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Supplementary material

Reverse Engineering for the Chronology of Medieval Aqueducts: A Case Study of the Holy Monastery of Dochiariou, Mount Athos

Nikolaos Papadodimas, Georgios David Laoutaris, Nikos Mamassis, and G.-Fivos Sargentis

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Contents

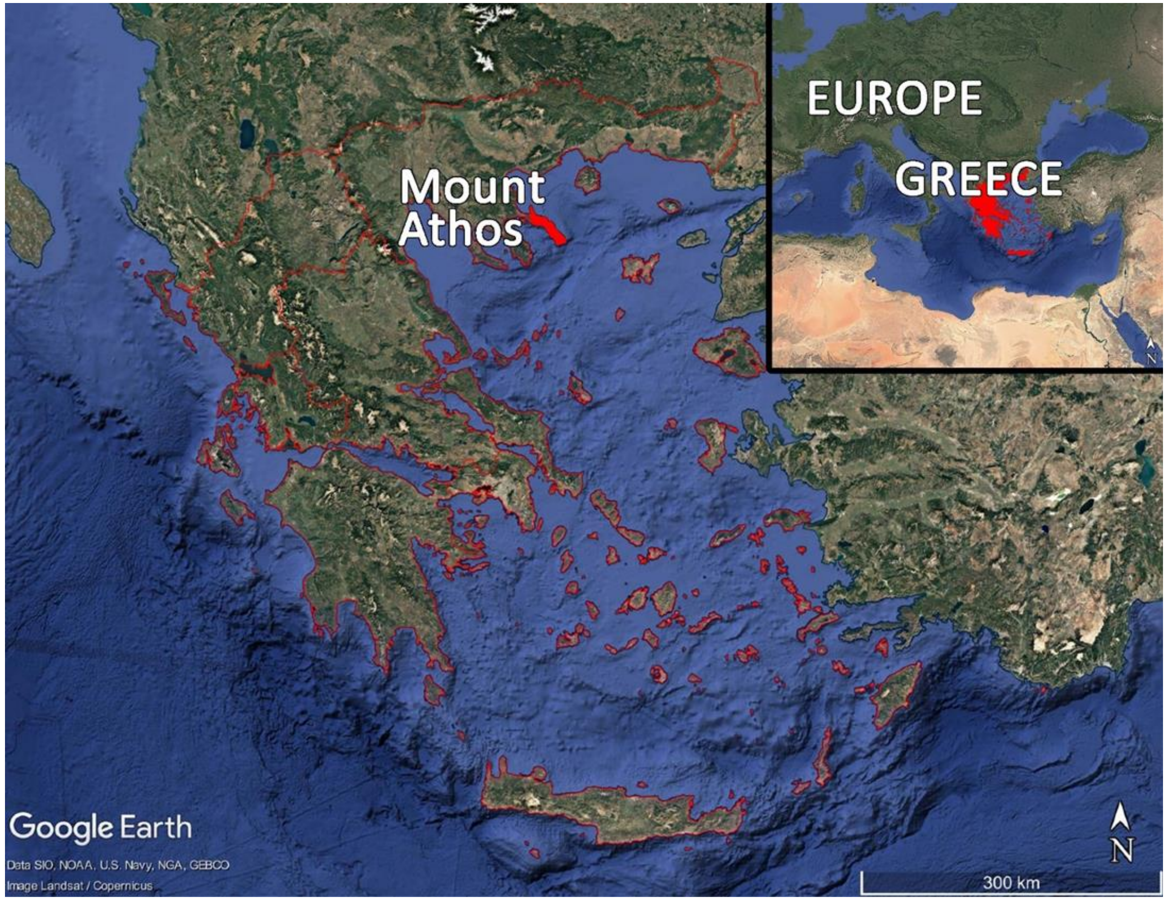
Abstract

- Establishing the timeline of hydraulic systems in isolated settlements, like monasteries, is challenging due to a lack of direct historical records or architectural clues.
- This study uses a reverse-engineering approach, viewing the aqueduct through the lens of the water–energy–food nexus required to sustain a pre-industrial society.
- A reconstruction was performed of the specific water demands needed to support the monastery's historically documented large-scale masonry projects.
- A modular workforce model was used to estimate that a small ten-person crew required roughly 10 m^3 of water daily in summer months. The majority of that volume is used for irrigated agriculture.
- The analysis determined that alternative methods, such as rainwater harvesting or manual transport, were insufficient to meet these needs during dry Mediterranean summers.
- Final findings conclude that the gravity-fed aqueduct was not just a convenience, but a functional necessity required to make the monastery's major construction phases possible.

Mount Athos

Mount Athos, located in the easternmost peninsula of Chalkidiki in northern Greece, has hosted monastic communities for over a millennium under conditions of geographic isolation, steep terrain, limited arable land, and uneven water distribution.

