MANAGING SOIL HEALTH WITH VETIVER (*Vetiveria zizanioides*) FOR CLIMATE AND FOOD SECURITY

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INTRODUCTION

Important among global issues of the 21st century are: population prone to undernutrition estimated at 1200 million and that to malnutrition at 2000 million, soil degradation affecting 2 billion hectare (B ha) of which that prone to water erosion at 1.1 B ha and that by wind erosion at 0.56 B ha, anthropogenic global warming at 1.1 ^{0}C since the Industrial Revolution and occurring at the rate of 0.2 ^{0}C/decade, the urgency to identify and implement no-carbon fuel sources viz. bioenergy, and put Sustainable Development Goals of the Agenda 2030 of the United Nations on track.An appropriate strategy to address these and other global issues is protection, restoration and sustainable management of soil health in agroecosystems. Adoption of effective measures of soil and water conservation, especially in fragile landscapes under harsh climates and on agriculturally marginal and degraded ecosystems, is critical to sustainable management of soil health. It is precisely in these eco-regions that establishment of contour hedges of Vetiver (khus) has proven effective. It is a perennial grass of the family Poaceae ,native of South Asia , and has traditionally been grown for oil content contained in its roots and used in perfumes and traditional medicine. While closely related to sorghum (*Sorghum bicolor*), Vetivers' root system and physiological characteristics are even better than other perennial grasses such as lemon grass (*Cymbopogon citratus*), citronella (*Cymbopogon nardus*), and palmarosa (*Cymbopogon martinii*). Specifically, Vetiver is characterized by a fibrous, massive, and deep root system which binds soil particles and resists the high erosivity of tropical raindrop impact and large kinetic energy of surface runoff on sloping lands. The high root: shoot ratio of 1:1, the highest among grass species, creates an extremely effective barrier against erosivity of tropical rains on sloping lands. Because of its versatility and adaptability to harsh environments , Vetiver has multiple applications to

agriculture, industry, climate change and water quality and renewability ,among others (Gnansounou et al., 2017; Oshunsanya & Aliku, 2017).

SOIL HEALTH IMPROVEMENT UNDER VETIVER-BASED FARMING SYSTEMS

The tufted vertically growing and deep root system of Vetiver has restorative effects on soil health (Holanda et al., 2022).The latter refers to biophysical and biochemical properties of soil as a living entity to generate numerous ecosystem services essential for human wellbeing and nature conservancy .Important among these ecosystem services are sequestration of carbon for adaptation and mitigation of climate change, improvement of soil structure and hydrological properties, and increase in eco-efficiency of finite resources including green water reserve and plant available nutrients . The massive root system of Vetiver improves soil biological properties (Maddhesiya et al., 2021) ,increases green water supply in the root zone, enhances shear strength, and provides an effective control of accelerated soil erosion (Kebede & Yaekob, 2009; Jotisankasa, 2015; Prakasa Rao et al., 2015; Niu & Nan, 2017; Amiri et al., 2017, 2019; Mondal & Patel, 2020; Badhon et al., 2021; Ewetola et al., 2021; Holanda et al., 2022). Vetiver has a high biomass production ranging from 22.8 to 27.5 Mg/ha in monoculture stand on marginal lands in India (Maddhesiya et al., 2021) to 67.7 Mg/ha on a good soil in Australia (Tessema et al., 2022). Under favorable conditions, the shoot and root production can be as high as 161 and 107 Mg/ha (fresh) and 67.7 and 52.5 Mg/ha (dry) biomass, respectively with 1:1.143 (fresh) and 1:1.125 (dry) production ratio (Tessema et al., 2022). Tomar and Minhas (2004) reported total mean biomass production of 30 Mg/ha. yr. in India and Thailand. In Texas, USA, Meki et al. (2020) reported biomass yield of 18.4 Mg/ha.

The high shoot biomass has multiple functions including the production of cellulosic ethanol or bioenergy feedstock (Meki et al., 2020; Kumar et al., 2023). Retention of biomass as mulch can conserve soil and water and lead to sequestration of soil organic carbon (SOC) stock in the surface and sub-soil layers. Biomass can also be used for industrial purposes.

