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Can Geographic Information Systems Help us to Better Understand Inequalities in Health Outcomes in the Era of Sustainable Development?

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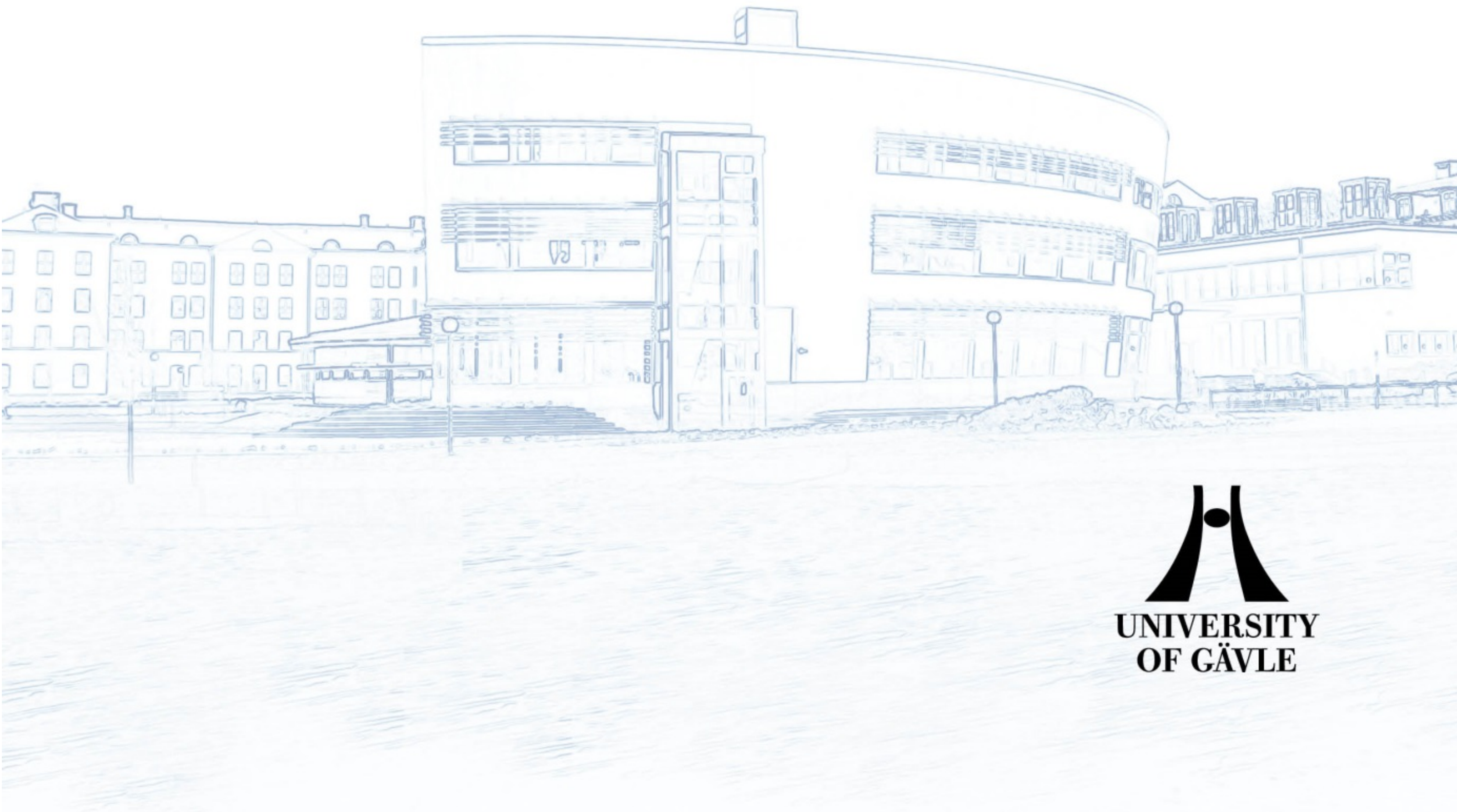

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Abstract

The objective of this working paper is to describe how geographic information systems can help the understanding of inequalities in health outcomes, including health care, in the era of sustainable development. Geographic information systems can help to reduce both social and spatial disparities in health outcomes (including health care location-based disparities) globally (in developed, middle-income and low-income countries alike), thus contributing to sustainable population health for today's and future generations.

