Geographic Information Systems as a Tool to Support the Sustainable Development Goals

Gulnara N. Nabiyeva, Stephen M. Wheeler

***Abstract*—**Geographic Information Systems (GIS) is a multipurpose computer-based tool that provides a sophisticated ability to map and analyze data on different spatial layers. However, GIS is far more easily applied in some policy areas than others. This paper seeks to determine the areas of sustainable development, including environmental, economic, and social dimensions, where GIS has been used to date to support efforts to implement the United Nations Sustainable Development Goals (SDGs), and to discuss potential areas where it might be used more. Based on an extensive analysis of published literature, we ranked the SDGs according to how frequently GIS has been used to study related policy. We found that SDG#15 "Life on Land" is most often addressed with GIS, following by SDG#11 "Sustainable Cities and Communities", and SDG#13 "Climate Action". On the other hand, we determined that SDG#2 "Zero Hunger", SDG#8 "Decent Work and Economic Growth", and SDG#16 "Peace, Justice, and Strong Institutions" are least addressed with GIS. The paper outlines some specific ways that GIS might be applied to the SDGs least linked to this tool currently.

Keywords—GIS, GIS application, sustainable community development, sustainable development goals.

I. Introduction

ONE of the main challenges of the twenty-first century is to bring about more sustainable development that improves the long-term health of human and ecological systems [1], 2]. In response to this challenge, in 2015 all United Nations member states adopted the 2030 SDGs as a universal call to end poverty, protect the planet, and ensure that all people enjoy peace and prosperity [3]. There are 17 comprehensive and integrated SDGs linked to specific 15-year targets (see Fig. 1).

Even though progress has been made in many areas, implementation of the SDGs is not advancing at the speed or scale required [5]. Hence, the oncoming decade must bring ambitious actions to deliver SDGs by 2030, and that is why there is a high demand for suitable tools to support these actions. As long ago as 1992, the United Nations Conference on Environment and Development suggested GIS as a suitable tool to support sustainable development efforts within the Agenda 21 Action Plan. As a big picture, GIS is "… a system of hardware, software, data, people, organizations and institutional arrangements for collecting, storing, analyzing, and disseminating information about areas of the earth" [6]. Within a more applied approach, GIS is "… any manual or computer-based set of procedures used to store and manipulate geographically referenced data" [7]. Cowen described GIS as a system for support of geographically based decisions, or a "Spatial Decision Support System", which allows creating a visual overlay of available geospatial datasets to reveal patterns and trends that may not be perceived otherwise [8].

According to Campagna, GIS has strong potential to support sustainability planning, decision-making, and management because of its sophisticated ability to map, combine, and analyze different data into spatial layers [9]. He had highlighted 5 capabilities of GIS for sustainable development: (1) to produce and maintain geographic information; (2) to support distributed access to (environmental) information (spatial data infrastructure); (3) to solve spatial problems (spatial analysis and environmental modeling); (4) to support collaborative decision-making (group spatial decision-making); and (5) to support public participation (public participation GIS). In turn, Kumar et al. have determined 8 capabilities of GIS regarded to any data: (1) to capture; (2) to store; (3) to maintain; (4) to query; (5) to analyze; (6) to manipulate; (7) to display; and (8) to output [10]. As they mentioned, there are 4 major GIS applications only within various disciplines: (1) mapping, (2) monitoring, (3) measurement, and (4) modeling.

Within SDGs, GIS helps to solve complex concerns by creating a geographic-design framework [11]. In 2019, Dangermond, a founder and president of Esri (one of the major companies in the field of GIS), suggested 5 consecutive steps the global development community can take to better leverage GIS in SDGs implementation [12]: (1) to gather geographic information; (2) to visualize the data; (3) to conduct spatial analysis by overlaying different maps and evaluating relationships between them; (4) to create geographic plans; and (5) to take an action. The first step aims to improve decision-making by capturing, organizing, and managing various data. Within the second step, Esri in cooperation with the United Nations had established a Data Hub to map out visually the ongoing work on SDGs. The third step – a spatial analysis - helps to determine the cause-and-effect relations in a particular phenomenon within any analyzed SDGs. The fourth step allows developing a scope of decisions about what to do where. During the fifth step, users can (1) verify relationships, complexity, and patterns, (2) map out different options, and (3) evaluate their benefits and risks to make the best possible decision.

