WATER, FOOD, AND ENERGY: A NEXUS FOR ADVANCING FOOD SECURITY AND SUSTAINABLE AGRICULTURE

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ABSTRACT

The subject of the water, food, and energy (WFE) nexus is becoming a worldwide issue that is explored on an academic, governmental, and social basis. It is of great importance to come up with the best management solutions and tools for the problems associated with the WFE resources, especially in resource-scarce countries, such as the Middle East and North Africa (MENA) region. Management tools should be simultaneously tackled without threatening the resource base of any sector. This dilemma necessitates an integrated strategy that takes into account all of the ecosystems. The aim of this study is to provide a conceptual framework for better understanding the relationship between human activity and the natural environment as well as guidelines for managing natural resources in a way that is consistent with our social, economic, and environmental goals. To achieve this objective, the nature of the WFE nexus challenges in the MENA area is reviewed, as well as the evolution of well-informed perspectives on these problems. All the energy, food, and water nexuses within the context of climate change were covered. The relationship between energy and water, the conservation of agriculture to save energy, and the energy and water nexus were also explored. The analysis showed that decision-makers at the governmental level must boost the use of renewable energy sources, adopt tools for sustainable agriculture, maintain management measures for the ecosystem, and integrated management of water, food, and energy must be given top priority. In other circumstances, a thorough analysis encourages the reuse of water and advancements in the agricultural industry rather than the construction of energy-guzzling and pricey desalination devices. This quantitative review can be a significant improvement in this area because one of the problems with the water-energy nexus in the MENA region is that it is difficult for policy and decision-makers to understand its patterns. The out comes of this work can direct managers and decision-makers to create potential remedies, ensuring water management tools are successfully applied in accordance with the visions of various perspectives, which can assist the relevant ministries and institutions in improving plans, policies, and strategy-making related to WFE Nexus.

Keywords: Water, food, and energy - Agricultural practices - Climate change - Nexus concept - Ecosystem processes - Sustainable natural resource.

1 INTRODUCTION

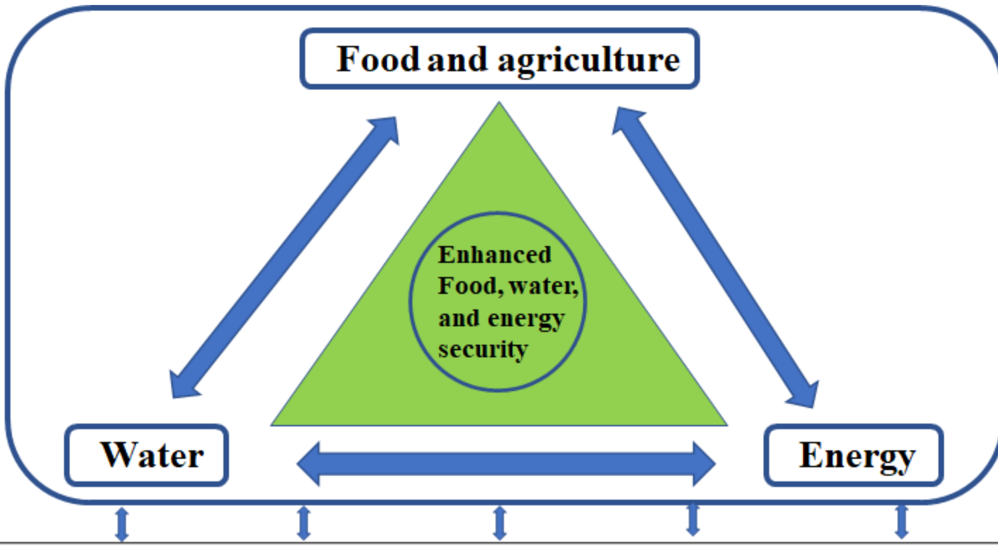
A growing global population, increased urbanization, shifting diets, and economic growth are all exerting pressure on the water, food, and energy (WFE) nexus. As wages rise in many nations, there is a noticeable global shift away from a high-starch diet toward meat and dairy products that use more water (FAO 2021). More than one-fourth of the world's energy is needed for food production and supply, which is also the largest consumer of freshwater resources. Water is used extensively in most energy production processes, including those in nuclear and coal-fired power plants as well as in the growth of biofuel crops (FAO 2022). Therefore, the WFE nexus is execrable and should be at the core of sustainable-management programs. Water is utilized to produce most forms of energy, with agriculture being the major consumer of freshwater worldwide. Decision makers at all levels must assure integrated and sustainable management of WFE to balance the requirements of people, the environment, and the economy in order to withstand present and future stresses (UN-Water 2021). Energy and food production both use ample amounts of water. Pressure on the water-food-energy nexus threatens the Sustainable Development Goals (SDGs 2014). Water scarcity greatly threatens to achieve the SDGs, particularly on poverty, hunger, and environmental sustainability. The relationship and integration of WFE are real and very nearby. The phrases "the future of food production," "the future of energy security," and "the future of water demands" shall never be used again.

