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ORIGINAL ARTICLE

A geospatial analysis of noncommunicable disease (NCD) burden in Indian agro-climatic and political regions

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Abstract

Aim To examine the burden of noncommunicable diseases (NCDs) in the Indian agro-climatic and political regions.

Subjects and methods Data from two rounds of National Sample Survey (NSS) 68th (2011–12) and 71st (2014) was used to estimate the subnational spatial heterogeneity of NCD burden across 87 agro-climatic and political regions in India. Quantile maps, local Moran's I, LISA cluster and significance maps were generated.

Results Results show a high spatial heterogeneity in disease burden across the agro-climatic regions. Moran's *I* scatterplot depict a significantly high level of regional dependence (Moran's $I = 0.558$) of NCDs with larger concentration of disease in southern states like Kerala (northern and southern), Tamil Nadu (inland, coastal, and northern-coastal), Karnataka (inland, coastal and Ghats) and Pondicherry. The proportion of the elderly population, those belonging to urban areas, widowed/divorced/separated population, high per capita alcohol and tobacco consumption were more likely to affect the prevalence of NCDs.

Conclusion Findings call for an immediate programmatic attention at the subnational level due to significantly high regional dependence of NCDs. Policies and programme should focus on strengthening the implementation of existing policies with a special focus on geriatric population to combat the disease burden.

Keywords Geriatric · LISA · Noncommunicable diseases · Regional dependence · India

Introduction

An important outcome of demographic and epidemiologic changes in the twenty-first century has been "health transition" which is marked by rapid growth in the density of chronic diseases among middle-aged and elderly persons (Caldwell and Caldwell 1991; Omran 1971). Considering the severity of the matter, the Sustainable Development Goals (SDGs) initiated by United Nations Development Programme (UNDP) in 2016, have placed health at the soul of the development due to the high imbalances and uneven progress of Millennium Development Goals (MDGs) across the globe. A potential rise in the morbidity level due to chronic diseases in developing nations and its overall impact on population health has been well documented in the literature (Kearney et al. 2005). Globally, noncommunicable diseases (NCDs) account for about 66% of all deaths (Lozano et al. 2012) and, 54% of healthy life years lost, as indicated by the measured disability-adjusted life years (DALYs) (Murray et al. 2012). In an aging nation like India, around 5.87 million deaths, which account for 60% of all deaths, are attributed to NCDs. Furthermore, among all the NCDs, cardiovascular diseases (CVDs) contribute to 45% of all the deaths followed by chronic respiratory disease (22%), cancers (12%) and diabetes (3%) (World Health Organization 2014).

The statistics also depict the inequalities between states with the highest disease burden in the states like Kerala (rural: 310; urban: 306 per thousand of population) and the lowest in Manipur (rural: 26; urban: 4 per thousand of population) compared to the national estimate (rural: 89; urban: 118 per thousand of population) (National Sample Survey Organization

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2014). In 2011, planning commission revealed a rapid rise in India's morbidity level during the last three decades (Government of India Planning Commission 2011). This rising burden of NCDs reflects numerous risks such as increased physical inactivity, high rates of abdominal obesity, untreated hypertension, and increased aged population (Popkin et al. 2001; Reddy and Katan 2004; Goyal and Yusuf 2006). In addition, the disease burden is also contributing to the exponential increase in the economic burden of NCDs in India. Data from 71st round of National Sample Survey Organization (NSSO) revealed that the NCDs contribute to a very high health expenditure in both in-patient and out-patient cases (National Sample Survey Organization 2014).

Despite the fact that NCDs are preventable, households face a high propensity of economic burden due to different NCDs (Engelgau et al. 2012; Karan et al. 2014; Bloom et al. 2014; Htet et al. 2015). Because the national level estimates do not deliver enough insights for targeted action, reliable subnational level estimation of disease burden in India will allow for making more cognizant decisions to expand quality population health. To fill the existing lacunae of research in this unfocused area, the present study aims to examine the subnational spatial heterogeneity of NCD burden across 87 agro-climatic and political regions; identify the regional imbalances in burden of NCDs through comparison with the contiguous regions by using subnational area level autocorrelation; establish the implication of space in analyzing the burden of NCDs; and understand how socio-demographic and behavioral indicators interact to produce observed patterns in NCD burden.

