Chapter

Transformation Action to Combat Desertification: A Direct Carbon Saving Mechanism in South Syria for Post-Conflict Management

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Abstract

Climate change has been visible through observed deterioration in the environment. Despite mitigation policies, greenhouse gas emissions (GHG) have increased over the last decade. Undeniably, war and conflict have the potential to further exacerbate inequalities and put major stress on meeting the sustainable development goals (SDGs). Despite the 10 year civil war in Syria, carbon emissions have declined by 1.5 percent since 2015 due to the economic slowdown, resulting in approximately 13 million Syrians in need of humanitarian assistance. As a consequence of the protracted crisis, families have suffered significant losses of assets and income generation opportunities, in both rural and urban areas, which has increased the vulnerability of the land, fostered illegal over-pumping of irrigation water. Investing in renewable energy, such as installing solar panels to pump water for irrigation, or operating medium-small factories, can help community resilience in response to climate change. The research investigated humanitarian initiatives on solar panels targeted at households and small/medium industrial uses. It also addresses this intervention as an approach that might have potential for transnational water sharing for humanitarian, development, and peace nexus. This process helps in laying the basis for climate change resilience, and combatting land desertification as part of a humanitarian, development and peace nexus.

Keywords: resilience, carbon trade, humanitarian, nexus, post-conflict

1. Introduction

Countries of the Middle East and North Africa (MENA Region) face major challenges in terms of food supply and food security. High dependency on food imports combined with ongoing conflicts and reoccurring climate shocks make the region particularly vulnerable to food crises. Among the 10 countries with the most people affected by food insecurity (IPC/CH Phase 3 or above), three are located in the Middle East including Yemen, Afghanistan, and Syria [1]. In Syria, approximately 9.3 million people were food insecure and needed food, humanitarian, and livelihood assistance between October and December 2020 [1].

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1.1 Syria double-headed problem: conflict and drought

Over the past decade, MENA countries have experienced severe land degradation which has led to reduced productivity, increased water scarcity, and loss of arable land [2].

The agriculture sector in South Syria relies heavily on irrigation, but ever since the start of the conflict the agricultural irrigation infrastructure has been severely impacted by the total damage to agricultural infrastructure and assets [19]. Farmers in the south governorates are still linked to their lands. To irrigate their lands, the wells used generators running on diesel to pump water, due to the depth of the ground water table. However, due to limited income, fuel, and power, many wells are non-operational as a result. Most of the KII respondents highlighted that solar-powered pumps should be installed in locations where wells are of an appropriate size and have a sufficient catchment area. Their main constrains from installing solar systems are that wells with a high volume of flow and outputs require large solar arrays to power water pumping. Arrays that are too large may be targeted for air strikes.

A country like Syria is facing a double-headed problem [3]: Syria is going into its 10th year of conflict while facing impacts of climate change, such as droughts. In 2006, at the beginning of the current drought in Syria, rainfall declined by 66 percent across the country [4]. As rainfall declined and temperatures rose, the rate of evaporation of groundwater also increased through the years, which has caused widespread evaporation to remarkably decrease the level of groundwater [5]. Much of the water used in Syria comes from the Euphrates River, which originates in Turkey; at the same time, Syria is sharing the Al-Yarmouk transboundary basin with Jordan.

The Syrian case illustrates the risk multiplier effect of climate change. Since the 2007/2008 agriculture season, around 75 percent of agriculture-dependent households suffered total crop failure, leading 1 million people into food insecurity and forcing many to join urban centers. The intense stress upon urban resources resulting from the increased demographic pressure is likely to have aggravated an already tense socioeconomic and political context [2]. In addition, the conflict has increased the cutting and burning of forests and caused agricultural land and rangelands pollution because of irregular oil refining activities. Between 2000 and 2015, forest land cover decreased by 8.04 percent; shrubs, grassland, sparsely, vegetated areas by 14.2 percent, and arable lands by 0.08 percent. On the other hand, artificial area land cover has increased by 50.10 percent, bare lands by 4.06 percent, and water bodies/ wetlands by 0.75 percent [6].

1.2 Strengthening preparedness for improving communities' resilience

The Sendai framework for Disateter Risk Reduction 2015-2030[1] prioritizes reducing social, economic, and environmental vulnerability, through improving early warning systems and strengthening preparedness for effective response, as a tool for enhancing disaster-resilient societies [7]. The impact of conflict in terms of weak governance and absence of governmental legislation and policies, will increase the risk of climate change, such as food insecurity and loss of livelihoods assists [8]. According to a CARE International livelihoods assessment report published in 2016, it was indicated that from the consequence of the protracted crisis in Syria, families have suffered from significant losses of assets and income generation opportunities,

[1] The Sendai Framework is the successor instrument to the Hyogo Frame for Action 2005- 2015. It ecognizes that the State has the primary role to reduce disaster risk but that responsibility should be shared with other stakeholders including local government, the private sector and other stakeholders.

in both rural and urban areas [9]. The losses in gross domestic product (GDP) in 2011 are four times more compared to 2010, which has increased vulnerability and poverty of the population across Syria accordingly [10].