The WFE nexus includes the fourth item, accepts the effects of climate change that have already manifested, and will likely soon add population growth to form a pentagonal nexus. The phrase "future of nexus of water, energy, food, climate change, and population expansion" has thus been in use from the year 2018. This coincides with that agriculture production cannot exist without energy, food cannot exist without water, and energy cannot exist without food and water, and the world's population will increase to 9.6 billion by. Thus, there is no way to separate any of the components of the integrated nexus from one another (Jialin et al. 2020; Salem et al. 2022). The FAO estimated that food production should be increased by 50% before 2050 from only 20–30% more water (WEF 2022). This implies that the demand for agricultural chemicals such as fertilizers, pesticides, growth regulators, and hormones will dramatically increase to meet the projected food production by 60%. The climate-change condition will reduce available water by 6%, as well as lowering its quality may increase the energy consumption to double before the year 2100 and by 50% by the year 2030, as shown in Figure 1 (ERD 2012; Livia et al. 2013).

Water security is essential in the Arab world, which is one of the regions of the globe most affected by water scarcity. The Nexus approach intends to make it easier to fulfill SDG-6 (SDGs. 2014) which calls for universal access to clean water and sanitation. Other SDGs also address the issue of water, e.g., SDGs 3, 11, 12, and 15. The WFE security nexus enables implementation that is concentrated on putting integrated water resources management (IWRM) principles and technologies to use and expanding on the knowledge gained from them.

The availability of energy security varies significantly among Arab countries. Incorporating regional initiatives to support the sustainable energy for all initiative as a means of enhancing energy security and achieving SDG-7 (SE4ALL 2022), would be possible because of the nexus approach.

The availability and consistent supply of water and energy in the area are directly related to food security. For the SDG-2 goals of ending hunger, establishing food security, improving nutrition, and promoting sustainable agriculture, dependable trade and sustainable agriculture are essential tools (SE4ALL 2022). The focus on interdependencies across a variety of sectors and the inclusion of sustainable natural resource management promotes the nexus conceptual framework. Although tradeoffs are to be expected, it is possible to identify political goals, challenges, and opportunities given by those connections by taking a nexus view of the connectivity across sectors (Maftouh et al. 2022). In addition, the current military and economic conflect between Russia and Ukraine threats WEF Nexus. Sargentis et al. 2022 analysed the social repercussions of the current conflict (2022), particularly the economic sanctions on Russia, using the WEF Nexus as an indicator. Therefore, Russia and Ukraine are two significant worldwide suppliers of oil, food, and fertiliser, now confront new threats as a result of their limitations and the increase in price. The problem was made worse in recent decades by extensive urbanisation, which lengthened the distance to food sources. They proposed that the decision by Western elites to punish Russia significantly changed the WEF equilibrium, which might lead to the breakdown of social cohesiveness.



Himalayan ecosystem services			
Regulating	**Provisioning**	**Supporting**	**Cultural**
• Climate regulation • Water regulation • Biological regulation • Disturbance regulation • Regulating precipitation, monsoon	• Food, fodder, fuel • Fresh water • Minerals • Raw materials • Pollination • Genetic resources	• Recharging groundwater • Soil formation • Erosion control • Water retention • Nutrient cycling, movement	• Traditional knowledge and practices of conservation • Recreation • Agrobiodiversity

Figure 1. Framework for the nexus of energy, water, food, and climate change (Source: based on ICIMOD 2015).

The aim of this study is to advance knowledge of the nature of WEF-nexus challenges and the development of informed viewpoints on these issues. To achieve the study's aim, we review (i) the concept of the energy-food nexus (ii) energy and land instead of food, (iii) the energy and water nexus, (iv) the conservation of agriculture to save energy (water for irrigation, storage and refrigeration, fertilizers and plant nutrients behavior, soil–water–plant relationships, and adding fertilizers in a sustainable way), and (iv) the linkage of the climate change with the WEF nexus.

2 ENERGY AND FOOD

The relationship between energy and food production is depicted in Figure 2 (FAO 2011). Examples of interactions are: (i) agriculture accounts for 70% of total global freshwater withdrawals, (ii) about 90% of the energy produced today is water intensive, and (iii) agriculture and the food chain account for 33%

of global energy demand. On the other side, using agricultural land for biofuels will put more pressure on agriculture's ability to produce food. The current food industry worldwide depends on energy.

While the agricultural green revolution's industrialization and technology have greatly enhanced crop yields, they have also raised the energy requirements of farming and food production. Currently, the worldwide food sector's end-use energy consumption amounts to about 2,270 million tons of oil equivalent (MTOE) per year, or 32% of the total global final energy demand (UNU 2013). From farm to table, energy is required along the entire food production value chain (Figure 3). The Arab world has challenges with food security, particularly in those countries attempting to improve their agricultural sector. These challenges include the depletion of natural water resources, diet change brought on by new cultural customs, economic progress, and globalization. Decision makers in the Arab countries realize that self-sufficiency in food through their agricultural activities is far from achievement due to mainly water shortage, population growth, and prolonged droughts due to climate change.