Keywords: geographic information systems, social inequalities, spatial inequalities, sustainable development

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Introduction

The evidence, accumulated since the 1980s, that social determinants of health (SDOHs) have an effect on physical and psychological health outcomes, is today overwhelming (1–7). According to the World Health Organization (WHO), SDOHs are the structural determinants and conditions in which people are born; grow up, live, work and age. They include factors such as socioeconomic status (SES), education, the physical environment, employment, and social support networks, as well as access to health care (1). However, SODHs also include upstream factors such as social disadvantage, risk exposure and social inequities, that play an important causal role in poor health outcomes (4). Overall, the SDOHs are shaped by the distribution of money, power and resources at the global, national and local levels, which are themselves influenced by policy decisions (1, 4, 6–8). A variety of cross-sectional and longitudinal studies (including those using life course and intergenerational approaches) carried out across the continents have demonstrated that poverty, education, income, occupation, employment, ethnicity/race and segregation are associated with mortality (premature death), morbidity (physical and psychological) and quality of life (1). In addition, evidence has shown that children born to parents who have not completed high school are more likely to live in an environment that poses barriers to health, as their neighbourhoods are more likely to be unsafe, have exposed garbage or litter, and have poor or dilapidated housing and vandalism (1). These neighbourhoods might further lack pavements, parks and playgrounds, recreation centres and libraries (5). It is suggested that in many developed countries, poor members of ethnic minorities/immigrants are more likely to live in neighbourhoods with concentrated poverty compared with the poor of their host countries (1, 3, 5).

There is also growing evidence demonstrating that stress negatively influences health for children and adults across the lifespan. Recent research has also indicated that where a child grows up influences their future economic opportunities as an adult and that the environment in which an individual lives may have multi-generational impacts (9).

According to the literature, there are three upstream approaches to SDOHs: the social disadvantage approach, life course approach and health equity approach. The social disadvantage approach attempts to understand the link between neighbourhood conditions, working conditions, education, income and wealth, and ethnicity (and race and racism in some contexts), factors which might have an influence, through stress mechanisms, on health and ways to cope with these factors (1, 4).

The life course approach addresses periods of exposure to risk (adverse childhood experiences and intergenerational transfer of disadvantage) as well as cumulative exposures, and the potential link that can derive from the effect of social status. Lastly, the health equity approach focuses on the relationship between health and social inequalities that arise from sociodemographic factors such as class, immigration status, gender, sexual orientation and disability status, to which social capital can be added as moderating factor (4).

However, it is also important to account for the downstream processes of social inequalities in health. For instance, individual, downstream efforts might prevent, minimize and manage the impact of chronic disease, or result in behaviour change, but they cannot alter the underlying social and economic conditions that gave rise to an individual's health problems. Furthermore, although contested, the role of the health care system vis-à-vis health and inequities in health is important. Overall, health and longevity are determined largely by whether one falls ill, rather than by medical care per se (1, 10). According to Adler and Stewart, inadequacies of health care, including lack of access and poor-quality care, are estimated to account for only 10% of premature mortality overall (10). Furthermore, medical care has accounted for only 5 of the 30 years of life expectancy gained over the course of the 20th century (10). It is argued that individual (lifestyle) interventions that fail to acknowledge and address the underlying SDOH inequities are victim-blaming in nature. Others argue that lifestyle interventions that assume individual behaviours are freely chosen and therefore can be altered by providing information and education or developing skills (10). However, choice is not free: choice is largely conditioned and determined by social and economic factors operating over the life course (11, 12).

Although much research has focused on understanding the impact of social determinants of health and health inequalities, in recent years, on account of the challenges posed by urbanization and the need for promoting a healthy urban environment, another type of determinants have emerged as of great importance. These are termed "spatial determinants of health" (12) and have been described as determinants of health and inequalities in outcomes in small places and small spaces (11, 13, 14). "Spatial inequality" can be defined as the unequal amounts of qualities or resources and services, such as medical or welfare, depending on the area or location (11, 12). It is suggested that some communities have a greater range of resources and services compared with others (11). The space within the different locations is the clustering of various groups of people with similar SES (which is typically related to SDOHs) (15). Furthermore, spatial inequalities are evident across continents in developed, middle-income and low-income countries, with differences between countries, regions, communities and neighbourhoods (15).

Understanding the relationship between geography, social processes and human health is therefore of paramount importance for improving population health (16). For instance, areas where people live in poverty are more likely to remain that way until various resources (e.g. fresh drinking water) and services (e.g. educational institutions, health services) are introduced. Within a geographical space, various regions (areas, districts, provinces, states) show different levels of socioeconomic development – referred to as "spatial inequality in regional development" (15, 16). In recent years, it has been argued that public health interventions, clinical management and urban planning policies aiming to improve the living conditions of the people residing in informal settlements, as well as strategies formulated by governments, need to consider the differences that exist between and within types of settlements that shape place-based physical and social determinants of health (15, 16).

