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Middle East and North Africa

Refugee and Host Communities & Frontier Agriculture: Climate Smart and Water Saving Agriculture Technologies for Livelihoods

Unleashing Climate-Smart & Water-Saving Agriculture Technologies In Mena

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FRONTIER AGRICULTURE FOR IMPROVING REFUGEE LIVELIHOODS:

UNLEASHING CLIMATE-SMART & WATER-SAVING AGRICULTURE TECHNOLOGIES IN MENA

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Abbreviations

ARIJ	Applied Research Institute – Jerusalem
CARE	Cooperative for Assistance and Relief Everywhere
CSIS	Center for Strategic and International Studies
DWC	Deep Water Culture
EU	European Union
FAO	Food and Agriculture Organization
FGM	Female Genital Mutilation
GBV	Gender Based Violence
GDP	Gross Domestic Product
HH	Households
IDA18	International Development Association 18th Replenishment
ILO	International Labour Organization
JD	Jordanian Dinar
MENA	Middle East and North Africa
NFT	Nutrient Film Technique
OECD	Organisation for Economic Co-operation and Development
pH	Potential of Hydrogen
PA	Principal Applicant
PGHV-C	Welfare and Poverty Dataset
SNCs	Special Needs Codes
UN	United Nations
UNDP	United Nations Development Programme
UNHCR	United Nations High Commissioner for Refugees
UNICEF	United Nations Children's Fund
UNRWA	United Nations Relief and Works Agency
WB	World Bank
WFP	World Food Programme

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Executive Summary

ES 1.1. Frontier Agriculture as a solution to improve refugee livelihoods

ES.1. Many refugee and host populations are food insecure and poor. In Syria, the UNICEF screened 2.3 million children and pregnant and lactating women for acute malnutrition.[1] In Jordan, approximately half of the refugee households have reported reducing the quantity and quality of food and skipping meals.[2] In Lebanon, only 7 percent of refugees are living with acceptable levels of food security.[3]

ES.2. This report shows that frontier agriculture, which comprises climate-smart and water-saving agriculture technologies, such as hydroponics, can contribute to improve well-being, including nutritional status for farmers and groups of people that are less integrated into the labor market. In the Middle East and North Africa (MENA), this includes women, youth, and those who are forcibly displaced.

ES.3. Frontier agriculture can leverage scarce resources, such as water and arable land, and promote inclusive economic activities that increase access to nutritious food, improve livelihoods, create jobs, promote entrepreneurship, enhance skills, and build social cohesion. It can also assist with building communities and help recover from the loss of assets and from trauma of fleeing from conflicts.

ES.4. There is an urgency to engage with and support refugee livelihoods. Previous experiences suggest that small-scale hydroponic projects targeting vulnerable populations can be implemented rather quickly and produce meaningful results within a short timeframe.

ES 1.2. Unprecedented levels of forced displacement in the Middle East and North Africa