Athonite monasteries operated as largely self-sufficient systems, where construction, food production, and resource management were organised locally under strong environmental constraints.



Water availability was therefore a critical factor, supporting domestic use, agriculture, construction materials, and ultimately governing the scale and duration of building activity within an integrated water-energy-food system.

Case Study: Holy Monastery of Dochiariou

Dochiariou Monastery, founded in the late tenth century on the rugged Athonite peninsula, underwent several transformative architectural phases that required immense logistical coordination within a resource-constrained environment.

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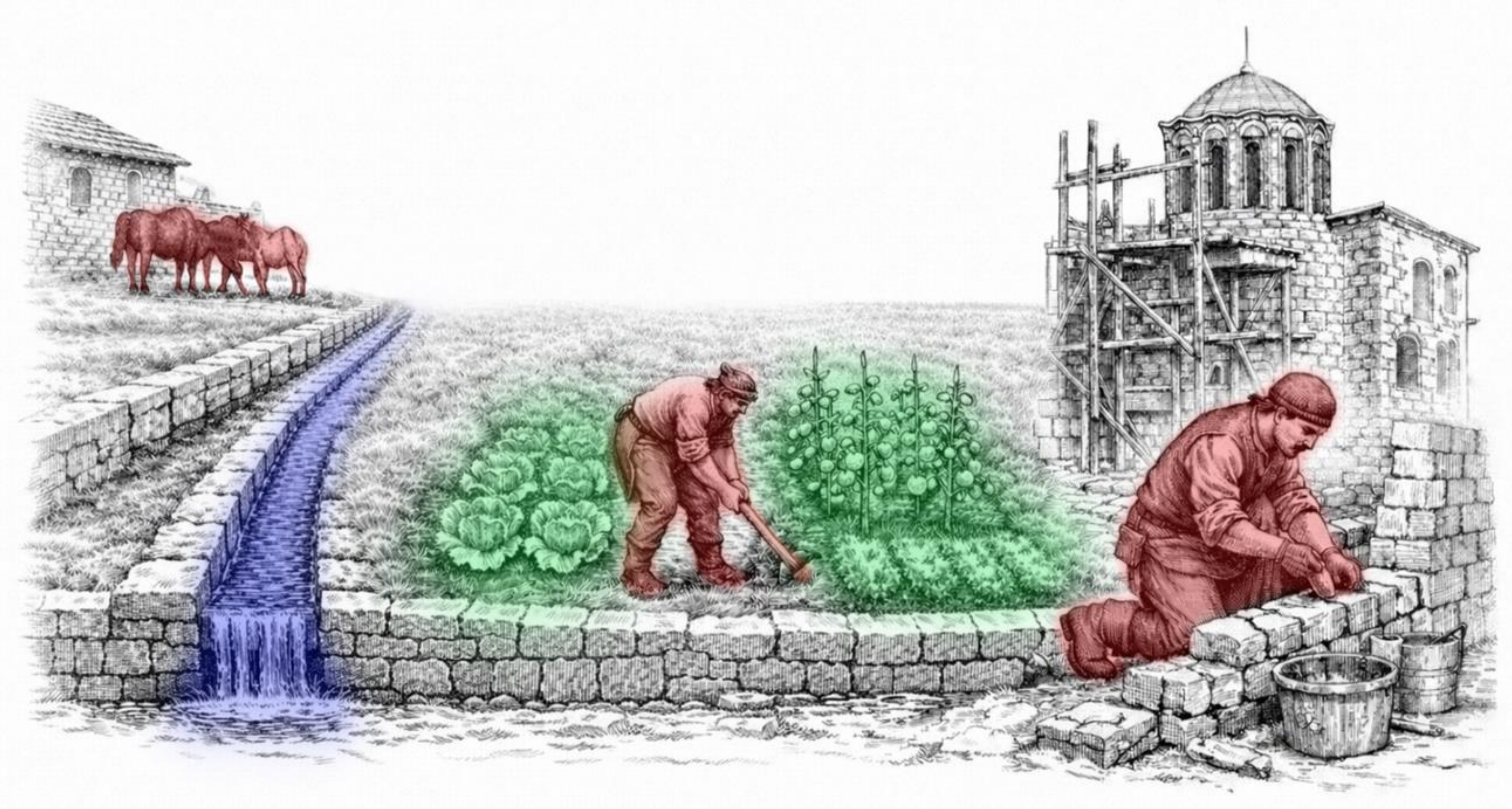
Water availability was therefore a critical factor, supporting domestic use, agriculture, construction materials, and ultimately governing the scale and duration of building activity within an integrated water-energy-food system.

