

1.7 KEYNOTE ADDRESS: “Managing Soil Health With Vetiver Grass for Food and Climate Security” by Dr. Rattan Lal



Urgent Need for Agricultural Transformation

The state of global agriculture raises serious concerns, as evidenced by alarming statistics. Currently, agriculture occupies 38% of the Earth's terrestrial surface, with 75% of agricultural land dedicated to raising animals. Additionally, agriculture accounts for 70% of global freshwater withdrawals for irrigation and contributes to 30-35% of global greenhouse gas emissions. Despite these significant land and resource demands, one-third of the Earth's surface is degraded, leading to food insecurity for 1 in 7 individuals and malnutrition for 2-3 in 7 individuals.

The impact of agriculture on greenhouse gas emissions and global warming is often underestimated, with land use conversion, deforestation, and agricultural activities being major contributors. Over time, carbon emissions from these practices have increased significantly, resulting in atmospheric carbon stock rising from 360 gigatons to 880 gigatons. In the past 10,000 years alone, land use conversion and agricultural activities have emitted 575 gigatons of carbon, surpassing emissions from fossil fuel sources (445 gigatons).

The cumulative impact of these emissions is evident in the rise of atmospheric carbon dioxide concentrations, which were around 200 parts per million before agriculture, increased to 280 parts per million during the Industrial Revolution, and presently stand at 420 parts per million. These figures highlight the substantial role of agriculture in contributing to global warming and emphasize the urgent need for sustainable agricultural practices. Recarbonizing the terrestrial biosphere by returning carbon to the land is a crucial focus to address climate change and enhance agricultural sustainability.

Land degradation, including soil erosion, salinization, and biodiversity loss, poses a major challenge to agricultural productivity and global food security. Approximately 3.5 billion hectares of land worldwide are affected by degradation, with water erosion impacting 33% of the Earth's surface (1.09 billion hectares), wind erosion affecting 0.55 billion hectares, and salinization impacting 0.85 billion hectares. Soil degradation threatens the sustainability of agriculture and the land's capacity to support food production effectively. Addressing and

mitigating soil degradation are vital steps toward ensuring a sustainable and secure global food system.

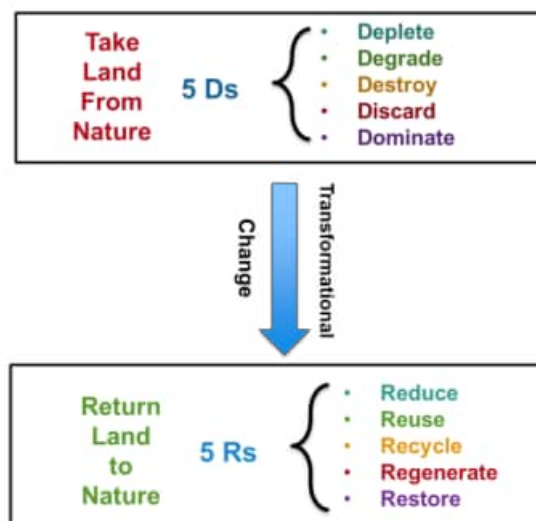
The current state of global food systems contradicts the Sustainable Development Goals (SDGs), posing challenges to achieving critical objectives, such as zero hunger. Recent statistics underscore the magnitude of global hunger, with approximately 700 million individuals undernourished in 2019 escalating to 782 million in 2020 due to the impact of the pandemic. The subsequent Russian-Ukraine war further exacerbated the situation, leaving an estimated 1.2 billion people experiencing hunger. These figures highlight the urgent need for comprehensive and sustainable solutions to address global hunger and ensure food security for all.

Progress toward the SDGs under Agenda 2030 is concerning, with targets related to zero hunger, poverty eradication, and climate action falling off track. This jeopardizes the goals of reducing hunger, taking climate action, addressing land degradation, alleviating poverty, improving healthcare, providing clean water and sanitation, and promoting renewable energy. Existing food systems have failed to provide sufficient nutritious food for the growing global population, projected to reach 9.7 billion by 2050. Moreover, these systems significantly contribute to global greenhouse gas emissions, accounting for approximately one-third of the total, while also driving soil degradation, water pollution, biodiversity loss, and deforestation. Therefore, an urgent and transformative shift in our approach to food systems is imperative.

