Protection, Restoration, and Utilization of Soil and Water Ecology under the Background of New Quality Productivity

Fazheng SUN*

Soil and Water Ecology Professional Committee of Guangdong Provincial Ecological Society, Shenzhen 518131, China

Abstract This paper discusses that soil and water ecology is a historical law of the Earth's evolution, and that the three major elements of water, soil, and vegetation, as well as their interrelationships, form a holistic natural view of soil and water ecology that "sees both forests and trees". The theory of soil and water ecology unifies ecology, environment, and resources, and is a common theoretical foundation in the field of ecological environment, laying a theoretical foundation for the establishment of an emerging interdisciplinary discipline called *Soil and Water Ecology*. The relationship between elements is expressed using the soil and water ecology equation $E(x) = f(S, W, V)T$, which is a conceptual representation of soil and water ecology. New quality productivity is green productivity. Under the background of new quality productivity, it should respect and conform to the laws of soil and water ecology, take green and low-carbon as the core, use Nature-based Solutions (NbS), and promote the protection, restoration and utilization of soil and water ecology. It is to address climate change, protect biodiversity, and achieve sustainable human development from the source. In this paper, the Nanling mountainous area in north Guangdong is taken as the research object. From the perspective of soil and water ecology theory, some suggestions on the protection, restoration and utilization of soil and water ecology in this area are put forward.

Key words Soil and water ecology; New quality productivity; Green and low-carbon; The Nanling mountainous area in north Guangdong; Protection, restoration, and utilization

DOI 10.19547/j.issn2152 - 3940.2026.02 - 03.007

In November 2004, as the cover person of the magazine *China Invention and Patent*, the author first proposed the term "soil and water ecology" in an interview with reporters. Subsequently, a series of discussions were published in domestic and foreign journals, which basically formed the theoretical system of soil and water ecology and received high praise and recognition from national regulatory authorities and peer experts. With the deepening development of practices such as soil and water conservation, ecological restoration, integrated protection and management of mountains, rivers, forests, farmlands, lakes, grasslands, and sands, as well as the increasing global ecological crisis, the theory of soil and water ecology will be more widely studied and applied, playing an increasingly important role in protecting the Earth home that humans rely on for survival and achieving harmonious coexistence between humans and nature. During June 23 - 27, 2025, the author was invited to attend the 11th Ecosystem Services Partnership World Conference (ESP11) in Australia and gave an academic report on the content of this paper, and proposed that the theory of soil and water ecology is a theoretical distillation of Nature-based Solutions (NbS) and a cornerstone of sustainable development, which has received widespread attention from the international academic community.

1 Soil and water ecology being the historical law of the Earth's evolution

1.1 The birth of life on the Earth depending on harsh natural conditions The formation and development of the Earth and its biosphere are a continuous process of interaction between various systems such as the lithosphere, hydrosphere, and atmosphere, as well as with external celestial bodies. The mechanism of this process not only constitutes the evolutionary history of the Earth, but also fundamentally determines the future of the Earth. Among the eight planets in the solar system, the Earth is the only known planet that nurtures and sustains life. This unique position confirms that soil and water ecology is an objective historical law of the Earth's evolution, and is the foundation and prerequisite for the birth, survival, and development of humanity.

The birth of life on the Earth depends on a series of harsh conditions. Among them, the Earth's possession of a natural satellite—the Moon, is an indispensable factor. The torque effect generated by the gravitational force of the Moon on the Earth ensures the stability of the Earth's rotation, the relative stability of atmospheric and oceanic circulation, and the regular alternation of seasons. During the Paleozoic era, autotrophic algae produced molecular oxygen through photosynthesis. The sun's ultraviolet radiation decomposed the molecular oxygen into unstable atomic oxygen, forming an ozone layer on the outer periphery of the atmosphere. This provided a barrier and filter for cosmic rays and ultraviolet radiation, thus protecting the safety of life on the Earth[1]. Under this series of balanced and stable conditions, the Earth has evolved into a complex soil and water ecosystem, giving birth to a complex and intricate life system.