Research Question

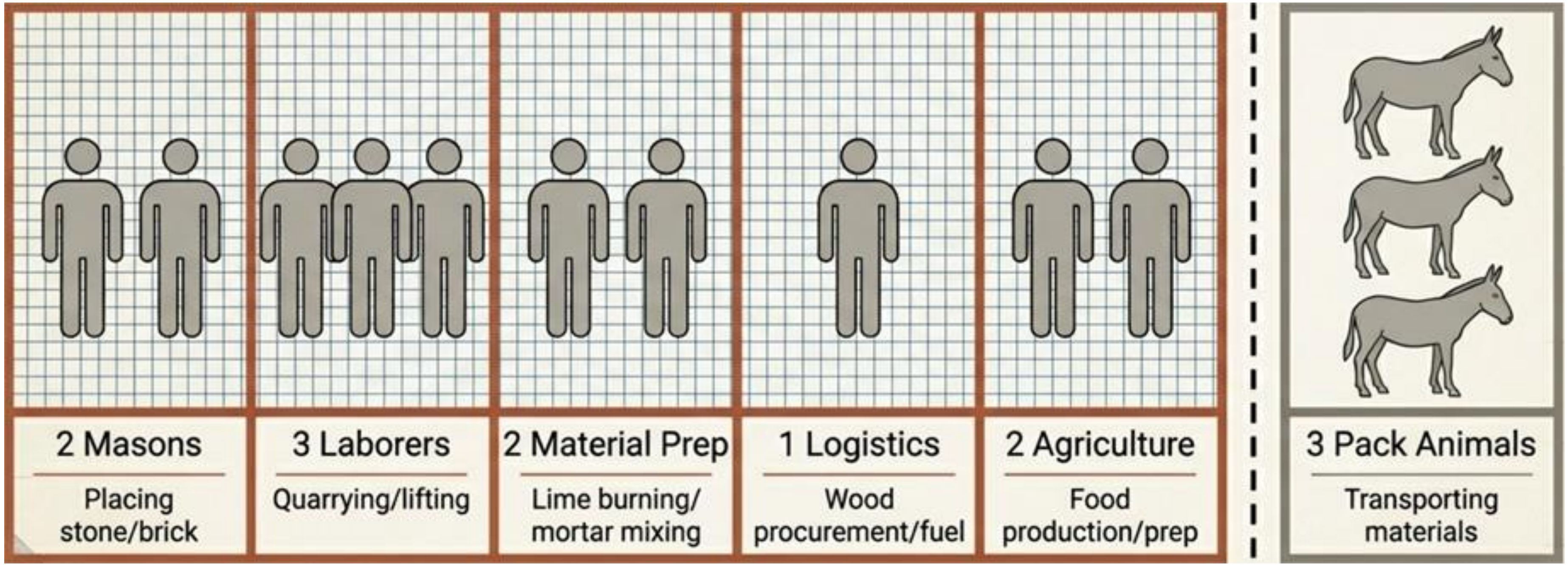
Hydraulic infrastructure is sparsely documented and its chronology remains uncetrain.

To what extent was the aqueduct necessary to sustain large-scale construction activities at Dochiariou Monastery?



Construction Framework

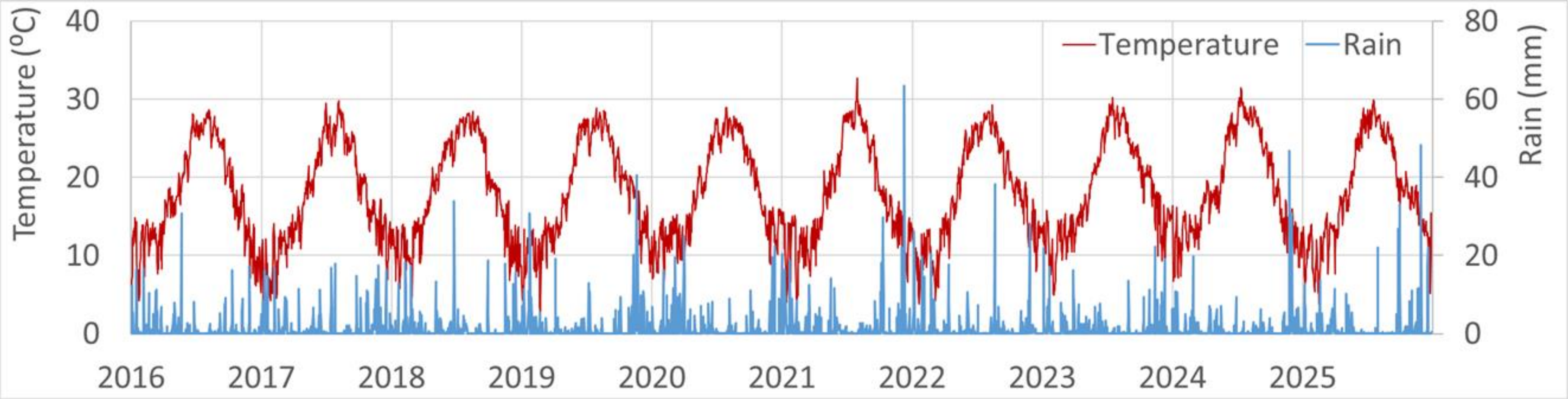
Construction activity is represented by a modular 10-person unit, including masonry, material preparation, logistics, and agricultural support. Productivity is estimated at 1-2 m^3 of masonry per day.