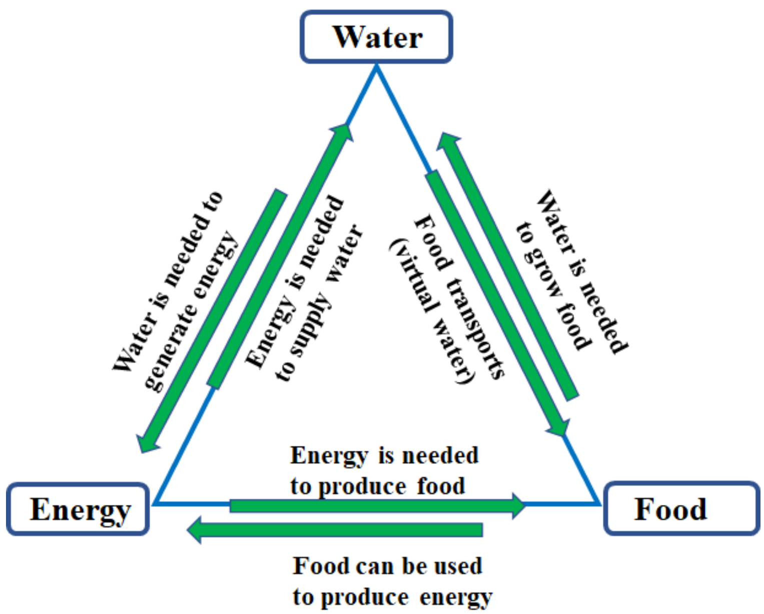


Figure 2. Interconnection between WEF nexus (Source: UNU 2013).

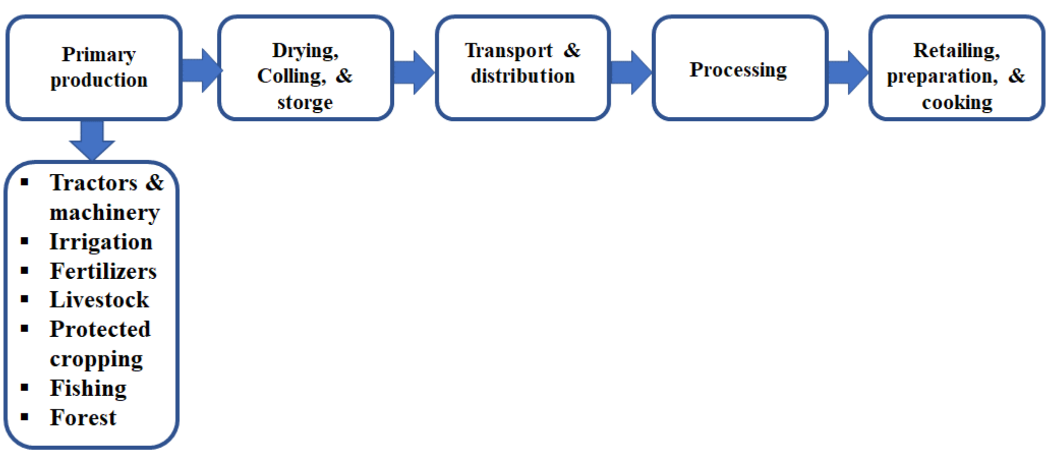


Figure 3. Energy uses along the food value chain (Source: Lee et al. 2020).

As a result, several Arab countries have turned to global commodity trading and international land agreements to guarantee food security and protect their limited water resources. Others have worked to increase agricultural production to sustain rural livelihoods and increase income, which is essential for ensuring family food security. Cereal production in the Arab region has raised by 50% between 1990 and 2011. However, such a rise failed to meet rising demand, as reflected in the 10% increase in the region's cereal import dependency ratio over the same period (FAO 2022).

3 ENERGY AND LAND INSTEAD OF FOOD

We can state that there would be no food (so far, under aquatic and hydroponic agriculture) without soils because soils create more than 95% of the world's food and agricultural production. The European report on development from 2012 recommended that "land" may be used in place of "food" to get the same logical sense as Figure 4 (ERD 2012). The Middle East and North Africa (MENA) Region has limited water and land resources and is one of the driest places on earth. As a result, the region imports more than half of its food (World Bank 2008). To fulfill growing demands for industrial, agricultural, and domestic use, the MENA countries are employing oil and gas to power desalination plants and close the growing gap in freshwater supplies (Metzger et al. 2015). The difficulty and cost of meeting these needs have risen. The consistent, cheap supply of the other resource is placed at risk when one resource (such as water or electricity) is produced in greater quantities. To provide more resilient development solutions, a "nexus" approach to water, energy, and food should be considered while developing and planning infrastructure. The difficult part is finding ways to increase production while preserving the environment for future generations. As a result, there is enormous potential for regional collaboration through the exchange of information and technology, the management of shared resources, and cooperative activities to support nexus-based solutions and cross-sectoral linkages (Maftouh et al. 2022).

