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Medieval and Modern Use of Soil Tunnels in Warfare (A Conversation with Kenneth R. Olson)

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Abstract

Medieval and Modern Use of Soil Tunnels in Warfare examines the environmental, geological, military, and historical dimensions of soil tunnels used in warfare and smuggling over more than 2,500 years. Drawing upon case studies from Vietnam, Korea, the Middle East, and the United States–Mexico border, the book demonstrates how soil properties, geology, hydrology, and landscape conditions determine the feasibility, resilience, and strategic value of underground tunnel systems. By integrating soil science with military history, environmental studies, and border security, the book introduces an interdisciplinary perspective rarely found in conventional military analyses. It also highlights the long-term environmental and public-health consequences associated with tunnel construction and destruction, arguing that military engineering should be evaluated not only in strategic but also in environmental terms. The work contributes to a broader understanding of how natural systems influence military operations and how military activities continue to shape landscapes long after conflicts have ended.

Keywords: Soil tunnels; warfare; military geography; soil science; border security; environmental impacts; military engineering; tunnel resilience; Vietnam; interdisciplinary research.

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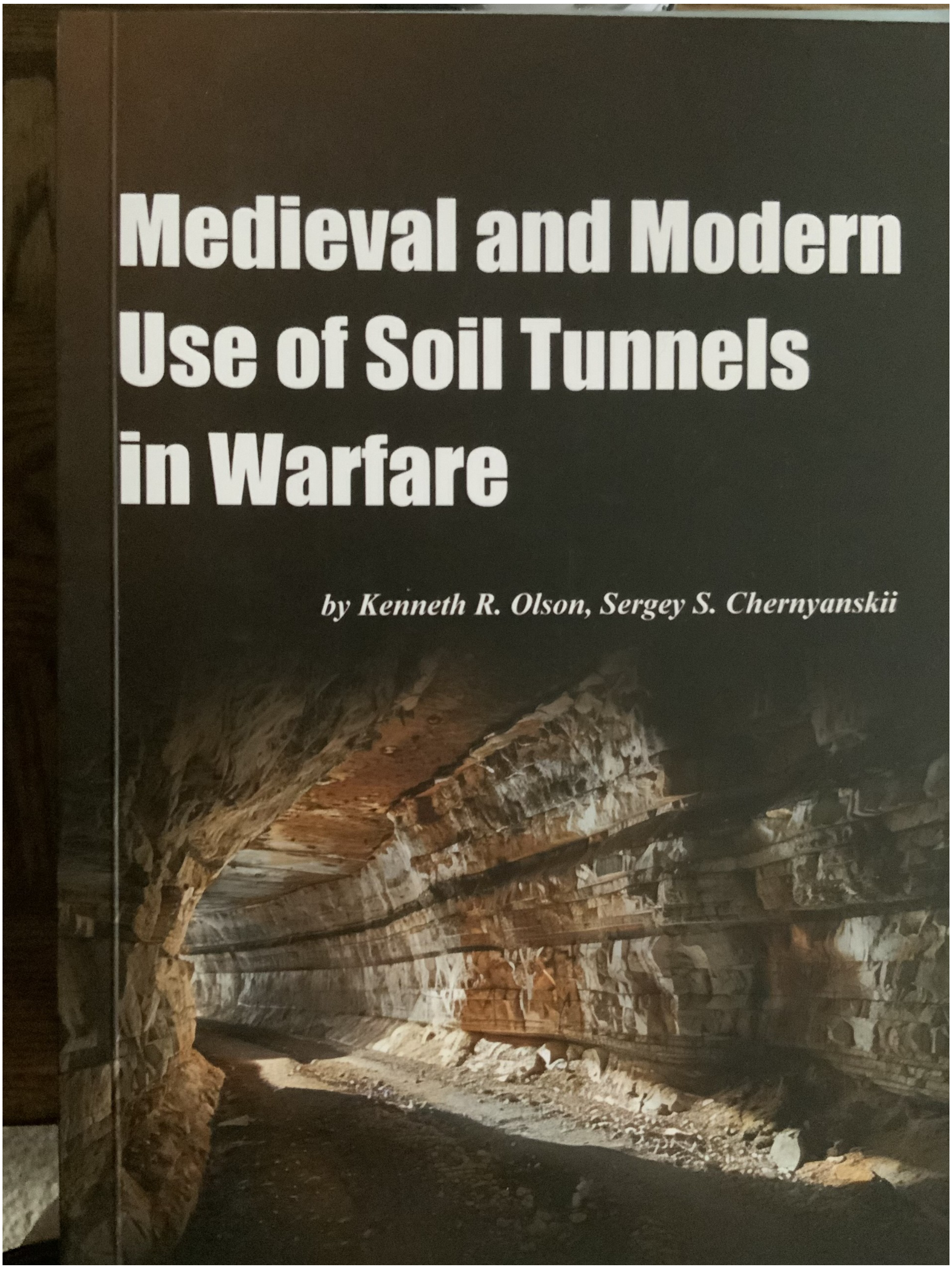

