Chapter 5

Water and Ecosystem Cycles Mediated by Plant Genetic Resources for Food and Agriculture

Masatoshi Funabashi

Additional information is available at the end of the chapter

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Abstract

Plant genetic resources for food and agriculture play essential roles in sustainable development and the conservation of global biodiversity. Especially, water cycle and related material circulation are deeply influenced by the loss of plant species diversity and external inputs through agricultural practices. This chapter overviews the water and ecosystem cycles mediated by the ecosystem functions of naturally occurring plant communities and discusses possibilities for the transformation of agriculture into sustainable modality with the primary importance on the recovery of water cycle. The transformation requires an intensive utilization of plant genetic resources in various ways compatible with a multi-scale integrated model of water and material cycles based on the processes of ecological succession and evolution. This foresight sheds light on the new importance and utility of plant genetic resources for food and agriculture, in the face of climate uncertainty and in repairing disrupted water and ecosystem cycles.

Keywords: water cycle, material cycles, biodiversity, ecosystem functions, plant genetic resources, ecological optimum, agriculture

1. Introduction

An abundant water cycle supports the ecosystem in the world we live in. Without water filling the earth's surface and flowing back to it, life would not have reached dry land and flourished. Water is the most important substrate for life. The underground water permeating the soil, the rivers flowing through the earth's surface, the lakes creating lush landscapes, and other components of the dynamic water cycle are all supported by the activities within the ecosystem. This chapter looks at the interactive relationship between the water cycle and the ecosystem.

From the total amount of water cycled across the entire earth, only 0.8% can be used for daily life, such as the underground water and the water in rivers and lakes. About 97% of the earth's water is seawater, and from the remaining 3% freshwater component, 2% is in the form of ice in glaciers in the polar regions. The water that we actually see in our daily life other than on sea is only a portion of the 0.01% water flowing on the ground, out of the 0.8% useable water [1].

This may be a very small number, but this 0.8% component of the water cycle supports the biodiversity on land. Our daily life, and industries such as manufacturing, agriculture, forestry, marine products, and livestock, is established from the various ecosystem services, including domestic water, derived from this component. Water flows in a form that we can use for daily life due to the power of the ecosystem, at the base of which are the plants.

Studying the impacts of agriculture by considering agricultural lands as artificially built ecosystems provides useful insights on the ecosystem and the water cycle. Conventional agricultural practices may be considered as a kind of disruption experiment on the water cycle that is mediated through the ecosystem. In addition, the kind of ecosystem that is created by agriculture is an important consideration in thinking about the future of the water cycle, which supports our daily life.

2. Soil functions, water retention, and water purification capacities afforded by the ecosystem

Let us look at how the ecosystem creates a water cycle that supplies water for our daily life. Plants, the primary producers of the ecosystem, play a central role in creating the water cycle for the miniscule 0.8% surface water component. Part of the rainwater supplied to the earth's surface by rainfall goes back to the atmosphere through evaporation and transpiration, and the rest repeatedly penetrates and flows out between the surface and the ground as it flows to the rivers. Within this process, plants—through photosynthesis—create the organic matter that becomes the source of energy for the entire terrestrial ecosystem. Other components of the ecosystem food chain, such as animals and fungi that degrade organic matter, are heterotrophs that depend on the organic matter produced by plants. Photosynthesis is the origin of all the processes on the earth's ecosystem. Thus, plants can be considered as the source of all organic matter on earth, including food and fossil fuel. Photosynthesis, by causing the formation of surface soil, serves as the driving force for the different cycling patterns of useable water, such as underground water, rivers, and lakes.

The electrical properties of surface soil provide clues for understanding the development of surface soil functions. Land, which was originally composed of rocks and minerals, is broken down into various sizes of gravel and eventually into fine clay through long years of erosion and weathering. In particular, since fine pieces of clay carry surface charges, they adsorb the ions needed for plant growth into the ground surface. In the same way that a piece of paper adheres to a sheet of plastic after producing static electricity by rubbing the surface of the plastic sheet, the ions contained in the rainwater are adsorbed by the clay and remain on the ground surface. The growth of plants on the ground and the resulting activities of microorganisms

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produce various organic substances, which further strengthen the electrical properties of the soil, thereby increasing its water retention capacity and the adsorptive power of microelements. Adsorption and retention of all sorts of substances by the earth's surface enhance the function of purifying the underground water permeating through the ground. As such, the electrical properties of the soil surface provide the key for the synergistic interaction between the production of organic matter and water retention and purification capacities of the soil.

