

Myco-Engineering Systems: Harnessing Fungal Networks for Carbon Sequestration and Sustainable Ecosystem Restoration

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Abstract

Fungal organisms play a foundational role in global ecosystem stability, particularly through their contributions to nutrient cycling, soil regeneration, and carbon sequestration. Recent scientific advances have highlighted the potential of fungal mycelial networks as natural bioengineered systems capable of supporting sustainable environmental restoration. This paper introduces the concept of Myco-Engineering Systems, an interdisciplinary framework that integrates fungal biology, environmental science, and artificial intelligence (AI) to enhance carbon capture and ecosystem rehabilitation strategies. The study conceptualizes fungal mycelium as a distributed biological infrastructure capable of storing carbon, improving soil fertility, and facilitating plant–microbe symbiosis. By combining ecological modeling with AI-based environmental analysis, the framework explores how fungal networks can be optimized for large-scale carbon sequestration and land restoration projects. Machine learning models are proposed to analyze fungal growth patterns, soil composition data, and climate variables to predict optimal conditions for fungal expansion and carbon storage efficiency. The paper further examines the application of myco-engineering in degraded ecosystems, agricultural land recovery, and climate change mitigation strategies. Emphasis is placed on low-cost, scalable implementation approaches suitable for both industrial and rural environments. Ethical and ecological considerations, including biodiversity balance and ecosystem interference risks, are also discussed. Findings from the conceptual analysis suggest that fungal-based ecological engineering offers a highly efficient and sustainable pathway for carbon management and environmental restoration. However, challenges, such as biological variability, data limitations, and integration with existing environmental systems, must be addressed. This study contributes to the emerging field of bio-integrated environmental engineering by positioning fungal networks as natural infrastructure for climate resilience and ecological sustainability.

Keywords: Myco-engineering, fungal networks, mycelium, carbon sequestration, ecosystem restoration, artificial intelligence, soil ecology, climate change, biomaterials, sustainable agriculture

INTRODUCTION

The accelerating impact of climate change has intensified global efforts to identify sustainable and scalable solutions for carbon reduction and ecosystem restoration. Among various biological systems,

fungi have emerged as one of the most promising yet underutilized components in environmental engineering. Their extensive underground mycelial networks play a critical role in nutrient cycling, soil stabilization, organic matter decomposition, and carbon storage.

Fungi exist in nearly all terrestrial ecosystems and form symbiotic relationships with plants through mycorrhizal associations. These relationships enhance plant nutrient uptake while simultaneously improving soil structure and

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carbon retention. Studies have shown that fungal networks can store significant amounts of carbon in soil systems, making them essential contributors to global carbon cycles [1].

Despite their ecological importance, fungi have historically received limited attention in large-scale environmental management strategies. Most climate mitigation approaches have focused on technological solutions such as carbon capture machines, industrial emissions control, and renewable energy systems. However, biological systems, like fungi, offer a naturally efficient and self-regenerating alternative that aligns with ecosystem-based adaptation strategies.

The concept of myco-engineering has recently emerged as an interdisciplinary field that explores the use of fungal systems for environmental applications, including soil restoration, biodegradable materials production, and carbon sequestration. Mycelium-based structures are particularly notable for their ability to grow rapidly, adapt to environmental conditions, and form complex underground networks that support ecosystem resilience.

Artificial intelligence (AI) and computational ecology further enhance the potential of myco-engineering systems. By analyzing environmental datasets, such as soil composition, moisture levels, temperature fluctuations, and fungal growth dynamics, machine learning models can identify optimal conditions for fungal expansion and carbon capture efficiency. This integration allows for the development of predictive systems that optimize fungal-based restoration strategies.

In degraded ecosystems, such as deforested lands, desertified soils, and industrially polluted areas, fungal networks can play a critical role in restoring ecological balance. They improve soil fertility, enhance microbial diversity, and facilitate plant recolonization. This positions fungi as a key biological tool in climate adaptation and environmental regeneration efforts.

However, the large-scale implementation of myco-engineering systems remains limited by several factors, including insufficient biological data, variability in fungal species behavior, and lack of integration with existing environmental technologies. Additionally, ecological risks associated with introducing or manipulating fungal species must be carefully managed to avoid unintended ecosystem disruption.

This study addresses these challenges by proposing a structured Myco-Engineering Framework that integrates fungal biology, environmental science, and AI-based modeling to support carbon sequestration and ecosystem restoration. The goal is to develop a scalable and sustainable biological infrastructure that contributes to global climate resilience efforts (Table 1).

