State of the Art and Trends in Cancer Control and Prevention in Asia: Geospatial Science towards SDG 3.4

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Abstract: *The scope of the subject of Geographic Information Systems (GIS) has risen far from mere production of maps to a multitude of interdisciplinary analytical scenarios like healthcare cum social sciences where environmental factors may have some direct or indirect impact on a disease in consideration. The United Nations (UN) has recommended framing health related policies with the application of GIS to achieve Sustainable Development Goals (SDGs) as it can help visualize the data which is difficult to understand otherwise. We know that healthy life and physical and mental well-being of human beings as mentioned in the United Nations' target SDG 3.4 is directly linked with the social, cultural and biological environment in which they live. GIS can aid in discovering the interlinks and implications such an environment may have on the incidence of a disease. This helps authors and institutions towards control and prevention of deadly diseases like cancer. While some developed countries like the USA have been using GIS for the last four decades reaching a peak in their cancer cases, most of the developing countries, are lagging behind in GIS application and also have been witnessing an alarming rise in the number of cancer cases year by year, thus far from their peak for their graph of cancer incidence and mortality. Therefore, this study is conducted to investigate the state of work done in geospatial analysis of cancer disease in Asian countries and then relate how such studies are aiding respective countries in their cancer control and prevention programs. The review provides a historical analysis of peer reviewed literature in this field, exploring the methodological attempts, diverse applications and challenges in cancer based clinico-epidemiological studies. Finally, recommendations and challenges are discussed so that developing countries can also achieve what the USA has done in this field.*

Keywords: *Cancer, GIS, Geospatial Analysis, SDG 3.4*

Introduction

Asia inhabits more than half of the world population. The continent accounted for 49.3 per cent of cancer cases worldwide, but, the number of deaths reported due to cancer stands much higher than the incidence rate – which is nearly 58.3 per cent of the global deaths. Therefore, while the cancer incidence rate in Asia is comparatively lower with respect to other continents, it has relatively bigger share of the burden of deaths (Bray et al., 2024). China tops the burden of cancer in Asia followed by India and Japan. The highest cancer incidence rate of 314 cases per lakh was observed in Republic of Korea, and the highest cancer mortality rate was observed at 170 per lakh in Mongolia (Huang et al., 2022). These trending peaks necessitates intervention and an immediate action to contain the fast-growing number of cancer cases in Asia. Not only the multidisciplinary experts in the field but also the basic oncological specialists now understand the importance of interdisciplinary work needed for sustainable development through cancer healthcare (Kraak et al., 2021; Mistry, 2020; Sahar et al., 2019). The multidisciplinary work in this field can have the requisite intervention through infrastructure development, patient centered care, technology development and most importantly decision making at all governance levels.

Geographic Information System (GIS) is one such tool that can help the decision makers as well as other stakeholders in prevention and control of cancer incidence and mortality at all spatial levels. GIS is a technique that can help us create, manage, analyze, and map various kinds of data including natural and built environment data, qualitative data and more precisely the spatial data (McHaffie, Hwang & Follett, 2023). The data describes the environment using its three characteristics – location, attributes and time and respective changes therein. GIS, is, thus broadly used to represent change regarding these three components which is nowadays highly being used in healthcare sector also (Kraak et al., 2021). The attributes in these spatial data may be risk factors for cancer which can greatly impact the health and lifestyle of a person and could be in the context of his personal, socio-economic, cultural, or historical information (Goodchild, 2015). John Snow was one of the earliest in making use of this technique in investigating the cholera outbreak in London in 1854. He mapped the data he collected on cholera patients' locations and analyzed these maps with respect to some other maps like that of handpumps and other

drinking water sources available in his study area (Tulchinsky, 2018). Gault, as early as 1955 discussed the impact of social factors like pregnancy, religion, ethics, hygiene, marriage, no of children, economic status with respect to incidence mortality of cervical and fundal carcinoma in India (Gault, 1955). A large amount of literature on the topic is found more recently, particularly from USA, Cananda and European countries. It all started with mapping of cancer mortality in these regions and an extensive review of such work could be found in (Gardner, 1984; d'Onofrio, 2016) for European countries and in (Pickle, 2009; Schootman et al., 2017; Sahar et al., 2019) with regard to that in USA. Thus, a number of classical studies shows the importance of applying GIS techniques in achieving sustainable development through disease control. *Mapping for a Sustainable World*, a report linked with United Nations more clearly states it that GIS can greatly help in understanding the context through visualizing the complications and implications of healthcare related ground reality and issues as well as in making the required policies at respective governance level (Kraak et al., 2021).