Methods

Data sources

We used data from the surveys conducted by the NSSO in India during 2011–2012 (68th round) and 2014 (71st round) to generate the estimates pertinent to household's consumption expenditure and social consumption regarding health. These are the latest available large-scale surveys which covered a sample of more than 101,662 households (59,695 rural and 41,967 urban households) in the 68th round schedule type 1 (ref. period 30 days) survey, whereas there were 65,932 households in the 71st round. As consumption expenditure data (68th round) were collected at the household level, the regional level aggregated estimates are based on household expenditure rather than individual expenditure. In the 68th round, NSSO collected information on household's consumption and expenditure on an extensive range of items, including health services and commodities for institutional and noninstitutional care. However, in the 71st round, details about age, sex, morbidity status of acute and chronic morbidities, the status of treatment and hospitalization were collected for each member of the selected households. Further, for each individual, episodes of ailments for 365 and 15 days preceding the survey, treatment status, inpatient and outpatient out of pocket (OOP) expenditures, duration of hospitalization and public or private affiliation of health facilities utilized for treatment were collected. The detailed description of both the survey designs, selection of regions, households, and individuals, geographical and population coverage have been briefly described elsewhere (National Sample Survey Organization 2014; National Sample Survey Organization 2012). Table 1 shows a brief description of the data sources with selected variables used in the analysis.

The immense Indian landscape, home to one of the world's most multifaceted and plural polities, can be divided into regions and subregions according to several guiding principles, namely natural regions based on geographic attributes, agro-climatic regions, socio-cultural and linguistic regions, etc. To generate regional level estimates, the study used regions based on agro-climatic characteristics utilized by the NSS. Merging the agro-climatically homogeneous districts within states, the NSSO classifies India into 87 regions. The fundamental reasons behind devising these agro-climatic regions for India were to highlight the inter-regional disparities within the individual states and connections between contiguous regions across states. Also, the sample sizes of these regions are adequate to provide robust estimates of various socio-economic, demographic and health indicators (Bhat and Zavier 1999).

Variable description

Dependent variable

The present study used the prevalence of NCDs as the main outcome for the analysis. All the morbidity conditions asked during the survey were matched to the 10th revision of

Table 1 Description of the outcome and other predictor variables

Variable description	Data source
Outcome variable	
Prevalence of NCDs (per 1,000 of population)	NSS 71st Round (Ref. period 15 days)
Predictors variables	
Elderly (60+) population (%)	NSS 71st round
Urbanized areas (%)	NSS 71st round
Widowed-divorced-separated (%)	NSS 71st round
Average per household alcohol consumption (INR)	NSS 68th round (Ref. period 30 days)
Average per household tobacco consumption (INR)	NSS 68th round (Ref. period 30 days)

International Statistical Classification of Diseases and Related Health Problems, a medical classification list to distinguish between major NCD categories (including injuries). Moreover, cancers (known or suspected by a physician) and occurrence of any growing painless lump in the body, diabetes, heart disease: chest pain, breathlessness, hypertension, bronchial asthma, psychiatric and neurological disorders and injuries were grouped under the "umbrella" of noncommunicable diseases.

Independent variables

Demographic and behavioral factors are suggestive determinants of NCDs established by existing literature. Behavioral factors, include consumption of alcohol and tobacco are the major risk, factors of chronic diseases which often modified by marital status, it is often propounded that widowed, separated and divorced people are often indulged in unhealthy lifestyle patterns owing to higher levels of psychological stress which further results by affecting physiological health (Sugathan et al. 2008; Chin et al. 2017; Trivedi et al. 2009). Also, studies suggest that the elderly are found to be more susceptible to suffer from one or more NCDs (Canbaz et al. 2003; Mini 2014); however, urbanized areas are also vulnerable with the changing lifestyles which are favorable for such chronic conditions (World Health Organization 2012). Thus, the average per household of alcohol (INR) and tobacco consumption (INR), the proportion of the elderly population (60 and above), urbanized areas and widowed-divorced and separated are considered to be the predictors in the present study. NSSO data provides information on alcohol and tobacco consumption at the household level and rest of the variables at the individual level; however, all this information was aggregated to the regional level by coagulating the information of all the preceding variables.

