	0.155
Pucca	44	930					
Total	256	4450					
Family size / Room							
Above 4 Members / Room	19	401	0.81	0.543	1.415	0.866	0.387
Less 4 Members / Room	237	4049					
Total	256	4450					
Consumed Tobacco							
Yes	51	469	2.112	1.532	2.912	4.56	<0.0001
No	205	3981					
Total	256	4450					

Source: Based on Field Survey, 2019-20

Lack of maternal education is significantly associated with the occurrence of pneumonia. Educated mothers recognize the signs and symptoms of pneumonia early and access health care earlier so their children have a better outcome than others (Tiewsohet al, 2009). Illiteracy is often associated with lower socio-economic status. Individuals from lower socio-economic backgrounds may live in overcrowded, poorly ventilated, and unclean households. Such environments promote the growth of bacteria and viruses, increasing the risk of pneumonia transmission. In the present discussion, Illiterate people comprise 30.5 per cent of pneumonia cases due to a lack of awareness about different responsible factors for the outbreak of pneumonia disease. Illiterate people are positively related to pneumonia cases, but coefficient determination (r2) highlights a very weak relationship between illiterate people and pneumonia cases **(Fig. 8.D)**. Moreover, the odds ratio (OR= 1.736 point) highlights that the prevalence of pneumonia is 1.74 times greater chance of risk in illiterate people than in literate people. On the other hand, unclean households are vulnerable to pneumonia outbreaks.Based on the study, people with weaker socio-economic status, illiteracy, living in dirty houses, and neglecting to maintain personal hygiene are all at a greater risk for an outbreak of pneumonia**(Table 2)**.It has been observed that residents of Kutcha houses account for 82.8 per cent of the total pneumonia cases. Moreover, People with poor socio-economic backgrounds reside in kutcha houses. In addition, 74.8 per cent of people live in kutcha houses with insufficient ventilation that restricts fresh air flow.This leads to an increase in the chances of respiratory infections like pneumonia.

Family income is directly related to pneumonia cases. Socio-economic conditions of the family depend on the income of the family. It helps access better healthcare services and a good lifestyle.Low family income and pneumonia cases are positively related. The regression coefficient (b) value highlights that per unit change in the population belonging to the low-income group has resulted in an increase of 0.894 unit in pneumonia cases. Furthermore, coefficient determination (r^2) shows that 32.8 per cent change in pneumonia patients is explained by people of the low-income group **(Fig. 8.E)**. On the other hand odds ratio (OR= 1.111 point) displays that the low-income group is at 1.11 times greater risk of pneumonia than the family income of above Rs. 20000/year.

The housing condition of the family is directly related to pneumonia cases. Environmental risk factors, and children living in kutcha houses has an increased risk of severe pneumonia. This corroborates the finding of Banstola &Banstola (2013), “Kutcha houses are typically built by the poor and are a recognized risk factor for pneumonia”. In tribal communities, kutcha houses might be small and overcrowded, with several family members living in a confined space. Crowding facilitates the spread of respiratory infections which can easily spread to the near ones.. People having kutcha houses comprise 78.9 per cent of pneumonia cases whereas poor ventilation system causes high humidity, allowing for the development of bacteria and increasing the prevalence of pneumonia. Based on observations, three-quarters of the population lives in kutcha houses, which are at high risk of being affected by a pneumonia outbreak. Moreover, 8.5 per cent of households are overcrowded (more than 4 persons/room) which occupies 23.8 per cent of pneumonia cases.