The present study analysis the work done in geospatial analysis of cancer control and prevention in Asia, a field which will not only help the poverty-stricken regions of the continent in better and healthy living but also ensure faster achievement of SDG 3.4. First of all, the methodology adopted in this systematic literature review is elucidated. Then, the results are shown and elaborated and discussed in next sections. Finally, conclusion is given with the recommendations that can thrust faster achievement of the said SDG in Asian countries.

Methods

Web of Science (WoS) was used for this systematic literature review in August and September, 2024 to find geospatial research in cancer control and prevention in Asia and any one of its high cancer incidence/mortality countries. The countries with high cancer rates in Asia include China, Japan, Korea, Israil, Mongolia, India and Sri Lanka. Thus, keywords were searched in WoS with respect to Asia and each of these countries. Keywords used in this search were "geospatial" OR "GIS" OR "geograph*" OR "spatial" OR "geocod*" OR "geographic information system" AND "cancer" or "tumour" or "neoplasm" or "lesion" or "onco*" which were searched with Asia and given countries' names.

After searching the geospatial terms, cancer terms and Asian geographic terms on WoS, some criteria were set to select the literature. English was the only chosen language and there was no time frame selected for the literature search. All titles and abstracts were screened manually by the authors keeping in mind that the work should have included geospatial analysis technique as first priority along with the cancer rates and risk factors. Thus, a study that enquired the impact of a social or environmental factor on cancer incidence on a geographic scale would be included, but a study that just explored an environmental factor without GIS and cancer rate/mortality would be excluded. Any work without a GIS based analysis was excluded. Also, if a study used GIS technique only for risk factor visualization, for example mapping of arsenic contamination, and didn't include any GIS analysis or visualization for cancer neither its correlation with risk factor based on GIS, was excluded. A study performed primarily at the global level but also including the Asian countries in it were also excluded in this review. The selected studies were classified based on the geospatial approach, type of cancer, software used and the scale of the study.

Authors categorized the relevant works into six approaches – distribution mapping, proximity analysis, geospatial comparison, environmental correlation, geospatial modelling and exposure studies. Mapping and map-based visualization studies were included in the first category. Any study with primarily focused on calculating patients' time of travel to the medical care unit or tried to find new potential regions for cancer hospital establishment were included in the second category. Abstracts which focused on regional comparison were included in comparison study class. Studies finding the impact of environmental and climatic factors on cancer cases were included in environmental correlation studies. Those which tried to explore new algorithms or models were included in the geospatial modelling category. Exposure studies included those which investigated the metals and chemicals on cancer incidence and mortality. Works that included proximity analysis but also contained environmental, distribution, comparison, modelling and exposure were included in proximity analysis only. Other category was dependent on the scale of the study area which might be at the regional level of country, state, city, town or village. If a work discussed all these scales, it was considered at the biggest level and if

the scale of a work couldn't be found or was unrecognizable, it was assigned to the lowest level. Authors also grouped abstracts according to the type of cancer under investigation. These included cancers of breast, thyroid, colorectal, esophagus, lung, gynecological and others. Apart from these the abstracts were also classified according to the risk factor discussed, source of such data, and the GIS software used for investigation.

Results

Web of Science search led to total of 2804 citations as: for China, it yielded 1634 citations, India – 472, Japan – 428, Korea – 219, Mongolia – 33 and Sri Lanka – 18. For Israil and the Asian continent as whole, no relevant citations were yielded. Citations which were found without abstracts in WoS were searched for its title on Google Scholar and to decide its further inclusion. After the manual screening of all the abstracts thus collected, a total of 44 abstracts that focus on geospatial analysis for cancer study, were included. Country wise count found was: China 43% (n = 19), India 39% (n = 17), Korea 11% (n = 5), and Japan 7% (n = 3). No qualified abstract was found for Mongolia and Sri Lanka.

The earliest study in selected citations was published in 1983 and thereafter a good lag period a quarter century was found for the next publication that happened in 2007 both from China and India. Majority of the studies (80%, n = 35) were published after 2015 (Figure 1). Most of these investigations were done at the country level (48%, n = 21). While 41% (n = 18) were performed at state and rest 11% (n = 11) were at district or lower regional levels. The most important cancer risk factors considered in these studies were socio-economic (14%, n = 6) and particulate matter, PM 2.5 (9%, n = 4). With regard to type of cancer geospatial analysis (Figure 2), most important type(s) were breast cancer with n = 8 (18%) investigations and lung cancer with n = 7 (16%) investigations. These were closely followed by esophageal (11%, n = 5) and gynecological (9%, n = 4) cancer related investigations. It was also found that most of the studies that were done at the country level were investigations regarding all cancer types. In this review work, ArcGIS was the most frequently used software for geospatial analysis, followed by R and SaTScan.