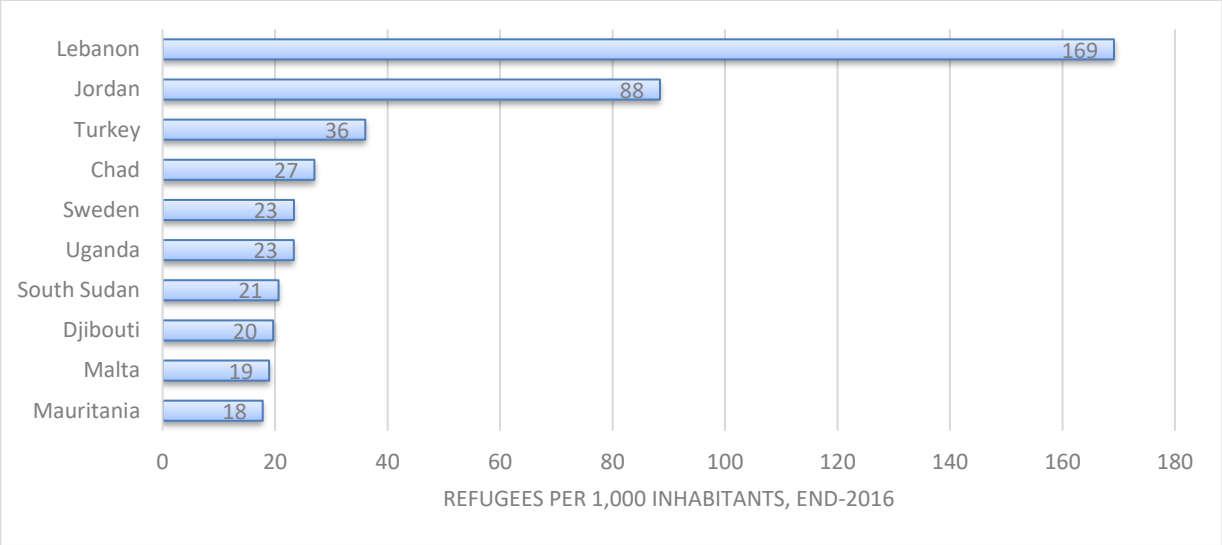
ES.5. As many as 65.6 million people worldwide were forcibly displaced at the end of 2016. UNHCR reports that approximately 18.2 million people, were living in refugee-like situations, out of which 12 million were registered as Internally Displaced People (IDPs) by the end of 2016. Syria is the number one source country of refugees worldwide; 5.5 million Syrians are registered refugees according to UNHCR, with approximately 2.8 million in Turkey, 1 million in Lebanon, 650,000 in Jordan, 231,000 in Iraq, and 116,000 in Egypt. Other major forcibly displaced populations in MENA include Iraq (5.6 million) and Yemen (3.0 million). [4]

ES.6. Four countries in the Middle East and North Africa (MENA) region are within the top ten countries worldwide with the largest number of refugees per 1,000 inhabitants; namely Lebanon, Jordan, Djibouti, and Malta (Figure ES.1). In Djibouti, Jordan, Lebanon, Morocco, and other countries in MENA, host countries and communities have been generous despite the number of

[1] UNICEF (2017). https://www.unicef.org/appeals/syria.html.
[2] Team's analysis using the UNHCR PGHV-C dataset; see Chapter 2.
[3] Saiid et al (2016, p. 97). Vulnerability Assessment of Syrian Refugees in Lebanon 2016. World Food Programme, UN Children's Fund, UN High Commissioner for Refugees. Published December 16, 2016. Available at http://data.unhcr.org/syrianrefugees/download.php?id=12482.
[4] UNHCR (2017). http://www.unhcr.org/globaltrends2016/.

refugees and the pressure on public services caused by the refugee crises. Turkey is the largest refugee-receiving country in the world.[5]

Figure ES.1 Number of refugees per 1,000 inhabitants (end of 2016)



Source: UNHCR (2017) Global Trends: Forced Displacement in 2016.

ES.7. The rapid and large influx of refugees adds additional pressure to the host countries' water and public resources, which amplifies the need for more climate-smart and sustainable food production.[6] Currently, agriculture uses nearly 85 percent of the water in the region.[7] While many farmers have implemented drip irrigation and other water-saving technologies in recent decades, more is needed to increase access to nutritious food and improve water efficiency and productivity.

ES 1.3. Refugees are poor or vulnerable to poverty and have an agricultural background

ES.8. The refugees in Jordan and Lebanon have similar characteristics, but refugees in Jordan are poorer. Approximately 88 percent of refugees in Jordan are poor or vulnerable to poverty.[8] In Lebanon, 71 percent of the refugees are living in poverty, though in some districts, poverty rates reach up to 80 percent.[9] Most of the Syrian refugees come from the poorer areas of Syria and have settled in relatively poorer areas of Lebanon and Jordan.