To tackle these challenges, adopting a nature-positive approach to agriculture is necessary. This involves implementing practices that mitigate climate change, reduce emissions, promote carbon capture, restore and protect critical ecosystems, improve water quality and availability, enhance soil health, and ensure sustainable food production. Additionally, prioritizing eco-intensification over conventional sustainable intensification is crucial. Eco-intensification aims to increase food production while minimizing the use of resources, such as land, water, fertilizer, pesticide, and energy. It also focuses on reducing greenhouse gas emissions and restoring land to its natural state.

Transforming Agriculture through Regenerative Practice and Vetiver Grass

TRANSFORMATIVE STRATEGIES



To address the urgent need for agricultural transformation, it is crucial to replace current practices with transformative strategies that prioritize resource efficiency and land restoration. This shift involves moving away from the harmful 5Ds (deplete, degrade, destroy, discard, and dominate) and embracing the 5Rs (reduce, reuse, recycle, regenerate, restore, and return land back to nature). With 40% of the world's land used for agriculture, reassessing unsustainable practices is paramount.

Soil, Human, Planet-Health Nexus



"When we try to pick out anything by itself, we find it hitched to everything else in the Universe."

(John Muir)

Soil health is a key focus in regenerative agriculture as it impacts plants, animals, humans, and the environment. Organic matter content is central to soil health, and returning biomass to the land is essential for maintaining it. Failure to achieve this balance leads to a decline in ecosystem services, affecting human well-being.

Regenerative agriculture takes a comprehensive approach to improve soil health by incorporating eco-innovation, circular economy principles, and green infrastructure. Recarbonization of the terrestrial biosphere is a crucial pillar, involving the restoration of 575 gigatons of carbon emissions released from land use conversion and agriculture. By implementing regenerative practices and returning carbon to the land, a resilient and productive agricultural system can be fostered.

Vetiver grass (*Chrysopogon zizanioides*) aligns perfectly with these regenerative goals, offering solutions for eco-intensification. Its dense and deeply rooted clump structure makes it non-invasive and infertile, thriving in extreme ecological conditions. Vetiver grass withstands drought, fire, flood, submergence, and extreme temperatures, acting as a nurse plant in wastelands or disturbed soils.

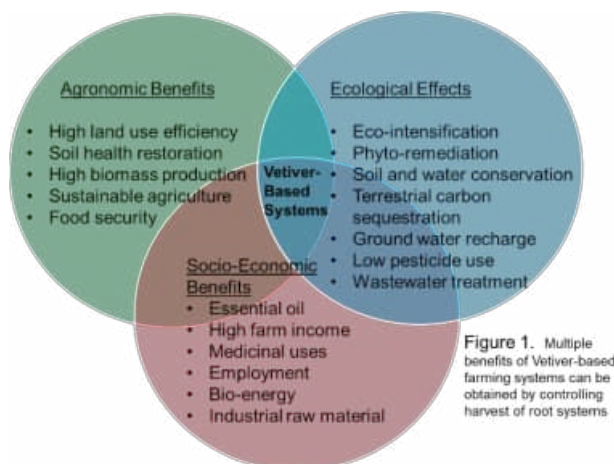


Figure 1. Multiple benefits of Vetiver-based farming systems can be obtained by controlling harvest of root systems

Cultivating and utilizing vetiver grass provides numerous advantages across different domains. Agronomically, it ensures high land use efficiency, promotes sustainable agriculture, and contributes to biomass production and soil health restoration. Ecologically, vetiver grass enhances ecological efficiency through phytoremediation, water conservation, carbon sequestration, groundwater recharge, reduced pesticide use, and wastewater treatment. Socio-economically, it generates income through essential oil production, offers medicinal applications, creates employment opportunities, serves as a bioenergy source, and acts as an industrial raw material.

The private sector plays a vital role in driving the adoption of vetiver grass-based systems. By supporting nature-positive agriculture, improving access to inputs, and investing in research and development, the sector can facilitate the widespread adoption of vetiver grass and its associated benefits. Furthermore, vetiver grass finds applications in industries, such as fragrance, medicine, and other sectors where its unique properties and potential can be harnessed.

