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GREENING THE SAHEL THROUGH WATER- ENERGY- FOOD TECHNOLOGIES

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Introduction

The Sahel region, directly south of the Sahara Desert, faces some of the highest rates of land degradation in the world [1]. Physical challenges in the environment such as water scarcity and irregular precipitation are exacerbated by overexploitation of natural resources, poor land-use practices, and increasing climactic impacts [2]. The region faces severe challenges, including land degradation, desertification, and food insecurity. Addressing these issues is crucial for achieving Sustainable Development Goals (SDGs). The Great Green Wall (GGW) initiative, which focuses on land restoration, is a key strategy to combat these issues in the Sahel. However, current efforts, primarily tree planting, yield limited short-term benefits for local livelihoods. To amplify impacts, innovative Water-Energy-Food (WEF) Nexus technologies, like Agrivoltaics (AV), present transformative opportunities.

Desertification in the Sahel

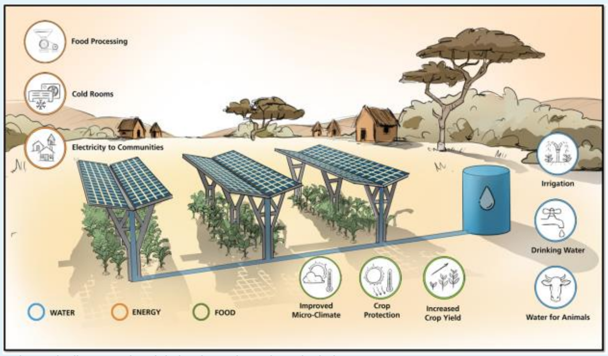
The Sahel is a semi-arid band approximately 500 kilometers wide that stretches across nearly all of Africa. With a total area of approximately 160 million hectares and a population of around 100 million people this region directly south of the Sahara Desert faces some of the highest rates of land degradation in the world [1]. Moderate to severe degradation has been identified in many key river basins in the region in recent decades including the Nile (42% of area), Niger (50%), Senegal (51%), Volta (67%), Limpopo (66%) and Lake Chad (26%) [3]. Physical challenges in the environment such as water scarcity and irregular precipitation are exacerbated by overexploitation of natural resources, poor land-use practices, and increasing climactic impacts [2]. With temperatures rising in the Sahel at a rate 1.55 faster than the rest of the world, severe droughts and flooding are increasingly impacting agropastoral activities and thereby smallholder livelihoods and economic productivity [4]. Sub-Saharan Africa has experienced the most severe land degradation worldwide where it is estimated that community- reliant degraded lands are approximately 135 million hectares of the region [1, 5]. Deforestation and land-use intensification are major drivers in land-use and land-cover change and degradation. The clearing of trees advised by colonial and post-colonial extension services to reduce competition for crops, increased sun and wind exposure causing the soil lose its capacity to absorb and retain water and decreased fertility [1]. The region faces these challenges that "limit the capacity of populations to develop local mechanisms for coping with increasingly severe episodic or chronic deficits of food, water, energy and physical security," increasing the environmental and social risks in the region. The decreasing land productivity – in conjunction with other factors – increases drylands vulnerability to socioeconomic instability. Years with low rainfall have been associated with increases in violent conflict. Over the last decades the region has been prone to recurrent droughts which coupled with land degradation have caused the deterioration of soil quality in the region, impacting agricultural productivity [2].

Map of the Sahel Region
Picture credit: UNOWAS

Water- Energy- Food Nexus Technologies

Increasing competition for decreasingly viable land places energy and agricultural intensification at odds. A more holistic and integrated approach that considers increasing energy demands, the land use footprint of energy development, and increased food production all while increasing water use sustainability and mitigating environmental impacts is necessary [6]. The WEF nexus approach considers the interdependencies of water, energy, and food as parts of a larger system. This is particularly necessary in regions such as the Sahel which are vulnerable to climactic impacts and shifts can have negative cascading effects [2]. People live in places, not in sectors and WEF nexus technologies embody this through the implementation of technologies focused on efficiency and holistic resource use in a particular context. Examples of WEF technologies include solar-powered irrigation systems, wind-energy-based desalination systems for irrigation, post-harvest processing such as solar drying, fertilizer solutions, and agrivoltaic systems.