Evidence has shown that there is an important link between health and the natural and built environment. This shapes the social, economic and environmental circumstances that determine health (17). The term "built and natural environment" refers to the characteristics (objective and subjective) of a physical environment in which people live, work and play, including schools, workplaces, homes, communities, parks/recreation areas, green (e.g. visible grass, trees and other vegetation) and blue spaces (e.g. visible water) (17–24).

Furthermore, evidence indicates that the environment in which we live is inextricably linked to our health across the life course (13, 17). It is argued that neighbourhood design can influence physical activity levels, social connectivity, travel patterns, mental and physical health, and wellbeing outcomes (25–31). However, the potential mechanisms linking the built environment and health are often complex, because of an array of factors (17).

To aid the understanding of the complex role of the natural and built environment, Barton and Grant devised the health map (32) using as base the Dahlgren and Whitehead model (33). The health map focuses on the role played by neighbourhood and planning and emphasizes the importance of the natural and built environment's contribution to health and wellbeing outcomes, in line with the socio-ecological approach to health (32).

The objective of this working paper is to describe how GIS can help the understanding of inequalities in health outcomes, including health care, in the era of sustainable development. The following questions are posed:

a. Can GIS contribute to the study of spatial determinants of inequalities in health outcomes?

b. Can GIS contribute to sustainable population health in the era of sustainable development?

Geographic information systems and their contribution to the study of spatial determinants of inequalities in health outcomes

As mentioned above, there is a connection between a population's location and its health status. The use of GIS has given an array of researchers in different areas, such as geography, public health epidemiology, clinical psychology and sociology, the possibility to explore the role location plays in human wellbeing (34). It has been suggested that in epidemiological studies, GIS has actualized the importance of geographical and temporal variations in population health (34–43). Geographic information systems are defined as an application-led technology, which can be used, in this instance, for monitoring and understanding observed spatial distribution of attributes such as the geography of environmental exposures (35). For example, GIS is required to transpose data stored in a health care-related database to a spatial-related database, assigning to each record a univocal spatial location, a process called "geocoding". As already stated, and supported by an array of scientific scholars (35,44), where people live, work and play matters to their health. For instance, Galster (44) has suggested four different mechanisms through which neighbourhoods can influence health: (a) social interactive processes (social processes such as collective norms or networks and cohesion between residents); (b) environmental processes (physical attributes such as public infrastructure and exposure to toxic substances); (c) geographical factors (particularities relating to macro-level political and economic factors, such as a limited local tax base or restricted job opportunities); and (d) institutional mechanisms (actions of persons/forces external to the neighbourhood, which may result in place-based stigmatization or unequal public and private resources) (44). In recent years GIS has played an important role in the study of environmental epidemiology. Applications include locating the study population by geocoding addresses (assigning mapping coordinates), using proximity analysis of contaminant source as a surrogate for exposure, and integrating environmental monitoring data into the analysis of health outcomes (31,35). Of current interest is the possibility to use the life course approach which allows the development of small area longitudinal measures. This possibility will enable a wide set of environmental measures that consider how health–place relations are formed through steady cumulative exposure over time (e.g. gradual improvements to local resources and infrastructure) and/or as a result of critical moments with sudden and perhaps profound implications for health (e.g. closure of an industry dominating local employment opportunities) (41). Helbich (31) argues that people are exposed to multiple health-supporting and harmful exposures not only during their daily lives, but also over the course of their lives. Furthermore, he stresses that mobility-based approaches facilitate an exploration of exposure duration, exposure sequences and exposure accumulation. However, he points out that dynamic exposure assessments are extremely data-intensive and require multi-temporal, high-resolution geodata, which is particularly challenging for long-term residential history analyses (31).

Another important use of GIS is in the area of environmental justice (EJ). The fundamental question of EJ is whether environmental hazards are concentrated in communities characterized by low SES (as indicated by income, educational attainment, wealth and other indicators of disadvantage). The concept infers a lack of equity or fairness because disadvantaged communities do not share equally in the production and consumption sectors that raise living standards and quality of life; and yet, ironically, they bear the brunt of the unintended but important "side effects" of the production and consumption (e.g. air pollution) (28).

