Synergizing Food-Energy-Water (FEW) Resources for Sustainable Benefits

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Abstract**—**The drastic pursuit of economic, urbanized and globalized growth in recent decades have impacted severely on the natural ecosystem and available resources. The insistent climate change is further sustained by enormous food and energy production wastages. This also accounts for the increased tension on water supply and organic practices as consequences of an upset ecosystem; leading to unstable temperature changes, changes to normal weather patterns, floods and drought, melting glaciers and rising sea heads- all to which potentially affects the sustenance of man and the environment. As such, synergizing the food-energy-water (FEW) scarce resources and understanding their potential interactive merits as against their isolated short lived advantages have become an area of interest in recent years. This has driven the discuss herein towards the sustainable benefits of knotting the FEW scarce resources, as all three elements must be unified for ensured beneficial outcomes. The paper also highlighted the FEW interactive challenges and pathways of resource conservation particularly, in the dire need for food security in present time. The paper therefore holds a general discuss that posits the interactive link between the limited FEW resources as a platform towards sustainable conservative benefits of all three elements to man and the environment.

Keywords**—***Synergy, Sustainability, FEW resources, Globalization*

I. Introduction

OVER the past decades, industrialization and technological growth have significantly increased yields particularly over the green revolution as noted by [1] which implied total global surplus production to total demand. This was mostly possible by increased use of mechanized and synthesized production i.e., genetically modified organisms (GMOs), fertilizers, pesticides, agricultural plants and equipments, irrigation systems [2]. These processes have over time strained scarce naturally resources such as water and oil while contributing to human and environmental associated impacts. However, it can be understood that food production and security is critical to man's survival as such, food security as recorded by [1] is when 'all people constantly meet their dietary standards by having access to adequate and healthy food'. As further emphasized by [1] this goes past food availability such that access via economic capacity to obtain food and sustainable food nutritional value and safety is paramount. It is noted however, that wide gaps currently exist with respect to food access across the globe irrespective of the higher food production as over growth in population [3]. A clear instance as given by [1] shows that in 2008 an estimated 2 billion people globally were obese while an estimated 842 million people were critically undernourished with no element of FEW. Industrialized and synthesized production activities in developed and developing countries constituting greenhouse gas effects are tenaciously exhausting scarce natural resources while impacting human and environmental health. The increased warming of the earth's atmosphere triggering various environmental and climate challenges is quickly affecting the food outputs of many nations invariably compromising security and sustainability for future generations [4]. It is pertinent to take into cognizance expected future strains on the already stretched FEW. According to [1] growing population is estimated to hit 9 billion by 2050, urban populations is estimated to double by 2050, economic growth and improved standard of living are expected to hike the demand for water $\leq 40\%$ and energy $\geq 40\%$ by 2030. In this light, conserving the FEW resources particularly towards accessible and sustainable food security requires a paradigm shift with zero or minimal impact on climate change as duly noted by [5]. For there to be an environmental cost effective and eco-friendly approach to a union of FEW resources, an interdisciplinary perspective as explained by [6] must be adopted. This paper therefore, bids to contribute to expressing the benefits and pathways of synergizing the FEW elements solely towards sustainable food security in line with similar discussions by [1], [4] and [6].

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II. Synergizing FEW Resources

A. Conceptual Meaning and FEW Relationship

The term synergy means 'the creation of a whole that is greater than the simple sum of its parts'. It comes from the Attic Greek word *synergia* and from *synergos*, meaning-working together. Hence, synergizing the FEW resources refers to the relationship between all three elements managed and working in unison towards a beneficial and sustainable outcome. The conceptualized meaning and explanation to this