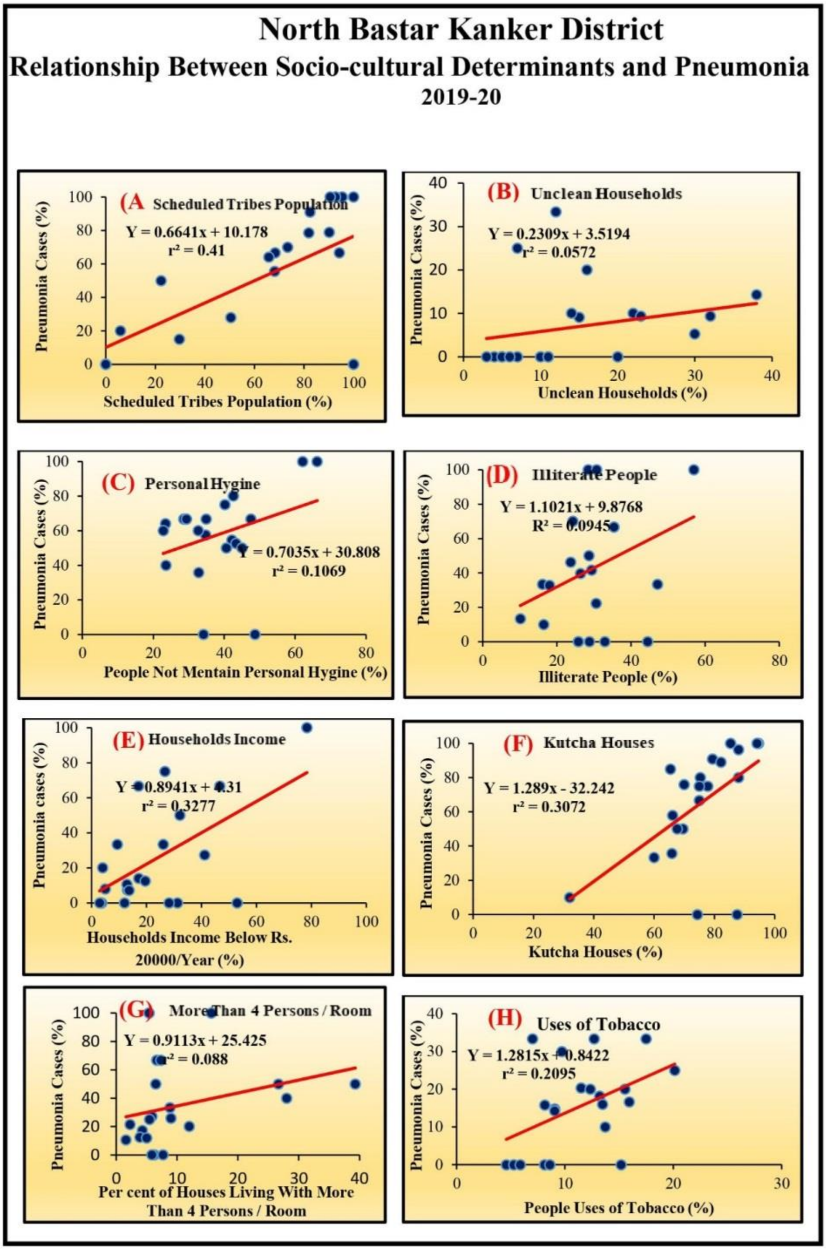


Fig. 8

Here, per cent of kutcha houses and the prevalance of pneumonia cases are positively related. The coefficient determination (r^2) value also indicates that 30.7 per cent total change in pneumonia patients is explained by residential kutcha houses in the surveyed households in the district **(Fig. 8.F)**. The Odds Ratio (OR= 1.273 point) highlights that people having kutcha houses have a 1.27 times greater chance of risk than people residing in pucca houses. It is an infectious disease so more number of family members living together in small number of rooms are at risk of transmitting bacteria and viruses of pneumonia disease. The house has insufficient ventilation and lighting due to unhealthy environmental conditions, resulting in high humidity, which allows for the breeding and transmission of diseases caused by bacteria, viruses, and fungi (Kurniasih et al., 2015). Here, family members living together with more than 4 persons per room share 23.8 per cent of pneumonia cases in the 8.5 per cent households. It is also positively correlated (r= 0.297) with pneumonia cases **(Fig. 8.G)**. Although, the odds ratio (OR) is 0.81 point, it shows that size of family has (large or small in reference to living room / bed room) has nothing to do with pneumonia cases.