Geographic information systems in public health

Geographic information systems have contributed to public health through bringing together methods from epidemiology and medical geography, which allow a variety of applications in the health sciences. Of great importance is the application of GIS in the study of health disparities, health care availability, health-related behaviours, environmental infectious diseases, and health care for cancer and other chronic diseases. Public health professionals, specifically epidemiologists, have used GIS to assess proximity, aggregation, and clustering, as well as to perform spatial smoothing, interpolation and spatial regression (34, 36). Worldwide, and especially in middle and low-income countries, the most common application of GIS in public health has been the identification of disease clusters, which refers to non-random spatial distribution of disease cases, incidence or prevalence, using: (a) global clustering, in which no cluster areas are pre-specified and the presence of clusters is derived empirically; (b) local clustering, in which specific small-scale clusters are evaluated statistically; and (c) focal clustering, which assesses clustering around a predetermined point such as an environmental hazard (38). In addition, in these contexts, GIS is extensively used for disease surveillance and intervention monitoring.

The mapping of disease cases in the geographic space – local, regional, or national – can easily identify the distribution and spread of disease across geographic regions, optimize planning of intervention locations and monitor the effectiveness of interventions at these locations. Such applications of GIS, in combination with other technologies such as global positioning systems (GPS) and remote sens¬ing (RS), have been successfully employed in the monitoring and control of diseases across several countries (34, 35, 43).

Geographic information systems, especially within the field of medical geography, epidemiology, environmental health and public health, have enabled collection and analysis of mass amounts of information, known as "Big Data". Many define Big Data as datasets that are beyond the ability of typical datasets and do not use typical database software for capturing, storing and managing data and conducting analyses (34). Two factors have been reported to have influenced the trend of Big Data: (a) the growing size of common datasets in the industry; and (b) the increased availability of software with ability to process such amounts of data (34).

Geographic information systems incorporate spatial analysis using readily available data. Thus the utilization of large datasets allows medical and public health researchers to provide up-to-date medical, health and social trends (e.g. data on social networking) (34). Furthermore, GIS can contribute by enabling use of social technologies in conjunction with the large datasets (31). This means that GIS can provide a digital platform for exploration of dynamic connections between people, their health and wellbeing, and changing physical and social environments. Also, it has been suggested that Big Data can contribute to better understanding of urban mobility, especially in catastrophic scenarios (45). For instance, Zia et al proposed scenarios using GIS tools that would enable city planners to consider information such as individual differences in behaviour and reactions in emergency (45). Overall, the use of Big Data will allow public health and urban planners to have information on illness patterns and availability of services for populations in need, and to improve the accessibility and utilization of health care (34, 35, 39, 42, 45).

Geographic information systems and health care services

Geographic information systems enable health and public health researchers to assess the spatial distribution and accessibility of health services. Globally, health care disparities are increasing, and many governments are urged to re-evaluate health care systems to accommodate current and future health care needs (39, 42). Geographic information systems can contribute by allowing visualization of health service utilization, taking into account the many factors related to locational constraints that may limit an individual from acquiring proper heath care.

In addition, location–allocation models can be used to identify how gaps in health services among specific communities can be reduced (39). For instance, existing health services can be mapped along with road networks to identify and facilitate patient travel. It is argued that access to health care is largely determined by cultural, social and economic barriers in addition to geography. Hence, simply adding more services at existing locations would not automatically increase population access (39). Using GIS techniques can improve distribution of health resources and identify service gaps. Geographic information systems allow the visualization of other valuable information such as population distribution, poverty levels and income, to better determine the best possible placement of new services, as well as identify specific regions that are underserved (39). An example from the literature is the gravity model which takes into account not only Euclidean distance between individual residences and health care providers, but also factors such as price, quality of service, accommodation, and cultural appropriateness in order to determine which particular facilities offer more "attractive" health care services to specific subsets of the population, thus helping to identify patterns of accessibility and providing insight into population composition and a population's specific needs (46).

Geographic information systems and life course epidemiology

For centuries, epidemiologists have used maps to analyse associations between location, environment and illnesses (47). Over the past few decades, spatial epidemiology has allowed new developments in epidemiologic methods. Spatial factors are today a part of research designs and methods, reflecting research related to aetiology, and host–vector agent interactions as well as social and environmental factors. According to Elliot et al (43), there are four types of spatial analysis in epidemiology: (a) disease mapping; (b) geographical correlation studies; (c) risk assessment in relation to point or line sources; and (d) cluster detection and disease clustering (43). The question is how spatial epidemiology can advance our knowledge of life course exposures (or intergenerational exposure). Adopting a life course as well as an intergenerational approach has important implications for prevention of non-communicable diseases, particularly in populations undergoing rapid economic transition (47, 48).