Analysis

The prevalence of NCDs in the last 15 days before the survey was used as a primary outcome and was measured as:

$$Prevalence\ rate(\mathrm{PR}) = \frac{\mathrm{All\ new}\ and\ existing\ cases\ during\ \mathrm{a}\ given\ time\ period}{Surveyed\ individuals\ during\ the\ same\ time\ period} \times 1000$$

Average per household (HH) alcohol/tobacco consumption in the last 30 days in a particular region (i) is measured as follows:

$$Average\ \mathrm{Per\ HH}\ Alcohol\ or\ Tobacco\ Consumption\ (\mathrm{Rs.})\ in\ region\ \mathrm{i} = \frac{Total\ Alcohol\ or\ Tobacco\ consumption\ (\mathrm{Rs.})\ in\ the\ last\ 30\ days\ in\ the\ region\ \mathrm{i}}{Total\ \mathrm{no.}\ of\ Households\ in\ the\ region\ \mathrm{i}}$$

A series of quantile maps were generated to explore the spatial pattern of NCD burden and its indicators in India. Spatial weight matrix (w) has been calculated to quantify the spatial proximity between each possible pair of regions. The matrix can be computed through different approaches depending upon the neighbor's definition such as Queen's, Rook's, Bishop's method (Anselin et al. 2006); however, this study is only limited to Queen's method to generate spatial proximity weight matrix of order 1 as it is more advantageous when dealing with regular square grids or rectangular lattices, where the spatial structure can be very easily summarized in sophisticated mathematical terms. In Queen's case, cells sharing a common edge or common vertex are considered contiguous. The simplest way to do this is to construct a binary connectivity matrix. An element w_{ij} of a binary connectivity matrix results $w = 1$ if region j adjoins region I and $w = 0$ in all the other case. To examine the spatial clustering of NCD burden, Local Moran's I statistic was computed which measures the spatial autocorrelation and indicates the degree to which data points are similar or dissimilar to their neighbors. P-value of Local Moran's I was generated using a randomization test on a Z score with 9,999 permutations. Moran's I is given by

$$Moran's\ I = C\ .\ \frac{\sum_i \sum_j w_{ij} z_i z_j}{\sum_i z_i^2}$$

where z_i is the standardized variable of interest; w_{ij} is the standardized weight matrix with zeroes on the diagonal, and C is the multiplier equivalent to= N/S_0

where N is the number of spatial units indexed by i and j; S_0 is the sum of all w_{ij}'s. A positive spatial autocorrelation would indicate that regions with similar attribute values are closely

distributed in space, whereas negative spatial autocorrelation would indicate a dissimilarity in closely associated regions. Univariate Local Indicators of Spatial Association (LISA) measures the correlation of neighborhood values around a specific spatial location and determines the extent of spatial randomness and clustering present in the data. It is given by

$$I_i = \left(N.z_i / \sum_i z_i^2\right) . \sum_j w_{ij} z_j$$

The following scenarios would be displayed which are linked to the quadrants of Moran's I scatter plot such as:

- Hot spots: regions with high values, with similar neighbors (high–high)
- Cold spots: regions with low values, with similar neighbors (low–low)
- Spatial outliers: regions with high values, but with low-value neighbors (high–low)
- Regions with low values, but with low-value neighbors (low–high)

Stata version 13 (StataCorp, Texas); Arc-GIS version 10.1, Esri, California and Geo-Da version 1.6.7, Teknowledgist, New York were used for the analysis. All the estimates provided in this study are derived by applying appropriate sampling weights supplied by NSSO itself.