Generally, the topsoil's water retention and purification functions increase proportionally with the diversity of vegetation. This is the reason for the preservation of virgin forests, which are composed of different tree species, as watersheds. Therefore, even under the same climatic conditions, the water cycle components available to living things vary greatly depending on the ecosystem formed on the ground surface layer. Even though the surface water component is only 0.8% of the water cycle for the entire earth, the circulation of this component has a significant impact on the habitat of terrestrial organisms. Imagine what would happen if there was no vegetation on earth, and there was no formation of soil due to photosynthesis. There would be no underground water, rivers, or lakes that would provide a ready supply of water for life. Rainwater would flow straight into the ocean, land would simply release rocks into the sea by erosion, and this world would be nothing but either raging streams of water or dried valleys.

3. Merits and demerits of agriculture: decline of usable water cycle components

We need to reevaluate agriculture in consideration of the general role of the ecosystem in soil formation. Usual agricultural practices involve the tillage of land to enhance water retention. This results in a sure but short-term increase of water retention in tilled agricultural lands, sometimes to a level similar to that of forest areas [2]. However, unless tillage is regularly and continuously done, the water retention capacity will not be sustained; that is, without continuous tillage, a hard crust will be formed on the surface to repel rainfall, and the capacity to retain water will eventually be lost. Also, since tillage disturbs the soil ecosystem, it will also eventually destroy the capacity of the topsoil to purify water. In reality, agricultural fertilizers are the biggest pollutants being released to rivers. There are reports of cases wherein, depending on crop species, more than 90% of the nitrogen, phosphate, and potassium—the major components of fertilizers—are not absorbed but become runoff, in agricultural practices that entail tillage and use of fertilizers. This percentage is not for only some farms, but represents the national average in Japan [3].

The emphasis on temporary water retention in conventional agricultural practices clearly does not take into consideration the environmental impact on the ground surface water cycle. Addressing this issue means having to deal with the complexity of the water cycle. First of all, underground water contamination caused by agriculture, unlike industrial and domestic effluent, does not have exact discharge locations, making it difficult to identify testing and sampling points. Also, due to the complex dynamics of underground water penetration, identifying clear causal relationships is not easy, preventing the analysis of the interplay of different farms and timings of fertilization that lead to contamination. If the contamination has accumulated along the river basin, the effects to distant areas, including the marine ecosystem, must also be considered. The complexity of the water cycle widens the extent of the impact, thereby obscuring the location of responsibility for contamination.

The most typical example I witnessed in the field is the runoff of red clay in sugarcane fields in Ishigaki Island. With subsidy from the government, farmers grow sugarcane by tilling land in summer when rainfall is heaviest on 1700 of the 22,900 hectares of the total island area [4]. From an airplane, you can clearly see the red clay flowing in all direction throughout the island and the coral reefs turning reddish brown in color during rain. Fertilizer-containing red clay causes significant changes to the environment of organisms living in the coral reefs, which are said to be responsible for 80% of the biodiversity of marine ecosystems. Recently, there has been an abnormal proliferation of crown-of-thorns starfish around Ishigaki Island, causing damage to the corals. Remains of dead crown-of-thorns starfish are washed up on the beaches, making some areas dangerous to walk barefoot because of their poisonous spines.

Long-time residents of Ishigaki Island claim that they have not seen such occurrences in the past few decades. Although crown-of-thorns starfish is important in creating the diversity of corals, eutrophication due to fertilizer runoff has caused its abnormal proliferation [5].

Thus, although it is clear that agriculture is affecting the environment, it is difficult to make comparisons to identify exact causal relationships and determine the extent of the effects. The selection of factors that must be quantified in order to understand the phenomenon also depends on the purpose and the scale of investigation. Understanding the effect of the coral reef on the ecosystem would require investigating an extensive range of factors that include the fluctuations in marine biodiversity. Likewise, finding correlations between climatic and agricultural factors and isolating individual effects would entail very complicated processes. Therefore, prior to quantifying the complex dynamics of the problem, it would be more effective to qualitatively identify upstream factors and remove them from the targeted systems.