Therefore, improving the resilience of Syrian communities, development and humanitarian actors should ensure having mutual benefits that are focused on improving the ability of the communities to anticipate, cope with, and recover from the double impact of climate change and war [11].

For example, due to electricity shortages, Syrians in the south governorates were forced to rely on diesel power generators to meet domestic, industrial, and agricultural needs. However, diesel is proving not to be the most stable source of energy, especially with its expensive cost, which impacted livelihood opportunities, and depleted communities' productive assets [12]. On the other hand, using diesel power as a source of fuel increases the emission of carbon dioxide "CO_2" in the atmosphere [13].

Therefore, shifting attention to the solar energy sector has potential for communities in South Syria to mitigate the impact of climate change and enhance their livelihoods resilience [14]. As for Jordan, this will provide it with more than enough energy to function, allowing for a decrease in dependency on the ever-shrinking water resources in the region [15].

The research was conducted in June 2018, prior to the conciliation agreement between the Syrian regime forces and opposition groups in the south. It aimed to investigate how the implementation of solar panel systems, as a source of renewable energy at the household level, or a small scale of enterprises, can increase the carbon saving for the direct measures of GHG emissions, caused by a specific activity [16]. This could lead to the strengthening communities' resilience. Accordingly, the research findings will discuss the importance of renewable energy for humanitarian livelihoods' resilience initiatives in South Syria. And lastly, the research will recommend the potential mechanisms that would empower communities, to participate more actively in community resilience.

1.3 Research objectives

The research assessed solar panel initiatives, implemented by humanitarian aids in South Syria, as a case study to highlight the importance of using renewable energy technologies for climate change mitigation and how such interventions could be articulated toward improving community resilience in South Syria. The research objectives are as follows: (i) to identify and critically review the importance of renewable energy resources for the humanitarian livelihood resilience initiatives in South Syria governorates; (ii) to infer the viability of using renewable energy (such as solar panels at a small scale of households and industrial uses) toward improving the communities' resilience in South Syria; (iii) in addition, to estimate the effectiveness of carbon trading in South Syria for post-conflict management, and climate change mitigation; and (iv) to propose potential mechanisms to empower communities in laying the basis for climate change mitigation and resilience.

1.4 Research questions

The research focuses on the following questions:

- What are the main challenges and opportunities to adopt renewable energy initiatives in the Syrian conflict context along with transboundary water resources management considerations?

- What percentage of households have benefitted from solar panel systems, reporting reduced reliance on negative coping strategies, and an improvement in their income in comparison with their results before using solar panel systems?

- What is the percentage of medium-small factories, which have benefitted from the solar panel system, reporting reduced electricity cost even under the impact of the crisis, compared with their results before using the solar panels?

- What is the reduction in CO_2 emitted as a result of households and medium-small factories, that have benefitted from solar panel system, compared to others still using fuel as a source of energy?

- How might CO_2 trading contribute to post-conflict management for Syrian communities?

1.5 Research methodology

The research used the remote management[2] modality (Cross- boarder humanitarian program) in collecting the data needed, local organizations and enumerators worked inside Syria during the reconciliation agreements between the opposition groups and the Syrian army on 2018. Humanitarian agencies that worked to support the most vulnerable people in need in South Syria. The analysis of data for the survey was carried out in two stages—univariate and bivariate analyses in order to assess the single variables, and the relation between two variables for the research demographic and objectives. At the univariate stage of the analysis, variations within demographic variables were explored, to support the analysis of carbon footprint for each installed system at 13 households and six rehabilitated factories, in terms of using renewable energy source, such as the solar panel to mitigate climate change.

The second stage of the analysis was the bivariate level, where relationships between sociodemographic characteristics and the resilience indicators were assessed, for the targeted household and factories, with main consideration to the gender-disaggregated data.

A flexible approach to the research was adopted, due to the security context in Syria as well as the remote management of this research. A purposive sampling approach was used, in order to ensure the survey finding is reflecting the realities faced by whom is using the solar panels for shallow aquifer wells, rather than the population at large [17]. The research used the sample as a case study for potential investigation, and due to the challenges that faced the data collection, more focus discussions were conducted in small focus groups with the enumerators, remotely for further understanding.