1.2 Soil and water ecology being a natural comprehensive system of the Earth's evolution About 600 million years ago, the land on the Earth was still bare rocks. In the near water areas

Received: February 20, 2026 Accepted: March 20, 2026

* Corresponding author.

near the ocean and lakes, the first type of terrestrial life emerged—lichens, which can survive in extreme environments with exposed rock surfaces. As early pioneers of lower organisms, lichens were able to secrete organic acids, accelerate rock decomposition, and thus promote soil formation. About 470 million years ago, with the adaptation and reproduction of moss plants, more complex vascular plants began to emerge. Vascular plants have true root, stem, and leaf differentiation, which is a revolutionary evolution that enables plants to effectively absorb water and mineral nutrients from the soil, greatly enhancing their survival ability and adaptability[1]. Afterwards, intense competition among plants began, completely changing the appearance of the land. Vegetation releases a large amount of oxygen through photosynthesis, effectively stabilizing the atmosphere. At the same time, it provides abundant food sources and habitats for animal survival and reproduction, promoting the diversity and complexity of the Earth's soil and water ecosystems.

1.3 The relationship between the elements expressed in the soil and water ecology equation In order to systematically explain the core components of soil and water ecology and express the element relationships of soil and water ecology, the following functional relationship is a conceptual representation:

$$E(x) = f(S, W, V)T$$

where E shows the status of soil and water ecology in a certain region; x shows specific geographical regions; S shows elements of geotechnical layer; W shows elements of hydrosphere layer; V shows vegetation elements (core layer of the biosphere); T shows time dimension, emphasizing the dynamic evolution characteristics of soil and water ecosystems.

The above equation indicates that the status of soil and water ecology and its basic pattern in a certain area are jointly defined by the structure and function of the three major elements of water, soil, and vegetation. This formula is a conceptual framework and system thinking tool, and is not an accurate mathematical model that can be analyzed for a single variable through mathematical methods such as calculus.

Vegetation provides energy through photosynthesis and forms ecological network, while water and soil transport nutrients to vegetation. These three processes support ecosystems and biodiversity through energy flow, material cycling, and information transmission. Vegetation is the ecological core, water is the carrier of life, and soil is the resource foundation, collectively forming the cornerstone of all ecosystems[2].

2 The three major elements of water, soil, and vegetation and their interrelationships being the holistic natural view of soil and water ecology

Water, soil, and vegetation are the three most fundamental core elements that make up the surface life support system. Water determines soil moisture and vegetation distribution; soil retains water, sequesters carbon, and provides nutrients and support; vegetation solidifies soil, purifies the atmosphere, and 99% of the biological productivity on the Earth comes from plants. Water, soil, and vegetation are closely coupled into an inseparable functional whole—the soil and water ecosystem through continuous energy flow, material cycling, and information transmission, forming a complex nonlinear relationship between macroscopic systems and microscopic subsystems, as well as between the whole and the local. This systemic view goes beyond the viewpoint of simply overlaying various elements. When understanding any one of them, it must be placed within the interrelationships of the three. This holistic, systematic, interconnected, and dynamic cognitive approach is the core of the holistic natural view of soil and water ecology. The dynamic balance relationship among water, soil, and vegetation, which is interdependent, mutually restrictive, mutually promoting, and developing, constitutes the holistic natural view of understanding the Earth's living environment, and also reflects the holistic natural view of soil and water ecology of "seeing both forests and trees"[3].

2.1 Soil and water being the physical carriers and material foundations on which vegetation relies for survival Rocks are the mother of soil. After billions of years of geological processes and soil formation, rocks have weathered into soil, providing support and nutrient sources for plants. As the source of life and medium of material transport, water dissolves and transports nutrients from soil to plant bodies. From hard rocks to fertile loose soil, it is the product of long-term interactions among water, soil, air, and life. The macroscopic process of the water cycle is still a key process connecting the climate system and the Earth's environment, and its dynamic changes directly shape the natural environment and climate characteristics of the Earth.