Many years ago, environmental contamination from pesticides, rather than from fertilizers, was the more urgent concern. Pesticides, which have direct toxic effects, more easily became subject to environmental and ethical discussions. At present, most of the pesticides used are highly degradable and do not leave residues in the environment. Even pesticides with low toxicity, however, when used in the long term or in combination, lead to indirect as well as direct effects on the ecosystem—effects that cannot be determined in advance. Likewise, even though fertilizers are in themselves not toxic, they diminish useable water resources once they enter the water cycle, leading to reduction in biodiversity of the water ecosystem, loss in income from fisheries, and damage to the water-related living environment. Also, when using organic fertilizers from livestock farms, there is a need to consider the risk of releasing antibiotics and other chemicals used for animals into the water ecosystem.

Therefore, before the contamination spreads throughout the complex components of the water cycle, the basic surface soil functions must be preserved, and fundamental measures must be implemented in agriculture to prevent the creation of contaminants in the first place. An example of these measures is the incorporation of cover cropping (planting of grasses and legumes in between cropping to prevent soil erosion, enhance the landscape, or suppress the growth of weeds) as part of conventional agriculture practices. Also, since chemical fertilizers and pesticides rely on petroleum resources and rare metals, they cannot be supplied sustainably. Therefore, as long as we do not make use of the natural water retention and purification capacities of the water cycle, which are underpinned by healthy ecosystem functions, the cost for investing on artificial measures would be too high.

The use of genetically modified crops, which have continued to improve in recent years, is gaining wide attention as a means to increase yield while decreasing inputs and environmental burden. This is an effort to shift from the control of environmental factors through the input of material resources to the manipulation of genetic functions. The basic framework of agricultural methods, however, still entails the destruction of soil functions through tillage. In other words, the priority lies in optimizing agricultural productivity under the conventional framework, without consideration of the water cycle functions of the earth's surface afforded by the ecosystem. As such, there are at most only around ten types of environmentally related genes incorporated in genetic modification of crops. This is in stark contrast to the innumerable number of genes that are related to the wide range of ecosystem functions supporting the water cycle and that are expressed by all organisms involved in the formation of surface soil.

It is therefore more important to figure out how to allocate vegetation that supports the core of the water cycle, which involves a numerous number of genes, rather than create a crop that incorporates around ten new genes, in thinking about agriculture that contributes rather than undermines the water cycle. The diversity of the countless genes expressed by plants, animals, and microorganisms in response to the environment is the foundation that supports the water cycle at the genetic level. The interspecific transfer of genes to the surrounding ecosystem through genetically modified crops, however, can have a negative effect on this diversity, and its actual risks are still unknown. In the same way that vigorously introduced species sometimes impair the diversity of indigenous organisms, there is also a risk of diminishing the genetic diversity of endemic species through hybridization with genetically modified crops endowed with dominant functions.

We need to give careful thought on whether it is worth the risk of adversely affecting the diversity of the immensely abundant genetic resources underpinning the water cycle for the sake of optimizing single-crop farming, which is based on the destruction of soil functions. Moreover, even if we can provide proof of whether the transfer of genes from genetically modified crops to the surrounding ecosystem has occurred in the past or not, it is in principle impossible to guarantee that it would not happen in the future.

4. Embankments and flood control

River embankments are an important consideration in thinking about the water cycle of rivers, which are important in agriculture. Rivers overflow by nature, and the riverbanks naturally formed from the flooding, as well as the fertile floodplains around the riverbanks, is in fact ecological structures that naturally create the river's water cycle. The vegetation on the floodplains is what sustains the underground water and functions to store the excess water during flooding, other than being an important source of biodiversity. The fertile floodplains near the rivers are suitable for agriculture and building cities. Due to the resulting advanced economic growth along the rivers, concrete embankments were built along the banks of rivers all throughout Japan to develop the alluvial plains along them. Meanwhile, the growth of the cedars and cypresses that were planted on the mountains in different areas in Japan after World War II has led to the decline of forest floor vegetation, making the mountains more prone to landslides. This has in turn led to the overbuilding of concrete embankments even for the small upstream rivers of mountains.