Table 1. Functional roles of fungi in ecosystem restoration.

Fungal function	Ecological role	Environmental benefit	Application area
Mycorrhizal symbiosis	Plant nutrient exchange	Improved plant growth	Reforestation.
Organic decomposition	Breakdown of biomass	Soil nutrient recycling	Agriculture.
Mycelial networks	Carbon storage	Climate regulation	Carbon sequestration.
Soil stabilization	Structural reinforcement	Erosion control	Land restoration.
Bioremediation fungi	Pollutant breakdown	Environmental detoxification	Industrial cleanup.

LITERATURE REVIEW

The study of fungi in environmental systems has evolved significantly over recent decades, shifting from basic ecological observation to advanced applications in climate science, soil restoration, and biomaterials engineering. This literature review examines four key areas: fungal ecology and mycorrhizal networks, carbon sequestration mechanisms, myco-engineering applications, and the integration of artificial intelligence (AI) in fungal and soil ecosystem modeling.

Fungal Ecology and Mycorrhizal Networks

Fungi are among the most ecologically significant organisms in terrestrial ecosystems due to their role in decomposition, nutrient cycling, and symbiotic relationships with plants. Mycorrhizal fungi form mutualistic associations with plant roots, enabling the exchange of nutrients, such as phosphorus, nitrogen, and water in return for carbon compounds, produced through photosynthesis [2].

These underground networks, often referred to as the “Wood Wide Web,” facilitate inter-plant communication and resource distribution across ecosystems. Research has shown that mycorrhizal networks enhance plant resilience, biodiversity stability, and ecosystem productivity, particularly in nutrient-poor soils [3]. This interconnected system forms the biological foundation for ecosystem resilience and long-term ecological sustainability.

Fungi and Carbon Sequestration Mechanisms

Fungi play a crucial role in global carbon cycling through both decomposition and carbon storage processes. While decomposer fungi break down organic matter and release carbon dioxide, mycorrhizal fungi contribute to long-term carbon storage by transferring plant-derived carbon into stable soil organic matter.

Studies indicate that fungal biomass and hyphal networks significantly contribute to soil carbon stabilization by binding organic compounds into persistent soil structures [4]. This process reduces atmospheric carbon levels and enhances soil fertility simultaneously. Certain fungal species also produce melanin-rich compounds that increase carbon retention in soils, further enhancing their role in climate regulation.

The dual function of fungi in both carbon release and sequestration highlights their complex but essential role in balancing terrestrial carbon dynamics.

Emergence of Myco-Engineering Systems

Myco-engineering is an emerging interdisciplinary field that explores the use of fungal systems for environmental and industrial applications. Applications include biodegradable packaging materials, sustainable construction materials (mycelium-based composites), soil restoration technologies, and bioremediation of polluted environments.

Recent studies have demonstrated that mycelium-based materials can replace conventional plastics and synthetic building materials, offering biodegradable and low-energy alternatives⁵. Additionally, fungi have been successfully used in bioremediation projects to degrade petroleum products, heavy metals, and industrial waste.

These applications highlight the scalability of fungal systems as living environmental infrastructure, capable of adapting to different ecological and industrial contexts (Table 2) [5].

Table 2. Key applications of myco-engineering.

Application area	Fungal mechanism	Environmental benefit	Example use case
Biodegradable materials	Mycelium growth networks	Plastic reduction	Packaging industry.
Soil restoration	Organic decomposition	Soil fertility recovery	Agricultural land repair.
Bioremediation	Enzymatic degradation	Pollution cleanup	Oil spill recovery.
Construction materials	Mycelium composites	Sustainable building	Eco-bricks.
Carbon sequestration	Soil carbon storage	Climate mitigation	Reforestation projects.

Artificial Intelligence in Soil and Fungal Systems

The integration of artificial intelligence into ecological and fungal research has enabled new approaches to environmental modeling and prediction. Machine learning algorithms are increasingly

used to analyze soil composition, microbial activity, and fungal growth patterns under varying environmental conditions.

Deep learning models can identify correlations between environmental variables (temperature, moisture, pH levels) and fungal growth rates. These predictive models assist in optimizing conditions for fungal expansion and carbon sequestration efficiency [6].

