Chapter 4
The Water–Energy–Food Nexus in Mexico

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Abstract The interdependence of water, energy, and food systems is widely recognized. Recently, this interdependence has generated significant concerns around the world, as global projections indicate that the demand for water, energy, and food will significantly increase over the next few decades. Mexico will confront several challenges given the simultaneous pressures of population growth, urbanization, climate variability, and climate change. Therefore, in this work, water, energy, and food resources in Mexico are quantified in terms of their availability and demand. Also, the disparities between the northern, southern, and central regions of the country are highlighted. Specific challenges to water, energy, and food systems are described, as well as the lack of an efficient approach for establishing the nexus between these systems. Finally, one approach for effectively measuring and establishing the water–energy–food nexus through emergy is proposed and exemplified. In this respect, emergy is an expression of all the energy used in the work processes that generate a service (water, energy, or food) in units of one type of energy (emjoules).

Keywords Water security · Energy security · Food security · Emergy

4.1 Introduction

Currently, the interdependence of water, energy, and food systems has increasingly generated concerns around the world because of the correlations among these sectors. Negative impacts on one system may affect one or all the other systems. The present focus aims to integrate the concepts of water security (*Ws*), energy security (*Es*), and food security (*Fs*) based on their connections and to therefore

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characterize the water–energy–food nexus (*WEFn*). The concepts of *Ws* and *Es* are still being developed and debated in the literature, and differing definitions have been proposed (Ang et al. 2015; Cook and Bakker 2012). However, the concept of *Fs* is widely accepted (Pinstrup-Andersen 2009). In addition, several problems impede the development of a *WEF-n*, for example, the inflexibility of research institutions, the lack of greater interdisciplinary collaborations, the complexity of the topic, current political economy, and the ambitious objectives of this approach. The identification of connections among these three overarching systems requires distinct disciplines and scales to be united (Leck et al. 2015). In the following, the most accepted definitions of *Ws*, *Es,* and *Fs* within the *WEFn* focus are presented:

Water security is defined as "the capacity of a population to safeguard sustainable access to adequate quantities of water of acceptable quality" (UNU-INWH 2013). In addition, water security is a key aspect of sustaining livelihoods and human well-being, which includes basic resources for a good life, health, happiness, freedom of choice and action, good social relations, and safety. Also, secure access to water can promote socioeconomic development and can protect individuals from water-related disasters and water-borne pollution. Finally, water security enables ecosystem preservation and promotes political stability and a climate of peace.

Energy security is defined as "the uninterrupted availability of energy sources at an affordable price" (IEA 2014). The four main characteristics of secure energy are availability, affordability, accessibility, and acceptability (Cherp and Jewell 2014).

Food security exists (i) when people have constant access to food, independently of economic factors, political instability, or adverse weather conditions; and (ii) when food is constantly available, which is related to the level of food production, stock levels, and net trade. In addition, food security is characterized by (iii) the physical and economic access to food, which is determined by available income, expenditure, markets, and prices; and iv) the sufficient availability of safe and nutritious foods that meet the dietary needs and preferences of a population, thereby enabling individuals to sustain active and healthy lives (FAO 2008).

According to the definitions of *Ws*, *Es,* and *Fs*, the *WEFn* focus can be defined as the establishment of the connections between water, energy, and food systems with the objectives of recognizing their interdependency and ensuring the future availability and supply of WEF. In addition, the access to WEF of an adequate quantity, quality, and price is important for sustaining livelihoods and protecting against disasters that could affect the equilibrium among the various systems (Fig. 4.1).

Despite the challenges presented by an integrative *WEFn* focus, worldwide population growth will increase the demand for energy, water, and food. For this reason, it is important to identify the connections among these sectors and to find an effective means to correlate them within Mexico and around the world, which could be one means of improving their management and efficiency in meeting the needs of distinct populations from an integrative perspective.

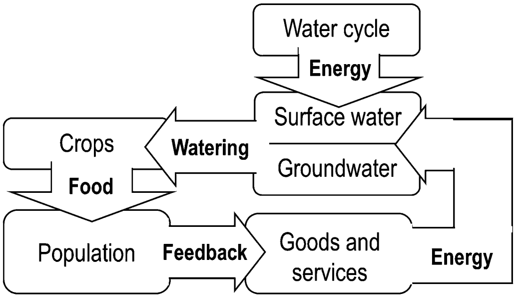


Fig. 4.1 Conceptual model of the water–energy–food nexus

4.2 Water, Energy, and Food Systems in Mexico

Currently, large amounts of data relevant to water, energy, and food systems have been integrated in databases at the national and international levels. Related indicators, including those developed by distinct institutions, are also widely accessible. The FAO previously developed a system called the *WEFn* Rapid Appraisal based on the Nexus Assessment (Giampietro 2013), which provides a quick way to assess specific interventions to promote development goals, such as food, water, and energy security. An online application was developed to perform this assessment (http://www.fao.org/energy/water-food-energy-nexus/, 2017), although Mexico is not on the list of the included countries.