Graphical representation of the modular workforce unit

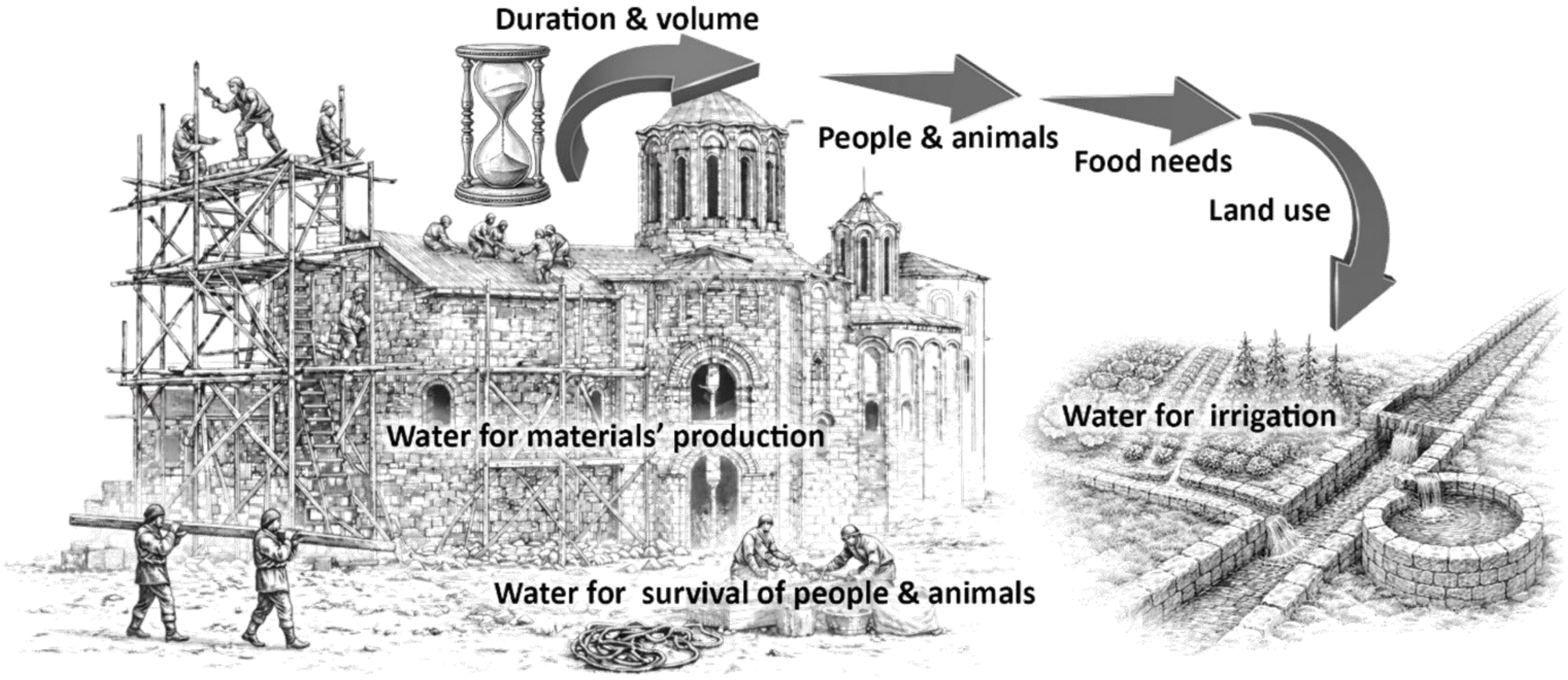
Construction Framework

This activity is constrained by climatic conditions and the Athonite liturgical calendar, reducing the effective construction period to approximately 200 working days per year.



