The Potential of Building Information Modeling in Agricultural Operations

Dario Rizzi
PhD IDAUP / University of Ferrara

DOI: 10.37199/o41009127

Abstract- *Building Information Modeling (BIM) has been widely adopted in the construction industry, providing a virtual representation of physical objects and systems. In the context of agriculture, BIM can be applied to monitor and manage the physical and operational characteristics of farms and agricultural facilities using BIM digital twins.*

A BIM digital twin is a virtual representation of a physical object or system that is based on data from BIM models and other sources. The integration of sensors is essential in creating a BIM digital twin as they provide real-time data that can be used to update and maintain the virtual representation. The use of BIM digital twins in agriculture has the potential to improve the management of agricultural facilities, reduce environmental pollution, and promote the sustainability of agricultural land.

Sensors can be used in agriculture to monitor various parameters such as soil moisture, temperature, and nutrient levels. BIM digital twins can also be used to monitor and manage sources of pollution, such as the use of pesticides and fertilizers, and to develop strategies to minimize their impact on the environment. BIM digital twins provide a comprehensive view of the condition of agricultural land and the factors that influence it, such as weather patterns, industry activities, and human activities.

4D BIM is an extension of traditional 3D BIM that adds a time dimension to the model. In the context of agriculture, 4D BIM can be used to visualize and simulate various processes related to time and soil management, such as planting and harvesting cycles, and to evaluate the impact of different planting strategies on crop yields. 4D BIM can also be used to model the impact of weather patterns on crop growth and to develop contingency plans for weather-related events.

The use of BIM in agriculture has the potential to transform the industry by providing a new level of insight and control over agricultural operations. BIM models can be used to simulate and visualize different scenarios for agricultural facilities, such as the use of water, fertilizer, and energy, leading to improved efficiency and reduced waste. By using BIM to optimize operations, agricultural companies can increase their productivity and profitability.

The integration of BIM digital twins and 4D BIM in agriculture has the potential to revolutionize the industry by providing new tools for monitoring and managing agricultural operations. The use of BIM digital twins and 4D BIM can help reduce environmental pollution, promote sustainability, and improve the efficiency and productivity of agricultural operations. Testing is needed to fully understand the potential benefits of BIM and BIM digital twins in agriculture and to develop best practices for their implementation.

Abstract- *BIM, Agriculture Context, BIM digital twins*

Fig1 / Screenshot of South Albania
source / Google Earth, 2023

State of Art - The current state-of-the-art publications and case studies focusing on the integration of Building Information Modeling (BIM) in landscape and agriculture reflect a burgeoning interest and exploration in this interdisciplinary field. A significant contribution is made by Junhwi Cho et al. in their work "Web-based agricultural infrastructure digital twin system integrated with GIS and BIM concepts," showcasing the integration of Geographic Information Systems (GIS) with BIM in creating comprehensive digital twins for agricultural infrastructure (Junhwi Cho et al., 2023). Furthermore, "Building Information Modelling (BIM) and the Impact on Landscape: A systematic review of Evolvements, shortfalls, and future opportunities" by A.Nikologianni, M. Mayouf, and S. Gullino (2022) provides a thorough overview of BIM's evolution and its impact on landscape management. Another notable study by A. Radulović, D. Sladić, M.Govedarica, and Dušan Raičević, "Using LADM and BIM for property and tourist taxation in the municipality of Bar, Montenegro" (2023), exemplifies the innovative application of BIM in municipal planning. These studies, alongside others in the field, focus on BIM's applications in agricultural planning and landscape design, emphasizing its role in enhancing sustainability, efficiency, and environmental stewardship. The integration of 4D BIM, as explored in various case studies, adds a temporal dimension that aids in understanding and predicting the impact of seasonal changes and climate on agricultural outputs and landscape resilience. Collectively, these publications and case studies represent a significant shift towards technologically advanced, data-driven approaches in agriculture and landscape management, paving the way for innovative and sustainable practices.

Introduction

Southern Albania is a mosaic of untapped opportunities and underutilized resources. Geographically, it's marked by a landscape of mountains that serve a crucial role as natural water reserves, particularly important in the context of climate change. These mountains, coupled with valleys and coastlines, create a natural tableau of considerable beauty, although it remains largely unexplored and underutilized. Despite a rise in tourism in Albania, these scenic resources are surprisingly undervalued.