2.2 Vegetation being a key engine for activating the vitality of water and soil systems The root system of plants is like a natural anchoring system, effectively maintaining soil and water, and enhancing the soil's resistance to erosion. The canopy and litter layer can intercept precipitation, delay runoff, and promote infiltration, directly altering the micro processes of the water cycle. More importantly, vegetation converts solar energy into chemical energy through photosynthesis. Through the decomposition of plant litter and root metabolism, it feeds back organic matter to the soil, driving nutrient cycling and energy flow in the soil and water ecosystem, thereby conserving and enhancing the production and ecological functions of water and soil, and creating conditions for animal survival and reproduction.

2.3 Water, soil, and vegetation forming an eternal feedback loop and dynamic balance The distribution and characteristics of water shape the types of soil and the morphology of landforms, and determine the types and distribution of vegetation to some extent. The succession of vegetation and the development of soil profoundly affect the pattern of water systems and hydrological processes. They evolve together and shape each other. Any change in any element will trigger a chain reaction, ultimately af-

fecting the stability and health of the entire ecosystem.

3 The theory of soil and water ecology unifying ecology, environment, and resources, and being a common theoretical foundation in the field of ecological environment

3.1 Soil and water ecology summarizing various ecosystems on the Earth Various ecosystems on the Earth, such as forests, grasslands, wetlands, and farmlands, can be classified under the category of soil and water ecology, including natural soil and water ecology and artificial soil and water ecology[4]. Glaciers, snow capped mountains, deserts, salt lakes, etc. are special or extreme types of soil and water ecology, as shown in Fig. 1. The health status of these ecosystems determines the ecological balance of the Earth. It can clearly understand and solve complex ecological and environmental problems by grasping the core contradiction of soil and water ecology.

The development history of human civilization is essentially a history of interaction with soil and water ecology. Human beings are constantly changing the pattern of soil and water ecology on the Earth through production and construction activities, which has a dual effect. On the one hand, it improves the living environment and promotes economic development. On the other hand, it has also triggered global ecological crises such as climate change, biodiversity loss, land degradation, and environmental pollution[5].

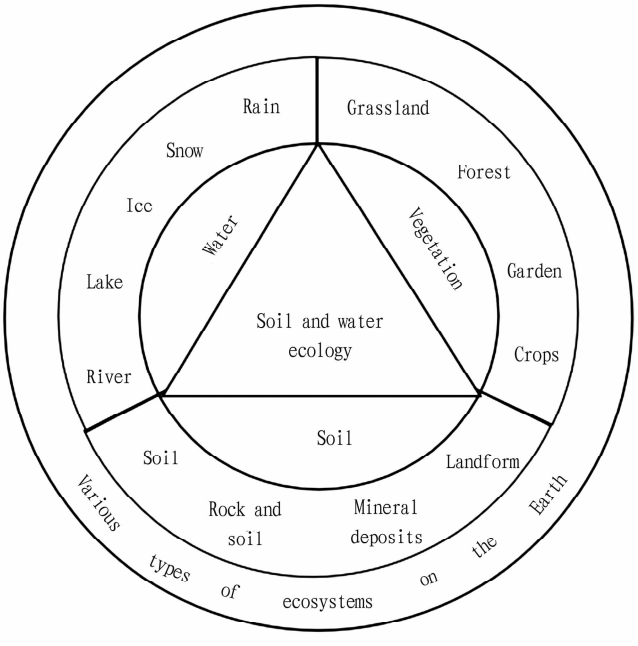

Fig. 1 Soil and water ecology encompassing various types of ecosystems on the Earth

3.2 The theory of soil and water ecology unifying ecology, environment, and resources As the three core elements of soil and water ecology, water, soil, and vegetation are not only the main components of the ecosystem, but also the basic carriers of the environment and resources, forming a three in one theoretical framework and a relationship of "one entity with three aspects", as shown in Fig. 2. For example, the three major elements of water, soil and vegetation in the Nanling mountainous area in northern Guangdong constitute a complete soil and water ecosystem, bearing the resource endowment, environmental capacity and ecological functions of the region.