1.6 Research sample demography

The research is based on a sample of 30 households (HHs) using solar panels and 21 households who did not install any. Of the HHs studied, 23.5 percent of HH heads are female and 76.5 percent are males. Women representing 17% of the total factories'

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[2] "Remote Management" refers to a set of adapted procedures put in place because the access to field offices and/or field sites is limited – for security, practical or logistical reasons. International Rescue Committee's Global Remote Management Guidelines 2016.

owners. With regard to the level of education, 32 percent of HHs had a high level of education, while 69.2 percent only attained a secondary level of education. Among the female respondents, 33.3 percent had no education, and a total of 16.7 percent of households that were headed by women completed a primary level of education.

The average household (HH) income was 345,782 SYP per month (~ 1,609.00 USD). Informal work, such as farming activities or cash for work, accounted for 80.4 percent of household's income. About 13.7 percent of woman-headed households' earned money from home production and handicrafts, while 5.9 percent of the total sample used their savings. As shown in **Figure 1**, the factories' average monthly production quantity increased after installing the solar panels (2016-2018). Dairy products, cheese products, and dry dairy represented 72.6, 12.2, and 5.7 percent of the production, respectively.

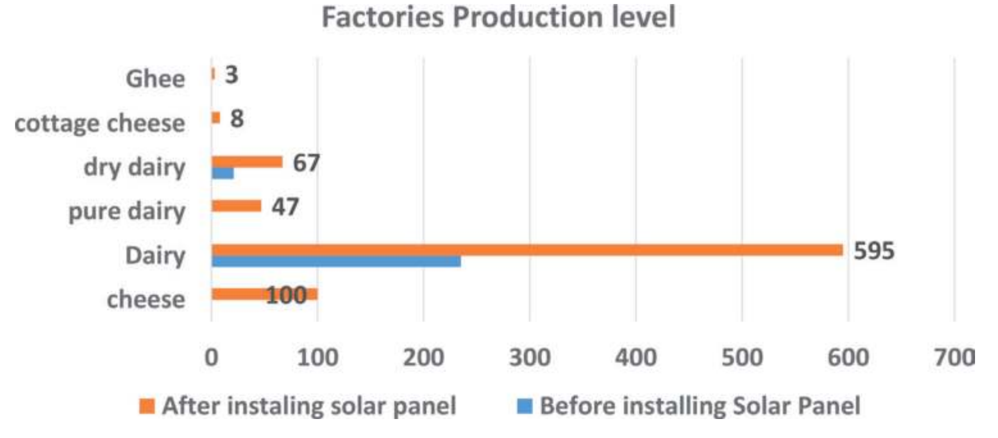

Figure 1.
Highlights of the production before and after installing solar panels for factories' operation.

2. Analysis and results

2.1 Importance of renewable energy resources for humanitarian-livelihoods initiative in South Syria

The primary data research was planned to investigate the impact of using renewable energy as one of humanitarian livelihood initiatives. Consequently, a number of questions were asked in order to identify the HHs' coping strategies to secure food and to what extent they used these strategies. According to the vulnerability analysis mapping unit at WFP (VAM), the Coping Strategy Index (CSI) is often used as a proxy indicator of household food insecurity. It can highlight the HH consumption behaviors, in terms of quantity and sufficiency of food, and can measure the adjustment the HH make in livelihood options and assets [18].

The first group consisted of those who installed solar panels—they showed positive behavior in their coping strategies, the second group consisted of HHs without solar panels who are still using the electrical pump for water pumping—they applied low coping strategy index.

Further disaggregated analysis of HH savings showed that the average saving for male respondents between those who installed solar panels and those who did not is 259,226 SYP (12,017 USD), with 25.8 percent as a positive increase of savings between the ones with solar panels and the ones without. Female respondents showed better improvement than male respondent: 169,444 SYP (788.7 USD) with a 40.4 percent improvement for families with solar panels. Women confirmed that last season, they used productions of their small yards to feed their children and to preserve food for winter.

Regarding the factories' owners, it is conveyed in the analysis that they showed positive behavior in their coping strategy after using renewable energy as source of electrical supply for their small factories, with 29.49 percent as mild the Reduced Coping Strategies Index (rCSi)[3] and 16.7 percent as low rCSi. The only female owner showed a sufficient ability in reducing the coping strategy index, which is a good indication that a woman can support her family financially and adapt to different situation.

2.2 Viability of using solar panels as the electric supply for the pumping irrigation of water at a household level in South Syria

The escalating of the conflict in South Syria increased food insecurity, as communities depended on agricultural and livestock activities for their livelihoods. The cost of food, fuel and transportation are usually linked with agricultural seasons [19]. The analysis below highlights the importance of using solar panels—as a source of electrical supply- to pump water to households to irrigate their small yards, which can be used for daily food supplies.

The analysis focused on the cost of HH electricity before and after installing the solar panels (2016-2018), and then linked these costs with the impact on HH incomes. The analysis was done by using the Statistical Package for the Social Science (SPSS) to extract arithmetic and standard deviations for the 30 HH samples on electrical consumption and income changes, before and after installing solar panels. About 100 percent of the sample showed that the fuel cost decreased in summer and winter after installing the solar panels. The electricity bill had an almost 1.5 percent difference between the before and after periods of solar panel installations.