Data show that pneumonia disease is dangerous for people who consume tobacco. Excessively consumed tobacco can damage the human body's natural defence mechanism against bacteria and viruses. As a result, people have a greater chance of being infected by pneumonia disease. Here, per cent of people use tobacco, and pneumonia cases are positively correlated (r= 0.458) and statistically significant at 0.05 level. The coefficient of determination (r^2) highlights that a weak relation between the use of tobacco and pneumonia cases, and 21 per cent of the change in pneumonia cases can be explained by people who have consumed tobacco **(Fig. 8.H)**. But in case of tobacco consumtions, a much higher odds ratio (2.112 point) reveals that the prevalence of pneumonia cases is 2.1 times greater amongst the tobacco consumers than that of the non tobacco consumers.

It is further observed that 55.5 per cent of pneumonia cases have been reported from the scheduled tribe population. This is also reflected in a positive correlation (r=0.64) between the share of tribal population and the prevalence of pneumonia cases; the relationship is significant at p 0.01. The unclean household environment is also positively correlated (r= 0.239) with pneumonia cases. Similarly, people not maintaining personal hygiene and pneumonia cases are positively correlated (r= 0.326). Illiterate people are more prone to pneumonia cases; the prevalence of pneumonia cases is 1.74 times higher among the illiterate people than that of literate people. It is observed that 14.8 per cent of pneumonia cases are found in 20.9 per cent of households in which families have monthly income below Rs. 20000 per year. Share of kutcha houses and occurrence of pneumonia cases are also positively correlated (r=0.554) where residing people residing in Kutcha houses have a 1.27 times greater chance of getting affected by pneumonia than those in pucca houses.

Conclusion

The study reveals that physical and socio-cultural factors are directly related to the prevalance of pneumonia in the study area. The northern parts of the district have a high prevalence rate of pneumonia compared to the southern parts. The study reveals that average monthly temperature and pneumonia cases are inversely related (r= -0.523), while the monthly amount of rainfall is positively correlated (r=0.258) with pneumonia cases. Vegetation cover is negatively correlated (r= -0.653) with the district's prevalence rate of pneumonia disease.The existence of water bodies and water logging areas of Kanker, Narharpur and Charama blockshave a high concentration of pneumonia cases. Socio-cultural determinants like scheduled tribes population, illiterate people, unclean household environment, low family income, not maintaining personal hygiene, and nature of housing condition (Kutcha house)are positively associated with pneumonia disease. The Odds Ratio reveals that an unclean household environment, illiteracy rate, and not maintaining personal hygiene are the main risk factors for the occurrence of pneumonia disease. The study suggests that increasing awareness about personal health and hygiene, equal access to health care services, increased literacy rate, and different health programs would reduce the magnitude of pneumonia cases in the district.

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A COMPARATIVE STUDY ON GROWTH AND INSTABILITY OF PRODUCTION AND PRODUCTIVITY OF RICE IN INDIA AND THAILAND

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Abstract

The majority of the people in both India and Thailand are directly or indirectly related to farming activities. Both nations are among the highest producers of rice of the world. The production of rice in India has been increasing since 2013-14 while in Thailand it has been decreasing since the last decade. Moreover, Thailand has been the highest exporter of rice in the world, but since 2013-14 the export of rice from Thailand has been decreasing. However, the export of rice has been increasing from India during the same period. In this research paper, we aim to compare the pattern of growth in the area used for production, production and productivity of rice in both nations. The study also examines the instability of growth of production, productivity, export and import. The finding shows that the change in climatic conditions has been the major factor for the decrease in production and productivity of rice in Thailand, while in India, the extensive use of fertilizers and pesticides results in increase of production of rice.

Keywords: Production, Productivity, Growth rate, CAGR, Instability.