To analyze indicators related to water, energy, and food systems, and their evolution in Mexico, data from the World Bank (2017), FAO (2017a, b) and Enerdata (2017) can be used. In Table 4.1, some indicators for Mexico are shown for 2015. In Fig. 4.2, the behavior of these indicators over time is shown.

One of the most important variables in Mexico that influences water, energy, and food systems is population because population growth exerts a significant pressure on resources. In 2015, Mexico had more than 127 million inhabitants and an annual growth rate of 1.3%. By the year 2030, a population of 137.5 million inhabitants is expected (CNA 2016). Nearly all variables related to consumption in the energy sector have also increased. Even so, energy consumption does not exceed production; therefore, food and water systems, which are dependent on energy, are not yet put at risk because of this factor. Notably, regarding the water system, access to sanitation facilities has markedly increased over time. In the year 2015, 95% of the population had access to sanitation facilities.

However, the population indicators, water resources, and GDP of Mexico at the national level hide the large variability of distinct indicators across various regions of the country (Cervantes-Jiménez et al. 2017). From an overall perspective, it might appear that the water, energy, and food systems of Mexico are not at risk. However, the reality at the regional level is different, and the wide variability in indicators is

Table 4.1 Indicators of the *WEFn* in Mexico for 2015

Water	
Long-term average annual precipitation (mm/year)	758
Water resources (m^3/person/year)	4000
Proportion of water devoted to agriculture (% of total)	77
Access to improved water sources (% of population)	96
Energy	
Energy consumed by power irrigation (million kWh)	985
Crop area irrigated (% area equipped for irrigation)	86.1
Subsidies for electricity used to pump irrigation water (%)	60
Food	
Agriculture, value added (% GDP)	3
Cultivated land (ha) per capita	0.20
Food exports (million US$)	16,230
Food imports (million US$)	21,503
Employment in agriculture (%)	13.4
Employment in agriculture, female (%)	3.6
Prevalence of undernourishment (%)	<5.0
Underweight, children under 5 (%)	2.8
Dietary intake of cereals/roots/tubers (%)	44
Cereal-import dependency ratio	30.7

Enerdata (2017), FAO (2017a, b) and World Bank (2017)

visible in Fig. 4.3. For example, two-thirds of Mexico is considered arid or semiarid (central-northern region) and has an annual precipitation of less than 500 mm. This region also contains 80% of the population (Becerril-Piña et al. 2016). Meanwhile, the southeastern region has an annual precipitation that exceeds 2000 mm per year and contains two-thirds of the renewable water resources of Mexico, too. The availability of water is seven times greater in this region than in the central-northern region. However, this region only contains one-fifth of the population. Also, in this contrasting panorama, the southeastern region presents the highest score on the Nutritional Risk Index despite having the greatest water availability. Meanwhile, the highest consumption of water for agriculture occurs in the central-northern region, despite this region having lower water availability and experiencing aquifer overexploitation. The use of water in this region has low efficiency because of the existence of several subsidies for energy (indirect) and water (direct) for both production and consumption. For example, users who utilize electricity to pump irrigation water are offered a 60% subsidy on the cost, regardless of their scale of production or income. Furthermore, the adoption of irrigation technologies in areas traditionally cultivated with rain-fed crops has not increased over the last 40 years, and the existing infrastructure has simultaneously deteriorated, generating usage inefficiencies (FAO 2016).

Also, in terms of food supply, Mexico imports a large quantity of food (US $21,506 million), especially cereals. As 40% of the Mexican diet is composed of