Results

Figure 1 presents a series of quantile maps of NCD burden and its different indicators. The color pattern shows the spatial pattern, where the darker colors indicate the higher densities and the lighter colors indicate the lower densities of the indicators. Results show strong geographical disparities of regions among almost all the variables along with the gradual spatial progression from high to low levels of NCDs. Spatial pattern explores that a very high level of NCD burden prevailed in southern regions like Southern Kerala (191.7) followed by Southern Tamil Nadu (118.8), Pondicherry (114.8), Daman and Diu (114.3), Northern Kerala (107.8) and Coastal Northern Andhra Pradesh (AP) (106). The other regions having a high level of disease burden were Lakshadweep (92.1), Coastal areas of Southern AP (87.3) and Coastal Tamil Nadu (84.6), Goa (81.6), Southern Plains West Bengal (81.6), Northern Punjab (77.6), and Inland Tamil Nadu (77). Contrary to these, the burden of disease was lowest in Cachar Plain Assam (0.1), Meghalaya (1.1), Central Assam (2), South Western Madhya Pradesh (3.2), Nagaland (3.4), and Tripura (4.4). The other low-level NCD burdened regions were Kachchh Gujarat (5.1), (5.7), Manipur Plains (5.7), Southern Chhattisgarh (6.4), Mahanadi Basin (6.6), South-Eastern Rajasthan (6.6), Manipur Hills (6.8), and Plains Eastern Assam (6.9). Thus, the level of NCD burden appeared to be much higher in specifically southern, eastern and northern regions as compared to the central, north-eastern, western (except Maharashtra and Gujarat) and eastern regions. Interestingly per-capita alcohol consumption was also very high in most of the southern (Kerala, Andhra Pradesh, Telangana, Andhra Pradesh, Tamil Nadu, Goa, and Pondicherry) and some parts of the north Indian regions such as Punjab, Himachal Pradesh, and Rajasthan). Similarly, per capita tobacco consumption was found to be higher in northern, southern and some of the western parts of India. As compared to the alcohol and tobacco consumption, the socio-demographic factors like the proportion of elderly (60 and above) and widowed-divorced-separated population were mostly clustered in southern and some of the northern parts of India with higher concentration of NCD burden. The proportion of urbanized areas were mostly concentrated across northern, southern, western and some parts of central regions.

To examine the spatial dependence and clustering of morbidity burden of NCDs, Local Moran's *I* and univariate local indicator of spatial association (LISA) cluster, and significance maps of the prevalence of NCDs were generated. Figure 2 presents Moran's *I* scatterplot and suggest a high level of spatial autocorrelation across Indian agro-climatic regions, i.e., a significantly high level of regional dependence (Moran's $I = 0.558$) of NCDs. Univariate LISA cluster and significance map revealed that all the hotspots were located in southern states like Kerala (northern and southern), Tamil Nadu (inland, coastal, and northern-coastal), Karnataka (inland, coastal and Ghats) and Pondicherry; however, most of the cold spots were present in central (Uttar Pradesh and Madhya Pradesh), some parts of eastern (Assam and Jharkhand) and western (Rajasthan) and north-eastern (Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura and Meghalaya) states of India. Table 2 presents the list of hotspots and cold spots of NCD burden across agro-climatic regions of India.

Discussion and conclusion

Using the data from nationally represented sample survey, the study makes an explicit attempt of understanding the spatial pattern of NCD burden across 87 agro-climatic and political regions and analyze the interplay between the proportion of urbanized areas, elderly (60 and above), per capita alcohol and tobacco consumption, and proportion of widowed-divorced-separated with the NCD burden. An important contribution of the study is the generation of the snapshots of NCD burden with the other major indicators at the subnational level. Findings revealed a high burden of NCDs in southern and some parts of the north, east and western states. Not only that,