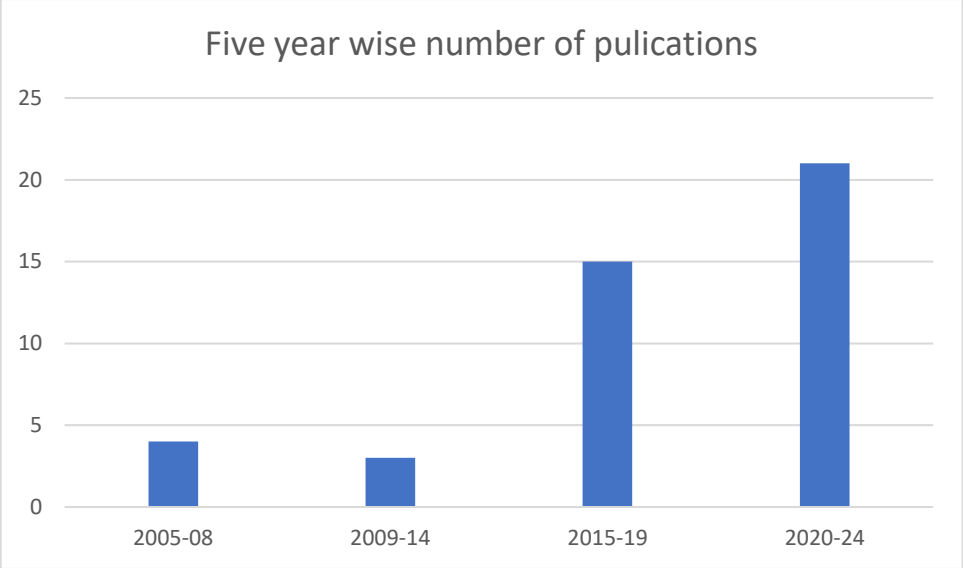

Figure 1: Number of publications in geospatial cancer research in five years periods (for year 2024 till September).

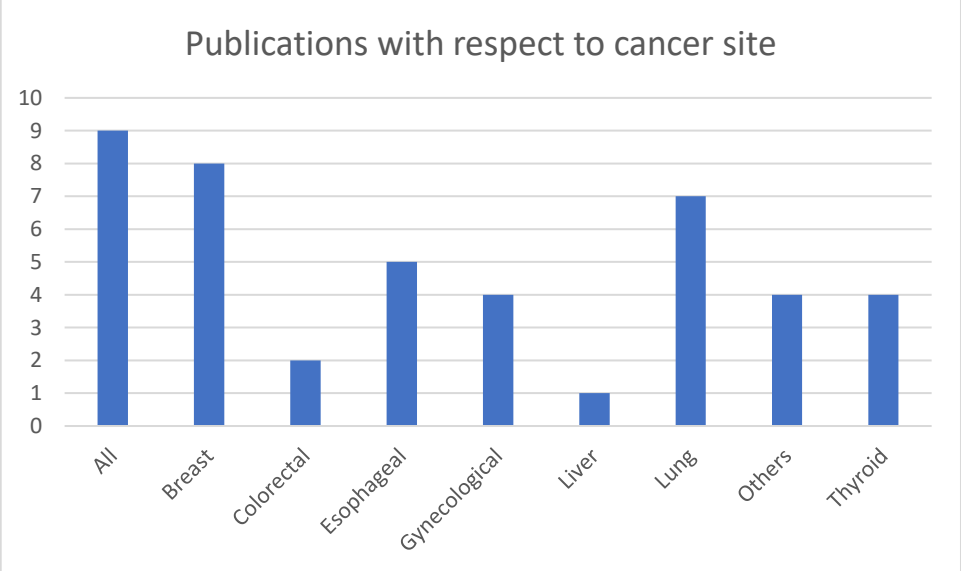

Figure 2: Number of publications with respect to the type of cancer.