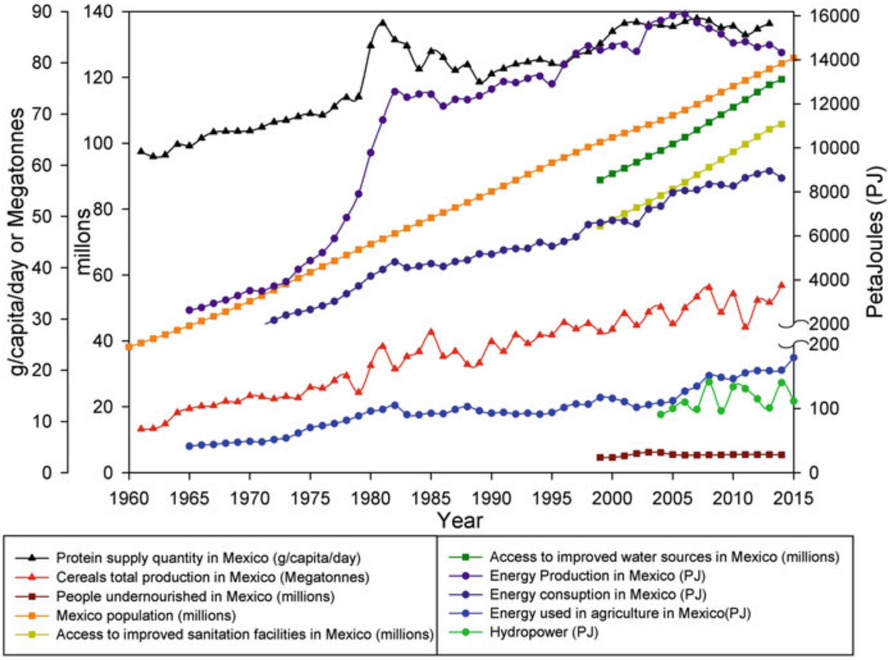
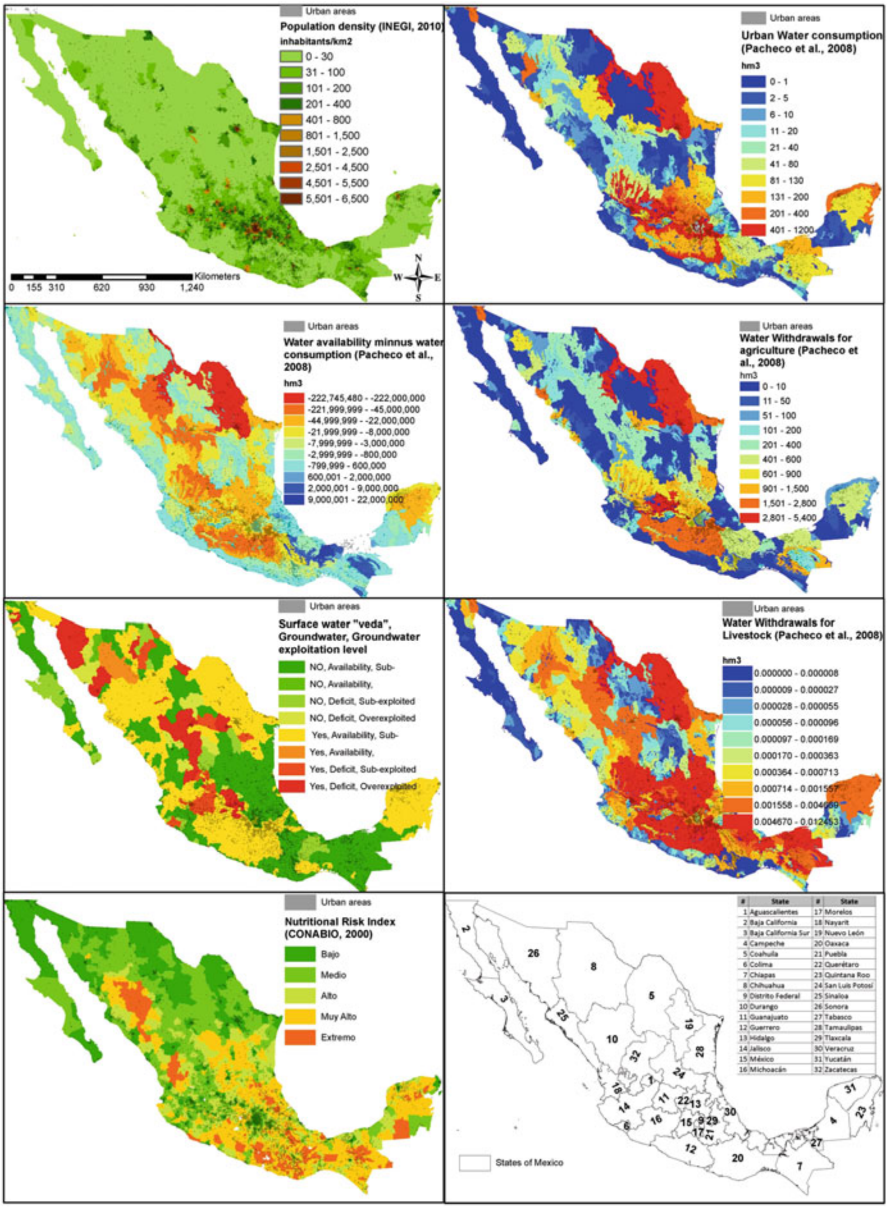


Fig. 4.2 Historical evolution of several indicators of the *WEFn* in Mexico. (Enerdata 2017; FAO 2017a, b; World Bank 2017)

cereals, roots, and tubers, this constitutes a large vulnerability in the food system. In addition, 46% of the population is living in poverty, and a large portion of the population is suffering from obesity, diabetes, and/or undernourishment.