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is appreciated from the instance given by [1] whereby, the relationship between the FEW resources goes like this: on one hand, food production needs water for crop yields with water often treated and pumped in irrigation systems using energy. On the other hand, electricity production relies on water for cooling and steam generation with both energy and water also needed for processing, packaging, delivery by industry and eventually preparation of semi-finished/finished products by final consumers. Association between the two elements is plausibly due to the dependence of mechanized and synthesized agricultural practices on natural deposits with huge pressures on alternative fuel sources in recent times. As duly observed by [1] energy and food production has been forced into desperate struggle for water and land. Again, the reach to sanitation, energy and food in various patches of the globe remains unequal regardless of the increased food production in recent years. Usually, water scarcity goes hand in hand with food insecurity. This buttresses the need for a unified, functional and sustainable operation and management of the FEW resources towards increased and easier reach by all. As is the motive of this paper, so it was also emphasized by [7] that synergizing the FEW resources is an urgent and inevitable approach for salvaging the persistent decrease of these elements by studying and understanding their cohesive interactions and relationships. This unison is geared towards sustainable utilization, conservation and beneficial outcomes from the elements to both man and the environment.

B. Triggers of Pressure on FEW Resources

The key factors affecting FEW resources supply discussed by [1] from [7] include the following:

i. Urbanization
ii. Population growth
iii. Economic development and improved living standards
iv. Climate change
v. Globalization (where externalities of supply 'hidden').

A lot of anthropogenic activities have in recent years contributed to the greenhouse gas effects which have together with other factors i.e., economic growth, globalization and urbanization as explained by [1] have impacted severely on the natural ecosystem and scarce FEW resources. It is generally expected that people's life styles/standard of living for instance, will change when relocated to a more developed place such that their eating habits and expectations changes. As observed by [8] they might shift to consuming particularly, more meat and water-carbon intense products. Where beef is estimated to have an average water demand of 15400m^3/ton and in England it has an average live weight carbon effusion of 12.65kg-CO_2e/kg. Also as explained by [1] cities just expect food to be available round year disregarding the actual processes and seasonal cycles in a natural setting for crop growth. This detachment of city people from the natural cycle of food production has increased chances for food wastages. The implication of such wastages as reported by [7] invariably ties to the waste of water and energy utilized in the production, processing and distribution phases. More to this, the shift from usual farm production to home growing has in recent years, inadvertently triggered food wastages as food waste is merely destined to disposal facilities and not considered resourceful for composting or animal feeds any more. Yet again, water supplies and agricultural activities are pressured by the insistent changing climate as a result of enormous energy consumption and production. The consequential impacts visible to all includes; fluctuating and unstable temperatures, disruptive weather patterns tentatively affecting agricultural outputs, melting glaciers and increasing sea levels, increasing catastrophic weather events i.e., famine, flooding and droughts [1]. Carbon sequestration measures e.g., CO_2 coal injection and concentrated bio-fuel harvesting options also triggers pressure on resources particularly of water and land [9]. As exemplified by [10] countries with low water availability resorting to imported water-intensive products from countries with unimpeded reach for blue (surface and groundwater), green (rainwater) and grey water (polluted freshwater), rather than desalinating seawater or harvesting water from other sources for irrigation, are likely to retain lower water and carbon footprints.

C. FEW Resources for Sustainable Benefits

Synergizing the FEW resources is a mode of mitigating the challenges induced by the exhaustive use of nature's providence. These elements are homogenized towards sustainable benefits as it is clear that separately dealing with FEW security issues without recognizing the implication of one on the other two will pose more challenges than provide viable solution [11]. As noted by [12] understanding the links between FEW resources and their eventual judicious management is required for necessary guided policy-making in line with sustainable beneficial solutions. At the 2011 World Economic Forum as reported by [13] in [1] issues engulfing FEW resources were recognized as one of the three utmost threats to global economy expressed as a 'security' nexus considering that; the reach for all three elements must be achieved to ensure peace and prosperity as it is a dire need. A clear instance was reported by [1] revealing how FEW interactions can advance guided policy-making suited for unified, sustainable and beneficial solutions. It is known that India at the end of the last century became the largest groundwater user in the world. Their agricultural irrigation system relied majorly on groundwater harvesting due to water challenges in the dry monsoon season (a seasonal prevailing wind in the region of South and South East Asia, blowing from the north-east between October and April). On the introduction of subsidized power, the reliance on groundwater use heightened thereby, exerting more pressure on aquifer reserves. Also as reported by [1], amidst the crisis of power shortages, outages and fluctuations, farmers resorted to leaving pumps constantly running which consumed enormous energy and water. The high reliance on groundwater extraction was strategically curbed by the state-government of Guarat through initiating innovative approaches. This included; splitting power lines feeding remote areas and irrigation pumps thereby, establishing a control pattern of daily 8hrs uninterrupted electricity supply for agricultural purposes and assured supply to other grid users. With this initiative, pressure on groundwater eased off alongside excessive power consumption. There was enhanced agricultural productivity made possible by reliable water supply and optional farming

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practices which ultimately improved livelihoods and opportunities for sustainable beneficial growth of dwellers [9].