Furthermore, AI-based spatial modeling allows researchers to simulate ecosystem changes under different climate scenarios, improving the planning and implementation of myco-engineering interventions [7].

Research Gaps and Challenges

Despite significant progress, several gaps remain in the application of fungi for large-scale environmental engineering:

- *Data Scarcity*: Limited high-resolution datasets on fungal biodiversity and growth dynamics.
- *Species Variability*: Different fungal species respond differently to environmental conditions.
- *Scaling Limitations*: Difficulties in scaling laboratory results to field-level ecosystems.
- *Ecological Risks*: Potential disruption of native ecosystems through fungal introduction or manipulation.
- *Integration Gaps*: Weak integration between biological research and AI-based environmental systems.

These limitations highlight the need for interdisciplinary frameworks that combine biology, environmental science, and computational intelligence [8].

Conceptual Contribution of This Study

This study proposes a unified Myco-Engineering Framework that integrates fungal ecological functions with AI-driven environmental modeling systems. Unlike traditional approaches that treat fungi as isolated biological agents, this framework positions fungal networks as active environmental infrastructure capable of supporting carbon sequestration, soil regeneration, and ecosystem restoration.

By combining ecological theory with computational intelligence, the framework aims to improve predictability, scalability, and efficiency in climate mitigation strategies [9].

METHODOLOGY

This study adopts a conceptual systems engineering methodology combined with a bio-computational modeling approach to develop the Myco-Engineering Framework. The objective is to integrate fungal ecological processes with artificial intelligence (AI) to enhance carbon sequestration, soil restoration, and ecosystem rehabilitation strategies.

The methodology is structured into four interconnected layers: data acquisition, biological system modeling, AI-based predictive analytics, and ecological application deployment. Each layer represents a functional component of the proposed myco-engineering system.

Data Acquisition Layer

The first stage involves the conceptual collection of fungal and environmental datasets. In practical implementation, data would be sourced from multiple channels, including:

- Soil microbial sampling and laboratory fungal identification.
- Remote sensing data for vegetation and land-use analysis.
- Environmental sensors measuring temperature, humidity, and soil moisture.
- Mycelium growth observation systems using imaging technology.

- Carbon flux measurement systems for soil carbon tracking.

Fungal systems are treated as biological carbon-processing networks, where mycelial growth, decomposition activity, and symbiotic plant interactions serve as measurable ecological indicators (Table 3).

Table 3. Myco-engineering data sources and functions.

Data source	Technology	Data type	Ecological function
Soil sampling	Lab microbiology	Fungal species diversity	Biodiversity mapping.
Environmental sensors	IoT devices	Temperature, moisture	Growth condition analysis.
Remote sensing	Satellite imaging	Vegetation cover	Ecosystem health.
Carbon flux systems	Gas analysis tools	CO ₂ exchange rates	Carbon sequestration tracking.
Imaging systems	Computer vision	Mycelium growth patterns	Network modeling.

Data Preprocessing and Integration Layer

The second stage focuses on transforming heterogeneous environmental data into structured analytical inputs. This involves:

- Data cleaning to remove inconsistencies in field measurements.
- Normalization of environmental variables across ecosystems.
- Feature extraction from fungal growth patterns and soil composition.
- Temporal alignment of climate and biological datasets.
- Dimensionality reduction using statistical and computational techniques.

This stage is critical because fungal ecosystems are highly sensitive to micro-environmental changes, requiring precise data harmonization for accurate modeling [10].

Biological System Modeling Lay

In this stage, fungal ecosystems are modeled as dynamic, self-organizing biological networks. Mycelial structures are represented as distributed systems capable of carbon transfer, nutrient cycling, and ecological communication.

Key modeling components include:

- Growth dynamics models representing hyphal expansion in patterns.
- Carbon transfer models simulating plant–fungi nutrient exchange.
- Decomposition rate models for organic matter breakdown.
- Soil interaction models describing fungal–microbial ecosystem relationships.

These models provide a biological foundation for integrating AI-based predictive systems.

Artificial Intelligence and Predictive Analytics Layer

The core analytical layer applies machine learning and AI algorithms to predict fungal behavior and optimize ecological outcomes.

- *AI Models Used Conceptually:* Convolutional Neural Networks (CNNs): Mycelium imaging and spatial pattern recognition.
- *Recurrent Neural Networks (RNNs):* Temporal fungal growth and climate interaction modeling.
- *Random Forest Models:* Soil fertility classification and ecosystem health prediction.
- *Regression Models:* Carbon sequestration rate estimation.
- *Clustering Algorithms:* Ecosystem segmentation and fungal habitat grouping.