In life course epidemiology, the main assumption is the accumulation of risks that also occur at the level of space and geographic location (49, 50). Two models have been important in this field, Barker's biological programming hypothesis, and the critical period model which is related to the critical timing of exposure to risk factors likely to cause irreversible effects on health outcomes (49, 50). Life –course epidemiology aims to assess the extent to which cumulative damage to biological systems occurs as the number, duration or severity of exposures increases, and as body systems age and become less able to repair damage (51). The accumulation of different types of exposures (such as environmental, socioeconomic, and behavioural) can cause long-term damage with exposure risk being either independent or clustered (50–52).

In an attempt to go beyond cross-sectional studies of neighbourhood context, Osypuk proposed looking at the geography of opportunity using a life course perspective (53). She suggested that it is important to incorporate life course concepts, data, and methods, including the modelling of residential histories, neighbourhood temporal change and residential mobility, starting early in life (53). Such a move, she argued, would "help inform when in life neighbourhoods matter most for health and health inequalities, as well as improve exposure assessment of residential contexts". Osypuk also argued for the need to create model mechanisms linking neighbourhoods to health, including the role of individual and household SES (53). Historical GIS can potentially provide more information about how space contributes to health inequalities. Supporters of the historical method suggest that GIS can help recreate several characteristics of urban neighbourhoods over time (53, 54). Examples of this are the studies being conducted in the US and Spain that use GIS to integrate historical data on urban space and socioeconomic differentials within selected cities over time (53, 54).

In other words, GIS can be used to access historical sources to obtain health-related, place-based data to create constructs of neighbourhood measures of the health-related environment at particular time points (55, 56). Such data can be operationalized in small-area measures of the health-related environment over time to develop a life course of place (53, 54, 56). Diez Roux and Mair argue that linking place-based information and cohort data is an important priority and that the integration of neighbourhood-level information from archival sources (medical records, census data, educational reports, social surveys, etc) with available cohort data for different time points can provide a deeper understanding of the role of place-based factors in affecting health over the life course. It can also give an insight into the complex processes leading to geographical inequalities in neighbourhood resources (57).

The contribution of geographic information systems to population health and sustainable development

Sustainable development is development that provides a better quality of life for populations, both now and in the future (58). The sustainability of societies is based on a balance between the efficient conservation of the environment and the social and economic development (58). In recent years, there has been an increased interest in sustainable cities because of rapid global urbanization. In the past two centuries, the world's urban population has grown from around 5% of the total human population, in 1810 to 54%, in 2016 (59). In addition, available projections suggest that by 2050, the urban population will amount to about 60% (about 2.5 billion) of the total population, with 90% of Africa's and Asia's population living in urban areas (59). The increase in the urban population will require more urban land, which in turn will affect biodiversity and ecosystem productivity (through loss of habitat, biomass and carbon storage) (59). In relation to health, the rapid urbanization in low and middle-income countries is resulting in inequalities in urban areas which at times may exceed those of rural areas (15). Furthermore, in low and middle-income countries many cities have higher infant mortality and neonatal mortality (47), traffic injuries and infectious diseases (15).

Urban planning has become one of the important issues in sustainable development (60–62) and goal 3 of the Sustainable Development Goals health targets for 2030 aims at making cities inclusive, safe, resilient and sustainable, which will consequently contribute to sustainable population health. Sustainability in urban areas is directly connected to health equity issues because where in a city one lives and how that city is governed can determine whether one benefits from city living (63). This paper has shown that GIS, GPS and RS can provide the necessary tools and techniques for urban development planning, and can help to improve population health by identifying environmental exposures, static and dynamic, that will allow a better understanding of how spatial determinants affect urban health, using a variety of data (Big Data).

Conclusion

This working paper sought to answer the question whether GIS can help to better understand inequalities in health outcomes in the era of sustainable development. All indications are that GIS has the potential to provide public health researchers with new tools and opportunities in addressing spatial inequalities in health and health care. For instance, using maps, GIS can contribute through visualization of the spatial inequalities and can help in the study of dynamic environmental exposures. Crucially GIS will aid public health researchers in the formulation of better conceptual frameworks and provide potential pathways (or mechanisms) for the understanding of life course of place. Overall, GIS can help to reduce both social and spatial disparities in health outcomes (including health care location-based disparities) globally (in developed, middle-income and low-income countries alike), thus contributing to sustainable population health for today's and future generations

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