III. FEW SYNERGY AND FOOD SECURITY EFFECTS

A. Challenges Associated with Food Security

A number of challenges have been identified from related works based on food security. This includes those grouped in [1] according to [4], [5] and [14]. However, the goal of striking sustainable beneficial equilibrium between growing demand for food and supply streams is highlighted herein in line with discussions by [1] as it knots tighter with the basis of synergizing FEW resources. Although, various approaches have been posited towards sustainable and beneficial contribution to systems of FEW resources, what counts the most however, is adopting measures with zero or reduced climatic change impacts thereby, enhancing conservatory outreach for the environment, biodiversity and ecosystem. This can be made possible by understanding the essence of a greener and optimized production, dietary switch as well as waste reduction thereof in conformance to [1], [4]-[9]:

B. FEW Synergy Consideration for Optimized Greener Output

As noted by [15] in [1] a number of countries in 2000, became water deficient as ≥ 40% of their water reserve was invested in irrigation farming. This has made it clear that a balance must be struck in harnessing the scarce FEW resources; which has triggered the consonance according to [5] that increased food production with minimal environmental implications most be optimized in the face of the drastically depleting natural resources and related ecosystems. Furthermore, it is recorded that the insistent rise in the price of phosphate stone for chemical fertilizer has in recent times, pressured agricultural outputs. However, it would be expected that such hikes in prices of chemical soil enhancers, sound the alarm for greener optional methods of agricultural practices to take effect i.e., vermicomposting is but one option that readily improves the health of the soil towards increased nutritious crop yields, invariably, improving the health state of humans and the environment. As such, it is also noted by [1] that fertilizers are highly energy exhaustive and excessive application to soil, destructs the soil biotic life which eventually decreases soil health, crop yield and nutritional value, as well as cause soil and groundwater contamination by chemical migration. Conversely, the health state of the environment and inhabitants is put at risk from chemical and synthesized energy intensive agricultural practices therefore; a shift in paradigm is dire. More to this, anthropogenic activities have strained the availability of land for large scale sustainable agricultural operations. Consequently, these activities have impacted land resource by increased pollution, contamination, urbanization and generation of alternative fuel sources thereby, decreasing space for agricultural purposes while depleting natural resources and the ecosystem. In other cases as recorded by [1], available cropping space may have been devalued by consequential impacts of climatic changes i.e., erosion, landslides, desertification and inland salinization (peculiar to irrigation practices in arid regions where water evaporates and salts accumulate in the soil hindering plant growth) or plainly due to preference given to land towards conservation of biodiversity and related ecosystems. In this light, the approach of synergizing the FEW resources necessitates optimization and incorporation of new, and improvement on old systems channeled towards agricultural production for food security or as the case may be. For instance, conservatory approaches for beneficial outcomes of FEW resources could include; rainwater harvesting, system controlled water distribution, appropriate technologies for cost-effective irrigation system, increased soil fertility through greener organic nitrogen fixers and cultivated earthworm resource in vermicomposting activities. Also eco-friendly and greener energy cultivation such as bio-fuels, solar and wind, geo and hydrothermal power can be optimized towards reducing the exhaustive pressures on carbon intensive fuels. This will ultimately decrease carbon footprints from anthropogenic activities while improving energy situations for sustainable and beneficial impacts [11].