This theory integrates ecological construction, environmental protection, and resource utilization, providing a systematic cognitive tool and practical guide for sustainable development.

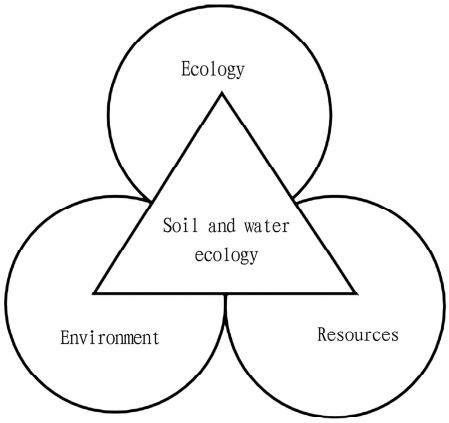

Fig. 2 The theory of soil and water ecology unifying ecology, environment, and resources, and forming a relationship of "one entity with three aspects"

3.3 The theory of soil and water ecology being a common theoretical foundation in the field of ecological environment Degradation of soil and water ecology, environmental pollution, and resource depletion are the three major root causes of ecological and environmental problems, and degradation of soil and water ecology is the fundamental problem[6]. The systematic protection and management of mountains, rivers, forests, farmlands, lakes, grasslands, and sands are essentially the systematic protection and management of soil and water ecology[7], as shown in Fig. 3. The fundamental reason for ecological crises such as climate change, global warming, and loss of biodiversity lies in the changes and destruction of the Earth's soil and water ecology by humans. The theory of soil and water ecology is related to the fundamental and global scientific issues of ecological environment. It is the golden key to understanding and solving contemporary ecological and environmental problems, and the common theoretical foundation in the field of ecological environment[8].

4 Core for protection, restoration, and utilization of soil and water ecology being green and low-carbon under the background of new quality productivity

4.1 New quality productivity referring to green productivity New quality productivity lies in higher technology, value, and green content. New quality productivity itself is green productivi-

ty[9]. The previous development model, which was based on the destruction of soil and water ecology, is no longer sustainable, and it will inevitably shift towards a path of resource conservation and environmentally friendly development; from "governance" to "intelligent management", from "consumption" to "value preservation and appreciation". Under the background of new quality productivity, it should respect and conform to the laws of soil and water ecology, take green and low-carbon as the core, use Nature-based Solutions (NbS), and promote the protection, restoration and utilization of soil and water ecology. It is to address climate change, protect biodiversity, and achieve sustainable human development from the source. In this paper, the Nanling mountainous area in north Guangdong is taken as the research object.