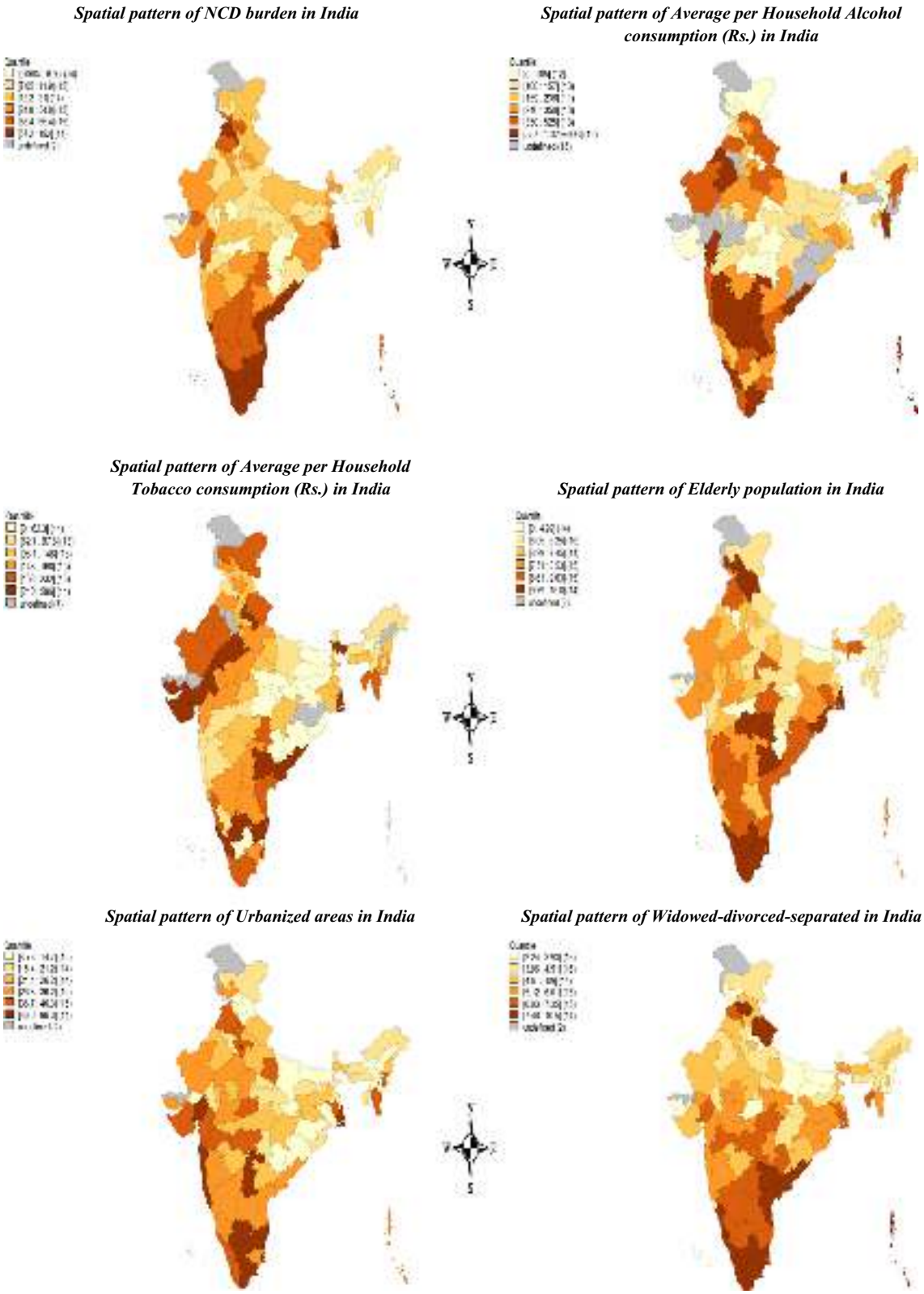

Fig. 1 Quantile maps exploring the spatial distribution of different indicators of noncommunicable diseases (NCDs) in Indian agro-climatic regions

the burden of NCDs were linked with various risk factors such as unhealthy dietary pattern, alcohol and tobacco consumption and the demographic conditions like aging and widowhood.

Findings on the high burden of diseases in the southern part of India and some segments of east and north India can be attributed to eating habits, especially the high consumption of