Climatic patterns 2016-2025

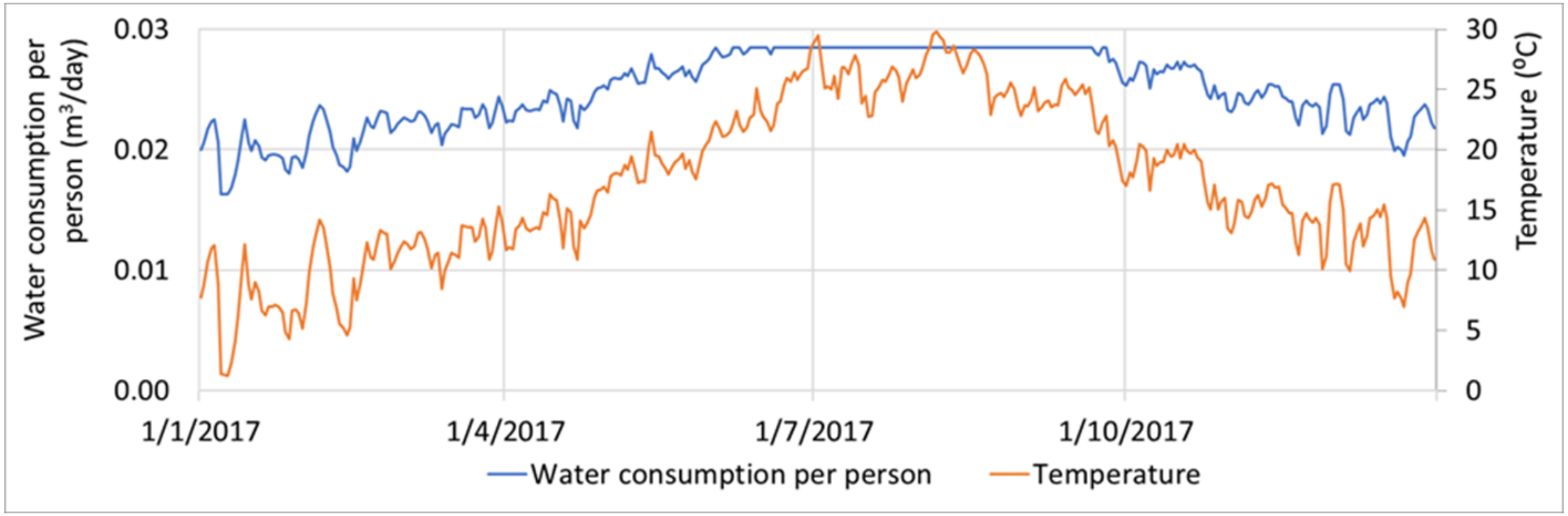
Water Needs



Conceptual diagram illustrating the relationships between construction activities (the need of materials), labourers, farms and irrigation

Daily Water Needs for Humans and Animals

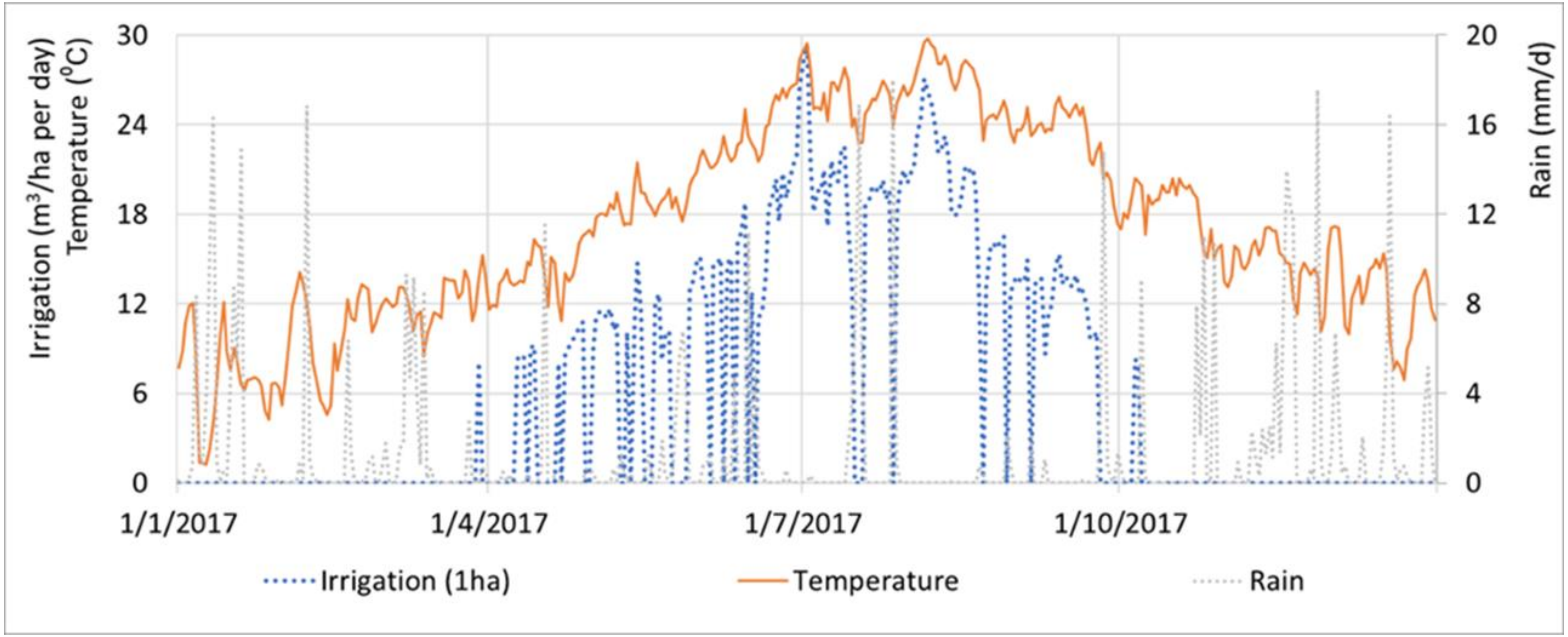
Today, modern use per capita is estimated to more than 100 liters per person per day. The minimum water needs are estimated to 18.5 m³ per year (which corresponds to 50 L/day) but the water consumption in preindustrial communities is estimated to 7.2 m³ per year (which corresponds to 20 L/day). Construction labor would have increased physiological demand, particularly during summer. The figure below shows a model of water consumption per person, based on temperature.