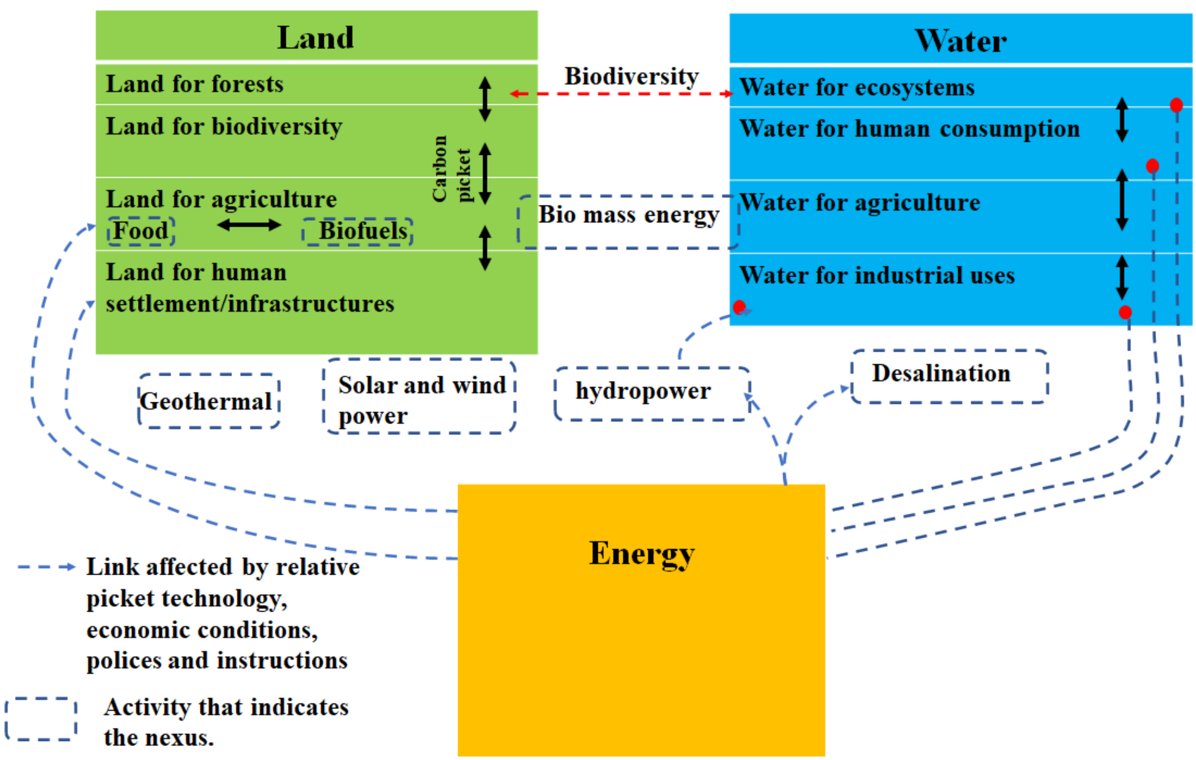


Figure 4. Variation in the concept to use land instead of food (Source: ERD 2012).

4 ENERGY AND WATER

While practically every energy-producing method uses a sizable volume of water, energy is necessary to purify and provide water. The interdependence of water and energy will intensify over the coming years, having a significant impact on the stability of both energy and water. Each resource faces rising demand and constraints in many parts of the world because of problems with finances, population growth, and environmental constraints (Wang and Zimmerman 2011). Traditionally, energy supplies per person are abundant, but the economy's receptivity to changes in natural systems is minimal (Fan et al. 2019)

There has been a sharp increase in the population's understanding of local climatic conditions and the hydrological cycle in recent years, which has resulted in a greater need for energy to integrate the planning of water and energy systems (Fan et al. 2019). The hydropower dam is an example of how important water is in the creation and use of energy. Energy is required to extract water, clean sewage, and drinkable water, and deliver water to populations. In the industries that produce fuel and energy, water is necessary for effective cooling, discharge, refining, processing, and other operations. The amount of energy produced by dams is significantly impacted by changes in the groundwater table and flow.

For the extraction of fossil fuels or the manufacturing of biofuels, adequate water is needed. The same applies to the removal of salt from seawater and the use of energy in the form of power. The relationship between water and energy may be concluded as follows:
Water in energy (Lee et al. 2021):

- Drinking water
- Pumping ground and surface water for irrigation
- Desalination of seawater
- Transport of water
- Water treatments for drainage, industrial and sanitation water.

Energy in water (Lee et al. 2021):

- Hydropower
- Thermoelectric cooling
- Extraction and mining
- Biofuel production
- Energy generation polluted water.

5 CONSERVATION AGRICULTURE TO SAVE ENERGY

This strategy involves limiting mechanical soil disturbance, providing permanent soil cover to maintain soil moisture content, and diversifying crop species produced in rotation to manage ecosystems for better and sustained productivity. Reduced energy can be attained by using less tillage fuel, less electricity for irrigation, and less indirect energy to suppress weeds per unit of production.