Another critical dimension is its history. In the post-communist era, the land in this region has seen significant structural changes. Privatization policies have left behind a legacy of land fragmentation, which has resulted in numerous uncultivated fields, especially in areas like Finiq and other southern parts of Albania. These uncultivated fields should not be seen as a problem but as an opportunity, offering potential for a variety of uses such as agriculture. The historical and cultural heritage sites add another layer of complexity to the regional context. The presence of archaeological sites like Adrianopoli, Butrint, and Phoeniciae opens a window into the area's rich history. However, these sites too are relatively underutilized and have not been fully incorporated into any local

Fig2 / Finiq valley
source / the author

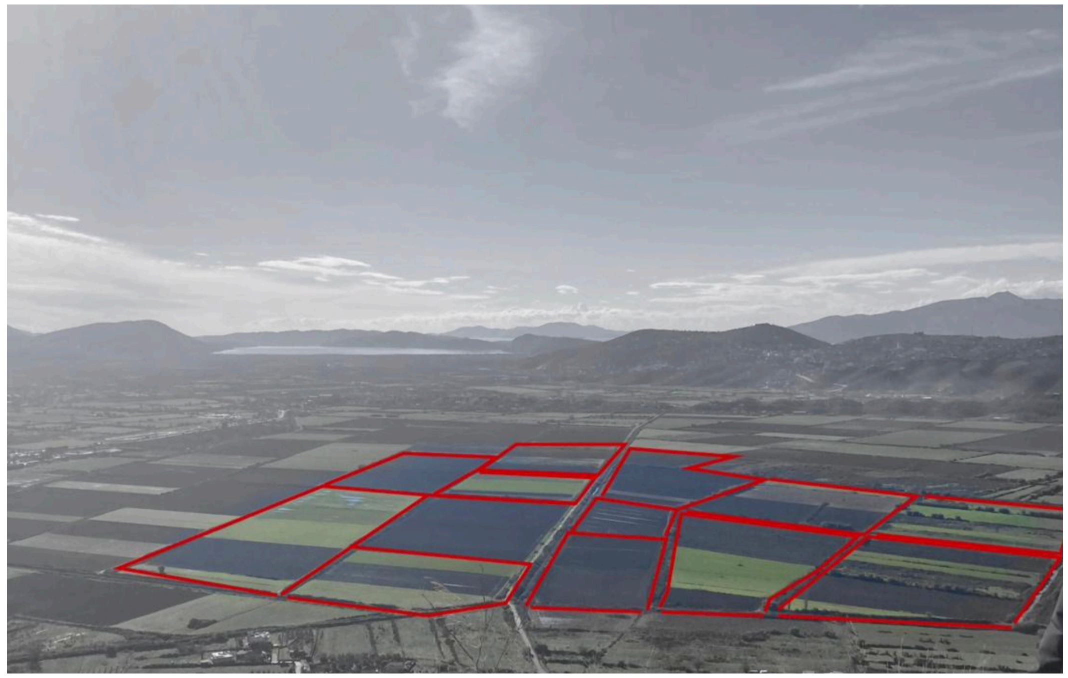

Fig3 / Photo of the fragmentation of the fields of the Finq valley
source / the author

development plans.

Research Question

The use of Building Information Modeling (BIM) in the valleys of Finiq stands out as an essential means to address some of the most pressing issues related to agricultural management and environmental sustainability. BIM offers a sophisticated set of tools that facilitate a deeper understanding and optimized management of the fragmented and underutilized agricultural landscape characteristic of this region.

In the specific context of the valleys of Finiq in southern Albania, land fragmentation has led to numerous fields that remain unused or poorly cultivated. In this setting, the implementation of BIM takes on a fundamental role.

The adoption of BIM allows for accurate mapping and three-dimensional modeling of the fragmented lands, creating an integrated and detailed database that is crucial for design, planning, and agricultural management. This unified database facilitates coherent land management, allowing for large-scale interventions that respect individual ownership. Even more importantly, it is possible to equip the fields with smart sensors to monitor real-time critical variables such as soil moisture and nutrient levels. This real-time information contributes to more effective and sustainable decision-making. For example, using 4D modeling, it is possible to simulate the impact of different irrigation or fertilization strategies, which in turn enables more efficient resource management and a reduced environmental impact.