Vetiver Grass as A Powerful Tool for Soil, Air, and Water Management

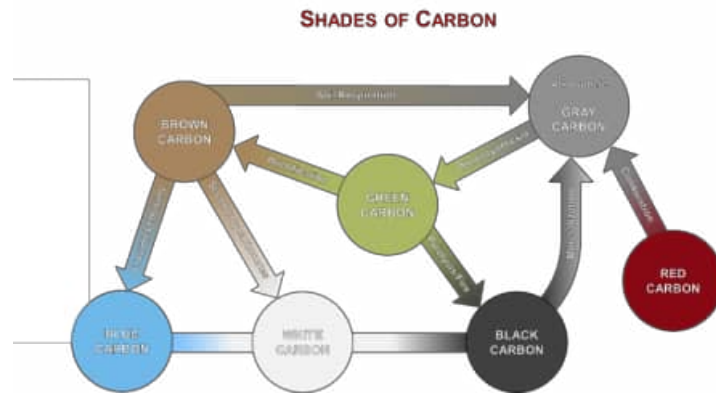
Vetiver grass, championed by the late His Majesty King Bhumibol Adulyadej the Great, plays a vital role in managing soil, air, and water on degraded steep lands. It promotes sustainable agriculture through carbon sequestration, soil conservation, bioenergy production, water storage, groundwater recharge, and enhanced agricultural productivity.

With its extensive root system, vetiver grass significantly enhances soil properties in biological, physical, chemical, and ecological aspects. This promotes eco-intensification and increases the availability of green water within the root zone. Contour hedges of vetiver grass also effectively mitigate soil erosion, particularly on steep terrains.

The global effectiveness of vetiver grass in controlling erosion has been demonstrated. Strategic planting at 5-meter intervals has been proven to reduce erosion from 829 tons per hectare to as low as 41 tons per hectare in the first year, and subsequently to just 6 tons per hectare. Vetiver grass plays an invaluable role in conserving soil through erosion mitigation.

Vetiver grass also holds potential for carbon farming by sequestering carbon in the soil, creating a valuable commodity. Farmers can generate income by cultivating vetiver grass solely for carbon sequestration. Leaving the biomass in the soil can therefore enhance carbon sequestration and soil health.

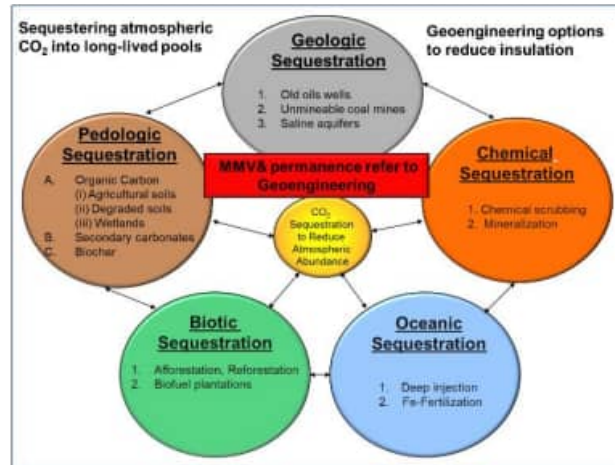
Under favorable conditions, vetiver grass exhibits impressive annual biomass production ranging from 3 to 9 kilograms per square meter. In optimal circumstances, it can yield remarkable growth levels of 161 and 107 megagrams per hectare (fresh) and 67.7 and 52.5 megagram per hectare (dry). Notably, vetiver grass also possesses a unique characteristic with a production ratio of approximately 1:1.143 (fresh) and 1:1.125 (dry) for roots to shoots. Vetiver grass has exceptional biomass productivity and income-generating potential.



Carbon is a versatile element with various forms, each serving distinct purposes. Understanding the different types of carbon is essential when discussing its properties and sequestration methods. Gray carbon, residing primarily in the atmosphere, serves as a fundamental reference for atmospheric carbon levels. In contrast, red carbon results from combustion processes, occurring during industrial activities or fires. Green carbon, associated with biological processes, involves carbon absorbed through photosynthesis. This crucial mechanism converts atmospheric carbon dioxide into organic compounds, actively contributing to the carbon cycle. Brown carbon, found in soil, undergoes respiration, releasing carbon dioxide back into the atmosphere.