5.1 Water for Irrigation

It takes a lot of energy to pump water for irrigation, drinking water, and food processing. Typically, internal combustion engines or electricity are used to power the pumps. Where there is the possibility for solar and wind energy, solar and wind-powered pumps should be encouraged (SE4ALL 2022), even though they are still more expensive than conventional electricity

Irrigation energy requirements can be cut by:

- Making use of gravity as much as possible.

- Using electric motors with high efficiency.
- Sizing pumping systems to provide crops with their real water needs while minimizing loss.
- Selecting highly effective water pumps that are well adapted to the job.
- Regularly placing a high focus on pump maintenance.
- Applying drip irrigation or low-head distribution sprinkler systems to row crops.
- Cutting down on water leaks in all irrigation system parts.
- Using the moisture content of the soil as a guide for applying water.
- Selecting suitable and drought-resistant crop cultivars.
- Calculating the timing and amount of water required for the fields using weather forecasts, particularly for warm wind and high-speed wind.
- Using global positioning systems (GPS) to varying irrigation rates across a field to match the soil moisture conditions.
- Conserving soil moisture by covering the soil surface with mulch and tree shelter belts.
- Maintaining all equipment, water sources, and intake screens in good working order.

5.2 Storage and Refrigeration

After harvesting and processing, food quality is maintained by cooling and cold storage, which also helps to cut down on supply-chain losses. Although new technologies like solar absorption chillers are starting to hit the market, reliable electricity supply systems are still necessary for refrigeration systems to function. On small and big sizes, several renewable electricity sources can be exploited. By improving insulation, keeping access doors closed, and reducing the heat load at the conclusion of the cold chain processing phase, cold shops can reduce their energy consumption.

5.3 Fertilizers and Plant Nutrients Behavior

Knowing how and in what forms the plant absorbs nutrients from the soil, how many nutrients are necessary for the plant's life cycle, and in which charge (positive or negative) will be available for the plant to adsorb are all important factors in understanding the role of energy in the production of fertilizers as a crucial component to agriculture. The nitrogen element, which is thought to be the most significant element that the plant absorbed from the soil to create the body of the plant and is responsible for its green color, will be the focus of this topic. The crucial problem with nitrogen demands needs to be clarified, such as the fact that there are no minerals or rocks in soils that may manufacture and release nitrogen when they are worn or decomposed.

As a result, nitrogen should always be given to the soil from outside sources, such as chemical nitrogen fertilizers or organic materials, as was the case in the past before the industrial revolution or in recent years on organic farms. The other reality is that the nitrogen element is easily lost from the soil as soluble nitrate (NO_3^-), which can be leached from the soil solution by deep percolation or seepage by the stream of rain or irrigation water. This explains why it is impossible to avoid regularly applying nitrogen fertilizers to the soil from outside sources in the proper dosages. The only option to lower these levels is to minimize the soil's rate of nitrogen loss under various soil conditions, such as warm, humid climates.

In order to find the best ways to deal with chemical fertilizers and minimize the amounts that should be added to the soil in order to prevent the contamination of both soil and groundwater by the elements of chemical fertilizers, especially the nitrogen and trace elements, the next discussion will explain the behavior of the plant nutrition in the soils and the "plant soil water relationship". In a growth season, according to Figure 5, plants will draw roughly 40% of their water from the top quarter of the root zone, 30% from the second quarter, 20% from the third quarter, and 10% from the bottom quarter (Loganathan 1987).

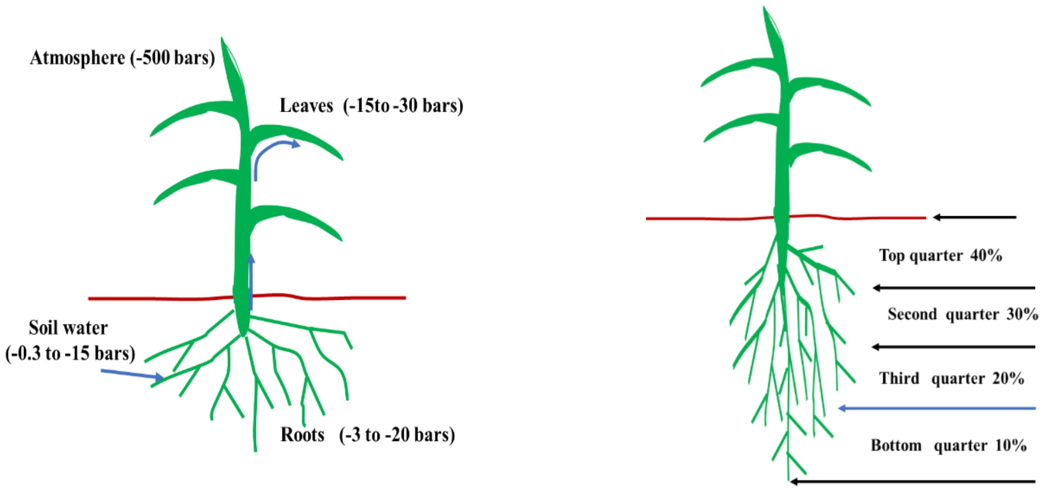


Figure 5. Adsorption of nutrients from the soil solution by root zone (Utah 1964; Payero et al. 2017).