These models analyze correlations between environmental variables and fungal growth performance, enabling predictive optimization of carbon sequestration systems (Table 4) [10].

Table 4. AI models and myco-engineering applications.

AI model	Function	Myco-engineering application
CNN	Image recognition	Mycelium structure mapping.
RNN	Time-series prediction	Growth cycle forecasting.
Random Forest	Classification	Soil health assessment.
Regression models	Quantitative prediction	Carbon storage estimation.
Clustering	Pattern grouping	Ecosystem classification.

Ecological Application and Deployment Layer

The final stage translates AI outputs into actionable ecological strategies. This includes:

- Identification of optimal zones for fungal-based reforestation.
- Prediction of carbon sequestration efficiency in degraded soils.
- Optimization of fungal species selection for environmental restoration.
- Guidance for agricultural soil rehabilitation programs.

This layer ensures that computational insights are directly applicable to real-world environmental restoration and climate mitigation projects [11].

System Architecture Design

The Myco-Engineering System is conceptualized as a multi-layer ecological intelligence architecture, consisting of:

- *Biological Layer*: Fungal networks and soil ecosystems.
- *Data Layer*: Environmental sensors and biological sampling systems.
- *Computational Layer*: AI and machine learning models.
- *Application Layer*: Environmental decision-support tools.

This architecture enables continuous interaction between biological systems and computational intelligence, forming a bio-digital environmental feedback loop (Table 5) [12].

Table 5. Myco-engineering system architecture.

Layer	Function	Components
Biological Layer	Ecosystem processes	Fungi, plants, microbes.
Data Layer	Data collection	Sensors, sampling tools.
Computational Layer	AI analysis	ML models, cloud systems.
Application Layer	Decision outputs	Dashboards, restoration plans.

Ethical and Environmental Considerations

The deployment of myco-engineering systems raises several ecological and ethical considerations:

- Risk of ecosystem imbalance due to fungal species introduction.
- Potential disruption of native microbial communities.
- Need for biodiversity protection during restoration interventions.
- Data ownership and environmental governance frameworks.

Sustainable implementation requires strict ecological monitoring and adherence to conservation principles [13].

Conceptual Validation Approach

Since this study is theoretical, validation is achieved through cross-disciplinary literature triangulation and ecological systems reasoning. The framework is evaluated based on:

- Compatibility with established fungal ecology research.

- Alignment with carbon cycle and soil science literature.
- Feasibility of AI integration in environmental systems.
- Scalability across different ecological zones.

Future validation requires pilot field experiments involving controlled fungal-based carbon sequestration trials.

RESULTS AND DISCUSSION

This section presents the conceptual findings derived from the Myco-Engineering Framework, focusing on the role of fungal networks in carbon sequestration, soil restoration, and ecosystem regeneration when integrated with artificial intelligence (AI)-based environmental modeling systems. As this is a theoretical study, results are interpreted through synthesis of ecological literature, systems modeling logic, and computational biology principles [14].

Enhanced Carbon Sequestration Potential

A key outcome of the proposed framework is the significant enhancement of carbon sequestration efficiency through fungal networks. Mycorrhizal fungi contribute to carbon storage by transferring carbon from plant roots into stable soil organic matter, where it can remain sequestered for extended periods.

When modeled using AI-based predictive systems, fungal growth patterns can be optimized for maximum carbon retention. Simulation-based interpretation suggests that environments with high fungal biomass density exhibit improved carbon stabilization rates compared to degraded or low-fungal-activity soils.

This indicates that myco-engineering systems can function as biological carbon capture infrastructure, offering a low-cost and self-sustaining alternative to industrial carbon capture technologies (Table 6) [15].

Table 6. Conceptual comparison of carbon sequestration systems.

System type	Mechanism	Efficiency	Sustainability
Industrial CCS	Mechanical capture	High	Medium.
Afforestation	Tree biomass storage	Medium	High.
Soil management	Organic carbon storage	Medium	High.
Myco-Engineering	Fungal network storage	High (modeled)	Very High.

Soil Restoration and Ecosystem Recovery

Another major outcome is the accelerated recovery of degraded soils through fungal activity. Mycelial networks enhance soil structure by binding organic matter, improving aeration, and increasing water retention capacity.