The population distribution of Mexico is also uneven, and the population density varies widely from 14 to 5967 inhabitants/km^2. In the highly populated urban regions, water consumption levels exceed 400 hm^3. In addition, the areas devoted to livestock and agriculture are largely located in regions with restricted aquifers that are overexploited. For this reason, these activities are increasingly insecure because of their dependence on decreasing water sources. The interrelationships among these indicators highlight the importance of using a *WEFn* focus at regional and local scales, in addition to considering regional and local socioeconomic conditions.

Furthermore, certain natural phenomena present challenges for future water, energy, and food systems. For example, extreme changes in the climate variability (e.g., droughts, floods, hailstorms, and frost), climate change, and desertification can compromise the connections and equilibrium between these systems. Changes in temperature, precipitation, and, consequently, evapotranspiration can exert greater pressures on agriculture, which compromise *Fs*. In particular, *Fs* is directly related to environmental conditions because food production, distribution, storage, and markets are affected by climate variability, mainly that of water availability (Mastachi-Loza et al. 2016). In one analysis of climate change scenarios in the irrigation



#	State	#	State
1	Aguascalientes	17	Morelos
2	Baja California	18	Nayarit
3	Baja California Sur	19	Nuevo León
4	Campeche	20	Oaxaca
5	Coahuila	21	Puebla
6	Colima	22	Querétaro
7	Chiapas	23	Quintana Roo
8	Chihuahua	24	San Luis Potosí
9	Distrito Federal	25	Sinaloa
10	Durango	26	Sonora
11	Guanajuato	27	Tabasco
12	Guerrero	28	Tamaulipas
13	Hidalgo	29	Tlaxcala
14	Jalisco	30	Veracruz
15	México	31	Yucatán
16	Michoacán	32	Zacatecas

Fig. 4.3 Spatial distribution of several indicators of the *WEFn* in Mexico

districts of Northern Mexico, according to the representative concentration pathways (*RCP*) 4.5 and 8.5, crop-water requirements were expected to increase by 8.5% and 21%, respectively, by the year 2100 (Paredes-Tavares et al. 2018). In addition, desertification or degradation of land as a result of several factors, such as anthropic activities and changes in climate, leads to a reduction or loss of economic productivity (UNCCD 1994). Becerril-Piña et al. (2015) analyzed the risk of desertification in central Mexico by examining the probabilities of various scenarios. In the last 20 years, a high rate of change of land use (34 km^2 per year) has been observed. In addition, urban zones increased by 40% and agricultural areas by 30%. Overall, the region presented a high risk of desertification, mainly along the agroindustry corridor of the central region of the country.

4.3 Challenges to the Water–Energy–Food Nexus in Mexico

One difficulty in establishing relationships between water, energy, and food systems involves evaluating these systems at a common scale. Also, traditional and, according on Kapp (1975), questionable economic indicators of development and production have taken precedence at the policy level to the disregard of social and environmental indicators.

In economic terms, the cost of supplying water for agricultural uses is determined by the investment in works and infrastructure to deliver water, as well as the operating costs required for water to arrive at its destination (Balairón Pérez 2002). However, the price of water is not completely reflective of all of the costs and benefits associated with water services (UNESCO 2006). For instance, the scarcity of water for human consumption has been increasingly recognized worldwide (increasing the supply and demand for water), but water is also largely considered as a renewable resource. In addition, the value of water cannot be solely measured in monetary terms because water also holds unique ecological and cultural values in distinct regions of the world.

The ecological value of water is associated with the water requirement of ecosystems and the services provided by ecosystems (physical environments, climate regulation, and biodiversity) that maintain the status and quality of water. Meanwhile, the cultural value of water is related to the inherent or “sacred” value of water resources, which is a reflection of certain societal beliefs and values (De Groot et al. 2002).

In response to the presented dilemma, several theories have created models for water management based on nature and natural water dynamics, rather than the economic aspects of water resources. For example, “opportunity cost,” defined as the loss of potential gains that could have been obtained from other alternatives when one alternative is chosen (Stevenson and Lindberg 2009), has been used to evaluate the various elements and scenarios of a system, including their effects on water supply and management.