Cemented riverbanks at a glance seem to protect us from flooding of rivers, but they in fact undermine the diverse water cycle and ecosystem functions of rivers. The water retention capacity and the many other benefits brought about by rivers to the surrounding ecosystem were lost as a result of cementing the passage of water to contain the rivers. Without embankments, the water in rivers freely flows to and from the nearby underground water sources while being filtered through the diverse soil environment. The purification process is compatible with the principle of septic tanks used for the domestic effluent such as from toilets, etc., which are based on physical filtration and adsorption and degradation of organic matter by both aerobic and anaerobic microorganisms. The more diverse the soil environment is, the higher is its capacity to purify water passing through it. The river basin water is purified as it passes through diverse soil types of different physical environments and microbial flora while at the same time enhancing their water-purifying functions.

Cemented riverbanks intercept the free flow of underground water and undermine the inherent purifying function of riverbanks. The Miya River flowing through Ise, Mie Prefecture, is one of the few Class 1 rivers in Japan. According to people living near the river's estuary, before the concrete riverbanks were built, there was no sewage system, there was a large population of residents, and there were some kitchen scraps and garbage floating around. The water, however, was clear, and people were able to dive into the river and catch fish. Presently, however, the population of residents near the estuary has declined, and while a sewage system has been put in place, sludge has built up on the bottom of the water channel and has created a stench. Since disposal of domestic and industrial effluent is restricted, the water quality problem is believed to be caused by fertilizer runoff from the upstream farms and by the loss of purifying capacity of the cemented riverbanks. Also, the decline in the population of eel, which has recently been classified as an endangered species, is believed to be caused, other than by overfishing, by the loss of their habitat due to the building of concrete riverbanks across Japan [6].

Thus, impediments to the natural water cycle result in various trade-offs in ecosystem functions, leading to risks of forfeiting the aggregate benefits afforded by rivers. Since rivers change their courses within the floodplain in response to the water cycle, restricting the flow of rivers at the convenience of human society would only be good for several decades. When we consider the movement of rivers over a hundred-year span, it is possible that the cost of floods that cannot be prevented by the concrete riverbanks and the ecosystem functions lost by building them would exceed the benefits of building concrete embankments. Even the cities

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and farmlands damaged by the tsunami during the Great East Japan Earthquake were alluvial plains close to the sea level (some were reclaimed areas built lower than the sea level), which basically serve as buffers of the effects of changes in the water cycle.

The Netherlands, Germany, Austria, and other countries have implemented flood control measures that take ecosystem functions into consideration through renaturalization of rivers by removing the embankments and restoring the floodplains. Conventional flood control by building concrete riverbanks has led to the worsening of environmental deterioration and loss of biological resources. Through citizen's movements and policy decisions, consensus is building toward solving these problems by allowing the water cycle of rivers to take its natural course [7].

Large dams built across the USA are approaching the end of their lifespans, and it has been pointed out that they have in fact not fully performed their intended functions in generating power, irrigation, and flood control. Rather, they have adversely affected water quality and the renewal of resources, reduced the underground water in the river basins, and restricted the movement and habitat of wildlife. Because of this, around 850 dams have been demolished in the last 20 years [8]. The dams built around the world are able to hold up to 15% of the total water flowing in all the rivers on earth—an indication of the magnitude of the effect of artificial water reservoirs on the water cycle on the surface of the earth [9].

The renaturalization of rivers is based on the recognition of the environmental deterioration caused by man's efforts to control rivers by artificial means. The concept of renaturalization also includes the extreme approach of completely letting nature take its course by disengaging from all human activity, such as agriculture, in the floodplains. Many aspects of the relationship between ecosystem functions and the water cycle in floodplains still remain unexplained. As the renaturalization of rivers continues to progress, it is therefore necessary to reassess its benefits and shift to a new form of industrial activities that maximize those benefits.