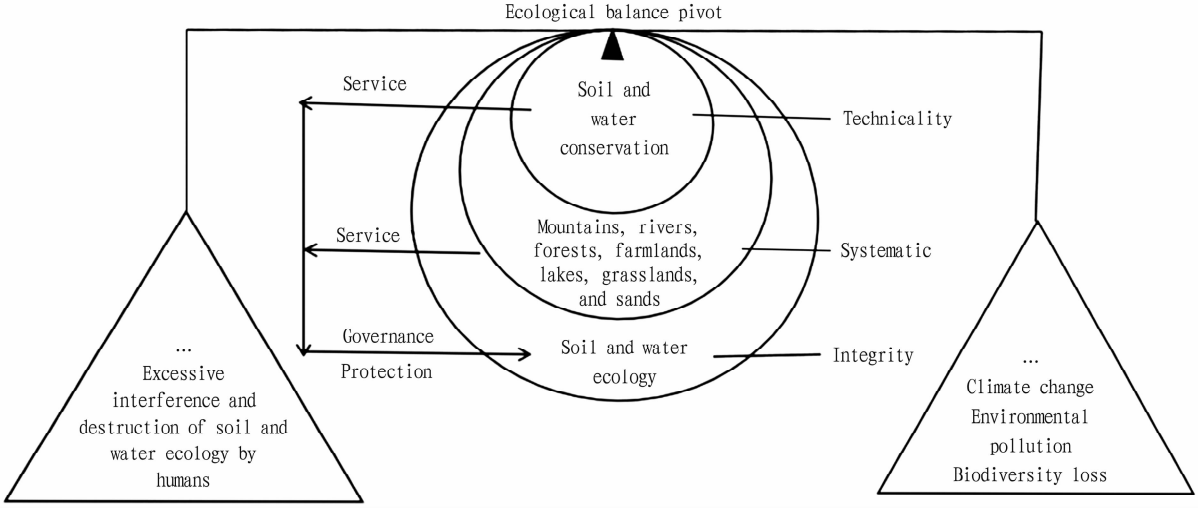

Fig. 3 Relationship between soil and water ecology and soil and water conservation, as well as mountains, rivers, forests, farmlands, lakes, grasslands, and sands

4.2 Protection of soil and water ecology As one of the most intact areas of subtropical evergreen broad-leaved forest ecosystem in the same latitude zone of China, the Nanling mountainous area in northern Guangdong is an important ecological security barrier in South China, known as the "Guangdong Water Tower". The conditions of soil and water ecology in this region are directly related to the economic and social stability of downstream areas and the water supply safety of urban agglomeration in the Guangdong – Hong Kong – Macao Greater Bay Area.

The biodiversity in this area is highly abundant. Serving as a "refuge" for Quaternary glacial organisms and a center of origin for numerous ancient relict plants, it holds a special position in international biodiversity conservation. There are 3 890 species of wild higher plants recorded in the Nanling Mountain National Nature Reserve, including 129 species of rare and endangered plants. There are 555 species of terrestrial vertebrates, including 33 nationally protected animals and a total of 108 threatened species both domestically and internationally; fungal resources are also extremely abundant[10]. It forms a complete biological chain and unique soil and water ecosystem in the Nanling mountainous area in northern Guangdong. Today, it needs to be treasured and protected with the rapid economic and social development.

4.3 Restoration of soil and water ecology The Nanling mountainous area in northern Guangdong is highly sensitive to soil and water loss due to natural factors such as topography, precipitation and thin weathered granite layer. Due to human activities such as road construction in mountainous areas, it has caused certain damage to native vegetation and geological landforms, exacerbating soil erosion and geological disaster risks, and also affecting biodiversity. Therefore, it is necessary to adopt soil and water conservation and ecological restoration measures based on natural solutions. The control measures for rocky desertification in karst areas include promoting clean energy such as biogas, optimizing the energy structure in rural areas, and promoting natural restoration of forests and grasslands in ecologically fragile mountainous areas.

The water and heat conditions in this area are good. Following the principle of soil and water ecology that "wherever there is soil and water on the Earth, there must be vegetation growth, and the growth of vegetation also protects the ecological resources of soil and water", a near natural ecological restoration strategy based on soil is adopted in the exposed areas of the project, especially the technical measures of soil conservation and erosion prevention. For example, by spraying annual pioneer grass seeds, soil and slope stabilization can be achieved quickly, creating habitat conditions for the natural recovery of local plant communities[11]. It should avoid excessive reliance on artificial seedling cultivation and invasive species, and achieve low-cost and high-efficiency near natural ecological restoration.

4.4 Utilization of soil and water ecology The water and soil

ecosystem in the Nanling mountainous area in northern Guangdong not only provides important ecological products and regulating services, but also contains rich cultural and scientific research values. It is an important ecological base supporting the green development of the Guangdong – Hong Kong – Macao Greater Bay Area.

The region has diverse landform types, with typical landscapes such as Danxia and karst. The "Tongtianluo" geological relic has high potential for tourism development and is a high-quality resource for the development of cultural tourism industry.

