Solutions for Off Grid Food-Energy-Water

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Abstract

The response to increasing strains on water resources, has led to an analysis of the Food-Energy-Water (FEW) Nexus and its role in development approaches for communities. The FEW Nexus concept developed because food, energy, and water, are inextricably linked and constitute essential human rights. A Nexus approach is a systematic analysis of interactions between human activities and their environment, with the purpose of working towards coordinated management on local, national and international levels. Addressing the FEW Nexus in an integrated approach is crucial in conflict zones with shared environmental resources. This paper presents a case study from Israel/Palestine.

Background

Water, energy, land, and food (WELF) resources are essential for human survival and growth, and are increasingly important in discussions about sustainable development (FAO, 2014, Wakeford et al., 2015a). Despite their importance, many people lack adequate access to sufficient resources (Wakeford et al., 2015a). While water is a renewable resource and there is enough for growing populations, demand exceeds supply in many places, including the Middle East (Hoff, 2011). Water is necessary for agricultural production, ecosystem services, and the systems and lives that depend on these services (Wakeford et al., 2015a). Energy resources are derived primarily from nonrenewable sources, but renewable energy is projected to increase and biofuels have been growing in recent years. A significant gap in energy use per-capita exists depending on location (Hoff, 2011; Wakeford et al., 2015a). Food production has grown in recent years, but food resources have not been distributed evenly across the world. Food production is integrally linked to land, as agricultural expansion affects land usage and quality (Hoff, 2011). Some notable interdependencies include agriculture using the largest amount of water - 70 percent of total global freshwater – and the food production and supply chain accounting for nearly 30 percent of the total global energy consumption (FAO, 2014).

Population and economic growth, resulting in growing demand on resources, coupled with resource limitations exacerbated by climate change, are expected to intensify the WELF resource linkages and interdependencies (Wakeford et al., 2015b; Martin-Nagle et al., 2012). By 2030, the global population is expected to exceed 8.3 billion (Ferroukhi et al., 2015). Consequently, global food demand is expected to grow by 35%, water demand by 40%, and energy demand by 50% (National Intelligence Council, 2012). Food production must increase by 60% in order to supply the population in 2050, with global water withdrawals for irrigation expecting to grow by 10% (FAO, 2014).

As WELF resources grow scarcer and demand increases from multiple sectors, it is increasingly important to use the nexus concept to understand how WELF systems are linked and affect the sustainability of each other, particularly for future development efforts and for various social, economic, and environmental goals (Miralles-Wilhelm, 2016; Leck et al., 2015; FAO, 2014). A nexus perspective assesses the complex interdependencies of WELF global resource systems by identifying "mutually beneficial responses and provides an informed transparent framework for determining trade-offs to meet demand without compromising sustainability" of resources (FAO, 2014; German Federal Ministry, 2012). Furthermore, a nexus perspective aims to increase WELF resource economic benefits by promoting the efficient use of resources, improving productivity, and reducing waste (German Federal Ministry, 2012).

The nexus concept involves a systems dynamics approach to analyzing the interconnections and interdependencies between the WELF resource sectors in communities and accounts for internal and external stressors on resource security. Systems dynamics is "a methodology to study how systems change over time and how the structure of systems affects their behavior" (Amadei, 2014, p. 221). It allows for the analysis of systems based on their complexity, which in turn demonstrates how systems change over time and have feedback loops (Amadei, 2014, p. 224).

While water, energy, and food resources are most commonly referenced in nexus literature, the "land" sector must also be considered. Land is an integral part of the nexus because the availability and quality of land affects production and consumption of the water, energy, and food/agricultural resources. (See Table 1) It is necessary to understand WELF systems cycles, from production to transportation, consumption, and waste disposal, and the infrastructures used in each stage. The nexus synergies and feedback loops demonstrate and emphasize system vulnerabilities, risks, and impacts. An integrated systems approach creates a framework for developing comprehensive policies that go beyond historical "single-issue solutions" and addresses sustainability of WELF resources for the future at local, regional, and global scales (Davis et al., 2016; McCormick & Kapustka, 2016).