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Key Points

1. Soil properties and geological conditions are fundamental determinants of successful tunnel construction in both historical and modern warfare.
2. The resilience of the Cu Chi and Iron Triangle tunnel systems can be explained by specific soil-forming processes involving clay-rich old alluvial terraces and iron oxide cementation.
3. Military analyses have traditionally emphasized tactical effectiveness while paying limited attention to long-term environmental and public-health consequences of tunnel construction and destruction.
4. Soil science provides new insights into military history by explaining why underground defensive systems succeeded or failed under different environmental conditions.
5. Integrating environmental science with military history creates a broader interdisciplinary framework for understanding both past conflicts and future border-security challenges.

Introduction

Interview conducted on July 18, 2026.

Prepared for the journal "Pollution and Diseases."

Interview conducted for the journal Pollution and Diseases. This text is part of the Kenneth R. Olson book-interview series. The purpose of the series is to make Professor Olson's long-term research on soils, rivers, floodplains, deltas, freshwater systems, environmental change and public policy accessible to a wider interdisciplinary audience.

Professor Kenneth R. Olson is an American soil scientist, environmental researcher and author whose work connects field-based soil science with geomorphology, environmental history, hydrology, agriculture, public policy and landscape management.

Why This Book Matters Now

This volume represents one of the first attempts to integrate soil science, environmental history, military geography, and border-security studies into a single analytical framework. Rather than treating tunnels solely as military infrastructure, the book demonstrates that their construction, stability, detection, and destruction are fundamentally controlled by environmental conditions. By connecting geological processes with historical military events, the work opens new opportunities for interdisciplinary research on warfare landscapes and illustrates how environmental science can contribute to the interpretation of military history as well as to contemporary border-security and environmental-management challenges.

INTERVIEW

Q: What is this book about?

A: For more than 2,500 years, soil tunnels have been used in warfare, defense, and smuggling. The earliest military tunnels were excavated beneath fortifications constructed on unconsolidated soils. Medieval armies undermined defensive walls by supporting tunnel ceilings with wooden beams, which were later burned to collapse both the tunnel and the overlying fortifications. With the introduction of gunpowder and later dynamite, explosive methods gradually replaced fire as the principal technique for destroying tunnels and defensive structures.

In modern warfare, underground tunnel systems evolved from simple military passages into extensive networks used for moving troops, weapons, supplies, and intelligence while avoiding detection. They also became important corridors for cross-border smuggling of people, weapons, and goods. Most tunnels were constructed in unconsolidated soils that were easy to excavate, had relatively low groundwater tables, and were not subject to frequent flooding. Advances in mechanical drilling later enabled tunnels to be excavated through bedrock, allowing deeper and longer underground systems. However, drilling through rock generates noise and vibration, increasing the likelihood of detection.

Once discovered, tunnels have been neutralized using explosives, toxic gases, flooding with water or wastewater, or by constructing underground barriers. This book examines a series of historical and contemporary case studies to identify the soil, geological, hydrological, and environmental conditions that determine successful tunnel construction. It also analyses the principal natural constraints on tunneling and the engineering methods developed to overcome them.

Particular attention is given to regions where underground tunneling continues to influence national security, including Vietnam, the Korean Peninsula, the Middle East, and the United States–Mexico border. The central argument of the book is that understanding soils, geology, groundwater, and landscape processes provides an essential scientific basis for evaluating both the military effectiveness and the environmental consequences of underground tunnel systems.

Q: Why did you decide to write this book specifically?

A: I am a Vietnam Era veteran who served in the U.S. Army from 1969 to 1973. As the American military involvement in Vietnam was winding down, my planned deployment to Vietnam was cancelled. I always hoped that one day I would visit the country as a civilian. Life, however, took me in other directions, and it was another 43 years before I was finally able to make that journey.