CARBON SEQUESTRATION IN BIOMASS AND SOIL

Because of its large biomass production potential, Vetiver has a high capacity to sequester atmospheric CO_2 in biomass and soil. Furthermore, Vetiver can be grown on marginal or non-agricultural lands, where it has potential to photosynthesize as much as 20 Mg C/ha-yr. In comparison with biomass production of 25 Mg/ha by Miscanthus, Vetiver can produce 100 Mg/ha of biomass under favorable conditions (Pinners, 2014). Root biomass production of Vetiver is more than that of Miscanthus. The biomass production capacity of Vetiver has been reported to be as much as 3-9 kg/m^2 depending on soil and rainfall (Pinners, 2014). Vetiver can produce high biomass even on degraded or agriculturally marginal lands, mine lands, steep road banks, along highways or on urban lands. In some marginal soils of India, Singh et al.(2014) documented that SOC concentration increased from 0.64-0.7% in croplands to 1.12-1.3% under Vetiver over a 5-year period. In Ethiopia, Hailu et al.(2020) reported that SOC concentration in 0-30cm layer under hedges was 1.61% compared with 0.19% on land farther away or without hedges. Deposition of surface soil under Vetiver hedges may be the cause of a high SOC content. Therefore, C sequestration in terrestrial biosphere by Vetiver is a natural approach to offset some of the anthropogenic emissions. Lavania & Seshu(2009) reported that Vetiver, with fast-growing tufted root system, that can reach 3-m depth in one year, has a potential to sequester 1 kg C/m^2-yr (10 Mg C/ha-yr.).

AGRONOMIC PRODUCTION IN VETIVER-BASED SYSTEMS

Vetiver, being tolerant to drought and able to grow on contaminated soils, is a versatile tool to enhance agronomic productivity even on marginal and degraded soils. Indeed, Vetiver is a cost-effective technology for soil and water conservation, integrated pest control, phytoremediation of polluted soils, improvement of water quality and renewability, bio-energy feedstocks production, and improving eco-efficiency of agronomic systems (Figure 1).Yes, Vetiver is a tool for sustainable agricultural production even under marginal conditions (Oshunsanya & Aliku, 2017). In Nigeria, Babalola et al. (2003) reported

increase in crop yield by 11-26% for cowpeas and 50% for maize by installation of Vetiver hedges at 20-m spacing on land with 6% slope. Oshunsanya et al. (2010) reported increase in maize yield by 13.5 to 26.6% and cassava yield by 7.9 to 11.2% with Vetiver hedges at 5, 10 and 20 m spacing. Combining Vetiver hedges with Vetiver mulch can enhance productivity even more than that by hedges alone. For example, based on a study in Nigeria, Babalola et al. (2007) reported that use of Vetiver grass mulch increased yield of maize by as much as 47.7% than that from un-mulched plots. Similarly, in Colombia, Laing (1992) reported higher productivity by combining Vetiver hedges with vetiver mulch because of increase in eco-efficiency. Inter-cropping with Vetiver, while reducing oil yield by 16.7% and also reducing crop yield, increased land equivalent ratio (1.54), land use efficiency (130%), relative net return (1.35) and total net returns of US $4802/ha. Intercropping enhanced profit by 35% over the sole cropping (Yaseem et al., 2014). In Ethiopia, Hailu et al. (2020) observed that yield of teff was 851 kg/ha with vetiver hedges compared with 660 kg/ha without, an increase of 29%. Branca et al. (2013) reviewed 160 studies on the effects of grasses (including Vetiver) on productivity. They concluded that Vetiver is a sustainable land management (SLM) system with multiple benefits such as food security ,adaptation/mitigation of climate change, ground water recharge, and remediation of polluted soils.