Minimum water consumption profile per person for basic needs

Irrigation Needs

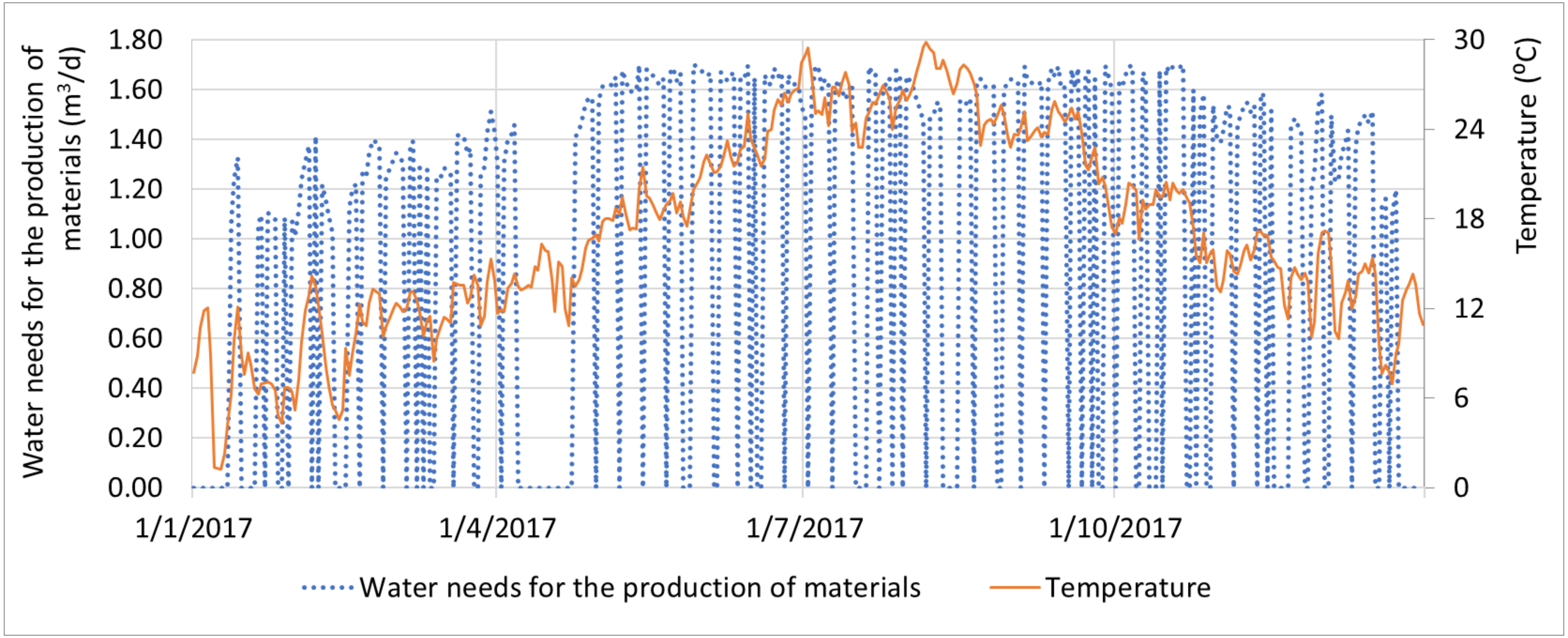
Water demand is dominated by irrigation, which is required to sustain agricultural production supporting the construction workforce. Under Mediterranean climatic conditions, irrigation demand exceeds 10 m³/day per ha during the dry summer months. It is estimated using a simplified evapotranspiration-based approach that relates temperature, solar radiation, and effective rainfall.