In this paper we ask how researchers have applied GIS to the SDGs to date, and speculate on ways that GIS might be applied to SDGs for which it is still not used widely.

Gulnara Nabiyeva is with the UC DavisUC Davis, United States (e-mail: gnnabiyeva@ucdavis.edu).

Land Use Modelling for Micro-Level Planning (Blocks) as an example of SDG#15 “Life on Land”. Specifically, GIS had provided the researches with the ability to support decision making with unbiased information for spatial analysis and management of natural resources. Also, they had integrated thematic maps, spatial and non-spatial databases to suggest alternative land-use models for agricultural land, wasteland, and forests of the Ferozpur Jhirka block of Mewat district in Haryana, India. In turn, we examined the five most frequently cited papers on SDG#11 “Sustainable Cities and Communities” and SDG#15 “Life on Land” according to Clarivate Analytics’ Web of Science Core Collection by Kumar’s major applications of GIS: (1) mapping, (2) monitoring, (3) measurement, and (4) modeling. As a result, (1) modeling along with (2) measurement and (3) mapping were the kinds of most frequently GIS applications in highly-cited papers (see Table IV).

To get more accurate findings, the same method could be utilized to analyze the larger number of papers in the field of each SDG. However, it will be a part of our further research on the topic. On the other hand, a suitable methodology should be developed to apply GIS into the area of SDGs from the bottom of Table III. We assumed that the critical point here is to determine the types of GIS major applications to SDG’s specific area or indicators. In such a case, the combination of Kumar’s major GIS applications [10] with Dangermond’s steps to better leverage GIS in SDGs implementation [12] seems to be a reasonable universal approach (see Table V). In other words, this combination shows the ways of GIS applications that most likely could be useful for the analysis of any SDG based on a stage of its analysis. Besides, to determine possible GIS applications more precisely, the SDG’s sub-targets could be considered separately, within specific analysis needs and sub-target’s indicators.

TABLE V
JUXTAPOSITION OF 4 MAJOR GIS APPLICATIONS [10] WITH 5 STEPS TO BETTER LEVERAGE GIS IN SDG IMPLEMENTATION [12]

Four Major GIS Applications	Five Steps to Better Leverage GIS in SDGs Implementation				
	(1) Gather Information	(2) Visualize Information	(3) Conduct Analysis	(4) Create Plans	(5) Take Actions
(1) Monitoring	×				×
(2) Mapping	×	×			
(3) Measurement			×	×	
(4) Modeling				×	×

V. CONCLUSION

In general, GIS implementation to support sustainable development is still very limited, even the number of corresponded papers is increasing. Based on a quantitative literature review, we determined that different actors utilize GIS mainly to address the following SDGs: “Life on Land”; “Sustainable Cities and Communities”; “Climate Actions”; “Quality of Education”. In opposite, GIS is still not addressed widely to the rest of SDGs, and the least frequently GIS had been utilized in the context of SDGs “Zero Hunger”, “Decent Work and Economic Growth”, and “Peace, Justice, and Strong Institutions”.

Future research on the topic could be focused on specific issues in the field of sustainable development GIS could best contribute, as well as on application of GIS to track some specific indicators in the field of sustainable development, including the development of recommendation about how different actors can apply GIS more fully to SDGs planning and implementation. Another perspective area for research is to determine why some GIS portals is far more transparent to the public and more clearly linked to policy in some locations than in others.