Introduction

Rice (*Oryzasativa*) being one of the staple foods for more than half of world population provides global food security (Thongrattana, 2012). Rice contributes around 41 per cent of total food grains production and nearly 58 per cent households are directly or indirectly associated with agriculture (Bandumula *et al.,* 2022). Though, India is the second largest producers of rice in the world after China while its productivity stands at 2578 kg per ha (Skand *et al*., 2020). India is the largest exporter of rice in the world followed by Thailand and Vietnam. Although with the increase in innovations of technology the production of rice has increased in the last two decades but instability in production increased distress to the cultivators (Singh *et al*., 2021) and this instability in production leads to the fluctuations of the price in the market (Jainuddin *et al.,* 2017). Also the land reform operation has structurally impacted positively in growth of rice production in various states of the India (Prasanna *et al*., 2009). But post the green revolution, the use of fertilizers has increased and adversely affected the fertility of the soil and altered the micro biota of the soil (Nelson *et al*., 2019). (Singh et.al, 2021) in their studies found that the production and productivity of rice in India is influenced by climatic conditions. The production of rice has a significance effect with the use of fertilizers. Lakshmi (2009) in her research work found change in the production of rice in the area treated with fertilizers. However, excessive use of fertilizers caused the imbalance in the productivity (Jayanti, 2012). (Widjajanto *et.al*, 2021) studied the use of silicate fertilizer on namely Pandanwangi and Mentiksusu rice. But it found that it has no effect on its growth and productivity. Moreover, the rice production in the state is highly dependable on rain fed area and lack of fertilizer management system is the main cause of instability in growth of rice productivity (Daimary and Barman, 2023). Majority of the production of rice are from the Asian nations. But Thailand was the largest exporter of rice of the world since early 2000's. However, since 2013-14 the export of rice from Thailand has been decreasing and took over by India.

From 1960 to 2000, the Govt. of Thailand allocated 35. 74 % of all agricultural research budgets for which a turning point can be seen in the improvement of rice production since 1966 in Thailand (Jaroensathapornkul, 2007). The government policies and supporting production of rice through Green Revolution initiatives and commercialization has embedded into the chain of business both domestically and internationally and became the top exporter of rice of the world (Kerdnoi et. al, 2014). The efficiency and effectiveness of rice production impacts the policy decisions in Thailand (Sachchamarga and Williams, 2004). Kawasaki and Herath (2011) predicted the productivity of Suphanburi rice, Sanpathong rice, and Chainat rice varieties in North Eastern part of Thailand and these varieties will appear to decrease during the years 2050-2059 and 2090-2099, which was presumably due to unpredictability of climatic conditions. But Chang rice variety was considered to maintain rice productivity under future climatic conditions. Hom Mali rice of Thailand comprises eighty per cent of total rice exported from Thailand (Changkid, 2017).

In the last decade the production of rice in Thailand has been decreasing (Table 3) while a spike has been seen in case of India (Table 1). A comparative study was carried out to determine the pattern of production and instability in the export and import of rice in both the nations. The study also aims in analysing the reasons for growth in productivity of rice as well as its export in India, moreover, for decreasing in export of rice from Thailand and losing its spot as a rice exporter nation. However, both nations have seen increase in import of rice and so we aim to explore the reasons behind it.

Materials and Methods

The secondary data of area, production, productivity, export and import used for analysing are collected from Food and Agriculture Organization (FAO) of United Nations

Organization from 2011 to 2021. Also the data and information are collected from the books, newspapers, research articles published in various journals and thesis. The collected data are used to assess the growth performance and instability of production of rice in India and Thailand.

Table 1: Area, Production and productivity of Rice in India

Year	Area	Production	Productivity
2011	44010000	157900000	35878
2012	42754000	157800000	36909
2013	44135950	159200000	36070
2014	44110000	157200000	35638
2015	43390000	156540000	36077
2016	43190000	163700000	37902
2017	43774070	168500000	38493
2018	44156450	174716730	39568
2019	43780000	177645000	40577
2020	45000000	178305000	39623
2021	46379000	195425000	42137

Source: Food and Agriculture Organization of United Nations; Area=in hectare, Production=in tonnes, Productivity= in hg/ha

Compound Annual Growth Rate (CAGR) calculates the average annual growth rate over a specific period of time. CAGR is used to estimate the growth analysis in area, production, productivity, export and import (Rani et. al., 2017). The CAGR is estimated using the following formula.

$$\text{CAGR (\%)} = (\text{Anti log } b-1) \times 100$$

Where, b is the regression coefficient.

The deviation in the growth of area, production and productivity of rice refers the instability and so the coefficient of variations (C.V) is used as tool to measure its instability. But the simple coefficient of variation over estimates the instability in time series data. The Cuddy –Della Valle Index shows the better results of instability (Y Manohar et. al, 2017). The formula to measure Cuddy- Della Valle Index is as follows:

$$\text{Cuddy- Della Valle Instability Index (\%)} = \text{C.V} \times \sqrt{(1-R^2)}$$

$$\text{And for CV} = \frac{\textit{Standard deviation of the variable}}{\textit{Mean of the Variable}} \times 100$$

Where, R^2 is the coefficient of determination of the time series.