Blue carbon pertains to carbon stored within coastal ecosystems, like oceans and lakes. These habitats play a critical role in absorbing and sequestering atmospheric carbon, thus aiding in climate change mitigation efforts. White carbon, an inorganic variant, coexists with brown carbon in soil, contributing to the overall carbon content. Black carbon comprises charcoal and biochar, resulting from incomplete combustion processes and requiring specific management approaches.

A comprehensive understanding of these diverse carbon forms is essential for comprehending carbon dynamics, exploring effective sequestration methods, and evaluating their environmental impacts. Consequently, when addressing carbon sequestration, it is crucial to specify the particular carbon type involved and understand the interrelationships between them. This distinction extends to soil carbon sequestration, encompassing both brown and white carbon components.



Carbon sequestration encompasses various mechanisms: geologic sequestration, chemical sequestration, oceanic sequestration, and biotic sequestration. Geologic sequestration involves injecting carbon dioxide deep into the ground, typically around a mile deep, while chemical sequestration converts atmospheric CO₂ into stable chemicals. Oceanic sequestration fertilizes the ocean to enhance carbon uptake by oceanic plants, and biotic sequestration relies on photosynthesis performed by plants, exemplified by vetiver. Pedologic sequestration stores carbon in the soil through organic matter and soil mineral interactions, including contributions from plants.

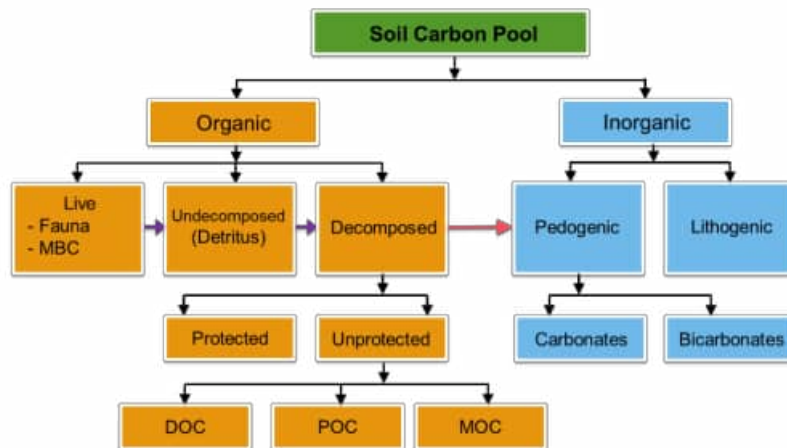
Photosynthesis contributes significantly to the global carbon cycle. The annual photosynthetic activity amounts to a staggering 123 gigatons of carbon, but only 3 gigatons persist as Net Biome Productivity (NBP), the significant portion that remains stored in the ground. Distinguishing these mechanisms and avoiding inappropriate terminology ensures clarity and accuracy in carbon sequestration discussions.



Source: https://www.researchgate.net/figure/Rendzina-or-humus-calcareous-soil-Bulgarian-classification-1976-Rendzic-Leptosol-WRB_fig2_312825283

Soil carbon can be categorized into two distinct types: organic black carbon and inorganic white carbon. Notably, white carbon predominantly exists in significant quantities within dry climates, encompassing approximately 50% of the Earth's land surface. This observation underscores the importance of understanding the prevalence of inorganic carbon in arid regions, signifying its substantial presence within the global carbon cycle.

CONSTITUENTS OF SOIL CARBON POOL



On a geological scale, black and white carbon interact with each other, shaping soil carbon dynamics. When examining soil carbon sequestration, it is essential to distinguish between its organic and inorganic components. Organic carbon includes live, undecomposed, and decomposed forms. Live organic carbon refers to carbon present in living organisms within the soil ecosystem, actively involved in biological processes and derived from recent photosynthetic activity. Undecomposed organic carbon consists of partially decomposed organic matter with recognizable structures, contributing to long-term carbon storage and nutrient availability in the soil. Decomposed organic carbon, on the other hand, can exhibit different characteristics, such as being protected, unprotected, dissolved, particulate, or mineral-associated. Among these, mineral-associated organic carbon has the potential to persist in the soil over extended periods.