Agrivoltaics or agrophotovoltaics (APV) systems are PV panels mounted at a sufficient height from the ground to allow for conventional cultivation practices underneath. These systems enable renewable energy generation without competing for agricultural land [7]. Studies of APV systems have shown their potential to increase the productivity of the crop systems through the creation of a beneficial micro-climate [6, 8] decrease the amount of water needed through a shading effect [7], and increase the renewable energy generated by the PV panels by moderating temperatures [6, 8]. The systems hold the potential to enhance food and energy security while conserving water. The impacts of agrivoltaic systems on both the natural environment and communities in Africa has been studied in Niger [9], Egypt [10], in South Africa [11], and more recently in Mali and The Gambia [12]. The impacts of the system are expected to go beyond the direct impacts by increasing access to electricity for rural communities. For communities, this offers socioeconomic benefits by providing decentralized energy and creating opportunities to participate in sustainable agricultural practices [2, 3]. In areas with few trees or high rates of deforestation, crop residues or manure are often used as fuel sources. Increasing access to electricity increases the amount of residues able to be used as soil amendments, improving the fertility, structure, and reducing soil erosion, which will in turn lead to greater rainwater infiltration [1]. Agrivoltaic systems embody the principles of the water-energy-food (WEF) nexus, addressing critical interdependencies in resource-scarce regions like the Sahel.



Schematic diagram of a triple land use through Agrivoltaics.
Picture credit: Fraunhofer ISE

Great Green Wall Initiative

Agrivoltaics align with the GGW's goals by rehabilitating degraded land and enhancing ecosystem resilience. Beyond tree planting, WEF nexus technologies can potentially provide immediate socio-economic benefits by creating jobs, improving agricultural yields, and fostering local innovation. Its implementation can stimulate youth employment and local business opportunities, addressing poverty (SDG 1) and hunger (SDG 2).

Additionally, the technology can help alleviate water scarcity (SDG 6) by supporting efficient irrigation techniques and conserving water resources. By leveraging WEF nexus technologies, the GGW can evolve into a multifaceted initiative, addressing land restoration, food security, and energy needs in an integrated manner.

Greening the Sahel

Agrivoltaic systems present an innovative solution for "Greening the Sahel" by creating a symbiotic relationship between agriculture, energy generation, and water conservation. By partially shading crops, these systems create a microclimate that reduces soil temperatures and evaporation, thereby improving soil moisture retention in arid conditions [6]. Studies have shown that crops grown under agrivoltaic setups experience more stable yields during droughts due to reduced water stress, demonstrating the potential of this approach to enhance agricultural resilience in the Sahel's challenging climate [6, 7, 8].

Transitioning to renewable energy through agrivoltaics can significantly reduce the reliance on biomass for energy in the Sahel, where energy needs are currently met by biomass fuels [2]. This dependency has contributed to widespread deforestation, degrading the region's environment and exacerbating climate change impacts [3]. By integrating solar energy production with agricultural practices, agrivoltaics provide a sustainable energy alternative that helps preserve forest resources, improving ecosystem health and reducing carbon emissions.

The increased albedo effect of agrivoltaic systems contributes to local and regional climate benefits. Solar panels reflect sunlight, reducing the heat absorption at ground level. This cooling effect, combined with reduced surface friction, can enhance rainfall patterns, further supporting vegetation growth [13]. Research also suggests that such installations could double precipitation in surrounding areas, amplifying the positive feedback for ecosystem restoration and agriculture [3].

Incorporating agrivoltaic systems into initiatives like the Great Green Wall can accelerate the Sahel's ecological restoration and development goals. These systems represent a scalable and adaptable solution for land rehabilitation, supporting biodiversity while contributing to climate change mitigation. The integration of agrivoltaics demonstrates a forward-thinking approach to addressing the Sahel's interconnected challenges of desertification, energy poverty, and food insecurity.

Conclusion

Innovation is central to accelerating SDG achievement and combating climate change in the Sahel. Tailored WEF Nexus solutions like Agrivoltaics must be developed with local involvement to ensure sustainability and acceptance. Collaborative planning with communities, policymakers, and regional institutions is essential for long-term success.

WEF Nexus technologies embody the interconnectedness of SDGs by addressing multiple goals simultaneously. Agrivoltaics exemplifies this approach, offering scalable, impactful solutions to desertification, land degradation, and socio-economic challenges in the Sahel. By fostering innovation and prioritizing inclusive implementation, these technologies can transform the Sahel, support the GGW, and drive global progress toward climate and sustainability targets. For more information visit the APV-MaGa Project Website.

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