My primary objective was to visit the Cu Chi and Iron Triangle tunnel systems (Figure 1) that once linked the Ho Chi Minh Trail with the approaches to Saigon. In March 2016, I finally travelled to Vietnam and explored the restored tunnel complex at the Cu Chi Memorial Park.

For decades I had wondered why these underground tunnel systems had proven so remarkably resilient during the Vietnam War. After crawling through the tunnels myself, I approached them not primarily as a military historian, but as a soil scientist. My objective was to understand why these underground structures survived years of bombing and repeated military assaults.

The answer, I discovered, lay largely in the unique properties of the highly weathered Old Alluvium terrace soils. During the monsoon season, the Viet Cong excavated the tunnels by hand while the clay-rich soils remained moist and workable. Over thousands of years of tropical weathering, iron had been leached from the upper soil horizons and redeposited deeper within the profile. During the dry season this iron oxide acted as a natural cementing agent, binding the soil particles together. As the tunnel walls dried after excavation, they acquired concrete-like strength and stability without requiring artificial supports. These exceptional soil properties largely explain why the tunnel systems remained so resistant to collapse despite extensive bombing.

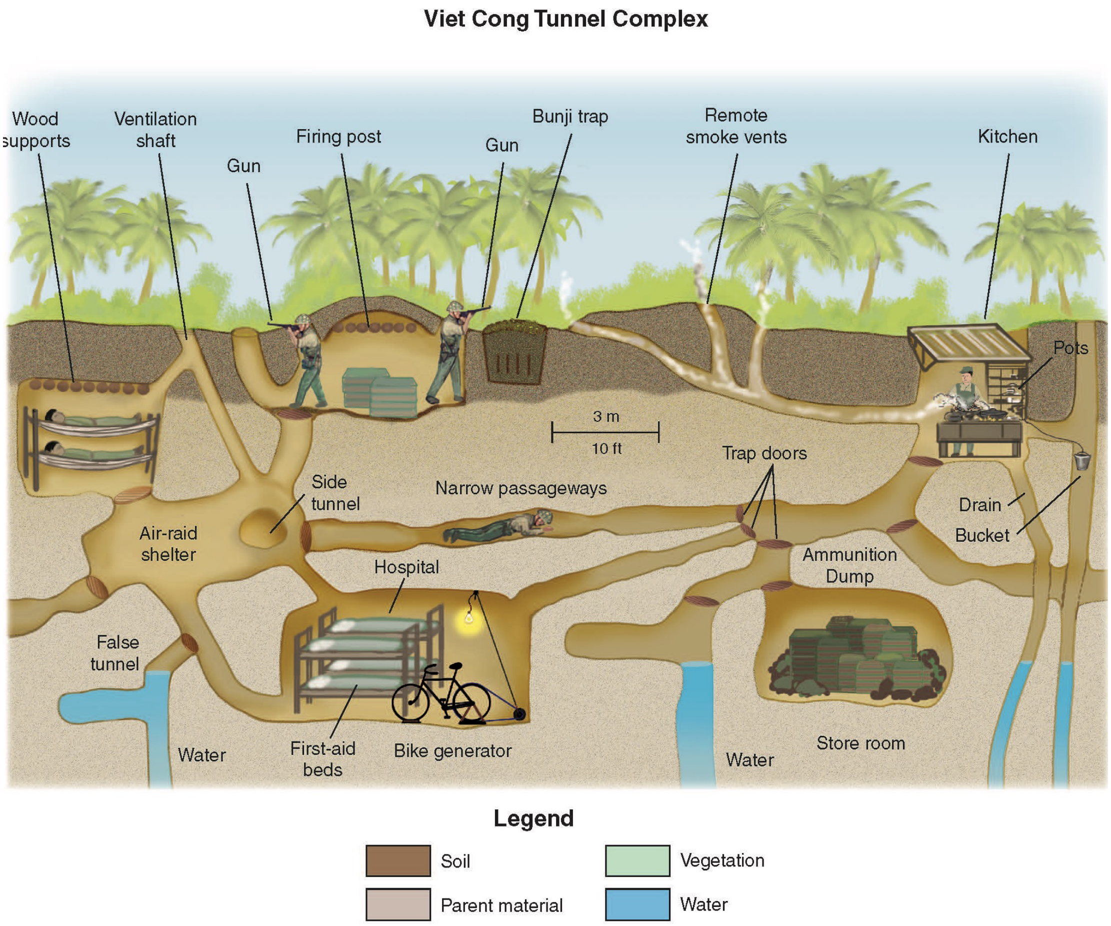

Figure 1. This diagram illustrates a multi-level North Vietnamese Army headquarters at Cu Chi soil tunnel complex used for living quarters and fighting. Diagram was based on displays at Vietnam Memorial at Ben Dinh near Ho Chi Minh City. Map was created by Mic Greenberg. Reprinted with copyright permission of the Managing Editor of Open Journal of Soil Science.