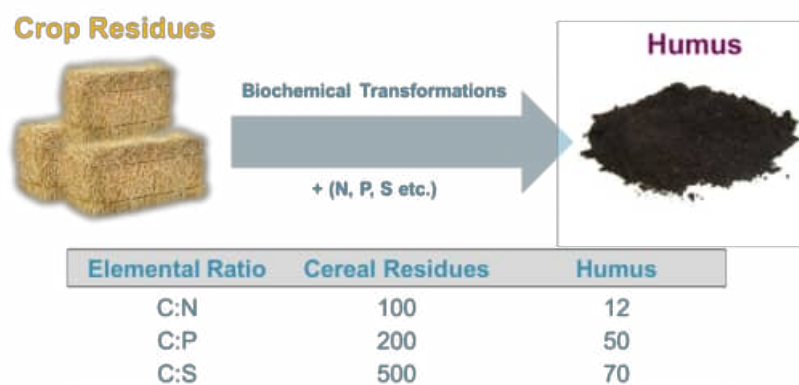
In contrast, inorganic carbon, also known as white carbon, comprises lithogenic and pedogenic forms. Lithogenic inorganic carbon originates from rocks, while pedogenic inorganic carbon can be newly formed, often referred to as secondary carbonates. Over geologic timescales, the secondary formation of carbonate has played a significant role in regulating Earth's temperature. This process, known as the Uri reaction, acts as a clock and thermostat, influencing the climate dynamics of the planet. Understanding the distinct components and interactions of black and white carbon is crucial for comprehending soil carbon sequestration processes and their implications.



Source: http://wwwuser.gwdg.de/~kuzjakov/soils/WRB-2006_Keys.htm

Secondary carbonates, when formed in arid soil environments, exhibit distinctive features, such as granules and films that are visually discernible. These formations contribute to soil carbon sequestration processes. Therefore, it is crucial to accurately identify and differentiate the specific type of carbonate being measured and to employ appropriate measurement techniques for a comprehensive understanding of soil carbon dynamics.

NUTRIENTS REQUIRED TO CONVERT BIOMASS INTO HUMUS



Sequestering 12 Mg of C would need 1 Mg of N.

Distinguishing between photosynthesis and sequestration is essential. For example, the conversion of vetiver piles into humus represents a biochemical transformation, altering the material's CN ratio to 12, C to P ratio from 200 to 50, and CS ratio, all while pertaining to sequestration. It is important to recognize that sequestration involves long-term carbon retention in the soil, unlike the transient nature of photosynthesis.

Carbon sequestration rates vary based on climate conditions. Wetlands generally exhibit the highest organic carbon sequestration rate, around 1.5 tons per hectare per year, while wet but drier regions like Thailand have a median rate of approximately 500 kilograms per hectare per year. Understanding these variations helps elucidate the factors influencing carbon sequestration.

Restoring carbon in global land resources, especially agricultural lands, where approximately 135 gigatons of soil carbon have been lost, is crucial for sustainable agriculture and global food security. While a soil organic matter content of around 3% is typically desired for optimal soil health and agricultural productivity, many developing countries suffer from organic matter levels below 0.5%, severely limiting the effectiveness of inputs. Vetiver grass emerges as a crucial option for soil carbon sequestration, contributing to the formation of organomineral complexes that interact with soil clays, stabilizing carbon and improving soil health. However, further research is needed to comprehensively understand this process.

Preliminary findings indicate that vetiver hedges significantly increase soil organic carbon content, with 1.01% in the 0-30 cm depth, compared to 0.2% in areas farther from the hedges. Vetiver grass has a potential sequestration rate of approximately 1 kg C/m² per year, but precise rates require additional data on bulk density. Investigation into biomass decomposition rates is necessary for a comprehensive understanding of the sequestration process.

Compensating farmers for carbon sequestration in agriculture is a complex issue. Initially priced at \$1 per credit, the market faltered due to a lack of demand caused by the absence of regulations on fossil fuel consumption. Determining fair compensation requires considering the societal value associated with carbon sequestration, including water conservation, climate change mitigation, biodiversity enhancement, productivity improvement, and sustainability. The estimated value is around \$200 per ton.

Additionally, vetiver biomass holds promise as a resource for cattle feed and energy production. Preliminary estimates indicate that it can yield an impressive 80 to 100 tons of dry leaves per hectare, with mowing and baling cycles every 3 to 4 months. The very young leaves, observed one month after mowing, prove to be valuable cattle feed, containing up to 14% protein.