	Water	Energy	Food/Agriculture	Land
Water		Water used for energy extraction and production, and bio (-fuel) processing	Water used for agricultural production and irrigation	Water contributes to soil and aquifer replenishing
Energy	Energy used to run water infrastructure, pumping, irrigation, and desalination		Energy used for mechanized agriculture in land preparation, irrigation, fertilization, etc.	Energy for field preparation and harvest
Food/Agriculture	Agriculture requires water. Practices must be respectful of run-off, groundwater recharge	Production of biofuels and biogas uses food, agricultural residues and biomass		Agricultural practices need to be respectful of land preservation
Land	Soil type and vegetation affect soil water saturation and ground water	Soil type affects the energy consumption for land use	Soil type and characteristics affect crop yield	

Table 1: Two-sector interactions in the WELF nexus

Justification

The synergies between WELF sectors are especially apparent in Israel, Palestine, and Jordan, where ongoing conflict, coupled with a growing population and climate change, increases the demand for natural resources in a water-scarce region with limited energy resources (Meisen & Tatum, 2011; Mohtar & Lawford, 2016). From 1964 to 2010, despite a tripling of the population of Israel, nine times more food was produced with only a three% increase in water consumption. At the same time, Palestinian populations have one-tenth the GDP per capita of Israelis, which leads to resource scarcity, water contamination, and unreliable and high-cost energy that also affects agricultural productivity (Meisen & Tatum, 2011). Palestinians obtain their water supply from underground aquifers and Israeli systems (Meisen & Tatum, 2011). However, less than 30% of off-grid wastewater treatment systems in Palestinian territories are working properly as a result of the “long-term sustainability of the off-grid approach”, insufficient capacity in technical operation and maintenance, affordability, and lack of local support and management, and national government support (Halasah, 2016).

Aim

This paper focuses on designing a framework to implement the WELF nexus for sustainable resource management. This approach engages local communities working to build capacity for sustainable resource management. Furthermore, it encourages transboundary collaboration to manage resources for peace building while simultaneously encouraging regionalism (Siegel, 2015; Waxman et al., 2015).

Methodology

Literature Review

Existing nexus literature consistently defines the nexus approach as understanding the complex and interdependent nature of global natural resource systems (FAO, 2014). A systems approach is often used to analyze the feedbacks and interdependencies of the food, energy, and water nexus (McCormick & Kapustka, 2016; Bell et al., 2016; Mohtar & Lawford, 2016; Scott et al., 2011). It allows for mapping the nexus and interdependencies, identifying important synergies, addressing risks and uncertainties, and modeling problems within the nexus, while also accounting for different time horizons and spatial scales (Mohtar & Lawford, 2016; IIASA). However, frameworks for analyzing natural resources differ. Nexus frameworks developed at the international level analyze cycles of food, energy, and water availability, supply, and security, and assess how governance and global trends such as population growth, urbanization, economic growth, and climate change impact security of these resources.

The nexus framework developed by the Bonn2011 Conference focuses on water resources and their relationship to water supply, food, and energy security and assesses how environment, economy, and society influence water, energy, and food security (Hoff, 2011). The World Economic Forum (WEF) 2011 established a nexus framework that depicts a two-way relationship between energy and food security, and a one-way relationship between energy and food security and water and food security (Bizikova et al., 2013). While the goal of the Bonn2011 nexus is to promote resource security, sustainable growth, and a resilient and productive environment, the WEF 2011 framework assesses how resource security results in geopolitical conflict. The International Institute for Sustainable Development (IISD) built on these two approaches by establishing five layers of analysis: assessment of food, water, and energy utilization, access, and availability; analyzing resource security in terms of influence by natural and built systems; and finally understanding the role of institutions and governance (Bizikova et al., 2013). Lastly, the FAO's nexus framework approaches the management of water, energy, and food resources through stakeholder dialogue about the resource base, and assesses how drivers like population growth, governance, and urbanization affect the resource base and interact with natural resource goals and interests (FAO, 2014).