5.4 Soil–Water–Plant Relationships

The majority of soil particles are charged mostly by negative charges and only sparingly by positive charges. This indicates that the nutrient with positive charges will bind to, absorb into, or be attracted to the negative charge sites of the soil particle by the attraction between positive and negative, to be as exchangeable cations holds by little force power to be ready to be taken by the roots systems at any time. The negative charges of the nutrients will repel the negative charges of the soil particles and make it easier for them to move down with the water stream to be lost by deep seepage. This also means that they will remain in the soil against gravity seepage (percolation) or be lost by the stream of rain or irrigation. The nitrate ion (NO_3^-), which is simple to leach from the root zones, is the form that is absorbed by the plants. In some crops grown in water ponds, like rice, ammonium in the form of NH_4OH may also be absorbed by the root systems and may also be lost as NH_{3-} gas, NO_{2-}, and N_2O, particularly in warm weather or in sandy and calcareous soils.

For plants to complete their life cycle, specific vital nutrients are required. These parts cannot be fully replaced by any other component. Currently, it is believed that at least 16 components are necessary for the growth of the majority of vascular plants. In photosynthetic reactions, carbon, hydrogen, and oxygen are mixed and come from air and water. 90% or more of the dry matter in plants is made up of these three substances. The soil provides the majority of the remaining 13 elements (Foth 1990). The macronutrients nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and Sulphur (S) are those that must be consumed in relatively high quantities. Micronutrients are substances that are needed in much smaller amounts. They include zinc, iron, manganese, molybdenum, copper, boron, chlorine, and chloride (Zn). Only a few plants require cobalt (Co), a micronutrient. When a plant lacks an important element, it often shows symptoms particular to that element. Roots take up nutrients as cations and anions from soil solution or soil water. Ions have an electrical charge. Ca^{++} and K^{+} are examples of positively charged cations, and NO_3 (nitrate) and H_2PO_4 are examples of negatively charged anions (phosphate). In the natural world, plants adapt to the availability of nutrients.

5.5 Addition of Fertilizers in a Sustainable Way

Farmers can indirectly reduce energy use by using less fertilizers and more precise application techniques, as suggested by the following:

- Crop rotation to reduce the amounts of nutrient depletion from the soil.
- Precision agriculture for the right amounts and type of fertilizers for given crops.
- Frequent smaller applications are more beneficial to the plant and its crops than a single large one.
- Fertigation through irrigation systems: saves application times for both water and nutrients.
- Use of organic manures as a slow-release fertilizer in accordance with proper agricultural management has a positive impact on soil aggregation, which improves water and nutrient retention (Table 1).

Table 1. Examples of direct and indirect improvement of energy efficiency in agriculture and fisheries through technical and social intervention (Source: Fang 2013).

Direct energy saving	Indirect energy saving
• Improved maintenance and more fuel-efficient tractor engines. • More exact use of irrigation water. • Using precision farming to apply fertilizers correctly. • Implementing minimal or no-tillage techniques.Better environmental control for buildings. • Improved greenhouse heat control.	• Breeds of animals and crop plants that require fewer inputs. • Agroecological agricultural methods and recycling of nutrients. • Lowering water use and waste. • Manufacturing of better machinery and fertilizers.

6 INTERLINKING CLIMATE CHANGE WITH WATER, FOOD, AND ENERGY NEXUS

With rising temperatures, decreasing snowpack, shifting precipitation for water, energy, and food as well as regional ecological processes, global climate change poses serious challenges. Environmental protection, goods, and natural resources including water, electricity, and food are all provided via ecosystem services (Teng and Lin 2022). Warmer air temperatures, declining snowpack, unpredictable precipitation, increased evaporation, protracted droughts, and raised sea levels are all predicted effects of climate change (Zhang et al. 2020). Figure 6 shows the proposed conceptual framework for the WEF nexus interlinked with climate change. According to the conceptual framework, the life cycle pathways of the WEF nexus are complex and include interrelated structures of the major climate change factors of temperature and snowpack precipitation. Sea-level rise and fire also affect these complex relationships in coastal and forested watershed environments. Table 1 shows the key components and pathways in the life cycles of water, energy, food, and ecosystem activities for fish and wildlife.

