

# Applications of Geospatial Mapping in the Assessment of Environmental Risk Factors for Dementia

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The Geographic Information System (GIS) and Global Positioning System (GPS) are fundamental tools for supporting public health research by providing a framework to collect, analyse and generate insights about the environmental, spatial and socio-economic variables that influence various health conditions.<sup>1</sup> Dementia is a neurodegenerative condition marked by progressive cognitive deterioration that hinders an individual's capability to perform daily functions independently. It confers a major physical, emotional and financial burden on patients, their caregivers and the community.<sup>2</sup> Dementia, being a multifactorial disorder, is influenced by a plethora of modifiable and non-modifiable risk factors among which environmental factors play a substantial role.<sup>3</sup> In this context, we highlight the applications of GIS and GPS technology in assessing environmental risk factors associated with dementia.

**Water quality:** Exposure to water pollutants such as arsenic has been associated with an increase in hyperphosphorylation of tau,  $\beta$  amyloid production, inflammation, endothelial dysfunction and oxidative stress all of which are putative mechanisms underlying Alzheimer's disease.<sup>4</sup> In a study from rural Texas, groundwater arsenic levels retrieved from the local administration were mapped to participants' residential addresses using an inverse distance-weighted interpolation method within ArcGIS (a GIS application). GIS-estimated arsenic concentrations were observed to be very close to the measured values of arsenic in groundwater and there was a notable association between exposure to arsenic and poorer scores in cognitive tests.<sup>4</sup> Similarly, autonomous water pollution monitoring using GPS sensors integrated into fish robots has been used to detect sources of water pollution.<sup>5</sup>

**Air quality:** Air pollution from exposure to traffic and industries or the use of solid cooking fuels has been shown to have a detrimental impact on cognitive performance in elderly populations.<sup>6–9</sup> Fine particulate matter (PM) has been found to cause oxidative stress, endothelial dysfunction, altered immune response and elevated risk of cardiometabolic diseases, all of which are known to increase the risk of cognitive decline and dementia.<sup>10</sup> The population-attributable

risk for dementia from air pollution is as high as 2%, similar to that due to hypertension and lack of physical activity.<sup>11</sup> GIS has been used to map the dynamic exposure of individuals to air pollutants like PM 2.5 and nitrogen dioxide by modelling the concentration of pollutants at the participant's location using spatial interpolation techniques.<sup>12</sup> GPS data combined with highly localised air pollution data and personal activity diaries can generate insights about the effect of location and activity on personal exposure to air pollution.<sup>13</sup> Thus, GIS/GPS can be a useful tool to map air quality in resource-poor settings, wherein monitoring stations might be sparsely located in order to examine the correlation between air pollution and dementia risk.

**Pesticide exposure:** Several studies<sup>14–16</sup> have linked an increasing trend in the use of pesticides to an increased occurrence of behavioural, cognitive and psychomotor dysfunction in people chronically exposed to pesticides. A study among rice farmers in Thailand used GIS to map spatial patterns of pesticide exposure and its impact by utilising its ability to record historical data about pesticide use.

Evaluate exposure levels, and estimate the proximity of residential areas to agricultural lands.<sup>17</sup> Additionally, GPS data integrated with GIS systems was also used to demarcate pesticide spraying locations.<sup>17</sup>

**Traumatic brain injury (TBI):** TBI has been well-established as a significant risk factor for dementia.<sup>18</sup> and is emerging as a major issue in urban areas due to increasing incidents of road traffic accidents.<sup>19</sup> GIS has been used to aggregate and map the counts of TBI hospitalisations and methods of spatial statistics have been employed to incorporate location and

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proximity relationships.<sup>20</sup> In the above study, distinct geographical clusters were detected with high rates of TBI-related hospitalisations, and geographic patterns relating to TBI causes were identified. GIS has also been found to help in indicating accessibility to healthcare, clearly differentiating patients who could receive care in areas, proximal to their residence, from those needing to go further to receive healthcare. GIS can thus help guide local planning of injury prevention services and strategies and assist policymakers in justifying resource allocation to certain areas. Further, a comparative spatial analysis of hospitalisation rates can be done, before and after specific injury prevention interventions to determine their impact.<sup>20</sup>

**Climate change events:** Elderly persons are particularly susceptible to heat-related illness, and individuals with dementia may have elevated risk given their impaired recognition of weather conditions and limited ability to identify and alleviate heat stress. GIS has been used to understand the spatial variations in heat-related risk among individuals, wherein older age groups and accommodation in rental housing were found to be significant indicators of heat vulnerability.<sup>21</sup> GPS technology has also been used to assess individual vulnerability to heat stress and to develop smart navigation systems to avoid areas vulnerable to heat hazards.<sup>22</sup> Thus, GIS/GPS could serve as effective public health response tools to mitigate the adverse effects of climate change.

In summary, these technologies can augment the existing methods for identifying risk factors for multifactorial disorders such as dementia. Analysing environmental exposures and their patterns could help identify vulnerable populations and guide the implementation of remedial measures including primordial prevention of dementia. However, there are some limitations. Incorporation of GIS within existing healthcare systems, particularly in low-middle-income countries like India, may be challenging due to limited resources and reliance on grassroots-level workers on hand-drawn maps. Spatial data used in GIS also needs to be frequently updated to accurately incorporate changes in local geography. Thus, GIS/GPS in public health may be most beneficial when used by health professionals well acquainted with the concerns and conditions of the region under examination to facilitate interactive mapping of diverse data sets and the development of novel hypotheses.

### Abbreviations

GIS—Geographic Information System

GPS—Global Positioning System

TBI—Traumatic brain injury

### Authors' Contribution

Study conception and design: Aishwarya B. Hiremath, Jonas S. Sundarakumar. Draft manuscript preparation: Aishwarya B. Hiremath, Sumedha Mitra, Pooja Rai, Shafeeq K. Shahul, Abhishek L. Menesgere, Thomas G. Issac, Jonas S. Sundarakumar. Literature

review: Aishwarya B. Hiremath, Sumedha Mitra. All the authors approved the final draft of the manuscript.

### Declaration of Conflicting Interests

The authors declare no potential conflicts of interest concerning the research, authorship and/or publication of this article.

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