Irrigation needs per ha (lower values)

Material Production

Water demand associated with the production of construction materials remains relatively limited, typically on the order of 0.4–0.6 m³/day. This component is primarily controlled by temperature-dependent processes and the availability of working days.

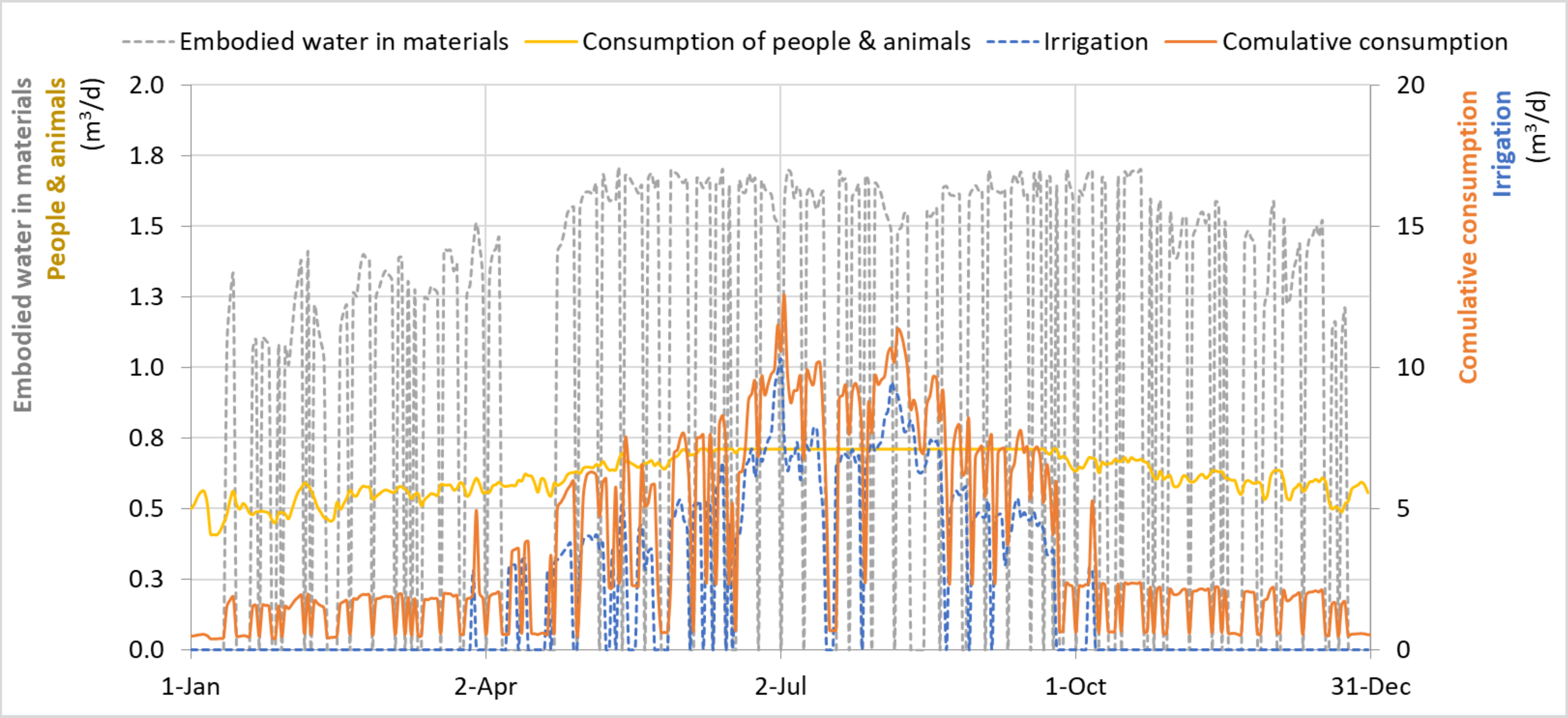


Daily water needs for material production

Cumulative Water Needs

Combining the individual components described previously allows an estimation of the total water demand associated with a single construction unit.