One relevant theory is the water footprint. The method to calculate the water footprint, as well as the considered parameters, is distinct from that used to calculate the economic footprint. The water footprint is determined in terms of “virtual water,” which is the quantity of water resources required to produce particular goods or services (Allan 1993; Hoekstra 2011). In this method, comparisons are made between products or services based on the quantity of water required to create and/or transform them. Thus, distinct commercial transactions can be compared in terms of units of water volume. For example, according to Mekonnen and Hoekstra (2011), Mexico exports 42.5% of its national water footprint (1978 m^3/year per capita), while the United States exports only 20.2% of its water footprint (2842 m^3/year per capita).

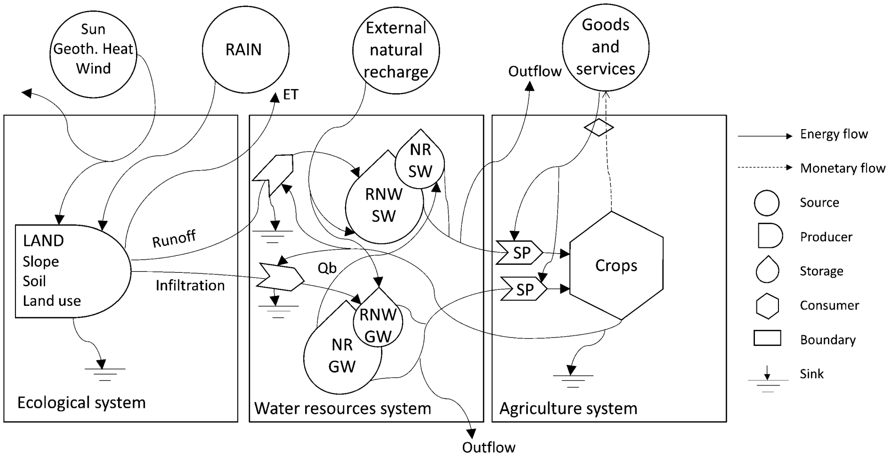
The water footprint has been promoted by worldwide organizations, such as the Water Footprint Network, yet presents one great disadvantage: It does not consider other natural resources that are equally necessary for society. For example, mineral products, such as carbon (e.g., a source of energy), iron, and copper (e.g., used as construction materials and to create tools), among others, are disregarded.

In this context, some models represent the behavior of physical systems through modeling the input/output of energy to a certain system based on the principles of thermodynamics (Bastianoni et al. 2007), especially according to the implications of the second law of thermodynamics: "Processes occur in a certain direction, and energy has quality as well as quantity" (Cengel and Boles 2002). In general, these models are based on the premise that classic parameters (the monetary cost of production and amount of capital) are not sufficient or significant indicators of the optimality of a production line or design (Sciubba and Ulgiati 2005). However, the best method to evaluate energy inputs/outputs has been widely debated, for example, the use of emergy versus exergy (Bastianoni et al. 2006; Herendeen 2004). Exergy analyses were mainly developed to study the processes involved in systems of energy conversion, while emergy analyses are commonly applied to the processes involved in generating products or services at a large scale (Lazzaretto 2009). Although some large-scale studies on water resources are based on exergy, such as the study of Chen et al. (2009), emergy analyses are more frequent at regional scales (Lv and Wu 2009).

4.3.1 Alternative Approach for the Assessment of the Water–Energy–Food Nexus (Emergy Accounting)

As Odum (1996) refers "Emergy is the available energy required, directly or indirectly, to generate a service or product." In emergy accounting, various forms of energy may also be represented by the solar emjoules (seJ) or equivalent solar emergy. In this sense, emergy is the amount of solar energy required per product or energy unit, expressed in seJ/J or other units. In addition, mass (seJ/g) can also be expressed in unit emergy values (Brown et al. 2010; Pulselli et al. 2011).

Systems evaluated in terms of emergy are usually represented by energy-flow diagrams. Figure 4.4 shows a water-supply system for urban users with urban demands but without restrictions for other uses, such as agricultural uses. In the socioeconomic subsystem, which is related to developed lands, water is transported from surface water and groundwater bodies toward through supply processes fed by goods and services.