ES.9. A large share of refugees had a background in agriculture in Syria. In Jordan, 17.2 percent of Principal Applicants (PA) who applied for UNHCR assistance worked in agriculture, 50.8 percent worked in non-agricultural occupations, and 32 percent were housekeepers. In Lebanon, 10.7 percent of PAs worked in agriculture, 66.8 percent in non-agricultural occupations, and 22.5

[5] UNHCR (2017, p. 3).
[6] Unpublished background, (GFADR World Bank) to World Humanitarian Summit, May 2016: Agriculture and Forced Displacement.
[7] World Bank: Water Sector Brief. Siteresources.worldbank.org.
[8] World Bank (2016, p.111).
[9] Saiid et al. (2016, p.51).

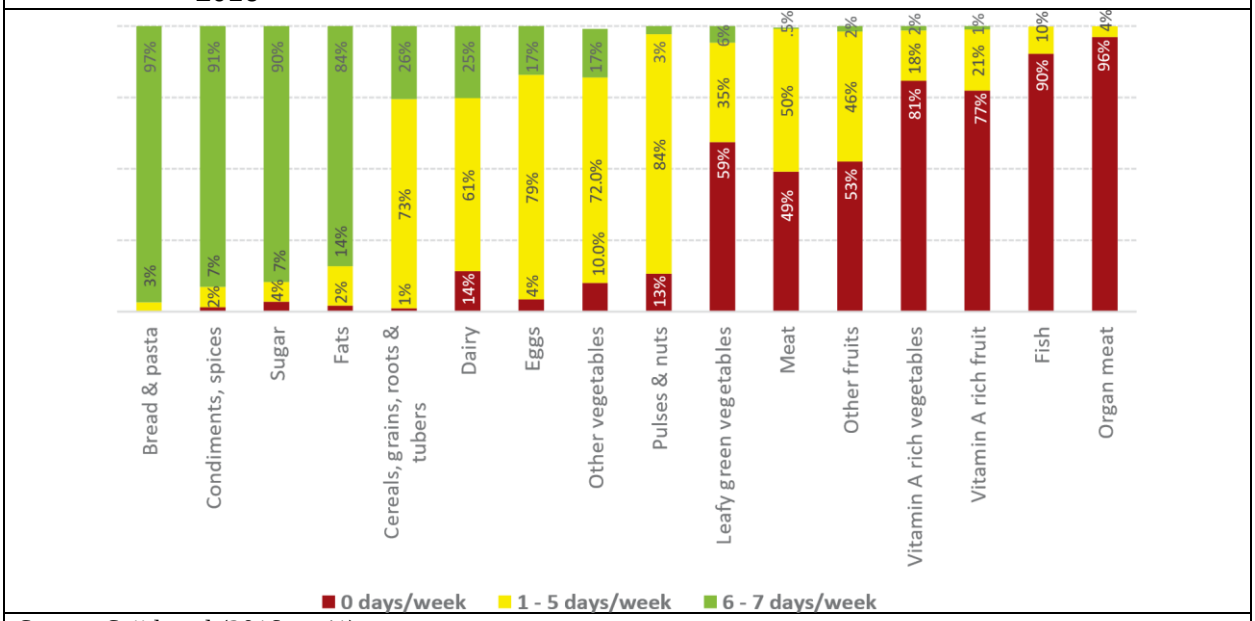
percent were housekeepers. It is very likely that there is a large amount of underreporting regarding home-based work including in farming, livestock herding, etc.

ES.10. Refugees are younger and there is a larger share of female PAs than in the host country. Moreover, there are many female PAs and they have a lower level of education attainment.[10] Male PAs also have low levels of education, particularly those who had agricultural occupations before leaving Syria**.**

ES 1.4. Refugees face severe food insecurity and deterioration of their dietary quality

ES.11. The vast majority of refugees in Lebanon have no access to animal protein (fish, organ meat) and fruit and vegetables that are rich in vitamin A (Figure ES.2). Only 7 percent of refugees have acceptable levels of access to food and are food secure, while 58 percent are living under mild food insecurity and 35 percent under moderate or severe food insecurity (Saiid et al., 2016).