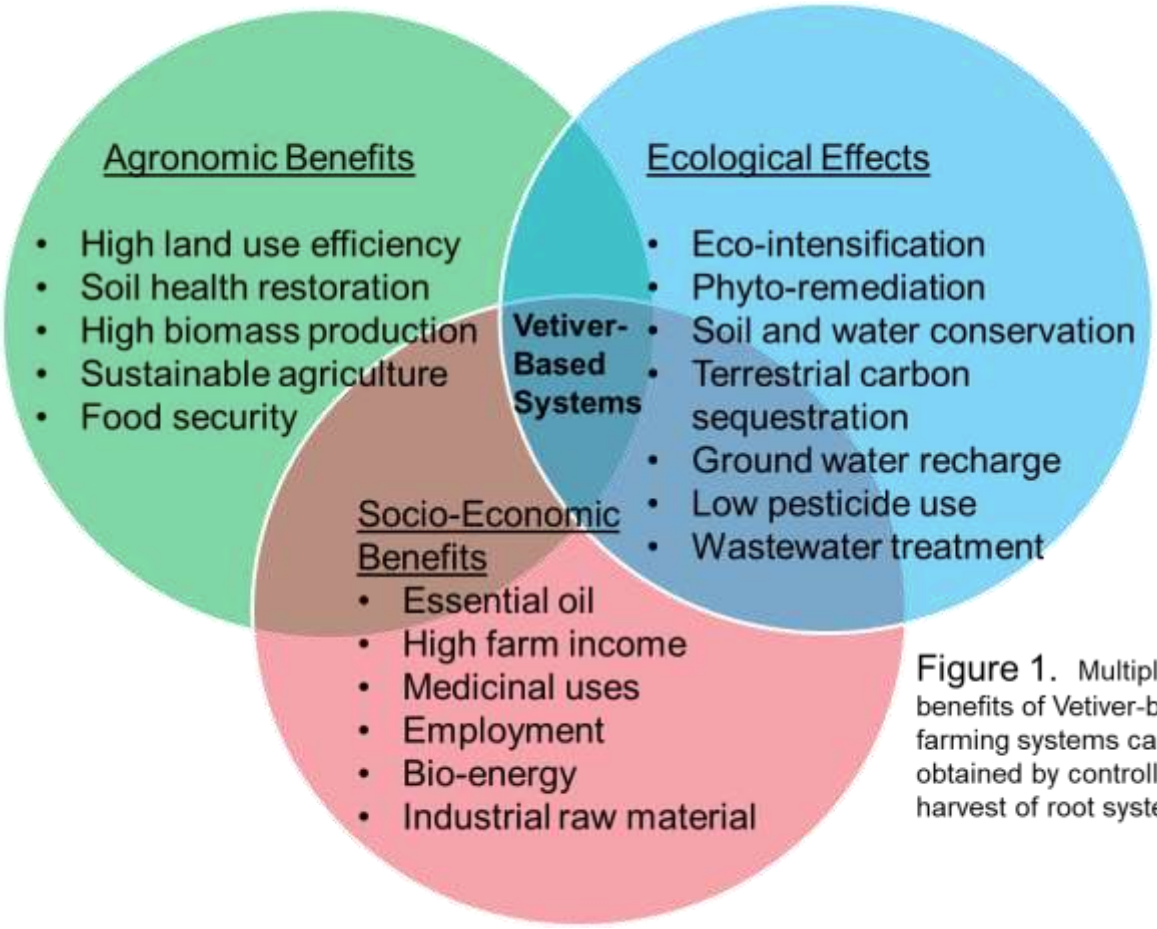

Figure 1. Multiple benefits of Vetiver-based farming systems can be obtained by controlling harvest of root systems

CONLCUSIONS

Use of Vetiver is a SLM system, especially for degraded soils, drought prone and erosion-susceptible environments, marginal lands and polluted soils. In addition to being a high-value essential oil crop, Vetiver has multiple benefits of enhancing agronomic productivity on marginal, degraded and polluted lands while conserving soil, recharging ground water, purifying wastewater, sequestering carbon in biomass and soil for adaptation and mitigation of climate change, improving productivity and advancing Sustainable Development Goals of the United Nations of the Agenda 2030. High biomass production can also be a feedstock for bioenergy production. Agronomic productivity can be enhanced to advance food and nutritional security by establishing contour hedges, mulching and with other Vetiver-based farming

systems. It is a multiple-purpose grass which can enhance farm income and alleviate poverty.

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