Similarly, the decrease in fuel consumption and cost to irrigate the small yards reflected positively on the HH income. All sampled HHs decreased their fuel consumption in summer and winter compared to their annual income expenses, and mainly from the source of seasonal heating activities. This explains the decrease of negative coping mechanisms which were adopted before installing the system. In contrast, female-headed household showed interest in their responding to the use of solar panels, but at the same time, worried about using them. Most of the women's concerns were on the solar panel's maintenance and sustainability, as they have to support their families' needs and income within limited time; the security issue is adding a critical burden on their mobility and safety. Furthermore, 80 percent of women interviewed that they need ongoing training and follow-up during early summers and winters, to make sure that they fully understood how to deal with the panels' maintenance, to ensure their productivity.

2.3 Viability of using solar panel as the electric supply for the industrial activities in South Syria

Conflict and war can weaken the market system. However, improving the medium-small enterprises can support local market adaptability, so that communities can secure their food needs [20].

[3] The Coping Strategies Index (CSI) measures behavior, in particular the things people do when they cannot access enough food, which is converted into a single index. ***(IPCC Glossary)***

Focus group discussions, with small and medium food factory owners in South Syria, indicated that high fuel and unavailability of skilled labor are the main obstacles to market participation under the recent conflict. 83 percent of the interviewed owners had confirmed the mentioned obstacles. The research assumes that applying the use of renewable energy as a source of electricity can improve the local Small and Medium Enterprises (SMEs) productivity and can improve market system overtime of resilience. The analysis showed that the average income increased for the factories' owners. Similarly, for the factories' maximum productivity level, the average significantly increased by 31 percent. On the other hand, the working hours for factories, rehabilitated by using solar panels, were reduced by 37 percent in average. This finding highlighted the assumptions of the research, regarding the link of using renewable energy to improve the income resilience of the affected communities in South Syria.

2.4 Estimated carbon reduction to mitigate the climate change, if solar panels were used across the targeted areas

Using solar panels will reduce carbon emissions [21]. The research used the survey data and the key informant interviews (KII), to calculate the amount of kilowatts of energy per month/ year that solar panels produce, in order to estimate the carbon footprints—if adapted as a source of renewable energy, by small factories and irrigated wells at the household level.

However, the analysis of the full life cycle assessment (LCA) for solar panels, including manufacturing, transportation, installation, and so on, must be considered to estimate the carbon emissions [22]. Additionally, considering the wastes produced by solar panels—especially its manufacturing materials—will help refine the calculation to estimate the clear reduction of carbon from the installed solar panels [23].

Presently, this research used a simple theory of calculation, based on the estimation of the energy produced by installing solar panels, multiplied by the remaining households with irrigation wells (50–200 m) and small factories/ workshops in South Syrian governorates, taking the estimated percentage for solar panel production into consideration.

2.4.1 Amount of energy produced at household level if installing solar panel for irrigation wells

The energy produced by solar panels depends on the location and shading, along with operational hours per day. The energy produced differs between summer and winter, based on sun exposure [24]. According to the Syria National Centre for Energy Research, the radiance period is 312 days/year. However, the USAID water resource assessment in 2016—conducted in South Syria—indicated that Syrians are relying on diesel power generators to meet domestic, industrial, and agricultural needs [25], but diesel is not the most stable source of energy. It is expensive which depletes communities' assets [26].

Generally, the calculation of the amount of energy produced in kilowatt hour (kWh) is done by a simple equation—of multiplying the watts of solar panel by the number of operational hours per day, with consideration of the 312 radiation days per year for Syria, to calculate the energy produced in 1 year [27].

The calculations for 30 HHs indicated that the average energy produced by households to pump irrigated water from wells—with depth between 50 and 200 m to support their small yard for basic food needs—is **5002.16 Kwh/year.**

2.4.2 Amount of energy produced if installing solar panel at medium-small factories

The amount of solar energy used for operating the electricity of factories' sample is calculated here by converting Amber hours to Watt hours, and out of the electrical grid.

$$\text{Watt hours} = Amp \times \text{Battery Voltage}$$

Then, the same equation of calculating the energy—produced by multiplying it with operational hours per day—was used,

$$\text{Energy produced } per \text{ year} = (\text{Battery power} \times \text{operation hours}) \times 312 \text{ days of radiation } per \text{ year}$$

The calculations for 6 factories indicated that the average energy produced is almost **3876.6 Kwh/year.**