The integration of AI models enables the identification of optimal conditions for fungal proliferation in degraded ecosystems. These conditions include temperature thresholds, moisture levels, and soil nutrient composition.

Results suggest that fungal systems significantly enhance:

- Soil fertility regeneration.
- Organic matter decomposition.
- Microbial diversity restoration.
- Plant re-establishment success rates.

This demonstrates that myco-engineering can serve as a biological rehabilitation system for damaged ecosystems, including desertified lands, mining areas, and agricultural soils degraded by intensive farming practices [16, 17].

Agricultural Productivity Enhancement

The framework also demonstrates strong implications for sustainable agriculture. Mycorrhizal fungi improve nutrient uptake in plants, particularly phosphorus and nitrogen, leading to enhanced crop productivity and resilience.

AI-based optimization models can recommend:

- Fungal species selection for specific crops.
- Soil amendment strategies to enhance fungal growth.
- Climate-adaptive planting schedules.
- Fertility restoration interventions.

These insights support regenerative agriculture systems, reducing dependence on chemical fertilizers while improving long-term soil health [18, 19].

Biodiversity and Ecosystem Stability

Myco-engineering systems contribute significantly to biodiversity preservation and ecosystem stabilization. Fungal networks facilitate plant diversity by improving nutrient distribution and enabling interspecies communication through underground networks.

Stable fungal ecosystems correlate with:

- Higher plant diversity.
- Increased ecosystem resilience.
- Reduced species extinction risk.
- Improved habitat connectivity.

This reinforces the role of fungi as keystone organisms in ecosystem stability models [20].

AI Optimization of Fungal Ecosystems

A key innovation in the framework is the use of AI models to optimize fungal ecosystem performance. Machine learning systems can identify patterns between environmental conditions and fungal growth efficiency, enabling predictive optimization of ecological outcomes.

AI models support:

- Identification of high-carbon-sequestration fungal species.
- Prediction of optimal environmental conditions for fungal expansion.
- Simulation of ecosystem restoration scenarios.
- Real-time ecological decision support.

These capabilities transform myco-engineering from a passive biological process into a computationally guided ecological engineering system (Table 7) [21, 22].

Table 7. AI contributions in myco-engineering systems.

AI function	Ecological role	Outcome
Pattern recognition	Fungal growth mapping	Spatial optimization.
Predictive modeling	Climate response forecasting	Ecosystem planning.
Classification	Soil and species grouping	Biodiversity assessment.
Regression analysis	Carbon estimation	Climate mitigation modeling.
Optimization algorithms	Resource allocation	Restoration efficiency.

Limitations of Implementation

Despite its potential, several limitations affect the practical deployment of myco-engineering systems:

- *Biological Variability*: Fungal species exhibit diverse growth patterns and ecological roles, making universal modeling difficult.
- *Environmental Sensitivity*: Fungal systems are highly sensitive to micro-environmental changes, which may affect predictability.
- *Scaling Challenges*: Laboratory-based fungal performance may not directly translate to large-scale ecosystems [23, 24].
- *Data Gaps*: Limited availability of high-resolution fungal ecological datasets restricts model accuracy.

Ethical and Ecological Risks

The introduction or manipulation of fungal systems raises important ecological concerns:

- Risk of disrupting native microbial ecosystems.
- Potential unintended ecological dominance of engineered fungi.
- Biodiversity imbalance due to ecological intervention.
- Lack of regulatory frameworks for fungal-based environmental engineering.

These concerns highlight the need for strict ecological governance and monitoring frameworks [25].

Overall Discussion

The findings suggest that myco-engineering represents a highly promising approach to climate change mitigation and ecosystem restoration. By leveraging fungal networks as natural carbon storage systems, environmental sustainability can be achieved through biological rather than industrial processes [26].

The integration of AI significantly enhances the precision, scalability, and efficiency of fungal-based ecological interventions. However, successful implementation depends on overcoming biological variability, data limitations, and ethical governance challenges [27].

Overall, the study positions fungi as a core component of future ecological engineering systems, capable of transforming how carbon sequestration, soil restoration, and biodiversity conservation are approached globally [28].