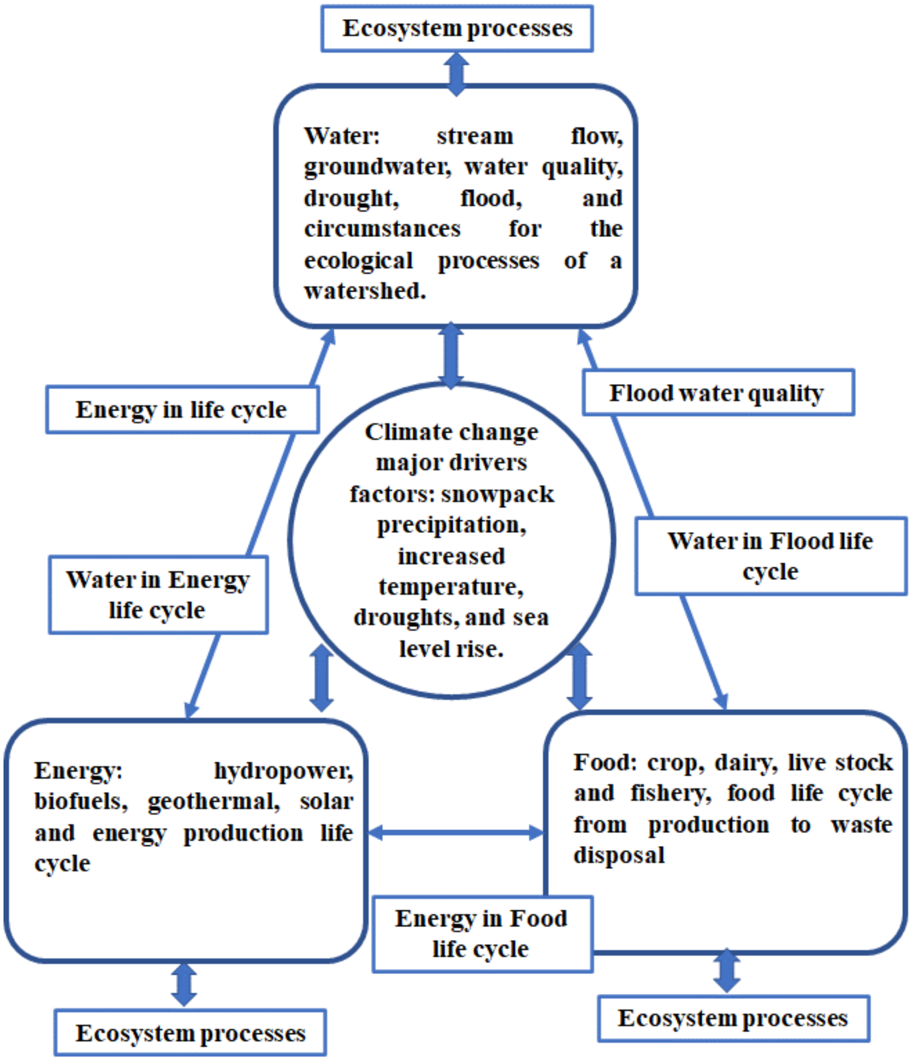


Figure 6. The proposed conceptual framework for water, food, and energy nexus. Note: Energy includes both renewable and fossil energy from the current practical perspectives in water-energy-food nexus (Source: Liu 2016).

Environmental water is essential for maintaining the integrity and operation of the watershed ecosystem as well as healthy fish and wildlife habitats, as shown in Table 3. Watershed ecosystem processes with healthier fish and wildlife habitats enhance water quality and steady water supplies for food, energy, and water. Through biological interactions between plants and insects for crop pollination, biodiversity and ecological circumstances also have an impact on agricultural food production. Water, energy, food, and habitats are increasingly competing for land and water, which could have an impact on the health of ecosystems and the changing climate globally. Increased efficiency and better sectoral coordination can be achieved through integrated resource management, which can be utilised as a strategy to improve the security of water, energy, food, and the environment (Liu, 2016).. In California, the following implications of climate change on water, energy, and the environment have been assessed (California Water Plan 2015). For instance, projected temperature increases range from 4 to 9 degrees Fahrenheit (°F) by the year 2100, which results in 48–65% loss of snow water, prolonged droughts with detrimental impact on the environment, food, and energy Table 3 shows the key components and pathways in the life cycles of water, energy, food, and ecosystem activities for fish and wildlife.

Table 2. Key pathways and components in conceptual framework (Liu, 2016)

Components	Key pathways and factors	Notes
Major climate drivers' factors	For surface water, groundwater, and stream flow, consider the temperature, snowpack, and precipitation. Fire for the watershed's water quality; sea level rise for the infrastructure along the coast.	Focused on how significant factors affect water supplies
Water life cycle	Urban and agricultural water use, as well as the pumping, transportation, distribution, and treatment of water.	Conveyance is a part of California water life cycle
Energy life cycle	Hydropower, biomass for biofuels, solar, wind, and geothermal energy generation, as well as cooling, extraction, and processing for the creation of energy.	Fossil energy has negative impacts on ecosystem processes*
Food life cycle	Food preparation (cooking), transportation (growing and harvesting crops, shipping, distribution, import, and export), fish and livestock production, irrigation (conveyance, treatment, pumping, pressurizing), harvesting and processing (cooling, washing, sorting, packaging, heating), and waste management (collecting and processing for food disposal).	Complex process related to water and energy
affected important ecological process components	The habitats of wetlands and watersheds, stream flow, water quality, biodiversity, and cold-water fish and mammal species.	Concentrating on the effects of the main sources of water resources

* Production and consumption of fossil fuels raise greenhouse gas (GHG) emissions and change ecosystem processes by lowering water quality and raising air pollution.