While most frameworks are developed at the global level, many case studies utilize participatory methods approaches to localize strategies and engage the community to respond to resource insecurities (Mohtar et al., 2016). IISD, for instance, utilizes a participatory planning process to assess water, energy, and food (WEF) security, develop landscape scenarios, communicate and invest in WEF systems, and transform the WEF system through communication, implementation, and system monitoring, adaptation, and improvement (Bizikova et al., 2013). Treemore-Spears et al. (2016) also rely on community engagement and community building to create connections and develop support among members so that they contribute to "unified, equitable, and sustainable approaches" at the WEF nexus. Other methods used to model nexus interdependencies include spatial computing and technologies (Eftelioglu et al., 2016), and combinations of multiple approaches, such as a study by Zimmerman et al. (2016) that combines network theory, applications of dependencies and interdependencies, and usage and recovery rate applications.

Overview: Community Appraisal and WELF Nexus

This framework differs from others because it both incorporates land into the water-energy-food nexus, and relies on community involvement to build capacity and sustainability. Additionally, this nexus approach seeks to facilitate transboundary cooperation between Israelis, Jordanians, and Palestinians to manage WELF resources in a geopolitically complex region. The approach is based on an initial definition and appraisal of the community and dependence on WELF resources. This requires understanding qualitative and quantitative data of a community's "operating environment (enabling and constraining) and that of its basic units, (the households)," particularly its relationship to WELF resources, to develop a baseline profile of the community and its needs regarding to the nexus before suggesting change (Amadei, 2014, p. 169).

Methodology Framework

The methodology is divided into three themes, including development of a system-based framework and community appraisal, justification for technological solution and its impacts on the community, and capacity building for sustainable management of technology and natural resources.

The first theme is ***Understanding the Dynamics of WELF Systems: From Data to Models***, with the goal **to develop a system-based framework and a community appraisal methodology to model the dynamics in the WELF nexus and the community dynamics in which the nexus takes place**. The rationale behind developing such a framework is that the Water, Energy, Land and Food nexus at the community level involves multiple systems and sub-systems and tangible (objective) and intangible (subjective) issues that are context and scale specific. Systems tools and associated decision making methods need to be developed to model the various systems and how they interact among each other and with the environment they depend on. Data collection and analysis at the community level is needed.

Theme 1 topics:

- Using system dynamics models to best represent qualitatively and quantitatively the dynamics of WELF systems at the community level.
- What data are needed to obtain a comprehensive representation of the various systems at play in the WELF nexus and to assess the level of community development?

- What participatory decision making methods are needed for collection and analysis of field data, to compare community model predictions to reality, and to decide how to improve the model prediction?

The second theme is ***Developing and Demonstrating the Technical and Economic Feasibility of Smart WELF Systems for Optimizing the Use of Renewable Resources and Increasing Food Productivity***. Facing emerging societal challenges of sustainable WELF security, the current state-of-practice and limitations of existing technology solutions for renewable resources need to be assessed in order to identify the WELF nexus industry needs (Bazilian et al., 2011; Lee, 2011). Field demonstration and deployment of innovative technology solutions for smart WELF systems are required. Furthermore, to ensure technology selection for the community to achieve financial sustainability after the project, it is necessary to develop and implement innovative resource management solutions across the different sectors of the WELF nexus that have proper design, certification criteria to approve the system's design, and efficient operation and maintenance practices (Halasah, 2016). Therefore, the goal of this theme is **to develop and demonstrate the technical feasibility and economic viability of innovative (smart) WELF Systems for optimizing the use of renewable energy and water resources, upgrading their efficiency, reliability, incident mitigation capabilities and sustainability, and increasing food productivity**.