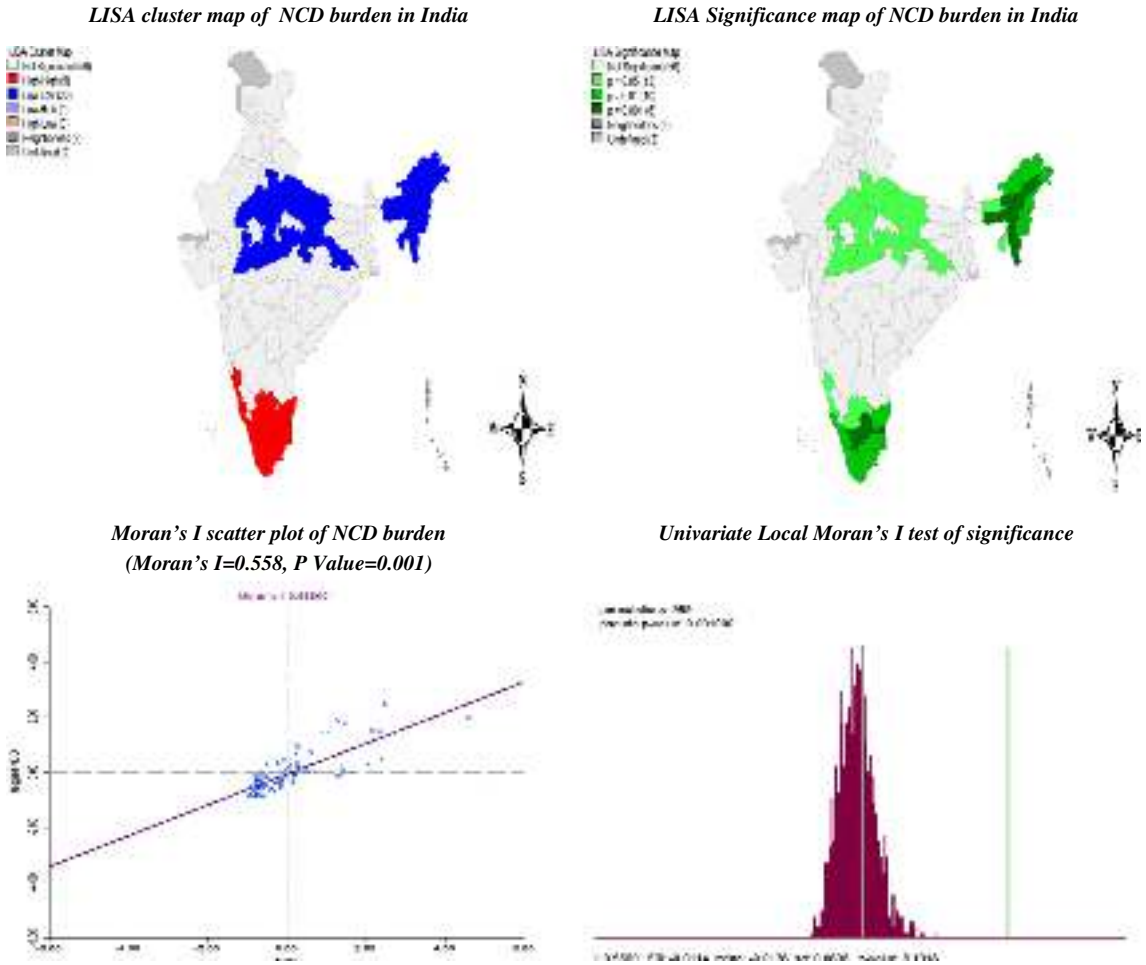

Fig. 2 Univariate LISA cluster and significance map and Moran's scatter plot showing the spatial distribution, clustering and spatial dependence of NCD burden across Indian agro-climatic regions

nonvegetarian food containing more fat and calories. Evidence does suggest an increased risk of NCDs due to high intake of fish, egg, chicken, mutton, beef, pork, etc. (Thow et al. 2014). As observed in the report regarding household consumption of various goods and services in India produced by NSSO in 2012, southern states like Andhra Pradesh, Telangana, Kerala, Goa, Tamil Nadu, Pondicherry, and states from other parts of India like West Bengal and Himachal Pradesh, have a very high proportion of population with non-vegetarian food intake, and thus, monthly per capita consumption of egg, fish, chicken, and mutton was highly observed (National Sample Survey Organization 2012). Noticeably, per capita, household consumption of alcohol and tobacco was also very high in the regions with high NCD burden. Findings of our study corroborate with other studies that suggest that consumption of an unhealthy diet, physical inactivity, and a high level of alcohol and tobacco consumption were the most significant risk factors for a high level of NCDs (Popkin et al. 2001; Reddy and Katan 2004; Goyal and Yusuf 2006).

Table 2 List of hotspots and coldspots of NCD burden across Indian agro-climatic regions, NSS 71st round (2014)

Hotspots of NCD burden	Cold spots of NCD burden
Northern Kerala (Kerala), southern Kerala (Kerala), Pondicherry, inland (Tamil Nadu), coastal (Tamil Nadu), coastal northern (Tamil Nadu), southern (Tamil Nadu), coastal and Ghats (Karnataka), inland southern (Karnataka)	Arunachal Pradesh, Nagaland, Manipur Plains (Manipur), Mizoram, Tripura, Meghalaya, Plains Eastern (Assam), Manipur Hills (Manipur), Cachar Plain (Assam), central Brahmaputra Plains (Assam), central (Madhya Pradesh), northern (Madhya Pradesh), central (Uttar Pradesh), eastern (Uttar Pradesh), north-eastern (Rajasthan), Vindhya (Madhya Pradesh), Malwa (Madhya Pradesh), plains western (Assam), Ranchi Plateau (Jharkhand), southern Upper Ganga Plains (Uttar Pradesh)