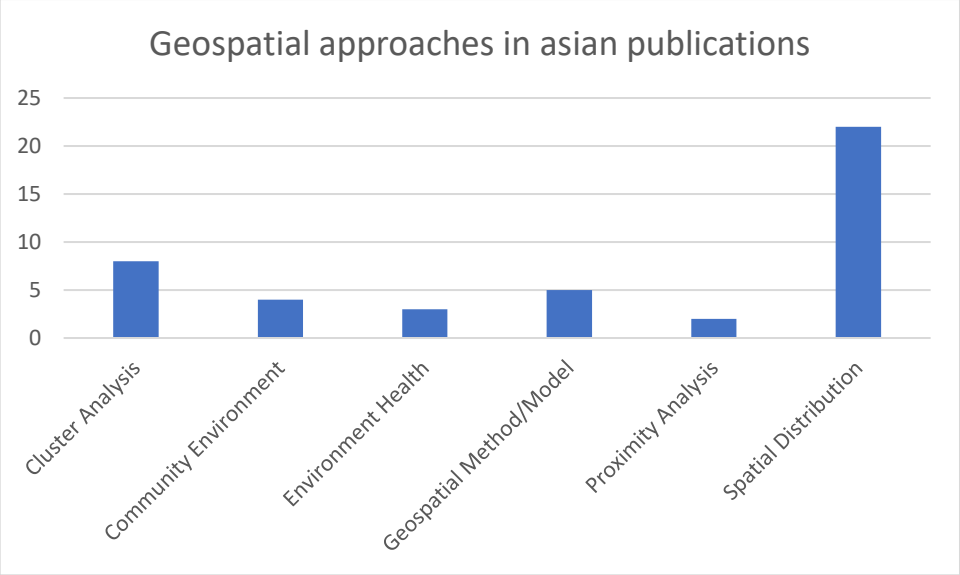

Figure 3: Various geospatial approaches used in publications.

Geospatial approaches of varied types were employed for these investigations (Figure 3). Around 50% (n = 22) of these studies investigated the spatial distribution of cancer and visualization of cancer rates, which obviously also included the cancer atlas related publications. Cluster analysis was the second most important type of investigations that accounted for 18% (n = 8) and focused on pointing out the hotspots and/or coldspots of cancer incidence in respective study areas. 11% (n = 5) of these investigations modelled algorithms to facilitate better cancer identification in respective study areas. The remaining studies were focused on investigation of environmental impact on community health and on understanding how distance related time can have health cost in society.

Discussion

The number of the geospatial works in cancer control and prevention found in Asian countries was not a very encouraging figure as compared to similar works going on in USA and European countries. (Boulos et al., 2010) had a similar review work but without any regional or geographical boundary and found around 92 works from around the world. Comparing this figure with Asian works during this period from our review, we could find only five studies from given countries of Asia which do account for a major burden of cancer. Thus, overall, the analysis leads to think that there is a rarity of geospatial research works in cancer in Asia currently and needs due attention.

Nevertheless, we find a notable increasing trend of geospatial works from given Asian countries as shown in figure 1, and the trend is quite encouraging. The three approaches which show rise during this period were – studies related to spatial distribution mapping, cluster analysis and geospatial modelling. Actually, while the overall number of geospatial investigations were having an increasing trend in last two decades, similar trend was not observed in investigations related to proximity analysis and community environment related geospatial analysis, which is a bit disheartening.

China, India and Japan have shown a remarkable progress in this field of research during last decade, which was important in accordance with the increasing cancer cases in these countries. However, Korea and Israil, which are also among the countries having highest cancer incidence rates among in Asia (the two countries are followed by Japan among the top three countries with highest cancer incidence rates in the continent), require more effort in this direction so that regional peculiarities of disease may be better understood and preventive measures could be taken in respective social and environmental contexts. Similarly, while the cancer rate in many other countries including Sri Lanka and Mongolia, is among the top ten countries in terms of cancer incidence rate, more interdisciplinary works like GIS, as recommended by UN, is thus prerequisite in these countries towards the sustainable goal.

The diversity of works found in this review with regard to regional scale, cancer site, and application of risk factor data and GIS software is encouraging. Geospatial investigative works were found at all the regional levels. While, country level studies have a bit more focus on all types of cancers, individual cancer site related studies are also available at this scale too, particularly with respect to lung, breast and gynecological cancers as can be seen in (Ran et al., 2023; Jang et al., 2021; Cho et al., 2014). Studies related to environment and socio-economic risk factors correlation have found an important place in geospatial analysis during last two decades. As the recent years have demanded attention towards global warming and climate change too, climatic and other related environmental risk factors have found emphasis in recent cancer geospatial investigations of community environment (Huang et al., 2023; Kumar et al., 2021; Wang et al., 2019; Yue et al., 2017; Wu & Li, 2007; Wu et al., 2008). Socio-economic risk factors have also found equal importance during last decade in both spatial mapping as well as geospatial modelling (Kazi et al., 2024; Parasar Babu et al., 2015). A peculiar case was the considering of

correlation of liver cancer incidence in China with respect to different types of medical treatment choices opted (Weng et al., 2017).