5. Agriculture that promotes the ecosystem functions related to the water cycle

Thus far, we have looked at examples of the major effects of both the natural cycling and artificial cycling of water on the ecosystem. The artificial water cycle created by dams and embankments was originally intended to enhance the production of drinking water, energy, and food needed by humans. Since they were built without regard for the effects on the ecosystem and on the natural water cycle, however, they have led to various ills as well. The renaturalization of rivers is a movement to return to the original course of nature upon the realization that the adverse impacts of development are far larger than its benefits. But, is there an example in which the artificial modification of the water cycle has positively enhanced both agricultural productivity and biodiversity?

There is a vast expanse of paddy fields around San Francisco in the USA. The area used to be dry like a desert, but a dam was built to collect water from melted snow from the Sierra Nevada mountains and irrigate the fields, enabling regulation of the water levels to the millimeter level and the cultivation of rice. Applying different concentrations of fertilizers depending on the previous year's harvest enables minimizing fertilizer runoff, and the percolation is blocked by the underlying bedrock. Even though rice paddies are man-made marshlands, they provide a habitat for ducks and various waterfowls and marsh animals. Thus, along with harvesting and other agricultural practices, local volunteers also conduct wildlife conservation activities to protect the young birds and other animals. It is therefore possible to enhance an aspect of biodiversity along with agricultural productivity, even within an artificially created water cycle. Globally Important Agricultural Heritage Systems (GIAHS) represent examples of agriculture that balances productivity and conservation in different countries around the world, wherein moderate disturbance by humans enhances the biodiversity of the environment, such as Satoyama farming (traditional farming in Japan at mountain skirts near the villages) [10, 11].

Would it possible, therefore, to more widely practice agriculture that is based on the relationship between biodiversity and the cycling of water and other resources within the ecosystem? Thus far, agriculture focused too much on continuous production of a particular type of crop, which required a different supply pathway from the natural system for the cycling of materials in the ecosystem, and could not be produced sustainably without the input of external resources. This is very similar to the destruction of floodplains of rivers contained by concrete embankments. The damage from continuous cropping, which is a normal agricultural practice, can be avoided by allowing the succession of vegetation in a natural ecosystem, which is premised on the mixture of a variety of species. In the same way that the natural ecosystem functions of rivers can be restored by enabling flooding to take place, would it be possible to restore the autonomous functions of ecological succession in agriculture?

Let us try to think of an agricultural production system based on the process of topsoil formation, the starting point of which is photosynthesis. This production system should effectively utilize the water cycle, which is nurtured by the process of topsoil formation. Going back to how the cycling of materials has evolved, we see that each material cycles between the various layers comprising the ecosystem. At the beginning, after exposure to rainfall and sunlight, the rocks and minerals were eroded and dissolved into soil solution, where microorganisms started to deposit organic matter, leading to the growth of plants on the first layer of soil formed. Eventually, animals arrived to take up a higher position in the food chain (**Figure 1**). The current composition of the atmosphere is a result of the total effects of the earth's ecosystem, which has been modified by the evolution of living organisms. Being formed from the lower layers beneath them, the higher layers are more complex, so that the layers can be arranged vertically based on their complexity. We will refer to this arrangement as "axial hierarchy." **Figure 2** illustrates how the cycling of materials between each evolution layer takes place. The succession of the ecosystem and the soil forms a network that is intricately entwined with the cycle of materials. By assigning a qualitative complexity score to the soil and ecosystem succession based on the stage of emergence and evolution, and averaging the scores of the layers related to each material cycle, we can arrange them based on the characteristics of emergence and evolution. The resulting order shows a close correlation between the evolution of the ecosystem and the cycling of materials in accordance with the acquired characteristics: In **Figure 2** right, the lowest complexity score of material cycle that is