This interdisciplinary interpretation formed the basis of my publication Why were the Soil Tunnels of Cu Chi and Iron Triangle in Vietnam so Resilient? (1). The study was among the first to combine military history with soil science in order to explain the remarkable durability of the tunnel systems.

The publication attracted considerably more international attention than I had anticipated. During its first seven years, it received more than 80,000 views, over 20,000 downloads, and approximately 30 citations. The paper has since been translated into Vietnamese by scholars at the University of Social Sciences and Humanities in Hanoi and is being prepared for publication in a Vietnamese history journal. It has also been archived by the Vietnam Center and Archive at Texas Tech University, while the Vietnamese translation is expected to become part of the archival exchange programme with the State Records and Archives Department of Vietnam. As a result, the study has become part of the documentary record available to future historians and researchers of the Vietnam War.

Q: What makes this topic scientifically important?

A: Earthen tunnels have been used in warfare, border conflicts (Figure 2), and smuggling for more than 2,500 years. They have served as hidden routes for the movement of soldiers, weapons, supplies, migrants, and contraband (Figure 3) beneath political borders and military front lines. Tunnel systems have been documented beneath the Korean Demilitarized Zone, along the United States–Mexico border (Figure 2), and in conflict areas throughout the Middle East, where they have also been used to conceal military infrastructure, including weapons and logistical supplies.

Figure 2. Map of the locations of the existing and proposed border walls which are often underlain by soil tunnels originating in Mexico. Map was created by Mic Greenberg. Reprinted with copyright permission of the Managing Editor of Open Journal of Soil Science.

From a scientific perspective, tunnels represent far more than military engineering structures. Their successful construction depends on a combination of soil properties, geology, groundwater conditions, climate, and landscape characteristics. Understanding these environmental controls makes it possible to explain why tunnels succeed in some regions but fail in others.

This book demonstrates that soil science provides an additional dimension to military history by explaining the environmental conditions that determine tunnel resilience, stability, detectability, and long-term performance. Integrating environmental science with military history creates a broader interdisciplinary framework for understanding both historical conflicts and contemporary border-security challenges.

Figure 3. Soil tunnel shaft used to access the tunnel 10 m below the soil surface. The drug packages are lifted by a pully system. Reprinted with copyright permission of the Managing Editor of Open Journal of Soil Science.

Q: Which regions or case studies are central to the book?

A: The central historical case study examines the Cu Chi and Iron Triangle tunnel systems in southern Vietnam. At the height of the Vietnam War these underground networks extended for approximately 250 km, linking Viet Cong support bases from the Cambodian border and the Ho Chi Minh Trail to the outskirts of Saigon.

As the American military presence expanded during the early 1960s, the Viet Cong continuously enlarged and reinforced the tunnel network. The United States launched four major campaigns to locate and destroy these underground systems, including Operation Crimp (1966), which incorporated geological and soil investigations, followed by the larger Operation Cedar Falls (1967). Beginning in 1969, intensive B-52 bombing campaigns destroyed substantial sections of the tunnel network, although not before the tunnels had already demonstrated their remarkable military effectiveness.

One of the principal scientific conclusions of this work is that the exceptional resilience of the Cu Chi tunnels resulted largely from the properties of the Old Alluvium terrace soils. These soils contain high clay contents together with iron that accumulated within the lower horizons after thousands of years of tropical weathering. During excavation in the monsoon season the soils were sufficiently moist to be dug by hand. After drying, however, iron oxides acted as natural cementing agents, giving the tunnel walls concrete-like strength and allowing the tunnels to remain stable without additional structural support.

This combination of military history and soil science provides a new explanation for one of the most successful underground defensive systems of the twentieth century.

Q: What were the most difficult aspects of the research?

A: The greatest challenge was not only reaching the tunnel systems but also examining them under field conditions that allowed their environmental characteristics to be properly understood. This required visiting several tunnel complexes, including Cu Chi and the Iron Triangle near Ho Chi Minh City, as well as the Vinh Moc tunnel system north of the former Demilitarized Zone (Figure 4).