Studies are also finding more and more attention on preventive measures like finding ways to adopt GIS analysis in improving the cancer screening scenario – thus, regarding both the ground reality as well as by finding potential areas which are more important for screening in containing cancer cases in future. China has accounted for high rates of gynecological cancer and preventive investigations using GIS has been found which has been used to drive the public health policy in Jiangxi province to better control such cancer types (Wan et al., 2020). India is the frontrunner in Asia in GIS based cancer screening studies. A country-based GIS model was developed and socio-economic and health data form NFHS (National Health Survey Data, 2015-16, Health Department, Government of India) was used to help contain breast cancer through identifying potential areas for screening of precancerous lesions in India (Nilima et al., 2023). Similarly, a couple of studies conducted for the whole of India and taking district level as unit were found where GIS based investigation aimed to prevent and control gynecological cancer (Puranik et al., 2020; Monica & Mishra, 2019). Clinical trial in cancer is considered one of the important contextual preventive measures and GIS investigation was found regarding this showing the situation of cancer clinical trials at country level in India (Chakraborty et al., 2021). Other important field of geospatial analysis that could greatly improve the preventive measures in cancer care is proximity investigation which have found emphasis in recent years worldwide. A GIS approach was modelled for Ahmedabad city in Indian context in 2007 to analyze the road network and time taken to cover the distance from residence to cancer care unit and along with this found potential areas for the establishment of new care centers (Ramani et al., 2007). Similar study was conducted in Japan in 2018 which additionally considered various individual patient data like age, type of cancer and environmental factors in performing proximity analysis and found that patients with cervical cancer and leukemia were taking higher time to reach to nearest hospital (Tanaka et al., 2018).

A number of studies focused on GIS investigations through spatial mapping and visualizing the distribution of cancer incidence and mortality in study areas, and all the four countries – China, India, Japan and Korea have such investigations published (Xu et al., 2023; Woo et al., 2019; George & Mathew, 2016; Sun et al., 2015; Katayama et al., 2014; Akhtar, 1983). Understanding the trend of cancer incidence and mortality was one

of the common and classical focus area of GIS distribution studies (Qiao et al., 2024; Won et al., 2018). Equally important topic was considered exploring the impact of socioeconomic, environmental and food related risk factors on breast, lung, thyroid and cervical cancer which could be said to be another common focus area of distribution studies (Kumar et al., 2021; Lie et al., 2021; Bray et al., 2020; Monica & Mishra, 2020; Fie et al., 2016; Madhu et al., 2016). However, last decade saw a very quick increase in gallbladder cancer cases in Gangetic belt in India and distribution studies have begun to cover this important aspect also (Sakamoto et al., 2024).

Finally, a variety of work was found with regard to geospatial models investigating impact of atmospheric pollution on lungs and a particular focus was seen on application of satellite derived particulate matter (PM 2.5) data in understanding the impact of PM 2.5 on lung cancer morbidity (Liao et al., 2022; Selvaraj et al., 2018; Han et al., 2017). Thus, geospatial modelling studies have tried to find the potential hazards associated with locations and many a times these studies were found to be merged with cluster analysis studies in better understanding the situation in place and find potential regions of cancer risks as can be seen in (Gangnon, 2010).

Conclusion

The Asian countries, particularly those which stay on top of the chart of cancer incidence rate in Asia, seem to lack in geospatial cancer research when compared with USA and European countries. Not only for individual countries, but a lack of study at Asian continent level is also there which can help explore the impact of Asian ethnicity and community environments on cancer rates in the region. Particularly lacking were the fields of geospatial investigations of community environment, proximity analysis and environmental health for a cancer free region. Multi-institutional collaborative multi-disciplinary works can pave the way for faster achieving SDG 3.4 as cancer control and prevention spans various disciplines (Mistry, 2020; Hall et al., 2012; Hall et al., 2008). Thus, interdisciplinary subjects like citizen science or participatory GIS needs to be integrated to collect community led data that may give wide information and knowledge to the progress ahead. Thus, a thrust in progress in multidisciplinary level geospatial cancer research can have deep impact on understanding the patterns of cancer and its treatment options, and importantly in decision making by the each and every level of decision maker hierarchy.

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