C. Optional Dietary Consideration

In many instances, agricultural production as indicated by [6] in [1] has shown meat production and consumption to insufficiently utilize and synergize chief resources i.e., land, water and energy towards beneficial ends. It is recorded that livestock contributes to a huge part of water pollution, land use and biodiversity as well as constituting greenhouse gas effects causing up to 18% of global effusions in its span [17]. Therefore, optional dietary considerations have been posited towards a switch from red (meat and dairy concentrated diets) to green (rich and balanced grains and vegetable diets) considered healthier for human consumption thereby; curbing health issues such as obesity, imbalanced diets and malnutrition. As such, saving significant amounts of money otherwise spent on public health ailments and similar conditions [4]. Nevertheless, meat in most countries, particularly in developing nations is a significant source of protein, vitamins and minerals vital for a larger part of the human population but specifically beneficial for growth and development in children [18]. Hence, synergizing the FEW scarce resources in line with understanding the inter-links between dietary food products based on their water and energy demands can ensure guided decisions and policy-making. This can further foster a decrease in the consumption of less concentrated singular diets. Also, initiating ways of quantifying energy, carbon and water footprint in foodstuffs together with their nutritional values could trigger optional dietary consideration [1] such that, precise and more informed consumer decisions can be beneficially made. Towards sustainable beneficial synergies of resources, studies by [17] as reported in [1] explained that an *app* by *Varkens in Nood*- a Dutch organization was built to enable purchasers scan products and get description on their environmental impact with proffered options for products with lesser impacts.

D. Consumption Habits and Waste Reduction Consideration

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According to [19] ≥ 30% of produced food is likely wasted than actually consumed. As revealed by [1] it is clear that food wastage is directly associated with the level of growth and development in a country. This implies that wastage varies considerably on a scale moving from developing to developed countries. An instance by [1] described that on the one hand, developing countries mostly experience food wastage at levels of post-harvest which is often caused by lack of appropriate technologies or storage infrastructure. On the other hand however, developed countries incur food wastage at the stages of distribution, retailing, food services and household consumption. Wastage on the side of the developed world could plausibly be accounted for by availability and affordability of food; surplus food production (by natural cycles or enhanced by GMOs) as against the demand, leads to lower food prices which invariably promotes wasteful behaviours. As rightly observed by [1] there is excessive dependence on 'best before' dates, which leads to wastage of food for safety reasons due to shelf life of the product; disposal requirements on retailers resulting from the hideous appearance of completely edible fruits and vegetables; jumbo portions specified by food service sector; as well as promotions, bonanzas and offers, encouraging consumers to purchase excessively beyond their consumption rate or capacity. For such reasons, synergizing the scarce FEW resources can harnessed towards drastic enhancement of sustainable and beneficial outcomes. Ultimately, FEW efficiency growths can be improved thereby, reducing unnecessary losses and wastages by virtue of habits or norms particularly, with products requiring highly intensive energy and water consumption. Also, synergizing the FEW resources can serve as an approach for facilitating productive recycling of food or water [5] deemed unfit for consumption thereby, converting them into sources of alternative energy, vermicomposted fertilizers and animal feeds with lesser consequential impacts on environmental and human health.

IV. Conclusions

The paper indicated the importance of synergizing the scarce FEW resources particularly geared towards food security for sustainable benefits. This could be somewhat difficult in the face of rising population, severe climate changes causing famines from droughts and destructive weather occurrences. However, understanding the interactions of FEW and land resources and applying their unified strengths can go a long way cushioning the present impacts and challenges. A few considerations towards resource management particularly for scarce FEW resources have been highlighted herein and the conclusions reached where found to be similar with studies by other authors [1], [4]-[9]. In this light, the following conclusions were drawn:

- That synergizing FEW and land resource is an approach requiring the understanding of the inter-relationship of these resources towards enhancing efficiency for sustainable benefits.
- That by synergizing these resources, consideration is easily made towards more environmental friendly alternatives thereby, reducing excessive dependence on carbon intensive options.
- Also that the idea of synergizing FEW resources as expressed herein and in similar studies, is a fast growing niche requiring diverse research engagements and attention towards. Ultimately, sustaining and conserving these scarce resources for beneficial outcomes whilst, reducing carbon footprints and fostering improved human and environmental health remains pertinent.

In a nutshell, synergizing the scarce food-energy-water (FEW) and land resources together with comprehending their potential interactive merits as against their isolated benefits for an optimized outcome is key to sustainable growth and development in present times.

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