Field observations were physically demanding. At Cu Chi, visitors can only examine the tunnel system by crawling through restored tunnel sections, providing a direct appreciation of the confined underground environment. At Vinh Moc, the tunnel entrances are reached by climbing more than 150 steep and often slippery steps from the shoreline of the South China Sea to the hilltop tunnel complex. Even inside the enlarged visitor tunnels, ceiling heights remain low, making detailed observation difficult.

Experiencing these environments firsthand proved essential for understanding how local soils, topography, groundwater conditions, and engineering techniques combined to create remarkably resilient underground systems.

Q: Did anything during the research surprise you?

A: Yes. One of the greatest surprises was discovering the enormous scale of the tunnel systems outside Vietnam. The tunnel complex in southern Lebanon, for example, is estimated to be approximately ten times larger than the underground network constructed beneath Gaza.

From an engineering perspective, the two systems differ fundamentally. The Gaza tunnels were excavated primarily in unconsolidated sediments, where manual excavation is comparatively straightforward. In contrast, many tunnels in southern Lebanon extend through bedrock, requiring substantially greater engineering effort and different excavation techniques. This comparison illustrates how geological conditions strongly influence both tunnel construction and military strategy.

Figure 4. Vietnam Era veteran entering the near South China Sea level entrance to Vinh Moc Village. Reprinted with copyright permission of the Managing Editor of Open Journal of Soil Science.

Q: Which environmental processes described in the book are the most underestimated?

A: One of the most underestimated aspects of underground warfare is its long-term environmental impact. Military analyses typically focus on tactical objectives, while environmental consequences often receive little attention and may remain undocumented for decades.

Both the construction and destruction of tunnel systems can significantly alter border landscapes. When tunnels are destroyed using explosives, large quantities of dust and potentially hazardous materials are released into the atmosphere, exposing nearby populations, wildlife, and ecosystems. Explosions frequently remove fertile topsoil, reduce long-term agricultural productivity, and accelerate soil degradation.

Additional methods used to neutralize tunnels—including flooding with seawater or wastewater and the introduction of toxic gases—may further contaminate soils, groundwater, and surrounding ecosystems. These environmental consequences often persist long after military operations have ended and therefore deserve considerably greater scientific attention than they have traditionally received.

Q: How are environmental systems connected with political or military processes in this topic?

A: Earthen tunnels have long been used in warfare, border conflicts, and smuggling (Figure 3) because they provide concealment for troops, weapons, supplies, and equipment while reducing the risk of detection. Their successful construction depends not only on military engineering but also on environmental conditions. The most favourable settings are typically arid or semi-arid regions with deep unconsolidated soils, relatively low permanent groundwater tables, and minimal flood risk.

Where shallow bedrock is present, modern tunnelling technologies allow underground systems to be excavated through rock, provided that drilling noise and vibration cannot be detected by opposing forces. Regardless of the engineering method, concealment remains the primary objective.

Environmental systems also influence how tunnels are destroyed. Flooding with freshwater, seawater, or wastewater, together with the use of gases or explosives, has frequently been employed to neutralise tunnel systems. Such methods may significantly affect soils, groundwater, vegetation, and surrounding ecosystems. In many cases these environmental consequences persist long after military operations have ended, although they have rarely been incorporated into conventional military analyses.

Q: Which chapter is personally most important to you?

A: Chapter 1 – Review and Analysis: Successful Use of Soil Tunnels in Medieval and Modern Warfare and Smuggling

Soil tunnels have served for centuries as defensive and offensive military structures, concealed transportation routes, and corridors for smuggling people, drugs (Figure 3), weapons, and goods. From the Cu Chi tunnel system in Vietnam to the Korean Demilitarized Zone and the tunnel networks beneath Gaza, underground systems have repeatedly altered the course of military conflicts.

Historical experience suggests several practical lessons for modern border security. Certain combinations of climate, soil properties, geology, and groundwater conditions create environments particularly favourable for tunnel construction. Detailed soil, geological, and hydrological mapping can therefore help identify sections of international borders where underground tunnelling is most likely to occur. In this sense, environmental science provides an additional tool for understanding both historical warfare and contemporary security challenges.

Q: What should readers understand after reading this work?

A: One of the principal conclusions of this book is that underground tunnel systems are neither randomly located nor equally feasible in all environments. Their successful construction depends on a combination of soil characteristics, geological structure, groundwater conditions, and climate.