2.4.3 Calculation of estimated carbon reduction at household level and small factories

Assuming that the recent average value of carbon emission for Syria—which was only available up to 2014 on the World Bank data system—is 1.6 tonnes of CO_2 with 312 days of radiation per year. The 1.6 tonnes of CO_2 were also adopted in 2016 for the world development indicators database; in this section, the calculation of carbon footprint will be using the IBRD–IAA [28]:

$$\text{Energy produced } per \text{ year} \times 1.6 \text{ tonnes of } CO_2$$

The calculation does not take into account the CO_2 from other parts of the solar panel life cycle, such as the manufacturing process or the transportation. The simple theory of CO_2 reduction calculation showed that the total of 240,103.47 tonnes of CO_2 can be reduced from operating solar panel at HH irrigation wells, and 37,215,360 tonnes of CO_2 by factories that were rehabilitated by using solar panel, as a source of electrical energy, out of electrical grid and the potential carbon.

2.4.4 Calculation of estimated carbon reduction if solar panels were installed at household irrigation wells, with 50–200 m small factories for electricity purposes in South Syria

Primary data mapping conducted for South Syria—which targeted wells—showed that in total, there were 69 wells with almost the same depth and capacity specifications. Thirty out of 69 wells were rehabilitated by solar panels; the calculation assumed that the average carbon reduction of the 30 wells can give an overall indication of how much—in total—the carbon reduction in South Syria governorates per year will be and prevented pollution that occurs when using diesel.

A total of **552,238.05** tonnes of CO_2 could be reduced by the rehabilitation of 69 wells in South Syrian governorates.

Correspondingly, a total of **291,520,320** tonnes can be reduced by the rehabilitation of 47 factories/ small workshops that were potentially mapped in South Syrian governorates in May 2018.

This means that there is an obvious carbon reduction from such solar panel initiatives with a total of **843,758.37** tonnes of CO_2, from both irrigation wells and small factories, in two of the South Syrian governorates. Particularly, the government of Syria can save up to **843,758.37** tonnes of carbon per radiation year (312 days) and can have opportunity to trade this carbon market globally.

Currently, this amount of carbon reduction does not take into account the life cycle cost of solar panel, as mentioned in Section 2.4.3. However, it must be noted that this approximation is speculative and needs thorough calculations of the energy inputs and emission outputs, throughout the whole production chain of solar panels, including its transportation and installation process.

Arguably, most research harmonizes the life cycle GHG emission from PV solar panels materials, in order to determine the average emission intensity. Production stage is significantly contributing with 30 percent of the total of GHG emission [22]. Hence, some research did not take into account the end cycle—such as recycling the system, which is contributing with 4 percent of the total GHG emission [29].

According to the report published by the World Nuclear Association in 2011 [30]—on the Comparison of Lifecycle greenhouse gas emissions of various electricity generation sources, the range between different studies for solar panels is 85 tonnes CO2e/Kwh, which specified that the manufacturing process is becoming more efficient compared to other sources of renewable energy.

Therefore, if the approximate 30 percent of the total carbon from solar panel lifecycle is considered, then it should be deducted from the first year of installation. Finally, the actual carbon saved from the solar panel initiative in South Syria will be calculated as below:

$$834{,}758.37 \times 30\,\text{percent} = 253{,}127.51\ \text{tonnes of}\ CO_2$$

$$\text{Carbon saving for year is} = 834{,}758.37 - 253{,}127.51$$

Based on the result, this initiative will save a total of **590,630.86 tonnes of CO_2**, which can be traded in year one. Starting from year 2, it will approximately be a total of **834,758.37 tonnes of CO_2**.

2.5 Potential impacts on transboundary water resources between Jordan and Syria

Both Syria and Jordan rely on different water sources to generate renewable energy. Precisely, the Yarmouk river basin is shared by both Jordan and Syria, and both of them receive energy from the Unity Dam [31]. With the decrease in precipitation and overall water levels, the dependency on hydroelectricity needs to shifted [32]. According to the Millennium Development Goals Report in 2014, water is becoming a scarcer resource in the region and is overall becoming a less reliable resource. This means that there will be a decrease in hydroelectricity coming from the dam, along with other water resources in the region [5]. This necessitates the need to find a new power resource [33].

Some of the main tools developed for this research are the focus group discussion (FGD) and the key informant interviews (KIIs). Due to the limitation and constrains during the data collection from South governorates in Syria, one FGD was conducted with the farmers group, and two KIIs were conducted with water engineers—who used to support the WASH[4] sector's actors in South Syrian governorates. On the other side of the Yarmouk basin—in Jordan, four KIIs were

[4] Water, Sanitation and Hygiene is the focus of the first two targets of the Sustainable Development Goal 6 – targets 6.1 and 6.2 aim at equitable and accessible water and sanitation for all. "Access to WASH" includes safe water, adequate sanitation and hygiene education.

conducted with related decision makers on water basin management, as well as wash cluster members, who used to support the people in need and the displaced people in South Syria with WASH assistance, such as sanitation, hygiene, and water access.