Results indicating a higher burden of disease in the regions having a higher proportion of elderly (sixty and above) again corresponded to the existing findings that suggested a positive correlation between the proportion of the elderly population and higher NCD (Feng et al. 2014). Studies have found that aging process often leads to the changes in hormone secretion, which consequently result in a decline in physical and cognitive functions (Chapman et al. 1997). Other critical findings of this study that higher NCD burden in the areas with a higher proportion of urbanized population goes well with the finding that urbanized areas are highly susceptible due to the changing lifestyles associated with globalization and technological advancements. As revealed by WHO, urbanization correlates with an increased incidence of chronic diseases in large urban cities for both men and women due to differences in lifestyle as compared to the lifestyles of the rural population (World Health Organization 2012).

We also found higher clustering of NCD burden in the regions having a higher concentration of a widowed, divorced or separated population. Findings have shown that marital disruption and poor marital quality have resulted into psycho-social distress leading to the adoption of risky behavior including consumption of alcohol, tobacco which were again associated with a higher risk of contracting NCDs (Prigerson et al. 1999).

The study is not free of limitations. Use of self-reported data on morbidity to perform the analysis is the critical limitation of our study; however, unavailability of measured data on noncommunicable disease prevalence in the public domain remains a main data limitation in India. As identified in other studies, the variation in self-reporting morbidities by socioeconomic strata always remains a major drawback (Prince et al. 2008; Yamaguchi et al. 2016). This could lead into an under- as well as over-estimation in the estimates.

Despite these limitations, the findings of this study revealed several relevant results, especially in the Indian context. Results show that it is important to develop effective strategies to reduce the NCD burden in the country like India due to high regional differences in the burden of NCDs. It would help the country in prioritizing the existing program aimed to curtail the prevalence of NCDs in specific geographic regions, especially the southern part of the country where the prevalence of NCDs is very high. Though demographic and epidemiological literature underscores the geographic space in assessing spatial heterogeneity of NCD burden, the study's findings help in theorizing the link between morbidity burden of NCDs and related risk factors at the regional level. In the present era of epidemiological transition, quick implementation of WHO's 'Best Buys' interventions at the grass root level including a tax increase on alcohol and tobacco, bans on tobacco and alcohol advertising, promotion and sponsorship, health information and warnings, public awareness through mass media on diet and physical activity and strengthening the National Program for Prevention and Control of Diabetes, CVDs, and stroke may help to improve the situation. Findings also underscore the need for community-level interventions needed for early detection of NCD and its treatment. Strengthening the service provision system for detection, treatment, and follow-up is paramount in those regions with high levels of disease prevalence.

The study also signifies that the country representative household data on consumption expenditure and social consumption can be effectively allied to examine the spatial pattern of NCD burden at the regional level. The strong geographic clustering and heterogeneities of the NCD burden were evident across 87 agro-climatic and political regions in India which established the significance of geography in assessing the burden of NCDs. The estimates computed here would serve as an input for government and policy makers for close monitoring and grass root level implementation of programs. Urgent attention is highly required to reduce spatial heterogeneity of NCDs by the effective implementation of cost-effective measures even at the smaller area level. Immediate attention is needed to be given with special focus to the identified hotspots by considering future perspectives on identified cold spots. Last but not the least, the program should also start putting an emphasis on the geriatric population to combat prolonged chronic diseases.

Authors contributions AS apprehended the idea. PP, RP and AS designed the experiment and analyzed it. AS, PP and RP interpreted the results and drafted the manuscript. All the authors take responsibility for the integrity of the work as a whole from inception to published article. RP is the guarantor. All the authors read and approved the final manuscript.**Funding** The present research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Compliance with ethical standards

Ethical approval The analysis is based on secondary data available in public domain for research; thus no approval was required from any institutional review board (IRB).

Conflict of interests The authors declare that they have no conflict of interests.

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