Countries facing border-security challenges, including Israel and the United States, can substantially improve tunnel detection and prevention by incorporating detailed soil, geological, and hydrological information into border management strategies. Scientific understanding of landscape conditions therefore becomes an important component of national security planning, complementing traditional engineering and military approaches.

Q: Who is this book intended for?

A: This book is intended for a broad interdisciplinary audience, including soil scientists, environmental scientists, military historians, geographers, geologists, hydrologists, conservation specialists, urban planners, public-health researchers, agronomists, border-security professionals, and policy makers. It may also be of interest to readers concerned with the environmental consequences of warfare and the relationship between landscape characteristics and military strategy.

Q: How does this book relate to current global environmental challenges?

A: Underground tunnel systems continue to play an important role in contemporary conflicts and border security. Along Israel's borders with Gaza, Egypt, Lebanon, Syria, and the West Bank, tunnels have been used for military operations, smuggling, storage of weapons and ammunition, and cross-border infiltration. Their construction, detection, and destruction have therefore become major environmental as well as security issues.

This book addresses four related questions. First, it evaluates how soils, geology, groundwater, climate, and topography influence the feasibility of tunnel construction along the Israeli borders (Figure 5). Second, it examines the use of tunnels during the Hamas attacks of October 7, 2023. Third, it reviews the evolving approaches developed by the Israel Defense Forces for detecting, blocking, and destroying underground tunnel systems. Finally, it considers how these experiences may contribute to understanding similar tunnel networks elsewhere, including southern Lebanon.

Throughout these case studies, the book emphasizes that tunnel construction and tunnel destruction both produce lasting environmental consequences. Soil disturbance, groundwater contamination, vegetation loss, and landscape degradation should therefore be considered alongside military and political objectives.

Figure 5. Middle East map show the soil tunnel locations on the Israel border between Gaza and Israel, Egypt and Gaza, Lebanon and Israel. Map was created by Mic Greenberg. Reprinted with copyright permission of the Managing Editor of Open Journal of Soil Science.

Q: Are the problems discussed in the book improving or worsening today?

A: Many of the environmental issues associated with underground warfare remain insufficiently recognised. Military planning understandably focuses on tactical objectives, whereas environmental consequences often receive only limited attention and may remain undocumented for many years.

The destruction of tunnel systems frequently generates substantial environmental impacts. Explosive demolition removes productive topsoil, releases dust and potentially hazardous materials into the atmosphere, and reduces long-term agricultural productivity. Other methods, including flooding tunnels with wastewater or seawater and the use of toxic gases, may contaminate soils and groundwater while creating additional public-health risks for nearby communities.

These environmental consequences often persist long after military operations have ended. Future research should therefore evaluate underground warfare not only from military and engineering perspectives but also through the broader frameworks of environmental science, public health, and long-term landscape management.

Q: Which future research directions emerge from this work?

A: One of the important findings emerging from this research is that the successful construction of tunnel systems depends on identifiable combinations of soil characteristics, geology, groundwater conditions, and landscape evolution. During the Vietnam War, understanding these relationships gradually became an important clue in explaining both vehicle mobility and the location of underground tunnel systems.

The Cu Chi and Iron Triangle tunnel networks were excavated within highly weathered Old Alluvium terrace soils whose unique physical properties contributed directly to their remarkable stability. At the same time, these landscapes became some of the most heavily bombed and chemically contaminated areas of the Vietnam War. Extensive defoliation, soil disturbance, erosion, and sediment transport fundamentally altered the surrounding environment.

When I visited the region in 2016, more than four decades after the military operations had ended, many parts of the landscape still showed evidence of long-term ecological change. These observations raised new research questions concerning the environmental and human-health consequences of tactical herbicides. Those questions became the starting point for the next volumes of this book series, which examine the impacts of Agent Orange (dioxin TCDD) and Agent Blue (cacodylic acid and arsenic) on soils, ecosystems, and public health.

Q: If readers remember only one idea from the book, what should it be?

A: In warfare and border conflicts, underground tunnels remain one of the great strategic equalizers. Their effectiveness, however, depends not only on military planning but also on the environmental characteristics of the landscape. Understanding soils, geology, groundwater, and terrain is therefore essential for understanding both the history and the future of underground warfare.

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The Editorial Board of the journal "Pollution and Diseases" wishes you continued scientific success, new discoveries, and inspiration in your work.

Conflict of Interest

The authors declare no conflict of interest.

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Data Availability Statement

No new data were created or analyzed in this study.

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