KIIs respondents mentioned that the wash assistance was focused on providing solar panels for households or villages, in order to support their access to water. Therefore, most actors need to consider the safety issues associated with arrays, and also need to have a clear discussion with the targeted communities before the confirmation of solar sites, and management of their operational modalities. Involving them will ensure the ownership, thereby, decreasing the likelihood of damage or theft of installation.

Most respondents from FGD and KIIs complained about the cost recovery practice that was introduced by different WASH actors. They complained about the inability of beneficiaries to afford the cost of the system's maintenance, due to their low land productivity, and the malfunction of surrounding market. However, they were interested in having cash vouchers or start-up kits to support the operation and maintenance of the system in the first 3 months, along with intensive capacity building on system operation and maintenance so that the communities will manage to run it efficiency and effectively.

Interestingly, all respondents believe that using solar panels is the most viable and appropriate solution for their water pumping. Respondents believe that using this system at the level of school and health care facilities will minimize electricity shortages. Hence, ensuring the working hours for these services are sufficiently increased, to support their communities. Unfortunately, although the drought seasons were mentioned by the respondents, no one linked using the solar panels of the potential mitigation activity to the impact of climate change on their country; this emphasizes the need to raise the communities' awareness on the biggest threat on their livelihoods assets, which is climate change. Moreover, there is an urgent need to bridge the gap between humanitarian aids - resilience and development activities to plan, monitor and track the different interventions to design and DO NO HARM to social and environmental interventions.

In Jordan, the other side of the Yarmouk basin has a different perspective on using the renewable energy technologies for communities that live in the basin areas. Jordan and Syria have a long history of nonsatisfaction on several treaties over the years, prior to the conflict in Syria. Both countries are facing drought, where the average precipitation dropped significantly [34, 35].

The main concern of the Ministry of Water and Irrigation is losing control of the measurement of the water table and flow, which will occur if such solar panel system becomes widely used in Syria. The ministry considered the electricity bill as the only enforcement measure that can control the illegal and over pumping of Yarmouk ground water. As a result, the Jordanian enforce limitations on trade the solar panels' items, with aims to control the flow level of water in their catchment areas as much as possible.

Additionally, the Ministry of Agriculture restricted the trade of seeds or seedlings for two reasons: The first is to avoid deficiency of native seeds in Jordan, such as wheat and barley, that already differ from the ones used to plant in Syria. The second reason is to avoid planting around drainage area, thus avoiding the low water table, changes in the land use in catchment areas, and water allocations to Jordan.

What also contributed to this problem was the agricultural lands inside of Syria, which led to decreases in the level of water, and increases in the level of salt by digging local wells [36]. This calls for both governments in Syria and Jordan to approach a more diplomatic way of ensuring the effective transboundary water management, by addressing the political and hydrological conditions of the basin [37].

WASH actors are also facing challenges in managing the water resources and needs in south governorates of Syria. The Syrian Human Needs Overview 2017 [26] identifies 14.9 million people in urgent need of support with WASH, in addition to the extensive needs across the sub-sectors of water in order to move toward increasing the resilience of affected population and ensure the sustainable access to safe water.

The main challenges facing the WASH actors are the inefficiency of piped water networks, which have been damaged, destroyed, or non-operational due to the lack of power and/or fuel. The 2017 WASH assessment conducted by the cluster members highlighted that the water networks currently operate at less than 20 percent of its real capacity. This added an extra burden on communities, mainly women and girls, due to the spending of more time in collecting and saving water during the day.

The Syrian communities recognize the importance of water resources and its safety; the cost of the fuel and irrigation systems is very high compared to the average monthly income. Most of the community members, mainly the medium or small businesses, cannot afford the high cost of fuel, which led to the non-functional Syrian market.

In 2018, the WASH and food Security clusters proposed multiple responses to provide multi-sectorial assistance to vulnerable people. The clusters' members highlighted that farmers and herders started complaining about the drought seasons—mainly the limited grazing lands—due to the highly displaced movement in south Syria governorates, and also the conflict which changed the access to land and water. This indicates that multi-clusters must address the potential impact of climate change, and include the environmental measures in their mandate and interventions, to ensure food security and reduce negative coping strategies for the affected communities in South Syria.

3. Research discussion

Renewable energy advanced rapidly in 2017 with the highest growth rate according to the Global Energy and CO_2 status report [38]. Solar panel technology is one of the green technologies that prove its efficiency among other technologies, such as wind, hydroelectric, nuclear, and biomass [30]. Although the improvement in global efficiency decreased to 1.7 percent in 2017 compared to 2.0 percent in 2016, the Arab countries recorded a 55 percent improvement in energy efficiency, whereas it was 35 percent in 2015 [39]. However, the demand of electricity and transportation is increasing due to higher temperatures [40], which will burden the energy efficiency performance especially with the conflict and political instability in the region [41].