Theme 2 topics:

- The role of innovation and integration of state-of-the-art artificial intelligence based Sensing, Command and Control System of Systems (SC2SoS) solutions in responding to the emerging WELF Challenges.
- The attributes of smart technology solutions leading to more efficient WELF resource management at the local community level in agricultural settings.
- Existing SC2SoS solutions used in high-tech infrastructure management systems to be adapted and integrated into economically viable, technically feasible, efficient and sustainable smart WELF system solutions for other applications.
- The technical and functional system requirements and performance measures needed to be integrated in the development, demonstration and assessment of smart WELF management systems with selected applications of waste recycling and intelligent greenhouse management systems.
- The non-technical parameters needed to be addressed in the monitoring and evaluation of smart technologies to ensure long-term performance and encourage scaling up.

The final theme, ***Developing Synergy and Community Capacity for Successful Transboundary Resource Management***, seeks **to develop a methodology and engagement platform to create synergy and collaboration among all stakeholders involved in successful WELF resource management at the community level**. Stakeholder involvement and dialogue creates a sense of ownership over the project, ensures mutual accountability, and supports decision-making processes (FAO, 2014). Building the capacity of a community to manage WELF resources more efficiently in a sustainable way requires education and training of all stakeholders involved in resource management. Co-evolving practices are needed to develop collaboration and synergy among stakeholders.

Theme 3 topics:

- The role of education, training, planning, and decision-support systems to ensure the long-term performance of WELF systems for communities.
- Best design of bottom-up, top-down, and outside-in partnerships across the WELF nexus?
- What new data, co-evolving knowledge, and decision processes are necessary to create long-term solutions in the WELF nexus?
- How to create a collaborative common ground, distributive/procedural ethics, design principles on the WELF nexus in a high-risk, conflict-prone environment with cross-cultural and transboundary issues.

	Theme 1	**Theme 2**	**Theme 3**
Theme 1	**Baseline Data and System Modeling of the WELF Nexus in Communities**	Current community dynamics explains the performance of existing WELF technologies and provides a baseline for smarter WELF technologies	Existing community dynamics helps in deciding how to educate and engage various stakeholders in using smarter WELF technologies
Theme 2	New WELF technologies contribute to community capacity building and lead to higher levels of development	**Monitoring impacts of new WELF Nexus Technologies in Communities**	Success of new WELF technologies requires stakeholder education, training and engagement for O&M
Theme 3	Education, training, and engagement change community dynamics and its level of development.	Community education, training, and engagement affect the success and failure rates of new technologies	**WELF Nexus Education, Training, and Community Engagement/ Shared Learning Processes**

Table 2: Methodology themes

Case Study: Date Farmers in Auja, West Bank

Background

Agriculture is one of the primary economic sectors in Palestine; 30% of Palestinians rely on agriculture as their main source of income, and most agricultural land is located in the West Bank (Ali et al., 2016). Date growing occurs primarily in the Jordan Valley, especially around Jericho, accounting for 14.68% of fruit production in the Jericho Governorate (David, 2015b). In Auja, a town of 4,500 people located north of Jericho in Area A of the Jordan Valley, West Bank, 10% of the land is used for agricultural purposes (Ali et al.,

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2016). In response to depleting water quantity and quality, Palestinian farmers have transitioned from high-value and water-intensive crops to dates (PWEG, 2015).

Auja's arid climate, its dependence on agriculture and declining quantity and quality of wells and springs for irrigation, and the town's high energy costs and unreliable power supply are obstacles to the date farmers' success (PWEG, 2015). Additional challenges to success are geopolitical. The Eastern Mountain Aquifer supplies water to the agricultural sector and to the Auja spring, but over-extraction causes the spring to dry often and water quality to decline (David, 2015b). The Israeli government restricts Palestinians from constructing new wells, and consequently they exhaust existing wells in the area (David, 2015b). Therefore, Auja must repurchase fresh water from Israel (David, 2015b). Additionally, despite date palms' ability to survive in hot, dry climates, Jericho is extremely hot and has the least effective irrigation system in the West Bank (Ali et al., 2016). As a result of the conflict, Palestinian communities lack needed infrastructure for date farmers, including storage and refrigeration (Ali et al., 2016).

