Transdisciplinary field science based on Land-Surface Management (LSM)

Land-Surface Management (LSM) technology, which is based on transdisciplinary field science, offers a solution for ‘Earth Regeneration’. The general principle behind LSM technology aims to control and manage three basic elements of our land surface – water, oxygen, and nutrients – even in different eco-types such as wetland or dryland. On a global scale, there are large areas of inferior soil (e.g., peat, acid sulphate, sandy, saline, and arid) and degraded agricultural land (which is devastated, abandoned, degraded, and/or contaminated). Under such conditions, Professor Mitsuru Osaki at Hokkaido University, Japan, and colleagues observe that the roots of plants have avoidance strategies to extend on land surface, rather than tolerance strategies to soil. This largely improves symbiotic systems function, nutrients cycling, and oxygen absorption in the rhizosphere (the thin area around the roots).

In the face of global social change, increasing population pressure, and the ever-worsening climate crisis, terrestrial land systems are under stress like never before. Issues arising from poor quality soils and degraded agricultural land require urgent solutions to ensure food security and effectively combat further environmental degradation. Professor Mitsuru Osaki at Hokkaido University, Japan, and colleagues Professors Nagayuki Kawakita, Tsyofuki Kato and Nobuyuki Tsuji, and researcher Silisga Siva are focused on developing Nature-based Solutions (NbS) for environmental issues, and have now turned their hand to the soil crisis. In particular, via transdisciplinary field science and observing the behaviour and evolution of biomass in areas of naturally low soil quality they have identified optimal strategies with the potential to be implemented in land management schemes.

TROPICAL TREE GROWTH PARADOX: GROWTH IN THE WORST SOILS

Despite covering just 3% of Earth’s surface, peatlands are a critical landscape and habitat. Peat in mainly tropical and boreal zones is an important carbon reservoir (holding more carbon than the forests of Britain, France, and Germany combined), it is critical for water management (capable of holding up to 20 times its own weight in water), and offers a window to past climates. In the tropical maritime continent Southeast Asia including Indonesia, Borneo, New Guinea, the Philippines, the Malay Peninsula, and Island and surrounding coastal areas – peat soils are common. Peat forms in areas with a high groundwater level, which results in naturally low oxygen and nutrients concentrations. Moreover, once peat becomes degraded, even poorer soils appear, including acid sulphate soil (extremely poor nutrients), and saline soil in Mangroves close to peat soils (Figure 1). Paradoxically, however, biomass productivity (tree growth) is much higher in tropical peat soil and sandy podzolic soil compared with that in tropical mineral soils. For example, wood production rates of around five tonnes per hectare per year (t/ha/yr) in mineral soils can be compared with around 10–15 t/ha/yr in peat soils, and approximately 12–20 t/ha/yr in sallow peat soil and sandy podzolic soil (Figure 2).

By understanding the mechanisms by which plants thrive in this challenging environment, Osaki and colleagues are shedding light on the potential for new management practices that harness natural solutions. They conclude that plants grown on poor-quality soil develop a common strategy roots extend into the humus on soil and develop a rhizosphere regulation system. The rhizosphere is the very thin area (10 µm) around the roots, which is improved by exudation of organic compound from roots and symbiosis with microorganisms. Rhizosphere function is mainly improved by these factors on land surface: oxygen supply, nutrients supply, and water (moisture) supply. The researchers’ observations reveal a multi-pronged natural strategy to achieve this goal. First and foremost, roots play an essential role in oxygen and absorption of nutrients. Tropical peatland/wetland and Mangrove plants have developed root systems that spread into humus on land surface. Examples include aerial roots, which absorb oxygen from the air; and mound roots, which absorb oxygen from the air and nutrients from forest litter. Second, to spread roots into humus on land surface, the humus must maintain a high moisture content. Third, symbiotic system with microorganisms, nutrients absorption and N₂ fixation are drastically improved. In conclusion, even in naturally inferior low quality soil areas, if we can develop an appropriate Land-Surface Management (LSM) technology for water, nutrients, and oxygen supply, we can regenerate degraded land (ie, which is devastated, abandoned, degraded, and/or contaminated) at a cheaper cost.

Based on their findings, Osaki and colleagues have developed LSM technology, which promotes both traditional approaches, for example, Zero tillage with grass mulching (Z-tillage) culture for arable land – and newly developed methods, including Aerohydro Culture for peat/wetland and Mangrove and HydroCycle culture for dryland and semi-arid areas.

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Figure 1. The poorest quality soils are found surrounding the tropical peatland and are degraded or disturbed.

Figure 2. Above-ground biomass and wood production rate in tropical peat soil, peat and sandy soil, and mineral soil (from T Kohyama).
Moisture by Sun energy from the air by the mulch (Figure 6). Thus, the porous water droplets within the bottom of with condensation of dew creating hot, while the bottom of the mulch cools latent heat. The mulch surface becomes the Sun, the water inside cotton porous mulch containing water is radiated by over the soil (Figure 5). When porous mulch (eg, a cotton-based mulch) is laid (Figure 4). In this process, a porous mulch, such as cotton (Figure 5). When porous mulch containing water is radiated by the Sun, the inside cotton porous vaporizes by solar energy, and removes latent heat. The mulch surface becomes hot, while the bottom of the mulch cools down because of latent heat removal, with combination of dew creating water droplets within the bottom of the mulch (Figure 6). Thus, the porous mulch on land surface can also extract moisture by Sun energy from the air by capturing dew, which becomes trapped below the mulch where it can be utilised by surface roots. Experiments have shown that this approach can increase the weight of biomass by up to 70%. Another porous metal-organic material developed by Massachusetts Institute of Technology [Zi, Oi, (2004)] can capture 2.8 litres of water per day using only solar radiation as an energy input, even when the relative humidity is as low as 20%.

2. TILLAGE CULTURE OF ARABLE LAND

Zero Tillage with grass mulching culture, referred to here as Z-Tillage culture, is proposed by Masanobu Fukuzaki in arable land. Tillage involves the preparation of average, it is critical for sustaining life on Earth and is integral to food production, forest management, and the restoration and regeneration of land ecosystems. The work of Osaki and his colleagues is raising the profile of soil science and offering new solutions, based on tried and tested natural methods, to improve and protect critical soil resources, especially in devastated, ruined, abandoned, and barren land.

Recognising the Importance of the SoilSphere

Soil is a critical but widely underappreciated resource. Osaki refers to it as Earth's skin. Much like human skin, it is often an afterthought, but we would be lost without it. While the atmosphere is extremely thin, 30-60 cm on average, it is critical for sustaining life on Earth and is integral to food production, forest management, and the restoration and regeneration of land ecosystems. The work of Osaki and his colleagues is raising the profile of soil science and offering new solutions, based on tried and tested natural methods, to improve and protect critical soil resources, especially in devastated, ruined, abandoned, and barren land.

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Research Objectives

Through transdisciplinary field science, Osaki, Kawakita, Kato, Tsuji, and Silva are developing methods to restore terrestrial land systems, applying three key technologies such as Aerohydro culture in peat/peatland, Z-Tillage culture in arable land, and HydroCycle culture in dryland-arid land.

References


Personal Response

Addressing soil degradation on a global scale will require the application of new techniques on a large scale. Are the methods described here scalable? What would be the economic and social costs of such a change? As the Land-Surface Management (LSM) technology is mainly composed of natural materials and minimum disturbance of soil and land, cultivation and fertilizer costs are drastically reduced compared to other methods. At the same time, this approach protects ecosystems by reducing soil erosion, which, in turn conserves both water and carbon within the soil, significantly increasing its natural capital value.