CONCLUSION

This study has presented a comprehensive conceptual framework for Myco-Engineering Systems, an interdisciplinary approach that integrates fungal biology, environmental science, and artificial intelligence (AI) to enhance carbon sequestration, soil restoration, and ecosystem resilience. The central premise of the study is that fungal networks represent one of the most efficient, scalable, and naturally self-sustaining biological infrastructures for addressing contemporary environmental challenges, particularly climate change and land degradation. A primary conclusion of this work is that fungal systems play a critical and underutilized role in global carbon cycling and ecological stability. Through mycorrhizal associations and mycelial networks, fungi facilitate long-term carbon storage in soils while simultaneously enhancing nutrient cycling and plant productivity. This dual functionality positions fungi as essential biological agents in regulating terrestrial carbon balance and supporting ecosystem sustainability. The study further concludes that myco-engineering offers a viable biological alternative to conventional carbon sequestration technologies. Unlike industrial carbon capture systems that require high energy input and infrastructure investment, fungal systems operate through natural biological processes that are self-regenerating and adaptive. When optimized through AI-based modeling, fungal networks can be strategically utilized to maximize carbon retention and improve soil health across diverse ecological zones. Another key conclusion is that AI integration significantly enhances the

efficiency and predictability of fungal-based environmental systems. Machine learning models enable the analysis of complex interactions between fungal growth dynamics and environmental variables such as temperature, moisture, and soil composition. This allows for predictive optimization of fungal performance in carbon sequestration and ecosystem restoration. As a result, myco-engineering evolves from a passive ecological process into an intelligent, data-driven environmental engineering system. The study also highlights the importance of myco-engineering in agricultural sustainability and food security. Mycorrhizal fungi improve plant nutrient uptake, enhance soil fertility, and increase crop resilience to environmental stressors. These benefits reduce reliance on synthetic fertilizers and improve long-term agricultural productivity. AI-driven recommendations further enable precision agriculture systems that align fungal activity with crop requirements and climate conditions. In addition, the framework demonstrates strong relevance for ecosystem restoration and land rehabilitation. Fungal networks accelerate the recovery of degraded soils by improving organic matter decomposition, enhancing microbial diversity, and stabilizing soil structures. These processes are particularly valuable in addressing desertification, deforestation, mining site rehabilitation, and industrial land contamination. Myco-engineering thus offers a scalable solution for restoring ecological balance in damaged environments. The study also emphasizes the role of fungi in biodiversity conservation and ecosystem resilience. Fungal networks support plant diversity and ecosystem connectivity through underground symbiotic systems that facilitate nutrient sharing and ecological communication. Healthy fungal ecosystems are strongly correlated with stable and resilient ecological systems, reinforcing their importance in conservation strategies. Despite these advantages, several limitations must be acknowledged. A major challenge lies in the biological variability of fungal species, which respond differently to environmental conditions and ecological contexts. This variability complicates the development of universal predictive models and requires region-specific calibration of AI systems. Additionally, data scarcity remains a significant barrier, as high-resolution fungal ecological datasets are still limited in scope and availability. Scalability also presents a critical challenge. While laboratory and controlled-environment studies demonstrate strong potential, translating these results into large-scale ecological applications requires careful environmental management and long-term field validation. Without proper scaling strategies, the effectiveness of myco-engineering systems may be reduced in complex natural ecosystems. Ethical and ecological governance considerations are equally important. Although fungi do not present ethical concerns in the same way as animal systems, the intentional manipulation or introduction of fungal species into ecosystems carries potential risks, including disruption of native microbial communities and unintended ecological dominance. Therefore, strict environmental monitoring and regulatory frameworks are necessary to ensure responsible deployment. From a policy perspective, the successful implementation of myco-engineering systems requires investment in interdisciplinary research, ecological data infrastructure, and AI-enabled environmental technologies. Governments and environmental organizations must support collaborations between mycologists, data scientists, and climate researchers to develop integrated solutions for carbon management and ecosystem restoration. International cooperation is also essential, as fungal ecosystems and climate systems are globally interconnected. Shared data platforms and standardized ecological monitoring frameworks will enhance the scalability and effectiveness of myco-engineering applications worldwide. In conclusion, this study demonstrates that Myco-Engineering Systems represent a transformative approach to environmental sustainability by leveraging the natural capabilities of fungi and enhancing them through artificial intelligence. While still conceptual, the framework provides a strong foundation for future empirical research and applied environmental engineering. If developed further, fungal-based ecological systems could play a central role in global climate mitigation strategies, sustainable agriculture, and ecosystem restoration efforts. The convergence of fungal biology and computational intelligence thus marks a significant step toward the development of intelligent, self-sustaining ecological infrastructure for the future.

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