Key details for specific connections between these crucial components are provided in Table 4. These intricate links and relationships comprise the following: (1) the reduction of snowpack, shifting precipitation patterns, and rising temperatures are all largely caused by climate change. Hydropower is produced using water as part of the energy life cycle. Water is extracted, transported, treated, distributed, and heated for urban and agricultural needs using solar, biofuels, and other energies.; and related frequent drought and flooding may significantly reduce water supply and increase water stress, (2) Food production impacts to water and watershed ecosystems through agricultural runoff containing fertilizers, herbicides, and pesticides as well as food waste in watersheds, which has long-term implications on the life cycles of water, energy, food, and the productive use of water for fish and wildlife.; (3) energy is needed to produce, transport, and distribute food; additionally, crops and biomass are used to produce biofuels; and (4) water, energy, and food production and uses have significant interactions.

Table 3. Important connections between the water, energy, food, and climate change nexuses, as well as related ecosystem processes (Liu 2016).

Key connections	Climate change (CC)	Water	Energy	Food	Ecosystem processes
Climate change [a] in temperature, snowpack, precipitation, fire, and sea level rise.	Mitigation and adaptation	Increases water stress, drought and flood, sea water intrusion, decreases stream flow and water quality, and has an impact on water supply and uses. It also leads to hydrological changes in surface water and subsurface water.	Affects water resources for energy with increasing water stress, which has an impact on the life cycle of energy production and energy usage.	Increases water stress, which has an impact on the water supply and utilization for food, influencing the food life cycle .	Climate change, increased fire and greenhouse gas emissions, decreased stream flow, poor water quality, and increased air pollution alter ecosystem processes, which have an impact on the forest, biodiversity, land, and watersheds.
Water[b]	Renewable energy use in the water cycle can reduce CC whereas fossil energy use can raise GHG emissions.	Integrated water management	Water affects in energy production life cycle (Table 3)	Water affects in food life cycle (Table 3)	watersheds and wetland habitats for animals are affected by the environment.
Energy [c]	Renewable energy sources reduce GHG emissions caused by fossil fuel consumption and production. CC	Energy affects in water cycle (Table 3)	Integrated energy management	Energy affects in food life cycle (Table 3).	impacts environmental processes with conflicts over habitat and land caused by energy production and distribution.
Food [d]	Use of fossil fuels in agriculture, soil management, and food production GHG emissions for CC rise; CC is lessened by renewable energy	Food production and uses as well as waste could reduce water quality in watersheds	Food products used in energy biofuels	Integrated food management	Conflict over land and habitat has an impact on ecological processes, lowering water quality in watersheds.
Ecosystem processes [e]	interactions between agricultural lands, practices, and biodiversity	Environmental management for reducing and adapting to climate change.	better ecological and hydrological conditions and improved water quality.	Species and landscape interactions with energy production and distribution.	Integrated environmental Management.

[a] The effects of climate change on water, energy, food, and ecosystem systems include changes in temperature, snowfall, precipitation, fires, and sea level rise.

[b] (1) Energy production, including cooling and the extraction of fossil fuels, hydropower, biofuels, and renewable energy sources; (2) the production of food and biomass; (3) the use of water; and (4) several advantageous applications, including species and habitats for ecosystem processes.

[c] Energy is used in two different ways: (1) to produce water, including desalination, conveyance, distribution, and treatment; and (2) to produce food and biomass, including water pumping, fertilizers, herbicides, pesticides, the food supply chain, transportation, and processing.

[d] Food crops and biomass are used to produce biofuels for energy, and they also have an impact on water quality due to food waste, fertilizers, pesticides, and herbicides from agricultural runoff.

[e] Environments are physical, chemical, and biological conditions that have an impact on ecosystem processes for water, energy, and food related to climate change. Ecosystem process (1) provides ecological function and services for water, energy, food, biomass, and the environment. Ecosystem process (2) connects natural resources for ecosystem function and process.

CONCLUSION AND RECOMMENDATIONS

Based on the WFE analysis and to achieve the WFE nexus:

1. Decision-makers at governmental agencies should focus on the use of renewable energy. The growth of less water-intensive renewable energy sources like hydropower and wind energy requires more public and official support. There is a huge potential for geothermal energy as a long-term source, a climatically independent resource that produces almost no greenhouse emissions and doesn't require any water.
2. Sustainable agriculture is crucial. Whereas the interconnected systems of the soil, water, and land are at capacity, water and energy can be saved by efficient measures taken along the entire agrifood supply chain, such as data-precision irrigation from water suppliers. Environmental integrity can be ensured by protecting ecosystems concurrently with agriculture and energy production.
3. The essence functionality of the ecosystems must be appreciated and protected. As, instead of allowing nature to be destroyed and degraded in the quest for food and energy, governments must harness its potential. Sustainable WEF nexus for an "environmentally-friendly" economy, more "green infrastructure" projects are required, such as runoff storage and recharge dams at arable lands, and land reforestation to reduce soil erosion.
4. A primary priority must be given to integrated management of water, food, and energy. Therefore, the decision-makers in all three sectors must collaborate on water resource management, ecosystem conservation, and water supply and sanitation due to this nexus' critical involvement in many SDGs.

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