The Pearson Co-efficient of correlation is calculated in order to find out the nature of relationship among the variables taken for the study.

Results and Discussions

The area used for production, its total production and productivity is shown in Table 1.

The Table 2 indicates about the percentage change in area, production and productivity of rice in India with respect to its previous year. The area used for production in India increased at the rate of 3.23 per cent in 2013 which is the highest in the last decade. It might be because of increase in global demand and domestic consumption. While it decrease for the next three years in India. But an increase in area of production can be seen in 2017 which increases at the rate of 1.35 per cent. Moreover, there is an increase of 3.064 per cent in 2021 from 2020 in the area used for production.

Table 2: Year-to-Year change in Area, Production and Productivity of rice in India

Year	Area(%)	Production(%)	Productivity(%)
2011	----	-----	-----
2012	-2.854	-0.063	2.874
2013	3.232	0.887	-2.273
2014	-0.059	-1.256	-1.198
2015	-1.632	-0.420	1.232
2016	-0.461	4.574	5.059
2017	1.352	2.932	1.559
2018	0.874	3.689	2.793
2019	-0.853	1.676	2.550
2020	2.787	0.372	-2.351
2021	3.064	9.602	6.345

Table 3: Area, Production and Productivity of Rice in Thailand

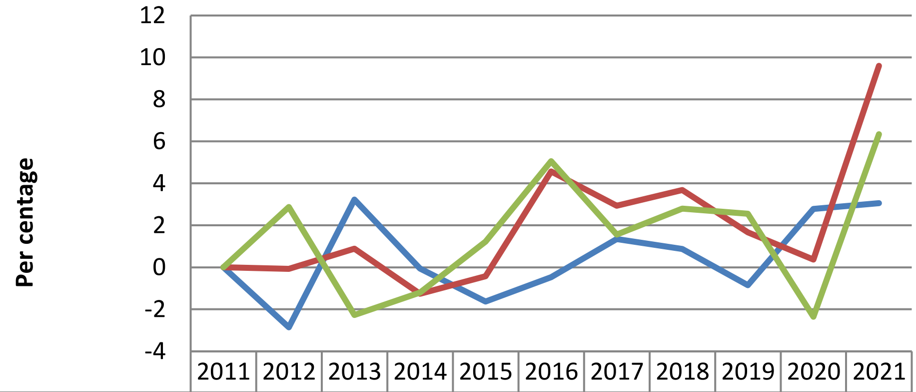
Year	Area	Production	Productivity
2011	11956638	38102720	31867
2012	11956781	38100189	31865
2013	11684315	36762277	31463
2014	10664923	32620160	30586
2015	9717975	27702191	28506
2016	10734279	31857000	29678
2017	10719698	32898903	30690
2018	10647941	32348114	30380
2019	9812614	28617948	29164
2020	10401653	30231025	29064
2021	11244000	33582000	29867

Source: Food and Agriculture Organization of United Nations; Area=in hectare, Production=in tonnes, Productivity= in hg/ha

The production of rice also increased from 0.37 per cent to 9.60 per cent in 2021. The increase in production of rice in 2021 results in increase in its productivity to 6.34 per cent from -2.35 per cent.

While there is a marginal increase in the area used for production in 2012 but it decreases for next consecutive years till 2015 in Thailand shown in Table 4. However, in the last decade the area used for production increases at 10.45 per cent in 2016 which lead to increase in production of rice to 14.99 per cent with respect to its previous year. It may be due to unpredictable climatic changes and rise in water sea level that leads to instability in the production. Moreover, the productivity of rice increased to 2.76 per cent from -0.34 per cent in 2021.