In comparison, 99 percent of the total installed capacity in Yemen are from fossil fuels, according to the Country Profile Energy Efficiency in Yemen 2012. About 40 percent of the total population still remains without electricity [42]. About 2 percent of the total installed energy capacity in Yemen is from renewable energy, reflected in 22 Million Mt. of CO_2 emission from the consumption of energy [14]. This is less than in Iraq, of 137 Million Mt. of CO_2 emission—from consumption of energy—compared to 87.3 percent of total installed energy capacity, which are from fossil fuels and 0 percent from renewable energy.

Prior to the conflict in Syria, two renewable energy master plans were developed in 2002 covered 10 years aimed at maximizing the use of renewable energy to increase the contribution of the in grid connected electricity generated, in order to reduce gas consumption [43]. The 2010–2030 scenarios of the Syrian master plans for Energy Efficiency and Renewable Energy projects prioritized solar energy for replacing fossil fuel in households, industry, and service sectors; it showed that 22 Mtoe[5] of conventional fuels will be substituted by using renewable energy. Therefore, 97 Mtoe of total energy will be saved.

However, due to the drop of the energy intensities in 2009, instability, and the lack of political commitment, the master plans failed to be implemented [44]. In view of these proposed scenarios, the research argument reveals that solar energy can be a smart source of electricity and support the country's master plan to increase the energy demand from renewable energy from 0 to 4.31 percent by 2030 [43].

Numerical validation of greenhouse gas emitted from using the renewable energy at household's level or small scale of enterprises to mitigate the climate change impact and can lead to strengthen communities' resilience need to be calculated. Evidently, the simplified approach that was adopted to calculate the data available presented that more than 12 percent adapted sufficient coping mechanisms, between families who installed solar panel and families that did not. In addition, between 25.8 –and 40.4 percent improved their savings. As for factories' owners, approximately 53 percent were able to profit from installing solar panel systems to operate their factories.

Monetarily, the average August 2018 carbon price, according to the carbon emission future price (*https://www.investing.com/commodities/carbon-emissions*), is approximately 19.30USD per 1 tonne of CO_2. This means that the Syrian government can trade the carbon and get:

$$590{,}630.86 \text{ tonnes of } CO_2 \text{ X } 19.30\,USD = 11{,}399{,}175.5\,USD$$

$$\text{in year } one \text{ after deducting the life cycle } GHG \text{ emission}$$

$$\text{While the actual trading starting from year 2 will } be\ 16{,}284{,}536.54\,USD \text{ / year}$$

If the lifetime for the solar panels of 30 years is considered, this means that over the 30 years of horizon, the Syrian government can trade with a total of **472,251,559.59 USD** at country level from two south governorates, keeping in mind that the calculations were done after deducting the production cost of the solar panel for the first year.

Having the recent conflict in Syria, the demand and price of electricity doubled, and increased by five times for Industrial and commercial tariffs, during the conflict years between 2014 and 2017, according to the recent Global Energy and CO_2 status report. Presently, based on the analysis, it is projected that each household with an irrigated well that uses an average of 16.03 Kwh per day can trade money with **154,466.56 USD** annually as out grid source. Likewise, the factories with average of 12.425 Kwh per day can trade with roughly **119,709,408 USD** annually. Therefore, as the economic burdens deepen with the recent conflict in Syria, communities increasingly adopt negative coping mechanisms, which pose protection risks, such as child labor or early marriage [12].

Such initiative can support the communities' resilience capacity and reduce the negative coping mechanisms, which are shown for families who installed solar

[5] Millions of tonnes of oil equivalent.

panel systems. For example, The International Organization for Immigration in Yemen reduced 400 tonnes of carbon emissions every year, and saved 121,000USD as a result of using solar energy projects, other countries have installed solar energy projects to serve water scarcity, which are a result of internal and external conflicts. For instance, Iraq started to recover from war and is now operating its main streets by solar powered lamps—around six thousand solar lamps light up the street in Baghdad. Moreover, Iraq is looking to subsidize solar panels through carbon trading, but still needs to establish internal resolutions and laws to promote and allow the trading of carbon [45].

The recent studies done by Intelligence 2017 highlighted that due to the instability, the energy revenue declined in Syria leading to high fuel costs and fluctuation in Syrian currency [46]. The primary data demonstrated such impacts on the communities' coping strategy, electricity costs, and industrial activities, to support the currency in the market. The purposive sample showed insights on potential solutions to such declines. For instance, the productivity level of targeted rehabilitated factories increased by 37 percent, which ensured the availability of their products in the market. Communities living around these factories expressed their satisfaction on availability of items during the week, compared to the usual demand and increased number of displaced folks, from time to time during the recent conflict in the south governorates. In contrast, a total of 8878.76 Kwh/year out of electricity grid can be produced from a small sample of HH and factories, which was intended to be much more, if applied to the whole HHs and small factories or workshops in south governorates.