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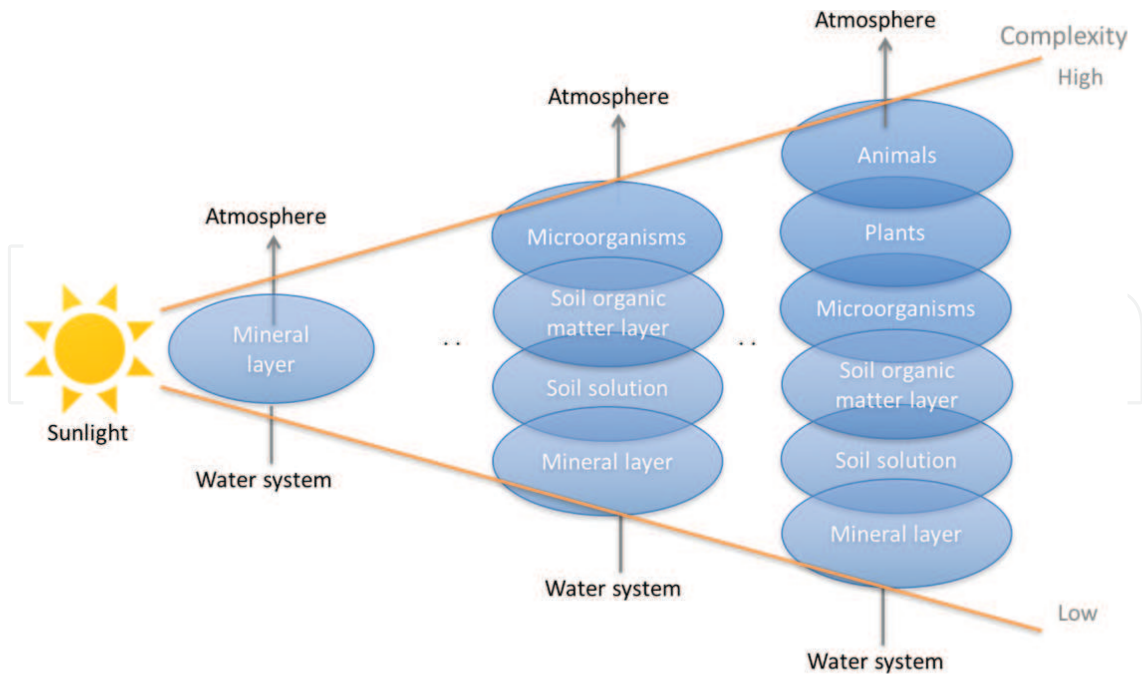

Figure 1. Axial hierarchy of emergence and evolution of land ecosystems.