Climate, Water, and Energy in Auja

The Jordan Valley is arid, with rainfall under 300 mm in the north and 150 mm in the south each year (PWEG, 2015). Rainfall has decreased in Israel and Palestine in recent years. In the Jordan Valley, rainfall has declined from 1,350 million cubic meters (MCM) in 1998 to 1,175 MCM in 2014 (Ali et al., 2016). The region's climate, ranging from 12°C in March to near 50°C from July to October, provides farmers in the Jordan Valley near Jericho, including Auja, with a comparative advantage in Medjool date production (PWEG, 2015). Dates thrive in Auja's hot, dry region and mild winters, although they require large amounts of water for irrigation, ranging from 300 L to 700 L daily (Ali et al., 2016). Furthermore, they are tolerant of high levels of salt, alkaline, and pH, but extremely saline water can limit their growth (Ali et al., 2016).

The West Bank lacks centralized water infrastructure, and consequently, Palestinians' water supply is fragmented (Ali et al., 2016). Agriculture in the West Bank receives over 60% of the water available to Palestinians and comes from private wells and springs (PWEG, 2015). Agriculture relies on the Eastern Mountain Aquifer, whose water is accessed through wells and streams. The Eastern Basin produces 1.81 MCM for non-agricultural purposes and 24.19 for agriculture (totaling 26.0 MCM) for the Jericho and Al-Aghwar regions (PWA, 2012).

The Eastern Mountain Aquifer is a source of political tension because nearly 80% of the aquifer's annual recharge is from precipitation in the West Bank (Ali et al., 2016). The aquifer feeds into the Wadi Auja stream, with a flow of 9 MCM of water per year (Ali et al., 2016). Like other springs in the Jordan Valley, the Wadi Auja spring has deteriorated both in quantity and quality due to insufficient rainfall along with over-extraction by the Israeli Mekorot Company, the five nearby Israeli wells and settlements, and Palestinians who are prohibited from constructing new wells in the region (Ali et al., 2016; PWEG). When the spring is dry, (much of the year) farmers pump water from wells to irrigate (PWEG, 2015).

Auja is connected to Mekorot's water network, which supplies Auja's drinking water

(PWEG, 2015). Because Palestinians do not have access to surface water, groundwater supplies more than 90% of their water supply (PWEG, 2015). Eight private wells supplement the irrigation water in the area, but five Israeli wells compete for the freshwater resources to supply nearby Israeli settlements. (Ali et al., 2016).

A partnership of 25 to 30 Auja date farmers owns a self-registered well (private pump), which uses electricity from the grid to pump water from the Eastern Mountain Aquifer. The pump is 100 meters deep, and its capacity is 50 m^3/hr. The pump operates 24 hours/day for nine months. For three months –late winter to early spring –the farmers use the replenished Wadi Auja spring.

Approximately 70% of the houses in Auja receive electricity from the public electricity network run by the Jerusalem Electricity Company (PWEG, 2015). Since the farming partnership owns the well, they pay for the cost of pumping. The electricity bill is high because the pump operates 24 hours/day for the majority of the year and irrigates a large amount of land. A pre-feasibility study conducted by the Palestinian Wastewater Engineers Group (PWEG) in 2015 revealed that high energy costs and electricity costs for pumping groundwater, as well as the unreliable power supply are significant issues that date farmers face.

The Project

Build Israel Palestine (BIP) contracted the Arava Institute for Environmental Studies (AIES) to implement a project in Auja that supports “water and agriculture related projects to improve the quality of life for people in Israel and the Palestinian Territories.” BIP provides the opportunity for Jews and Muslims in the United States to build cooperation through funding such projects in order to address the lack of joint Jewish-Muslim funded projects (Build Israel Palestine, 2015). BIP provided $100,000 to finance the project. AIES then contracted PWEG to conduct a pre-feasibility assessment of the stakeholder community to determine its needs.