RNW SW: Renewable surface water
NR SW: Non-renewable surface water
RNW GW: Renewable groundwater
NR GW: Non-renewable groundwater

ET: Evapotranspiration
Qb: Base flow
SP: Supply processes
NR GW: Non-renewable groundwater

Fig. 4.4 The water supply system using a diagram of Emergy. (Díaz-Delgado et al. 2014)

Fonseca et al. (2017) propose three indicators to evaluate these systems: (a) the water deficit, (b) the environmental sustainability index (*ESI*), and (c) the economic impact. The water deficit is the difference between the supply and demand of water. The ESI (Eq. 4.1) is the relationship between the output of emergy and the environmental load (Almeida et al. 2007; Brown and Ulgiati 1997; Lv and Wu 2009). It is a function of the emergy flows associated with renewable resources (R), nonrenewable resources (N), and feedback (F) in the form of goods and services. The four thresholds of this index are as follows: (a) $ESI = 0$ (null sustainability), (b) $0 < ESI < 1$ (environmental load greater than the output), (c) $1 < ESI < 10$ (persistent influence of nonrenewable resources and socioeconomic feedback), and (d) $ESI > 10$ (greater influence of renewable resources) (Fonseca et al. 2017).

$$\mathrm{ESI} = \left(\frac{\mathrm{R+N+F}}{\mathrm{F}}\right)\left(\frac{\mathrm{R}}{\mathrm{N+F}}\right) \tag{4.1}$$

With respect to the discussion on whether water resources should be considered as renewable, the current proposal favors the arguments provided in Díaz-Delgado et al. (2014), who classified water under an integrated management framework. In particular, various types of nonrenewable and renewable water resources were distinguished. Nonrenewable water resources were geographically and temporally delimited and were mainly associated with groundwater flows directly originated from precipitation. In addition, these researchers proposed the use of the filling index (Pernıa et al. 2005; Vrba et al. 2007) to identify the exploitation of groundwater in areas where groundwater reserves are declining.

The economic impact, the third indicator proposed to evaluate water-supply systems, is “the sum of the variable energetic requirements in relation to the annual volumetric flow of water and the monetary production cost of electrical energy” (Fonseca et al. 2017).

The estimation of the unit emergy value (*UEV*) of water resources has been defined by some authors (Buenfil 2001; Díaz-Delgado et al. 2014) as the proportion in relation to the precipitation volume of both the flow and potential chemical energy (given by the Gibbs free energy) associated with the recharge of water bodies (via run-off or infiltration). For more detail, see Díaz-Delgado et al. (2014).

Meanwhile, the emergy flow associated with supply processes, such as water extraction and treatment, can be estimated as a polynomial function of the water supplied flow. This emergy flow tends to represent the emergy of installation maintenance and type and work requirements and the piezometric head to overcome (regarding even friction losses). For more detail, see Fonseca et al. (2017).

4.3.2 Emergy-Accounting Case Study

In the energy–water–food nexus framework, the emergy accounting of an agricultural district in the Upper Course of the Lerma River (*UCLR*) basin, Mexico, is presented as a case study. The *UCLR* basin has an average altitude of 2600 m.a.s.l. The valley has a mean annual rainfall of 900 mm and a subhumid temperate climate, while the mountainous region has a mean annual rainfall of 1200 mm with a semicold or cold climate (Esteller and Diaz-Delgado 2002). The aquifer of the Valley of Toluca (*VTA*) is freely developed and reaches depths of over 500 m in the valley (Esteller et al. 2012). According to the DOF (2003), the *VTA* (with a discharge of 53.6 hm^3/year, recharge of 336.8 hm^3/year, and extracted volume of 422.4 hm^3/year) has a deficit of 152.4 hm^3/year, which is obtained from groundwater reserves.

The corresponding irrigation district (Fig. 4.5) has a crop area (maize) of 50.32 km^2 and a surface water concession of 10,500 m^3/year. According to Díaz-Delgado et al. (2014), the approximate supply from deep wells is 151,330 m^3/year, and the water demand is 4.4 hm^3/year.

Under the conditions of the current scenario, an emergy analysis of crops was carried out for one calendar month (July). All water subsidies (water or energy) were omitted from the analysis. The monthly water demand was 100,000 m^3, and the water deficit was 61% (Table 4.2). The *UEV* associated with the 875 m^3 of supplied surface water was 1.00E+12 seJ/m^3 (ID = 1903). With respect to groundwater resources, the piezometric level of the study area indicates that the aquifer is being recharged. In this respect, 238.12 m^3 of water was estimated to be renewable from 37,832.75 m^3 of groundwater that was supplied from two deep wells (IDs = 26 and 451) (Díaz-Delgado et al. 2014; Fonseca et al. 2017). The *UEV* associated with the extraction of groundwater was estimated using the method proposed by Fonseca et al. (2017) considering the following operation characteristics of the wells:

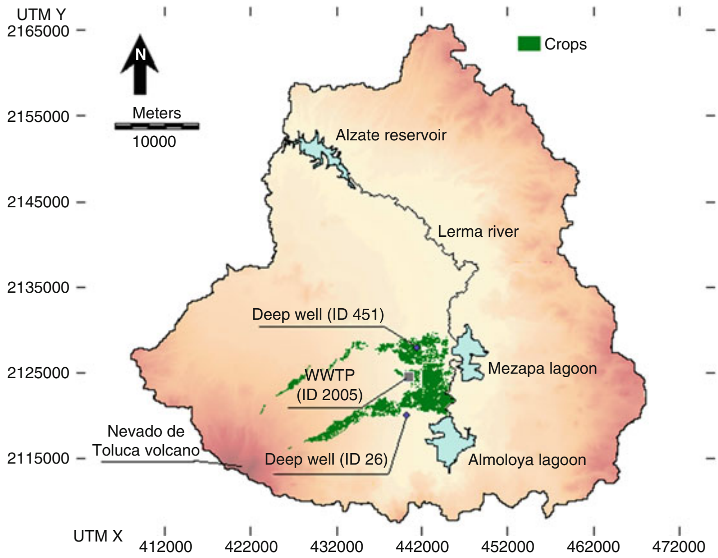


Fig. 4.5 Upper Course of the Lerma River (UCLR) basin, Mexico (case study)

(a) extraction depths of 11 and 35 m, (b) 0.30 m in diameter, (c) storage coefficient of 0.15, and (d) transmissivity of 0.005 m^2/day.

The resulting ESI score for the *UCLR* basin under these conditions was 2.62. According to Fonseca et al. (2017), this score resulted from a large emergy flow because of the economic feedback and the use of nonrenewable versus renewable resources. Energy consumption (1.36E+10 J) in this scenario had an economic cost of US$408 resulting from the production cost of electrical energy (Ávila et al. 2005; Fonseca-Ortiz et al. 2013).

The economic impact, just of energy consumption because of water extraction, does not appear to be significant. However, this consumption is not representative considering that the water supply deficit is greater than 50%. If the entire water demand can be satisfied by deep wells under current conditions, the approximate economic cost to extract groundwater would be US$1075 monthly.

One alternative is to use renewable water resources recycled at a wastewater treatment plant to satisfy the water demand. In the study area, the nearest wastewater treatment plant treats water using stabilization lagoons and has a capacity of 37 L/s.

Table 4.3 shows the emergy count considering the use of renewable water resources. In comparison to current conditions, the emergy flow is 7.5 times greater, but the ESI increases 7.8 times. The percentage of renewable resources rises to 74%, and the economic impact is USD $1,591 monthly. Summing up, current practices for agricultural watering depict lower economic impacts. Nevertheless, the observed *WEFn* from an emergy-accounting perspective (Fig. 4.6) highlights environmental benefits associated with the increased use of renewable resources.

Table 4.2 Emergy accounting of the case study under the current conditions

Source node	Source description	Input	Flow (m^3)	C_1	C_2	C_3	C_4	Emergy (seJ)	Type	C_{2e}	C_{3e}	C_{4e}	Energy (J)
Demand (m^3)	100,000												
26	Deep well	Water	21245.85	0	1.00E+12	0	0	2.12E+16	N	0	0	0	0
		Infrastructure	21245.85	2.11E+14	0	0	0	0	F	0	0	0	0
		Energy	21245.85	0	1.49E+10	1.58E+05	8.05E-03	3.87E+14	F	1.49E+05	1.58E+00	8.05E-08	3.87E+09
26	Deep well	Water	120.57	0	1.00E+12	0	0	1.21E+14	R	0	0	0	0
		Infrastructure	120.57	2.11E+14	0	0	0	0	F	0	0	0	0
		Energy	120.57	0	1.49E+10	1.58E+05	8.05E-03	1.80E+12	F	1.49E+05	1.58E+00	8.05E-08	1.80E+07
451	Deep well	Water	117.55	0	1.00E+12	0	0	1.18E+14	R	0	0	0	0
		Infrastructure	117.55	2.13E+14	0	0	0	2.13E+14	F	0	0	0	0
		Energy	117.55	0	3.79E+10	1.61E+05	1.97E-02	4.45E+12	F	5.61E+05	1.83E+00	1.12E-07	6.60E+07
451	Deep well	Water	16348.78	0	1.00E+12	0	0	1.63E+16	N	0	0	0	0
		Infrastructure	16348.78	2.13E+14	0	0	0	2.13E+14	F	0	0	0	0
		Energy	16348.78	0	3.79E+10	1.61E+05	1.97E-02	6.62E+14	F	5.61E+05	1.83E+00	1.12E-07	9.67E+09