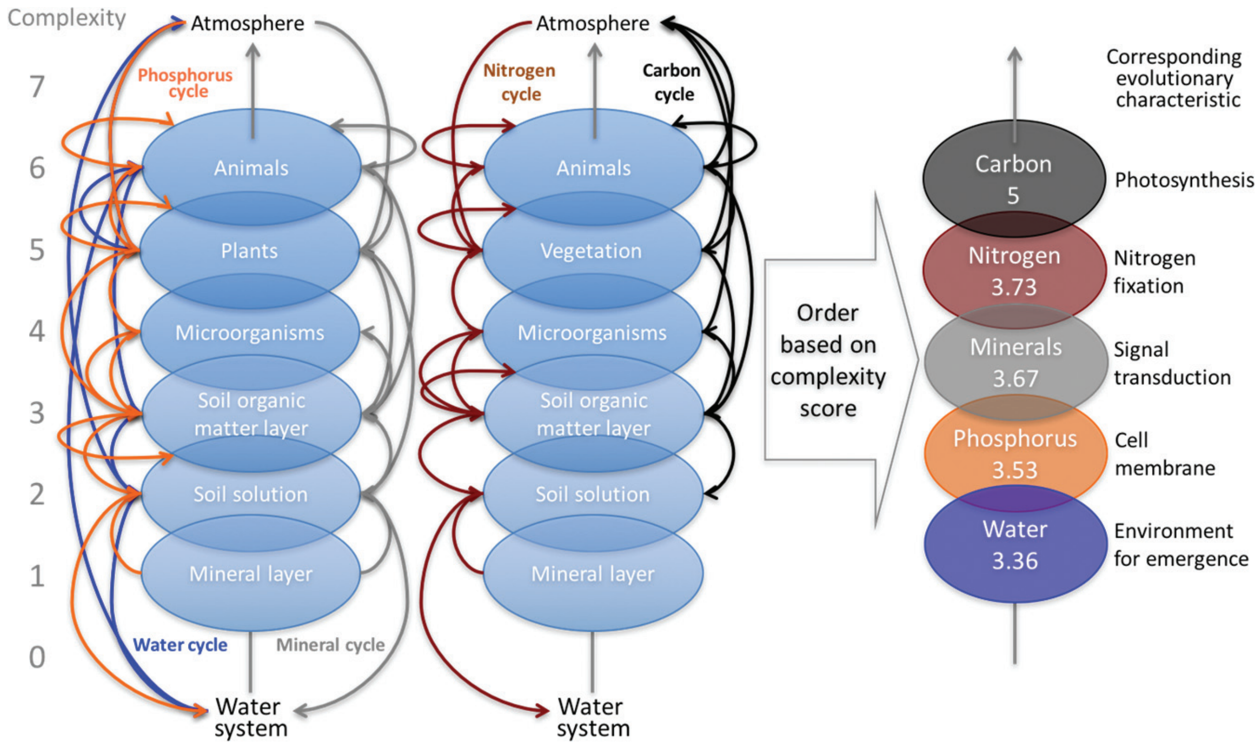

Figure 2. Axial hierarchy of material cycles of land ecosystems. Prepared based on the Figure 18-2 in Ref. [21] by adding the animal layer and leguminous nitrogen fixation. Water movement between animals and transpiration of water from animals were excluded from the relative amount of water.

most involved in the initial process of land ecosystem evolution is the cycle of water, which provides the environment for the emergence of life. Then, on the upper layer followed by the cycle of phosphorus, which is responsible for cell membrane formation, followed by the cycle of minerals, which mediate the signal transduction systems needed for the independent activities of the cell, followed by fixation of nitrogen, by which *Archaebacteria* carry out nutrient transformation. And, at the top with the highest complexity score of land ecosystem, is the fixation of carbon, which is carried out through photosynthesis, which is in turn responsible for the vegetation covering the entire surface of the earth and for creating the topsoil. Thus, the cycling of materials depicts the evolutionary history entwined within the ecological succession process.

In terms of ecosystem management, if a certain element in the hierarchy is lacking, then a problem occurs. Traditional agriculture tries to solve the problem by supplying the lacking element. However, if the level supplied by the natural cycle is lower than the artificially supplied level, then the system cannot be sustained unless the input is continually made. Conversely, to realize a sustainable culture systems, we need to think about how to change the ecosystem to enable a natural remediation of the material cycle without supplying the lacking element. By fixing the ecosystem layer where the cycle of the lacking element is mostly occurring, it is possible to enhance the cycle of that element within the natural cycle.

For example, to enhance the water cycle, you can plant vegetation with high biomass on fine-textured soil to increase the accumulation of organic substances on the topsoil and improve water retention. This increases the volume of water retained by the topsoil for the same amount of rainfall. Also, since the purifying function of the topsoil is dependent on the thickness of the topsoil formed by the vegetation, the capacity to decompose organic substances in the topsoil also increases. Likewise, to increase the amount of phosphorus, minerals, and other microelements, you can plant tree species and vegetation that attract insects and small animals carrying those elements to the field and collect them from surrounding ecosystems. These microelements, other than being supplied through weathering of minerals and through rainfall, are dispersed and retained on land through the activity of fish-eating birds and other animals that collect them from sediments originating from the oceans. Meanwhile, nitrogen, carbon, and other important components of organic matter are accumulated through photosynthetic activities by plants and through the activities of symbiotic microorganisms; therefore, succession of vegetation can be allowed to proceed until the necessary soil formation level is reached.

These measures, however, cannot be expected to immediately satisfy the recommended rates of fertilizer application for single cropping of particular varieties selected by modern agriculture. In contrast, they can enhance the biodiversity of microelements and phytochemicals that are important for exhibiting the ecosystem's functions. It is therefore possible to sustain productivity based on the ecological optimum under mixed growth conditions, which is the basis for primary productivity in natural ecosystems [12].