To lower the costs for pumping groundwater and establish a more stable power supply, the project installed a 25 KW Photovoltaic (PV) system and connected the system to the farmers’ water pump. The goal was to reduce the electricity from the Israeli Electric Company (IEC) by installing a more stable, cheaper energy source (Ali et al., 2016). Two farmers suggested solar panels as a solution for reducing energy costs. The solar energy grid offsets the total electricity consumption and cost by 32%, meaning that 32% of the electricity used for pumping comes from the PV system while the other 68% comes from the grid.

Methodology

In Auja, a system-based framework and community appraisal was first developed through understanding the synergies between the WELF resources, evaluating the available WELF resource insecurities, and analyzing community needs through stakeholder mapping and a stakeholder needs assessment. Justification for technological solutions and impacts on the community were analyzed by comparing existing energy costs from the grid and potential savings of the proposed solar PV system. Finally, capacity building for sustainable management of technology and natural resources was initiated through the engagement of the private sector, establishment of a contractual relationship with the farmers, and lastly through workshops for the farmers to develop improved farming skills.

Theme 1. Baseline Data and System Modeling of the WELF Nexus in Communities

System-Based Framework for WELF Nexus

Date farming in Auja is part of the WELF nexus in the following ways: "...date production relies on water for growing date palm crops and washing the picked dates" (Ali et al., 2016). According to Ismail et al. (2013), "The central well that supplies the majority of water for agriculture in Al'Auja formerly relied on energy from the power grid that came from the IEC, which supplies 80% of the energy to the West Bank. Energy from the IEC has been reported to be both expensive and unreliable" (as cited in Ali et al., 2016).

AIES and PWEG addressed date farmers' greatest needs in relation to water resources, electricity costs, and agricultural capacities. Since the farmers own the well and the land on which it is located, they pay for their water through pumping. The cost for pumping is therefore determined by their electricity bills. To account for this, AIES utilized a nexus approach to respond to the issue of water usage for agriculture and food production by means of the energy sector.

Community Appraisal Methodology

The project began with a design-driven "top-down" approach, where experts from AIES and PWEG drove the project and worked with the agricultural community on the feasibility assessment and scoping the situation and issues (David, 2015b). After analysis, AIES and PWEG conducted stakeholder mapping and adopted aspects of a bottom-up approach and participatory management. They engaged the stakeholders – the Date Farmers Cooperative – through a survey and interviews to cooperatively decide on the project intervention. The project focused on having an open and inclusive process, early participation to increase support for the project, and capacity building to ensure long-term sustainability (David, 2015b). The ultimate goal of the project was for the farmers' partnership to "develop a sense of ownership in their projects to become more self-sufficient and less dependent on PWEG and AIES in the long run" (David, 2015b).

Following stakeholder mapping was a stakeholder needs assessment. The methodology used relied on local community involvement. AIES and PWEG interviewed nine farmers in the partnership of 25-30 farmers that owns the well and finances its operation and maintenance. They used a questionnaire to assess their needs. The questions addressed date farming issues, including water quality and quantity, energy demand, harvesting, storage and post-harvest, and marketing. The farmers were asked to rank the different issues they are facing.

The primary concern indicated by the survey and interviews was high-energy costs for water pumping, refrigeration, and lighting (PWEG). 67% of the farmers identified high energy costs as a "very important problem," 22% indicated they were an "important problem," and 11% stated that energy costs were not a problem (David, 2015a). In addition to high energy costs, one farmer stated that the power supply was also weak. He explained that the weak power supply was a result of the high energy costs; the high electricity cost for pumping meant that farmers did not pay their bills. As a result, the electricity company failed to supply a sufficient amount of electricity. (David, 2015a).

Theme 2. Monitoring impacts of new WELF Nexus Technologies in Communities

The Date Farmers Cooperative's large pump is expensive because it operates 24 hours/day and irrigates a large amount of land (42 hectares), for date production. Solar energy proved a viable solution for offsetting the high costs of electricity for pumping because of the region's solar potential. Palestine's "daily average of solar radiation intensity on horizontal surface is 5.4 kWh/m^2" and Auja in particular has "high solar energy potential and low wind energy potential" (PWEG, 2015).