REFERENCES

[1] Wheeler, Stephen M. Planning for Sustainability. Creating Livable, Equitable and Ecological Communities. Routledge. Taylor & Francis Group. London and NY. 2013.
[2] Wheeler, Stephen M., and Beatley, Timothy. The Sustainable Urban Development Reader, 2nd edition, London and New York: Routledge, 2009.
[3] 2030 Sustainable Development Goals. Knowledge Platform. Received from https://sustainabledevelopment.un.org/?menu=1300
[4] The United Nation Sustainable Development Goals. Received from https://srasiaconference2015.files.wordpress.com/2015/09/sdgs_logos_banner.jpg
[5] Sustainable Development Goals. Decade of Action. Received from https://www.un.org/sustainabledevelopment/decade-of-action/
[6] Duecker, K., Kjerne, D. Multipurpose Cadaster: Terms and Definitions. In: Proceedings of the ACSM-ASPRS, vol. 5, 1989, pp. 94–103.
[7] Aronoff, S. (1989). Geographical Information Systems: Management Perspective. WDL Publications, Ottawa.
[8] Cowen, D.J. GIS versus CAD versus DBMS: What Are the Differences? Photogrammetric Engineering and Remote Sensing, Vol. 54, №.11, November 1988, pp. 1551–1555.
[9] Campagna, M. GIS for Sustainable Development. Boca Raton. Taylor & Francis Group. London and NY. 2006.
[10] Kumar, D., Singh R.B., Kaur, R. Spatial Information Technology for Sustainable Development Goals. Springer. 2019.
[11] Narain, A. What Is the Strategic Importance of Geospatial for SDGs (Geo4SDGs or GEO-for-SDGs)? Received from Geospatial World https://www.geospatialworld.net/blogs/importance-geospatial-for-sdgs-geo4sdgs/
[12] Cheney, C. GIS for SDGs: “See things that were impossible to see,” ESRI founder says. 2019. Received from https://www.devex.com/news/gis-for-sdgs-see-things-that-were-impossible-to-see-esri-founder-says-95255
[13] Elsevier’s Scopus. Received from https://www.scopus.com
[14] Clarivate Analytics’ Web of Science. Received from https://apps.webofknowledge.com
[15] Google Scholar. Received from https://scholar.google.com/
[16] The 10 Countries Most Active in Space. Received from https://www.aerospace-technology.com/features/featurethe-10-countries-most-active-in-space-4744018/
[17] Narain, A. The World’s Most Geospatial Ready Countries. 2018. Received from https://www.geospatialworld.net/article/worlds-geospatial-ready-countries/
[18] Narain, A. (2018). What Constitutes the Geospatial Technology Ecosystem? 2018. Received from https://www.geospatialworld.net/blogs/geospatial-technology-ecosystem/
[19] Roy, M. Planning for sustainable urbanisation in fast growing cities: Mitigation and adaptation issues addressed in Dhaka, Bangladesh, 2009. Received from https://www.sciencedirect.com/science/article/pii/S0197397508000684
[20] Wang, H., Shen, Q.P., Tang, B.S. GIS-Based Framework for Supporting Land Use Planning in Urban Renewal: Case Study in Hong Kong. 2015. Received from https://ascelibrary.org/doi/full/10.1061/%28ASCE%29UP.1943-5444.0000216
[21] Cinderby, S. How to reach the ‘hard-to-reach’: the development of Participatory Geographic Information Systems (P-GIS) for inclusive

urban design in UK cities. 2010. Received from https://rgs-ibg.onlinelibrary.wiley.com/doi/full/10.1111/j.1475-4762.2009.00912.x
[22] Banai, R. Land resource sustainability for urban development: Spatial decision support system prototype. 2005. Received from https://link.springer.com/article/10.1007/s00267-004-1047-0
[23] Niblick, B., Monnell, J.D., Zhao, X., Landis, A.E. Using geographic information systems to assess potential biofuel crop production on urban marginal lands. 2013. Received from https://www.sciencedirect.com/science/article/pii/S0306261912006770
[24] Kayastha, P., Dhital, M.R., Smedt, F.De. Landslide susceptibility mapping using the weight of evidence method in the Tinau watershed, Nepal. 2012. Received from https://link.springer.com/article/10.1007/s11069-012-0163-z
[25] Ansal, A., Akinci, A., Cultrera, G., Erdik, M., Pessina, V., Tonuk, G., Ameri, G. Loss estimation in Istanbul based on deterministic earthquake scenarios of the Marmara Sea region (Turkey). 2009. Received from https://www.sciencedirect.com/science/article/pii/S0267726108001279
[26] Van den Bosch, M.A., Mudu, P., Uscila, V., Barrdahl, M., Kulinkina, A., Staatsen, B., Swart, W., Kruize, H., Zurlyte, I., Egorov, AI. Development of an urban green space indicator and the public health rationale. 2016. Received from https://journals.sagepub.com/doi/full/10.1177/1403494815615444
[27] Boateng, I. An application of GIS and coastal geomorphology for large scale assessment of coastal erosion and management: a case study of Ghana. 2012. Received from https://link.springer.com/article/10.1007/s11852-012-0209-0
[28] Sharma, T., Carmichael, J., Klinkenberg, B. Integrated modeling for exploring sustainable agriculture futures. 2006. Received from https://www.sciencedirect.com/science/article/pii/S0016328705000765