In order to increase productivity in a highly diverse plant community, there is a need to find the right set of useful plants that grow under the niche of that community rather than practice continuous cultivation of a specific crop. This is the same as improving the cycling of materials by changing their relationships rather than by input of lacking elements. It is possible to balance productivity with the natural ability of the ecosystem to adapt to environmental changes by designing vegetation to enable productivity in a diverse community, in accordance with the cycle of materials and the environment established in the field. Agricultural crops are basically introduced species, wherein despite having more than 30,000 species of agriculturally useful plants, there are only around 120 species actually being cultivated for agriculture. About 90% of all food is derived from only 30 species of plants [13]. Enhancing the water cycle and other ecosystem functions based on biodiversity requires the development and cultivation of underutilized or neglected plant resources in accordance with the ecological succession stage. Synecological farming, or synecoculture, is such an approach to agriculture that emphasizes the management of ecological relationships.

In synecoculture, an extremely wide variety of useful plants are densely cultivated together based on the ecological optimum. This results in a condition wherein the water retention capacity and permeability of the topsoil enhance the water-buffering capacity of the soil while supporting the growth of aboveground vegetation and at the same time enhancing the biodiversity and activity of soil microorganisms [14]. Field experiments conducted in Burkina Faso, sub-Saharan Africa, showed that synecoculture was more efficient in the consumption of water relative to productivity compared to other cultivation methods [15]. These examples indicate that the intensive introduction of diverse genetic resources from useful plants into an agriculture based on the ecological optimum is very effective in improving ecosystem functions, such as the cycle of water and materials.

6. Target areas for implementing agriculture that is adaptive to fluctuations in the water cycle

In particular, which places would benefit from an agriculture that emphasizes uninhibited ecological dynamics and the conservation of the water cycle? Governments, NPOs, and scientists from more than 110 countries have submitted an international report stating that agriculture based on large-scale monocropping is not sustainable from the standpoint of environmental burden and fair distribution of food [16]. Also, those who are at higher social risk against the effects of climatic changes are not the developed nations with advanced large-scale agricultural systems, but the small and developing countries in the tropical and subtropical regions [17]. In particular, the increasing expanse of flood-stricken areas in Southeast Asia is at a high risk of being unable to cope with dramatic changes in the water cycle if conventional agriculture is continued, pointing to the urgent need for developing agriculture that leverages the inherent water-buffering capacity of the ecosystem. In China, 200 million small-scale farms are pursuing modernization with support from the government. There is a need, however, to implement measures to improve food production based on the ecological optimum rather than through conventional agricultural practices, both from the standpoint of environmental burden and the available materials and resources in the future [18]. In India, where the Green Revolution has since steadily increased food production and enabled overcoming hunger, restoring the biodiversity and ecosystem services (particularly pollination and purification of water and air) that were lost as a result of the agricultural activities must be addressed [14]. Moreover, African countries undergoing rapid development in recent years must develop self-sustaining agriculture practices based on the characteristics of the ecosystem in each region, in order to combat desertification in arid areas, correct the disparity in wealth, and stabilize their society [15, 19]. To arrest the deforestation of the few remaining tropical rainforests in Indonesia, the Amazon in South America, the Congo Basin, and other susceptible areas, we need to nurture the capacity of local communities to use forest resources sustainably based on the ecological optimum of useful plant resources. We also need to create regulations that favor local economic development and involve stakeholders from a wide range of sectors. These regions will benefit from the rapidly increasing uptake of mobile terminals and other IT devices through the development of databases and tools for understanding relationships with the water cycle and biodiversity primarily pertaining to useful plant resources. These databases and tools will serve as effective infrastructures for underpinning next-generation ecosystem management and food productivity [20].

7. Conclusion

This chapter reviewed the relationship between biodiversity and ecosystem cycles in plant communities with a particular focus on water cycle. A wider introduction of plant genetic resources for food and agriculture into the establishment of novel agricultural practices that make use of ecologically optimum formation of mixed communities is needed to overcome sustainability burdens, cope with the climate change, and recover globally disrupted water and material cycles. Guidelines for the resolution through ecosystem management are explained along with the "axial hierarchy," as a structure traversing ecosystem cycles closely related to the emergence and evolution of land ecosystems.

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Conflict of interest

The author declares no conflict of interest.

Author details

Masatoshi Funabashi[1,2]*

*Address all correspondence to: masa_funabashi@csl.sony.co.jp

1 Sony Computer Science Laboratories, Inc., Tokyo, Japan

2 Japan Agency for Marine-Earth Science and Technology, Yokosuka, Japan

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