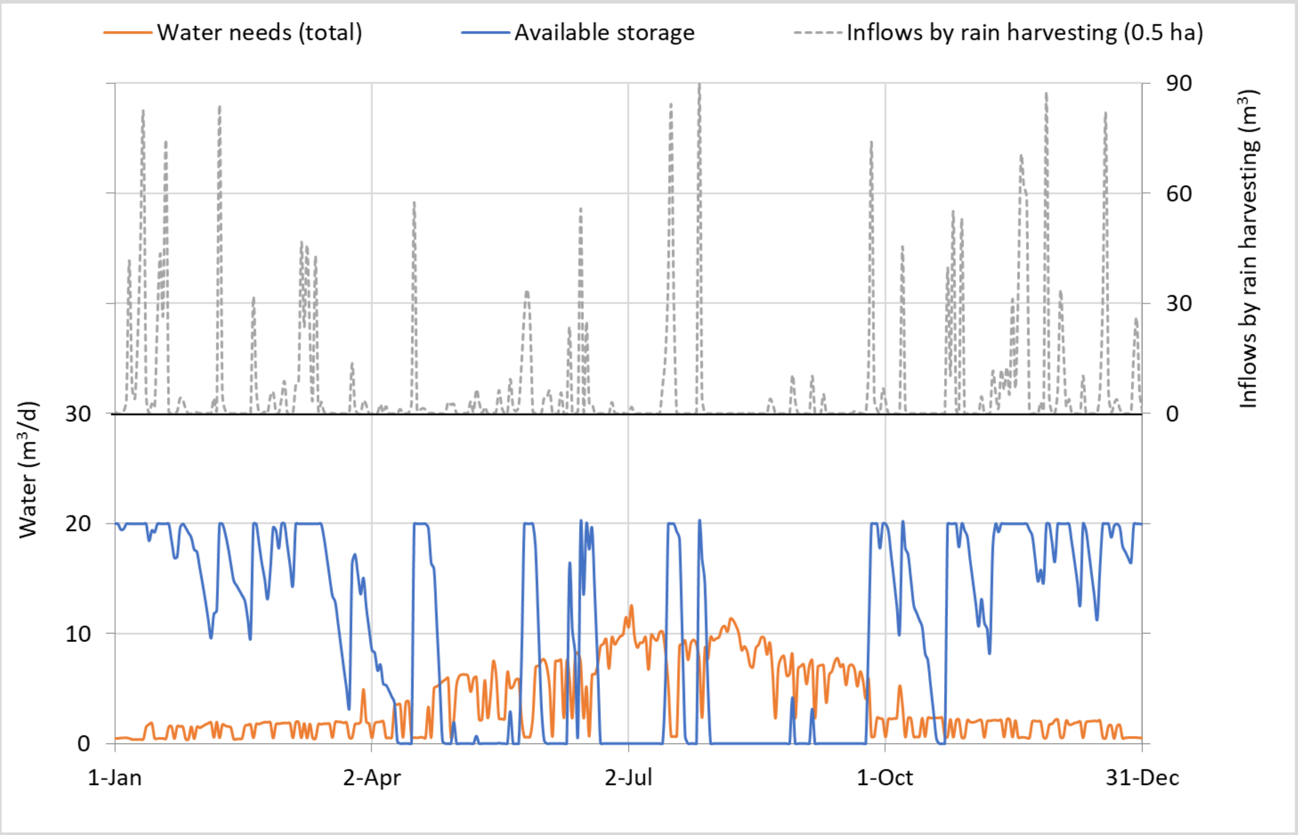
Construction materials account for approximately 1,2–1.6 m³ per day, while direct consumption by humans and animals contributes an additional 0.6 m³ per day. Irrigation demand required to sustain agricultural production represents the largest component, reaching approximately 10 m³ per day during the dry season.



Cumulative water needs

Water Harvesting

Rainwater harvesting represents the most immediate form of water collection available to monastic settlements. Roofs, courtyards, and paved surfaces could potentially function as catchment areas, directing runoff into storage cisterns for later use.



Top: Inflows by rain harvesting; bottom water needs and withdrawal from rainwater harvesting

Water Transport

Pack animals such as mules or donkeys are capable of carrying approximately 100–150 liters of water using containers mounted on either side of the saddle.
Given the distance and steep terrain, a round trip between the springs and the monastery would likely require approximately 1.5–2.5 hours, including stops (loading/unloading, rest).

Under these conditions, transporting 12 m³ of water per day during the summer months would require roughly 80-140 individual transport trips daily.

Discussion and Conclusions

An aqueduct provides the continuous gravity-fed supply from higher elevations, delivering water volumes that exceed the reconstructed demand and enabling sustained construction and agriculture.

The reconstructed maximum water demand (≈12 m^3/day in summer) exceeds the capacity of local sources, indicating that the aqueduct was essential for sustaining construction and monastic self-sufficiency. More broadly, the analysis demonstrates that water availability acted as a key limiting factor in pre-industrial construction systems.

Contact:

- Nikolaos Papadodimas nicholas.papadodimas@gmail.com
- Georgios David Laoutaris higeorge98@gmail.com
- Nikos Mamassis nikos@itia.ntua.gr
- G.-Fivos Sargentis fivos@itia.ntua.gr

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