Methodology Used

In the context of the Finiq valleys, where land fragmentation and underutilization of fields are urgent issues, the digitalization of the agricultural sector is acquiring strategic importance similar to that observed in the construction supply chain. Just as emerging technologies such as sensors and Big Data are revolutionizing the construction sector, they have the potential to bring significant innovations to agriculture as well (Planu, 2023).

Building Information Modeling (BIM) has been identified as a key tool to address these challenges, accompanied by growing interest in its application for agricultural management. Data interoperability, particularly through standards such as IFC, offers a method for developing integrated digital environments that can go beyond simple three-dimensional modeling by incorporating a variety of information. (Bianchini, 2021)

The established methodology of creating 3D point cloud models, often obtained through LiDAR-equipped drone surveys, offers a reliable basis for the representation and management of fragmented agricultural land. This technology represents a significant step forward in the evolution of digital agriculture, providing tools for more effective and sustainable field management.

However, like the problems encountered in the construction sector, agriculture is also plagued by fragmented information and heterogeneous data sources that need to be integrated and organized. The need to advance towards a single convergent data context for digital visualization and representation is therefore fundamental.

We propose the development of a collaborative platform, with the aim of monitoring the health of the soil, crops, and water resources, rather than buildings, in real-time. This platform is based on a network of IoT sensors spread across the territory and connected to a model or platform, providing a fundamental tool for studying the terrain. The project for Finiq focuses on natural and agricultural heritage, leveraging survey technologies such as LiDAR and photogrammetry to create detailed 3D models of the terrain. This data is then integrated with other datasets, such as those relating to climate and resource use or GIS maps, to provide a complete and real-time view of the health of the territory. (Raco, 2022)

In Finiq's valley-ready platform developed to manage agricultural and soil data, it is able to receive, archive, and analyze incoming data from a network of IoT sensors scattered throughout the valleys. The platform is therefore divided into functional areas depending on the agricultural and territorial needs or specific properties of the Finiq context.

The heart of the platform is where maps and diagrams intertwine and visualize recorded data, such as the health of soil, crops, and water resources. The platform is made up of thematic sheets adapted according to needs and offers details, allowing you to view the monitored terrain in relation to radar points, subsidence maps, and the use of water resources. It is also possible to display information related to data acquisition and directly connect to 2D representations and the specific BIM model for agricultural management in the Finiq valleys.

Thanks to the visualization of the three-dimensional model of the digital twin, it is possible to navigate through all the connected information, thus facilitating the transition toward greater accessibility to the recorded data. (Maietti, 2018). This BIM model, enriched with the sensors of the acquisition system, makes it possible to access all the data, making it available for possible algorithms. For example, predictive algorithms use machine learning and artificial intelligence models to analyze historical and current data, identifying patterns and trends that may not be immediately obvious. This allows us to predict with a high degree of accuracy a range of future scenarios, from changes in soil and crop health to changes in water resources.

Even though technology improves exponentially, the difficulty with which a community manages to acquire and use certain technological tools should not be underestimated. Clearly, to use this method of resource management 100%, it is necessary to have competent personnel, but to make these tools active it is necessary to directly involve local farmers. Integrating traditional agricultural knowledge and practices into the digital platform can further customize the technology to adapt to local conditions and improve its acceptance within the community. The implementation of pilot projects in selected areas of the Finiq valleys can demonstrate the practical benefits of