Figure 1: Year-to-Year change in Area, Production and Productivity of rice in India



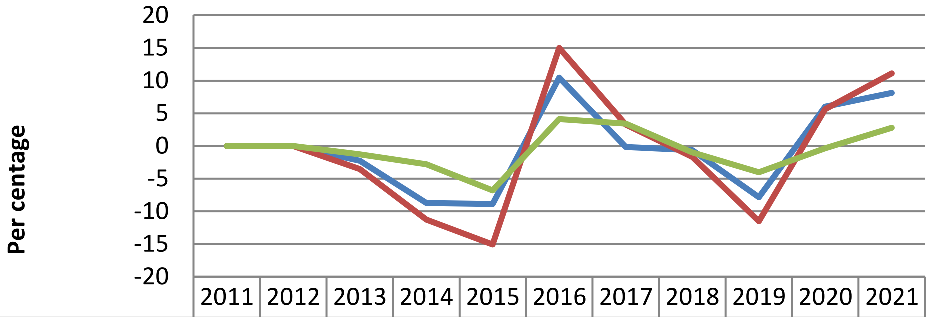
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Area(%)	0	-2.85	3.232	-0.06	-1.63	-0.46	1.352	0.874	-0.85	2.787	3.064
Production (%)	0	-0.06	0.887	-1.26	-0.42	4.574	2.932	3.689	1.676	0.372	9.602
Productivity (%)	0	2.874	-2.27	-1.2	1.232	5.059	1.559	2.793	2.55	-2.35	6.345

Table 4: Year-to-Year change in Area, Production and Productivity of rice in Thailand

Year	Area (%)	Production (%)	Productivity (%)
2011	----	----	----
2012	0.001	-0.007	-0.006
2013	-2.279	-3.512	-1.262
2014	-8.724	-11.267	-2.787
2015	-8.879	-15.076	-6.800
2016	10.458	14.998	4.111
2017	-0.136	3.271	3.410
2018	-0.669	-1.674	-1.010
2019	-7.845	-11.531	-4.003
2020	6.003	5.637	-0.343
2021	8.098	11.085	2.763

The Table 5 shows the compound annual growth rate in both India and Thailand. The growth rate of area use for cultivation increases at the rate of 0.41 per cent over the period of time in India. But the area in Thailand decreases at the rate of 1.16 per cent during the same period. The area used for cultivation in India is fluctuating with a marginal increase in the last decade. The reason for this marginal increase is may be due to shifting of farmers to different cash crops and fetching higher income opportunities through export opportunities. While majority of rice in Thailand is cultivated in North-East region of Thailand (Kawasaki and Herath, 2011). The region is cultivated in rain fed conditions and due to erratic climatic conditions and heavy flooding often results in making unfavourable conditions for the cultivation of crops.(Kawasaki and Herath, 2011 ; Anuchiracheeva and Pinkaew, 2009).

Figure 2: Year-to-Year change in Area, Production and Productivity of rice in Thailand



	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Area (%)	0	0.001	-2.28	-8.72	-8.88	10.46	-0.14	-0.67	-7.85	6.003	8.098
Production (%)	0	-0.01	-3.51	-11.3	-15.1	15	3.271	-1.67	-11.5	5.637	11.09
Productivity (%)	0	-0.01	-1.26	-2.79	-6.8	4.111	3.41	-1.01	-4	-0.34	2.763

Table 5: CAGR of Area, Production and Productivity of Rice in India and Thailand

Country	Area	Production	Productivity
India	0.41**	1.99*	1.57*
Thailand	-1.16***	-1.93**	-0.77**

*, **, *** indicates level of significance at 1%, 5% and 10% level of significance respectively

The production of rice in India increases at the rate of 1.99 per cent over the years while Thailand shows a decrease at the rate of 1.93 per cent over the same period. The increase in use of HYV seeds and extensive use of fertilizers and pesticides results in positive growth in production of rice in India. While in Thailand due to change in climatic conditions, change in patterns of rainfall and lack of irrigation facilities in north-east Thailand, and also increase in sea level that brings soil salinity impact the production of rice.

With the increase in production in India, the productivity also increases at the rate of 1.57 per cent over the same period while in Thailand its productivity decreases at the rate of 0.77 per cent. The analysis indicates that with the marginal increase in area used for production and its 1.99 per cent increase over the years in production has positive impact in the overall increase of its productivity in India. While in Thailand increase in drought leads to decrease in its productivity.