Figure ES.2 Proportion of households by consumption frequency categories, Lebanon, 2016

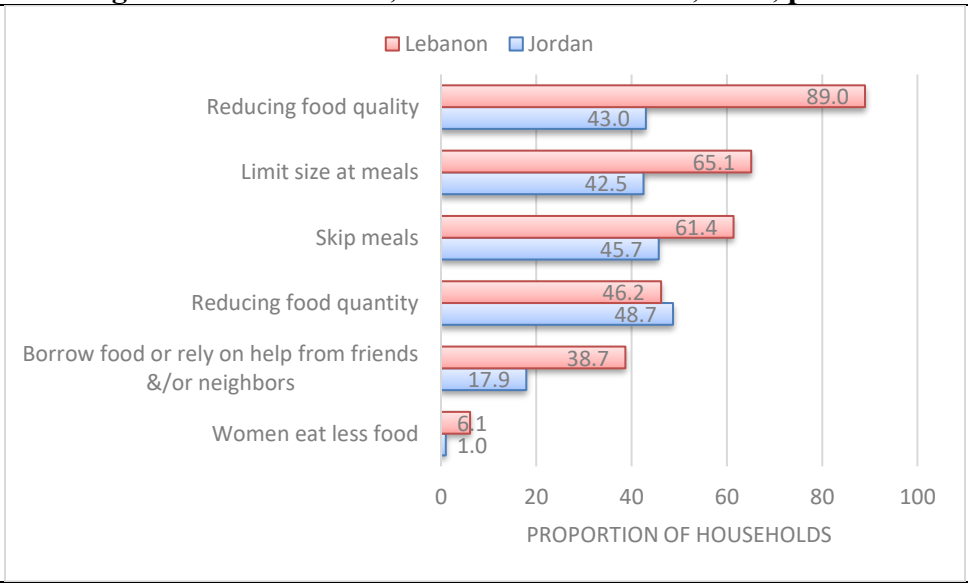


Source: Saiid et al (2016, p. 41).

ES.12. A significant share of Syrian refugees in Jordan and Lebanon are not only food insecure, but have recently been faced with deterioration of their dietary quality and reduction in the number of daily meals. In Jordan, 48.7 percent of the PAs reported reducing food quantity, 45.7 percent skip meals, 42.5 percent limit meal sizes, and 17.9 percent borrow food or rely on help from friends and/or neighbors. Refugees in Lebanon are also subject to significant food insecurity and Figure ES.3 shows that 89 percent of the PAs reported reducing food quality, 61.4 percent skip meals, 46.2 percent reduced food quantity, 38.7 percent borrow food or rely on help from friends and/or neighbors, and 6.1 percent reported that women in the household eat less than men.

[10] World Bank (2016), p. xv.

Figure ES.3 Refugees' Access to Food, Jordan and Lebanon, 2014, percent



Source: Authors' compilation using the UNHCR PGHV-C dataset.

ES.13. A variety of nutritious food items are not consumed by refugees on a regular basis due to shortages including nutrient-rich foods such as fruits and vegetables, eggs, and meat. In Jordan, refugees were deprived of oils and fats (about 5 out of 7 days), eggs, dairy, cereal, pasta, canned food, and vegetables (about 3 days out of 7 days). The lack of sufficient nutritious food affects refugees' health outcomes and is especially critical for children as it affects their brain and early childhood as well as long-term development.

ES.14. The data suggest that Syrian refugees in Jordan and Lebanon encounter significant barriers to consuming nutritious food, which may affect their health and ability to engage in income-generating and other activities that could facilitate social and economic wellbeing. In addition, children are particularly at risk of long-term development impacts if they remain in food-insecure conditions during their upbringing. Interpreting the data, refugees are in a situation where they need opportunities to alleviate nutrition and food shortages. This situation includes not only refugees with a background in agriculture, but all groups.