As illustrated in Table 3, the price of the energy that comes from the Solar PV system is less expensive than from the electric company. These calculations are based on the assumption that there are six hours of peak solar radiation. The electricity from the grid costs $0.14USD/kWh/month. The installed Solar PV system costs $1.45 USD/watt installed, which equates to $0.033 USD/kWh/month. The return on investment does not account for interest rates, and the calculations do not include land or maintenance costs of the 20-year lifespan of the project.

However, the electricity cost after installation of the Solar PV system is $630 USD cheaper each month, a 32% savings. Furthermore, farmers rely on spring flow for irrigation rather than electricity for three to four months, so they gain additional income from the electricity credits they accumulate during these months (Ali et al., 2016). The savings in electricity costs demonstrate the success of addressing the water issues through the energy sector.

Item	Unit	Value
Required budget	USD	36,000
Price of solar PV (unit cost in watts)	USD/Watt	1.44
Price of electricity from the grid	USD/kWh	0.14
Monthly electric consumption for the pump	kWh/month	14,000
Electricity cost per month from the grid	USD/kWh/month	1,960
Size of solar PV system to be installed based on current consumption	kW	25
Solar PV potential electricity production (6 hours peak operation)	kWh/month	4,500
Electricity cost from the grid after installation of solar PV	USD/month	1330
Savings in electricity costs	**USD/month**	**630**
Percent savings	**%**	**32%**
Payback time	**Years**	**4.8**

Table 3: The financial analysis of a solar water pumping system

Theme 3. WELF Nexus Education, Training, and Community

The first step to develop the date farmers' capacity to improve yields and sustainably manage their WELF resources over the long term was to engage the private sector. In Auja, the date farmers belonged to the partnership through which they own their own agricultural land and water pump. Engagement of this partnership in the private sector allowed AIES to streamline the process of addressing the farmers' energy needs as well as build trust and cooperation between the date farmers, AIES and PWEG (Ali et al., 2016).

Another important component of the project's long-term sustainability was the relationship established between AIES and the Date Farmers' Cooperative. AIES developed a contractual relationship with the partnership, rather than a donor-beneficiary relationship. The contract between AIES and the Date Farmers' Cooperative, (Table 4), required AIES to invest $36,000 to build the Solar PV System, and the Date Farmers' Cooperative to provide $5,000 for the land, fencing, security, and pumphouse. This relationship established accountability and cooperation between AIES and the Date Farmers' Cooperative. It also ensured the project's long-term sustainability because it required the community to invest in the project in order for it to be successfully implemented. Because the Date Farmers' Cooperative invested in the project and it is not a donor-beneficiary relationship, the partnership earns the $630 USD/month in savings from their reduced energy costs.

Finally, to build the farmers' knowledge and capacity to improve their yields and effectively and sustainably manage their farms in the future, AIES hosted a workshop in March 2016 for the farmers involved in the partnership. The workshop included a tour of the AIES experimental orchards to learn about dry land agriculture, site visits to Kibbutz Grofit to learn about plant protection, the Research and Development Center located in the Central Arava and a date packing house. Additionally, lectures were given on engaging young farmers in dry land agriculture in the Southern Arava, biology of date trees, date farm management, and the history of transboundary date cooperation between Israel and Jordan.

Conclusion

The WELF nexus approach illustrates the synergies between natural resource systems and increases understanding how these transboundary systems can be sustainably managed. The Auja case study illustrates AIES' WELF nexus approach and facilitation of transboundary cooperation to address geopolitical challenges to environmental resource security and the importance of building stakeholder capacity to ensure long-term project sustainability. AIES continues to develop this WELF nexus approach by collaborating with American universities to implement the nexus framework, engagement with communities, and development of nexus technologies on a wider scale in Israeli, Jordanian, and Palestinian communities. The long-term objective of this transboundary nexus approach is to promote environmental peace building in this region. This nexus approach creates feasible and sustainable technological solutions at the community level in response to natural and geopolitical challenges to WELF resources.

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