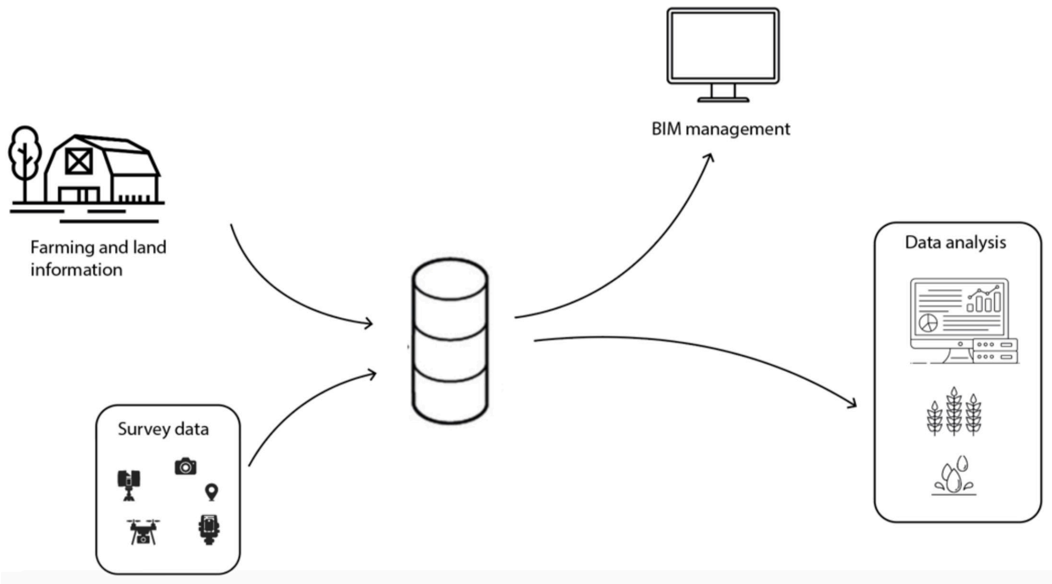

Fig4 / Methodological diagram for BigData and Agriculture
source / the author

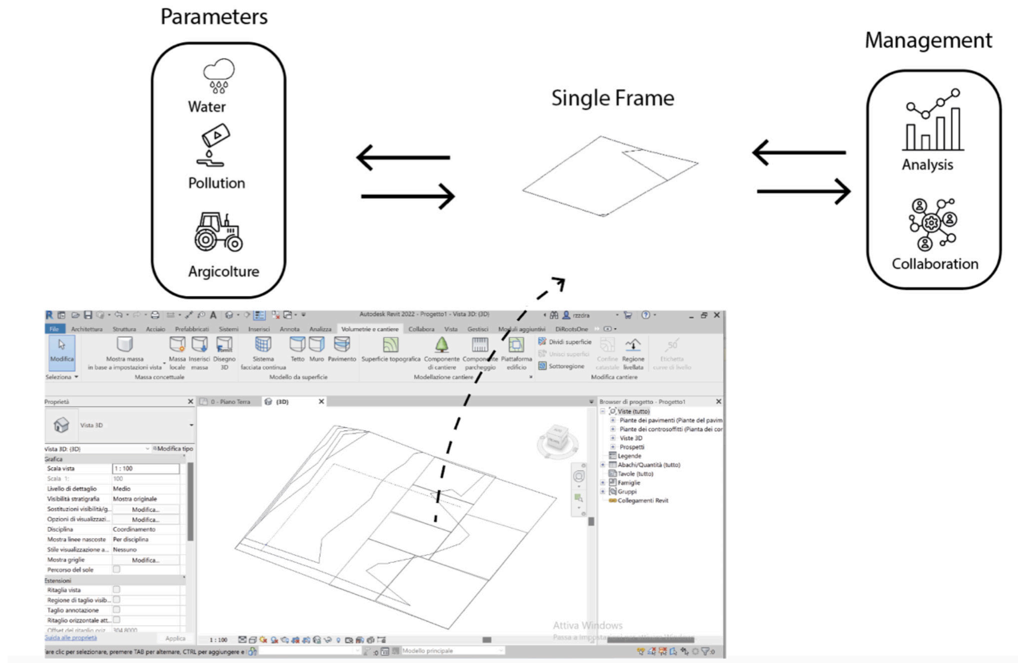

Fig5 / Revit Model and diagram of BIM Agricolture
source / the author

the platform. Showcasing the successes of these pilot projects to the broader community can illustrate the effectiveness of the technology in real-world scenarios.

Result

This document highlights the advanced potential of the Finiq platform, highlighting how the integration of 3D surveys and BIM models provides a multifunctional database for a variety of spatial and structural applications. In detail, the platform proves to be essential for the management of terrain data, acting as a fundamental tool for the development and implementation of effective projects.
BIM models and digital twins, which can be scaled from individual fields up to entire regions, serve as pillars for formulating long-term strategies in land management. These advanced tools facilitate planning and enable a broader scope of action, from simple conservation and preservation projects to more complex initiatives. By analyzing the state of the art and also in other contexts in which a product like this is already active, it is possible to understand that these platforms have a strong impact on the economy and on the management of resources, significantly increasing the profitability of the territory and strengthening its management. The functionally organized Finiq platform not only serves as a solid professional tool for stakeholders engaged in territorial development but also expands access to regional knowledge. This is particularly useful for the community at large, as it facilitates the dissemination of vital information on various aspects of the area.
A further strong point is represented by predictive analysis, possible thanks to the implementation of machine learning algorithms. These algorithms allow the platform to predict a range of potential future issues, such as structural vulnerabilities or asset management challenges, thus enabling stakeholders to take preventative measures. In this way, the effectiveness and sustainability of territorial and structural initiatives are increased.