ES 1.5. The vast majority of Syrians refugees live in suboptimal housing conditions

ES.15. In Jordan, 58.9 percent of PAs who worked in agriculture live in places that need urgent repairs or are in bad conditions. This figure contrasts the 46 percent of housekeepers and non-agricultural workers who live in places that need urgent repairs or are in bad condition. Over 90 percent of PAs who were housekeepers or had non-agricultural occupations have access to piped water, compared to 77 percent of PAs who worked in agriculture. In Jordan, even if the PAs live in houses that need urgent repair, there seems to be access to piped water in the majority of cases, which coupled with access to electricity, offer some of the basic inputs for production of different kinds.

ES.16. A large proportion of Syrian refugees in Lebanon live in dire housing conditions: 59 percent of male PAs and 57 percent of female PAs reported living in structures in poor conditions.

Moreover, 20.2 percent of female PAs and 12.5 percent of male PAs live in spontaneous settlements or tents and about 10 percent of female PAs and 12 percent of male PAs live in mud huts or in other housing arrangements that include caravans, incomplete structures, or living as guests with host families in Lebanon. Refugees in Lebanon face significant water shortages and have limited access to piped water. According to Saiid et al (2016), only 27 percent of the refugee households reported having access to piped water. The vast majority of the refugees relied on bottled water (42 percent), wells (11 percent), public water taps (5 percent), trucked water (8 percent), and springs (3 percent).[11]

ES 1.6. Women, younger, and older refugees are disproportionally more likely to report needs

ES.17. In Jordan, 40 percent of those that had a PA who worked in agricultural occupations reported that a member of their case had some need, compared to 35.2 percent of cases of PAs who were employed in non-agricultural occupations, and 52.2 percent of cases of PAs who were housekeepers**.** In Lebanon, thirty percent of cases that had a PA who worked in agricultural occupations reported at least one member with a need, compared to 23.2 percent of cases of PAs who were employed in non-agricultural occupations, and 45 percent of cases of PAs who were housekeepers.

ES.18. The data for Jordan and Lebanon show that younger and older individuals are disproportionally more likely to report some form of need regardless of their previous occupation. Regardless of gender, young (18 years and younger) and old (66 years and older) PAs are subject to increased needs compared to other age cohorts. In addition, old PAs are subject to the largest number of needs. The number of children also significantly increases the number of needs. Overall, as the refugee gets older, the needs increase and more rapidly for refugees with an agriculture background than those with a non-agriculture background.

ES 1.7. Refugees have low cash incomes and the vast majority are not engaged in paid work

ES.19. The refugee women working in agriculture and as housekeepers are those with the lowest cash incomes. Per capita income of forcibly displaced women is significantly lower than that of their male counterparts. With regards to economic integration, about 44 percent of female PAs reported no income; the figure for female PAs with non-agricultural occupations was 65.5 percent, while for housekeepers, it was reported that 69.5 percent had no cash income. In Lebanon, only 7 percent of refugee women reported income in 2016 compared to 70 percent of men. The majority of women are not engaged in paid work in Lebanon and Jordan. In Djibouti, women and girls, from both refugee and host communities, face constraints to economic opportunities. In all locations, private sector jobs and incomes from work can provide the resources to purchase food and other necessities. This need to be created and launching support for a new subsector is one possible solution. This includes hydroponics.

[11] Saiid et al (2016, p.24).

ES 1.8. Frontier Agriculture Technologies can contribute to improve food security

ES.20. Traditional farming methods are often difficult in arid areas with little arable land and with populations facing water scarcity and a harsh climate. About 1.1 billion people worldwide lack access to water and 2.7 billion people face water scarcity for at least one month of the year. According to the UN, nearly two-thirds of the world's population may face water shortages by 2025 (UN 2016).