On the other hand, the changes at the political border level between Syria and Jordan showed the over abstraction variated on water-related records [47]. The two countries should review their agreements on including the impact of climate change on water flow, and to ensure the role and impact of communities' activities and behaviors on transboundary villages [48].

Interestingly, the effect of using renewable energy, such as solar panels at a small scale of households and factories, would have a remarkable impact on the national footprint, eventually mitigating the impact of climate change on the environment [49].

4. Conclusion and recommendations

With temperatures in drylands currently twice the global average, there is an urgent need for adaptation to mitigate climate change. The level of downside climate impacts is directly correlated with the level of development. Climate change is expected to have significant impacts on extreme poverty by 2030, affecting communities already coping with livelihood limitations and inequalities, resulting in increased resource competition and conflict.

The recent 2017 Arab climate change assessment report underlined the droughts in Syria of 1998–2000 and 2007–2010, impacting substantial economic losses and the displacement of more than 1 million people [40]. Therefore, seeking alternative sources of subsistence and income, and building the resilience of the communities will enable them to adapt to the impact of climate change, and to deal with shocks, such as security conflicts, to improve their livelihoods opportunities and assists [9].

Despite the challenges that faced this research, the recommendations have been structured into the level of transboundary management, national efforts, and communities' behaviors and equity. The interaction of these levels will contribute to avoid further degradation and help in post-conflict recovery plans:

Complementary assessment of the transboundary water management for the Yarmouk basin is a must to improve the regional understanding of climate change impacts on transboundary water basins [40]. Particularly after 10 years of crisis and leakage of joint treaties between Jordan and Syria, so as to investigate on the way to optimize its infrastructure for saving energy costs and reduction in carbon emissions [37].

Initiating the joint projects between communities that live on the transboundary in Jordan and Syria, such as implementing joint projects to support the water demand and legal use according to international water law, which could promote peace building and hence effective climate change mitigation policies.

Bridging the gap between humanitarian aids and early recovery stages in Syria will support the communities' resilience and inclusiveness. Considering future projections of climatic impact on livelihoods assets, in terms of environmental resources, will foster the understanding of vulnerability and capacity to design DO NO HARM social and environmental interventions' components that deal with current and future risks to prevent food insecurity. It will encourage communities to reduce cutting the trees and using sustainable practices to avoid further land degradation.

Investment in renewable energy as a source of reducing vulnerability, and improving the local economy through supporting the renewable energy subsidies. This can be done by promoting the public and private cooperation, in order to decrease installation costs of solar panels. A country like Syria needs to re-build the trust between the government and communities, post 10 years of conflict; building such solar panel initiatives as proved in this case study can assist the country in entering the global carbon markets, and support its re-construction, respectively. Moreover, environmental agencies can help both Jordan and Syria to apply different schemes of payment of water ecosystem services "PES," which stand for incentives offered to stewards of ecosystem services [50] including public and private scheme that can be legally bound by a specific legal framework of transboundary basin.

Recognizing the link between climate change adaptation and mitigation under security conflict could entirely reduce the human impact on carbon emissions. During the conflict, prioritizing the climate change adaptation activities to build the communities' resilience will improve the country's mitigation targets in the long run. The case presented by this research showed the improvement in income and coping mechanisms for communities, which used solar panels to reduce fuel cost, to pump irrigation water and feed their families from planting small yards; this adaptation technique impacted positively on saving energy out of the electrical grid and reduced carbon emissions.

Ensuring gender equality and women economic empowerment could achieve resilient livelihoods. Dealing with women as "agents of change" [51] based on their skills, capacities, and opportunities to engage with such initiatives could strengthen their role in households and communities, in more economically productive parts, therefore, securing their food to absorb the shocks.

Improving the communities' adaptation of climate smart technologies could help in reducing CO_2 emissions. The recent publication by The Center for Behavior & the Environment [52] showed that dealing with solar energy resources can support a decrease of 24.6–40.3 GtCo2- eq in 2020–2030. This means that although in Syria the conflict increased the carbon pollutions [53], the government should focus on building the knowledge and skills for communities in adapting to climate smart technologies, to support achieving the primary renewable energy targets or updating the country's target.

Strengthening governance of the energy sector could support the government in identifying how much electricity can be generated to feed into the grid is thought to improve the policy with international practices, to support trading the carbon, thus using the revenue for country re-construction and resilience activities.

Approaching the post-conflict from the lens of complementarity between humanitarian and development activities presents a transforming action toward peace and turning environment into an asset for food security. Hence, there is an urgent need to promote innovative, integrated approaches, shift paradigms, and share the best practices to build back better and to reduce the impact of conflict on desertification.

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