Vetiver biomass also shows potential as an energy source. With an energy value of 16.3 gigajoules per ton and an economic value of \$30 per ton or \$3,000 per hectare, it competes well against other energy sources. Notably, it outperforms diesel, offering approximately 2 megajoules per kilogram compared to diesel's 13.42 megajoules per kilogram. However, balancing energy production with soil health benefits is essential, as energy utilization may compromise carbon sequestration. Further research is needed to validate these findings and explore vetiver biomass's broader applications.

The impact of vetiver grass on crop yields varies depending on specific crops. Preliminary findings indicate that cultivating teff in vetiver hedges at different intervals can result in a notable 29% increase in yield, while other crops like maize experience enhancements ranging from 11% to 25%. Vetiver grass has a more pronounced impact on productivity in degraded soils with limited inputs, but its benefits become less prominent when soil supplementation includes fertilizers and pesticides. Further research is required to further understand the mechanisms behind vetiver grass's impact on different crops and soil conditions, as well as to optimize its cultivation techniques for maximum yield improvements.

Vetiver grass has shown promising results in improving productivity. Preliminary findings report Teff yields of 851 when vetiver is utilized compared, compared to 660 without significant statistical difference. However, precise calculations of carbon stock change are challenging without bulk density measurements. Further research is needed to understand the relationship between vetiver grass, productivity, and carbon sequestration.

The estimation of economic value of vetiver grass is often based on the oil component of the plant. While the oil extracted from the plant can be quite valuable, ranging from \$200 to \$400 per kilogram, when biomass is left in the field and the roots remain intact, it allows for eco-intensive ecological benefits that may surpass the value of the oil itself. Therefore, when assessing the overall value of vetiver grass, it is crucial to consider both its ecological benefits and economic potential.

Vetiver Grass as a Promising Tool for Sustainable Development Goals

Vetiver grass holds immense potential in aligning with various Sustainable Development Goals (SDGs), including poverty eradication, hunger reduction, clean water, healthy environments, climate action, biodiversity preservation, justice, peace, and cooperation among nations. Its multifaceted benefits make it a promising tool for achieving these goals.

With the anticipation of a new farm bill in the US in 2024, it is crucial to recognize that a clean environment cannot be achieved without addressing soil health. Soil is a crucial component of the environmental Trinity, along with water and air. Therefore, it is time to consider the implementation of a Healthy Soil Act, incentivizing farmers to adopt improved soil management practices and rewarding those who do so. This approach should be embraced globally, initiating discussions with relevant stakeholders in countries like Thailand.

Soil possesses a unique power to transform "death" into "life" and supports the existence of 25% of all living organisms. Recognizing the rights of soil implies acknowledging its significance and considering soil degradation, pollution, and depletion as moral and ethical violations requiring legal intervention. The belief in soil rights emphasizes the importance of safeguarding and restoring soil for the well-being of the planet and its inhabitants.

The late King Bhumibol's name, derived from "Bhumi" meaning soil and "Bol" meaning power, exemplifies the profound importance placed on soil. The notion of soil rights encompasses the belief that soil, as a living entity, deserves the opportunity to thrive, flourish, and receive protection. These rights are not driven by economic benefits but by the imperative to safeguard and restore soil for the greater well-being of the planet and all its inhabitants.

Empowering communities to advocate for soil rights is therefore essential to ensure a sustainable future for upcoming generations. The period from 2020 to 2050 is expected to bring transformative changes in agriculture. By reducing our ecological footprint, we can pave the way for a brighter agricultural outlook and foster environmental stewardship.

The interconnections between soil health, plant vitality, and climate considerations are of paramount importance. To address the mistreatment and neglect of soil in food production and resource procurement, a prudent approach involves integrating soil, water, and agriculture. This empowers farmers and land managers to achieve greater productivity with fewer resources, reduce waste, enhance eco-efficiency, restore degraded soils, afforest barren lands, and safeguard soil and water for the benefit of nature. Vetiver grass can play a distinct and valuable role in this process.

Famine, which affects 1.2 billion people, is a man-made tragedy despite sufficient food production to feed a population of 10 billion. Instead of solely focusing on increasing production, addressing the staggering 50% food wastage is crucial. Utilizing existing resources fairly and efficiently is key. A healthy soil equals a healthy diet, resulting in healthy people, ecosystems, and planetary processes.