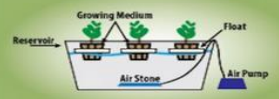
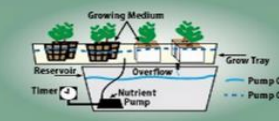
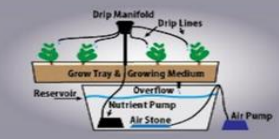
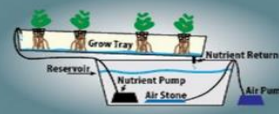
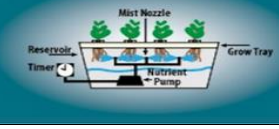
ES.21. In MENA, a shift from immediate, reactive responses to a balanced, long-term development approach is necessary to address water and fragility challenges (World Bank, 2017c). There is a vicious cycle of water and fragility due to their compounding nature. Water scarcity challenges are exacerbating with climate change, rising demands, inter-sectoral competition and urbanization. Water-saving technologies, such as hydroponics and aquaponics, may not only help address food security and other basic needs, but may also help achieve water security through leveraging the opportunities and productive potential of water (World Bank, 2017d).

ES.22. The MENA region faces two large challenges. First, the increasingly water-scarce region applies 85 percent of its water in agriculture and second, the recent escalation of the global refugee crisis, which to a large extent, is a MENA crisis. There is a huge need for increased intake of nutritious food, livelihoods, and jobs for a large share of the 18.2 million adult and youth population living in refugee-like situations in MENA. It is necessary for the protracted situation to be addressed through the development lens to provide development solutions that reactivate the lives and skills of the displaced populations. Moreover, the humanitarian system is under pressure and cannot provide sufficient resources to meet the needs of forcibly displaced people in the MENA region and beyond.

ES.23. Given that water and arable land are scarce in MENA, one way of increasing food production is through land- and water-saving frontier agriculture. Hydroponics is a climate-smart, innovative, efficient, and effective technology that produces more nutritious food with less water (at least 80 percent) and no arable land. Some hydroponic systems are relatively easy to operate and can be installed for small-scale use for homes and communities to large, commercial farms (see Figure ES.4). The scale depends on the system being used and its design, which depends on the objectives and priorities as well as the local conditions, circumstances and existing skills as well as teachability.

ES.24. The basic inputs to hydroponics seem to be available or acquirable in all countries in MENA. Hydroponic systems provide high-cost savings on water, land, fossil fuels, and chemical purchases compared to traditional farming. The startup and operating costs entirely depend on the type of system chosen and its level of complexity. The more advanced and complex the system, the higher the startup and operating costs. There also tends to be less waste with hydroponics and overall better resource management. This system allows for more crop cycles in a year than traditional farming and more high-value crops in some areas.

Figure ES.4 Types of hydroponic systems and advantages and disadvantages

Simple & Less Water Saving	Hydroponic Systems	Advantages	Disadvantages
	Wick Systems 	• Affordable • Simple set up • Low maintenance • No nutrient pump or electricity needed	• Limited oxygen access • Slower growth rate • No nutrient recirculation • Prone to algae growth • Less efficient than other hydroponic methods • Salt build-up needs flushing
	Deep Water Culture 	• Inexpensive • Simple set up Low maintenance • No nutrient pump or electricity needed with Kratky Method • Reliable	• Risk of root rot if not cleaned regularly • Slower growth rate • Must top water until roots are long enough to fall into the nutrient solution • Must frequently refill reservoir
	Ebb & Flow 	• Affordable • Low maintenance • Excess nutrient solution recirculates	• Prone to algae growth • Technical malfunctions could result in crop loss
	Drip Method 	• Excess nutrient solution recirculates • Sufficient oxygen flow	• Prone to clogging • Prone to algae growth • Requires regular cleaning
	Nutrient Film Technique 	• Excess nutrient recirculates • Plentiful oxygen flow • Space sufficient	• Prone to clogging • Technical malfunctions could result in crop loss
	Aquaponics 	• Ability to raise fish • Recycles 95%-99% of water • Completely organic • Uses 90% less water than traditional farming • No chemical pesticides	• High startup costs • High risk of system failure • Needs regular monitoring • High energy usage • Needs technical expertise • Needs reliable electricity
Advanced & More Water Saving	**Aeroponics** 	• Maximum nutrient absorption • Excess nutrients recirculate • Plentiful oxygen flow • Space sufficient • Approximately 70% less water than hydroponics	• Prone to clogging • Technical malfunctions could result in crop loss • High-tech • Time intensive • Poorly suited to thick organic-based nutrients and additives

Source: Authors' Compilation.