At the same time, the Nanling mountainous area has a large number of paleontological fossils and relict plants, such as dinosaur fossil groups, which provides rare physical materials for carrying out natural education, scientific popularization and biological evolution research, and helps to form a cultural green industrial system with the Nanling characteristics[12]. It should scientifically transform the advantage of soil and water ecological resources in the Nanling mountainous area into the value realization of soil and water ecological products.

5 Conclusions

5.1 The relationship between humans and nature can be traced back to the relationship between humans and soil and water ecology With the continuous expansion of human production and construction activities, the pattern of soil and water ecology on the Earth is undergoing profound changes, which in turn have a profound impact on the global ecological environment. This process has not only improved the living environment and promoted economic development, but also triggered a series of ecological crises such as climate change, biodiversity loss, land degradation, and environmental pollution[13].

5.2 Soil and water ecology being the greatest common divisor of various ecosystems and the key to maintaining the ecological balance of the Earth The theory of soil and water ecology unifies resources, environment, and ecological issues within a holistic framework, providing a common theoretical basis for the field of ecological environment. In the context of the development of new quality productivity, it is necessary to take green and low-carbon as the core, and promote the protection, restoration, and sustainable utilization of soil and water ecology based on natural solutions.

5.3 The theory of soil and water ecology revealing the universal laws of the global ecosystem and being the golden key to solving ecological and environmental problems The theory of soil and water ecology is applicable to the protection and governance practices of global ecosystems. It is a theoretical distillation of Nature-based Solutions (NbS) and a cornerstone of sustainable development, and is a theoretical and systematic study and exploration of the scientific proposition that "lucid waters and lush mountains are invaluable assets", which lays the theoretical foundation for the establishment of the *Soil and Water Ecology*[14].

References

[1] QIN SH. Biogeography[M]. Beijing: Science Press, 2010: 266 – 271.

[2] SUN FZ. Discussion of several problems about the soil and water ecology and the soil and water ecological conservation[J]. Journal of Soil and Water Conservation, 2011, 25(2): 262 – 264.

[3] SUN FZ. The theory of soil and water ecology is a major scientific issue [J]. Soil and Water Conservation in China, 2020(12): 1 – 3.

[4] SUN FZ. Protection and restoration of soil and water ecology to achieve harmonious coexistence between human and nature[J]. Soil and Water Conservation in China, 2022(11): 1 – 3.

[5] SUN FZ. Soil and water ecology is the core issue in contemporary biodiversity conservation: A case study of the Pere David's deer population, a species endemic to China[J]. China Animal Industry, 2022(12): 80 – 82.

[6] SUN FZ. Innovating soil and water conservation theory and scaling commanding height in ecologic protection and building[J]. Soil and Water Conservation in China, 2007(6): 13 – 15.

[7] SUN FZ, HUANG CY, HU R. The contribution of herbaceous plants and their status and role in the soil and water ecosystem[J]. Soil and Water Conservation in China, 2023(12): 70 – 73.

[8] SUN FZ. Research on theoretical basis in the field of ecological environment[J]. Soil and Water Conservation in China, 2021(12): 10 – 13.

[9] ZHOU HC. Some reflections on "new quality productive forces embody green productivity"[J]. World Environment, 2024(2): 30 – 34.

[10] LI DQ, ZHOU P. Research on the geographical environment and biodiversity of the Nanling Mountains[M]. Beijing: Science Press, 2024: 170 – 203.

[11] HUANG CY, WANG ZC, HU R, *et al*. Application of grass in soil and water ecological restoration of large mine group in Shuijing of Shenzhen [J]. Soil and Water Conservation in China, 2021(12): 14 – 16.

[12] SUN FZ, SUN Y. Cultivate ecological culture of soil and water ecology and build beautiful homes[J]. Soil and Water Conservation in China, 2013(5): 11 – 14.

[13] SUN FZ. Philosophical thinking on soil and water ecology[N]. China Science Daily, 2017 – 03 – 13(7).

[14] SUN FZ, HUANG CY, HU R. Soil and water ecological insights from the Australia investigation and the international conference on healing riverscapes[J]. Meteorological and Environmental Research, 2025, 16 (6): 15 – 18.