The instability of area used for production in India (1.79) is comparatively much more stable than that of Thailand (6.26) as indicated in Table 6. The erratic climatic change in Thailand has adversely affected the area used for production. The data also shows instability in production of rice in India (3.25) and that of Thailand is 8.89 which indicate higher instability in the production of rice since 2011 in the country. This is because of change is government policies since 2014-15 and direct payment to rice producers with other input subsidies affected the income of the farmers overall (Pilavong, 2012). The policy was not able to achieve the purpose effectively to support producers' income and rather distort the market because somebody other than rice producers has to bear the burden at the end of the day (Kobayashi, et.al, 2016). But overall the instability in productivity of rice in both the nations is relatively less than its rate of production. While the instability in the productivity of rice India at the rate of 2.49 (India) and that of Thailand at 2.90.

Table 6: Instability indices of area, production, productivity of rice in India and Thailand

Country	Area		Production		Productivity	
	CV	CDVI	CV	CDVI	CV	CDVI
India	2.19	1.79	7.40	3.25	5.73	2.49
Thailand	7.10	6.26	10.64	8.89	3.78	2.90

Table 7: Export and Import of Rice in India and Thailand

Year	Export		Import	
	India	Thailand	India	Thailand
2011	5004280	8905751	1093	5269
2012	10470312	10671194	539	10630
2013	11300105	6704304	1323	25742
2014	11092731	6787796	1727	21306
2015	10953469	10951021	1308	6964
2016	9869281	9781624	995	26875
2017	12060844	9870079	1874	14627
2018	11579628	11616113	6502	19500
2019	9731549	11073000	5753	14946
2020	14462834	7751119	4435	29637
2021	21034658	6065097	3650	25211

Source: Food and Agriculture Organization of United Nations; Export=in tonnes, Import=in tonnes

Table 8: Year-to-Year change in Export and Import of Rice in India and Thailand

Year	Export (%)		Import (%)	
	India	Thailand	India	Thailand
2011	----	----	----	----
2012	109.227	19.824	-50.686	101.746
2013	7.925	-37.174	145.455	142.164
2014	-1.835	1.245	30.537	-17.233
2015	-1.255	61.334	-24.262	-67.314
2016	-9.898	-10.678	-23.930	285.913
2017	22.206	0.904	88.342	-45.574
2018	-3.990	17.690	246.958	33.315
2019	-15.960	-4.676	-11.520	-23.354
2020	48.618	-30.000	-22.910	98.294
2021	45.439	-21.752	-17.700	-14.934

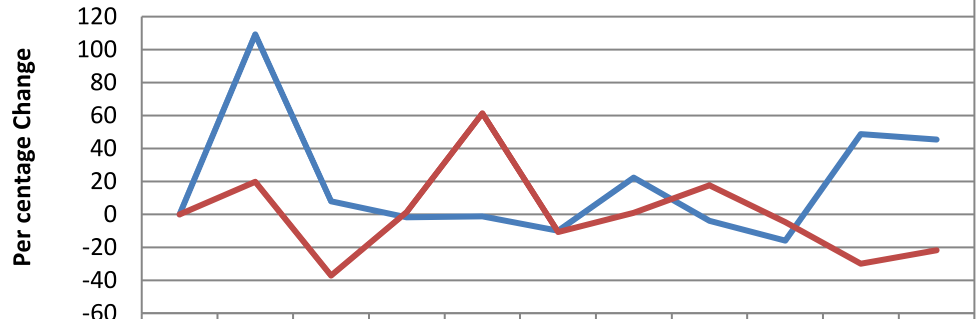
Table 9: CAGR of Export and Import of Rice in India and Thailand

Country	Export	Import
India	7.74**	22.01*
Thailand	-0.65	10.37***

*, **, *** indicates level of significance at 1%, 5% and 10% level of significance respectively

The export of rice from India increased to 109.22 per cent in 2012 while in the same year the import of rice in Thailand increased to 101.74 per cent. However, in the following year the import of rice in India increased to 145.45 per cent followed by Thailand to 142.16 per cent. The above data shows that export of rice from India increases to 48.61 per cent and 45.43 per cent in 2020 and 2021 respectively while for Thailand its export decreases since 2019.