1903	Surface water	Water	875.00	0	3.80E +12	0	0	3.33E+15	R	0	0	0	0
		Consumable	875.00	0	2.82E +09	0	0	2.47E+12	F	0	0	0	0
Total	38,707.75		4.26E +16										1.36E +10
Deficit	−61,292.25												
	61%												
ESI	2.62												

Table 4.3 Emergy accounting of the case study under the alternative scenario

Source node	Source description	Input	Flow (m^3)	C_1	C_2	C_3	C_4	Emergy (seJ)	Type	C_{2e}	C_{3e}	C_{4e}	Energy (J)
	Demand (m^3)	100,000											
26	Deep well	Water	1.21E+02	0	1.00E+12	0	0	1.21E+14	R	0	0	0	0
		Infrastructure	1.21E+02	2.11E+14	0	0	0	2.11E+14	F	0	0	0	0
		Energy	1.21E+02	0	1.49E+10	1.58E+05	8.05E-03	1.80E+12	F	1.49E+05	1.58E+00	8.05E-08	1.80E+07
26	Deep well	Water	2.12E+04	0	1.00E+12	0	0	2.12E+16	N	0	0	0	0
		Infrastructure	2.12E+04	2.11E+14	0	0	0	0	F	0	0	0	0
		Energy	2.12E+04	0	1.49E+10	1.58E+05	8.05E-03	3.87E+14	F	1.49E+05	1.58E+00	8.05E-08	3.87E+09
451	Deep well	Water	1.18E+02	0	1.00E+12	0	0	1.18E+14	R	0	0	0	0
		Infrastructure	1.18E+02	2.13E+14	0	0	0	2.13E+14	F	0	0	0	0
		Energy	1.18E+02	0	3.79E+10	1.61E+05	1.97E-02	4.45E+12	F	5.61E+05	1.83E+00	1.12E-07	6.60E+07
451	Deep well	Water	1.63E+04	0	1.00E+12	0	0	1.63E+16	N	0	0	0	0
		Infrastructure	1.63E+04	2.13E+14	0	0	0	0	F	0	0	0	0
		Energy	1.63E+04	0	3.79E+10	1.61E+05	1.97E-02	6.62E+14	F	5.61E+05	1.83E+00	1.12E-07	9.67E+09

1903	Surface water	Water	8.75E +02	0	3.80E +12	0	0	3.33E +15	R	0	0	0	0
		Consumable	8.75E +02	0	2.82E +09	0	0	2.47E +12	F	0	0	0	0
2005	Wastewater treatment plant	Water	6.13E +04	0	3.80E +12	0	0	2.33E +17	R	0	0	0	0
		Infrastructure	6.13E +04	4.01E +16	0	0	0	4.01E +16	F	0	0	0	0
		Energy and consumable	6.13E +04	0	4.83E +10	0	0	2.96E +15	F	6.43E +05	0	0	3.94E +10
Total	100,000		3.19E +17										5.3E +10
Deficit	0												
	0%												
ESI	20.58996												

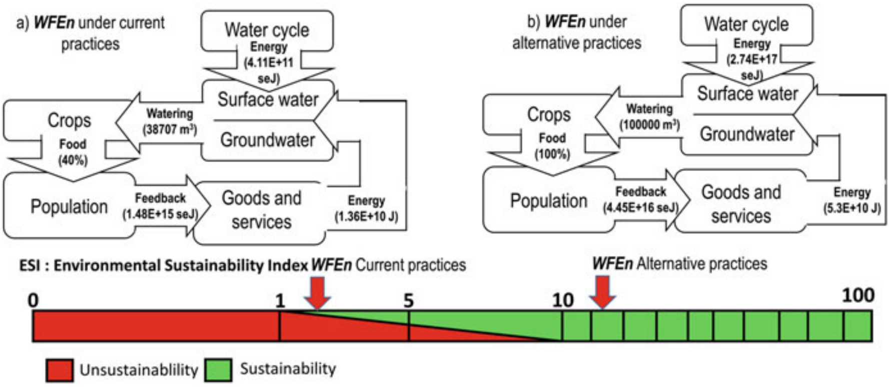


Fig. 4.6 *WEFn* evaluation through the environmental sustainability index (*ESI*) under current and proposed alternative practices for the case study

Despite the greater economic impact of this alternative supply scenario, the following factors should be considered: (a) the relationship between energy consumption, extracted water volume, and extraction depth is not linear. For this reason, the extrapolated economic impact of deep wells may be greater than determined in this first attempt to calculate the associated economic impact; (b) the extraction of greater volumes of water from deep wells results in the depletion of aquifers over time. This impact should also be contemplated in the analysis at a rate of US\$0.03/m^3.

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