Conclusions and Recommendations

In the context of the Finiq project, the digital platform integrated with BIM models revolutionizes territorial management, even in rural areas like that of Finiq, which present unique challenges and opportunities. Although the initial financial investment may seem considerable, it is essential to consider the phased methodology, which allows the cost to be distributed over time, ensuring sustainable implementation of the project. In the long term, data obtained from models and sensors can support sustainable territorial development, improve infrastructure connections, and form the basis for the preservation and valorization of the territory. These improvements represent an investment to increase agriculture, resulting in economic benefits that can generate income and job opportunities, supporting local businesses. However, there is a shortage of skills and capabilities in the Finiq region when it comes to running sensors or building BIM models. Even the technological infrastructure of the local public administration is currently insufficient to effectively manage such investigations. Therefore, it is essential to undertake initiatives that include professional training and awareness of the local community on the principles and practices associated with correct land use.
In this context, the Finiq platform with the addition of BIM models not only provides the tools for advanced management but can also act as a catalyst for developing local expertise and increasing public interest. This holistic approach not only preserves the land but also initiates a virtuous cycle of sustainable economic growth for the municipality of Finiq and surrounding areas.

References

Banfi F., Brumana R., Salvalai G., Previtali M. (2022). Digital Twin and Cloud Development: From Scan-to- BIM-to-DT Process to a 4D Multi-User Live App to Improve Building Comfort, Efficency and Costs. In Energies, No. 15, 4497, pp. 1-26.

Maietti, F., Di Giulio, R., Piaia, E., Medici, M., Ferrari, F. (2018). Enhancing Heritage fruition through 3D semantic modelling and digital tools: the INCEPTION project. IPO Conf. Series: Materials Science and Engeneering 364, DOI:10.1088/1757-899X/364/1/012089.

Raco F., Balzani M., Planu F., Cittadino A. (2022). InSPiRE Project: Integrated Technologies for Smart Buildings and Predictive Maintenance. In The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XLVIII-4/ W3-2022, pp. 127-133.

Bianchini, C., Attenni, M., Potestà, G. (2021). Regenerative Design Tools for the Existing City: HBIM Potentials. In M. B. Andreucci, A. Marvuglia, M. Baltov, P. Hansen (Eds.), "Rethinking Sustainability Towards a Regenerative Economy", Springer, Cham, pp. 23-43, DOI:10.1007/978-3-030-71819-0_2.

F.Maietti, F. Planu, F.Raco, G.Giau, M. Suppa, (2022). Progettazione strategica integrata per la gestione dei rischi e la salvaguardia del patrimonio esistente, Il progetto Firespill. In Paesaggio Urbano, Maggioli, 3/2022 pp 9-25.

Lazarova-Molnar S., Mohamed N. (2020). Collaborative data analytics for smart buildings: opportunities and models. In Cluster Comput, No. 22, 2020, pp. 1065-1077.

F. Planu, R. Dario, G. Freduzzi, (2023) Piattaforme digitali integrate per la gestione del patrimonio costruito esistente: il progetto InSPiRE. In Atti Convegno UID 2023 Palermo

A. Nikologianni, M. Mayouf, S. Gullino, (2022) Building Information Modelling (BIM) and the impact on landscape: A systematic review of evolvements, shortfalls and future opportunities, ISSN 2666-7916, https://doi.org/10.1016/j.clpl.2022.100016.

A. Radulović, D. Sladić, M. Govedarica, D. Raičević, (2023), Using LADM and BIM for property and tourist taxation in the municipality of Bar, Montenegro,ISSN 0264-8377, https://doi.org/10.1016/j.landusepol.2023.106715.

J.Cho, C. Kim, K.Jae Lim, J. Kim, B. Ji, J. Yeon, (2023) Web-based agricultural infrastructure digital twin system integrated with GIS and BIM concepts, ISSN 0168-1699, https://doi.org/10.1016/j.compag.2023.108441.