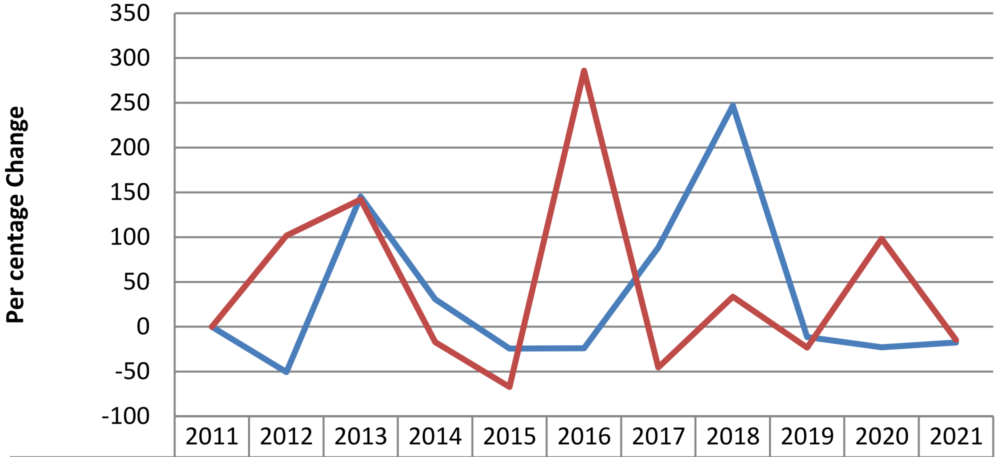
Figure 3: Year-to-Year percentage change in Export of Rice in India and Thailand



	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
India	0	109.23	7.925	-1.835	-1.255	-9.898	22.206	-3.99	-15.96	48.618	45.439
Thailand	0	19.824	-37.17	1.245	61.334	-10.68	0.904	17.69	-4.676	-30	-21.75

Since 2011 the export of rice in India has been increasing at the rate of 7.74 per cent. This is because of high domestic stocks and comparative cost advantage against other exporting nations allowed India to offer at high discount over the years and that leads to increase in export. However, the import of rice in India is higher than its export due to increase in its domestic consumption. While the export of rice from Thailand have been decreasing at the rate of 0.65 per cent over the years. Droughts and unpredictable rainfall in the tropics where agricultural activities are practiced becomes vulnerable to temperature rise and leads to low productivity in the region (Kawasaki and Herath, 2011). Moreover, the appreciation of Thai Baht in the last decade and costly freight charges leads to decrease in export of rice from Thailand (Pilavong et.al., 2012). But the import of rice in both the countries has been increasing over the years. The import of rice in India is increasing at the rate of 22.01 per cent since 2011. While in Thailand import has been increased at the rate of 10.37 per cent.

Figure 4: Year-to-Year percentage change in Import of Rice in India and Thailand



	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
India	0	-50.7	145.5	30.54	-24.3	-23.9	88.34	247	-11.5	-22.9	-17.7
Thailand	0	101.7	142.2	-17.2	-67.3	285.9	-45.6	33.32	-23.4	98.29	-14.9

Conclusion

The study finds that with the increase in production, the export of rice from India has been increasing at a positive rate. The export of rice from Thailand has been decreasing since 2013-14. Due to erratic climatic conditions and heavy flooding often results in making unfavourable conditions for the cultivation of crops in Thailand, which leads to negative growth rate in production over the years. With the increase in its domestic consumption, the import of rice has been increasing with each passing year. Moreover, the growth rate of import of rice is higher than its export in India. The government of India should set a proper strategy to balance the export and import of rice, so that it won't have to import from other nations. Moreover, the government of Thailand should focus on other parts of country also rather than only in north east region for cultivation of rice. Proper irrigation system in both nations will have a major role in its production as major portion of the production depends on rain fed area.

Reports

Food and Agriculture Organization of United Nations

Oxfam Disaster Risk Reduction and Climate Change Adaptation Resources: Jasmine Rice in the Weeping Plain: Adapting Rice Farming to Climate Change in Northeast Thailand

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