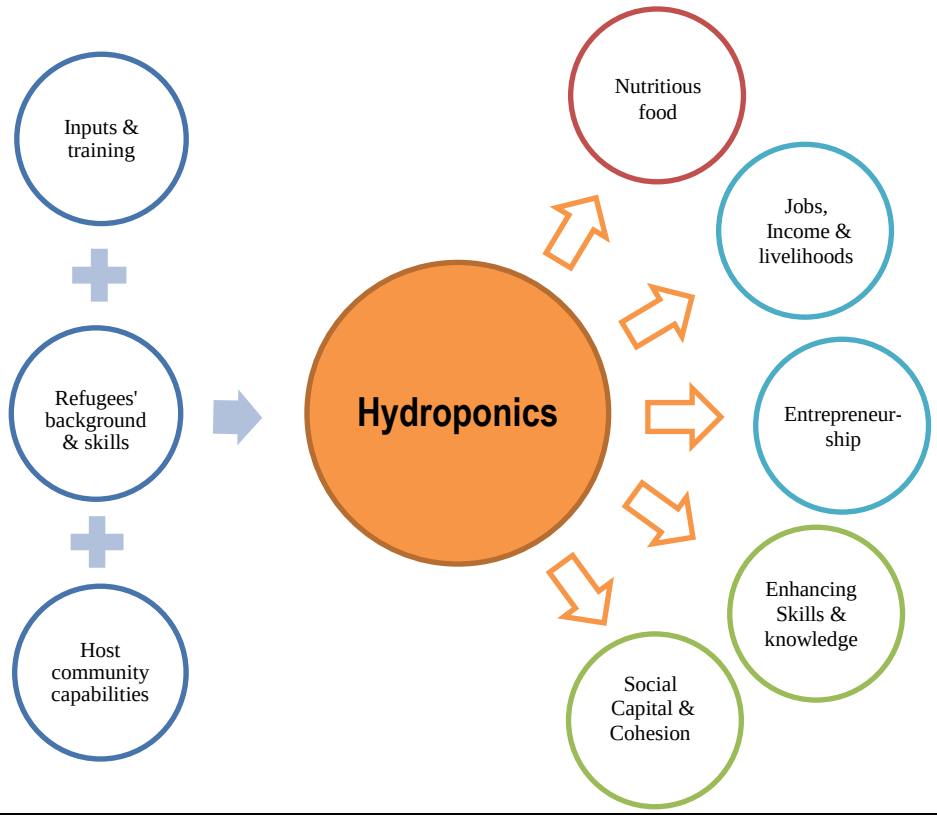
ES 1.9. Matching Needs of Refugees and Hosts with Frontier Agriculture Technologies

ES.25. Besides contributing to food security, climate smart water-saving agriculture technologies and innovations are ways to improve livelihoods and provide jobs with skills and human capital upgrading for both host and forcibly displaced populations in MENA, and, in particular, those most in need. The report provides a three-prong model to address the needs and focuses on (Figure ES.5):

- Increasing access to nutritious food,
- Improving livelihoods, providing jobs, and entrepreneurship,

- Enhancing skills and building social capital and cohesion.

Figure ES.5: Hydroponics and Refugees' livelihoods



Source: Team Compilation.

ES.26. Job opportunities need to be created for both displaced populations and host community populations to reduce rampant poverty and vulnerability. Creating economic opportunities can be a game changer for forcibly displaced populations, host communities and countries. Also, jobs and livelihoods will reduce the fiscal pressure and burden on the host countries. Hydroponics provides different types of employment and the types and amounts of jobs depend on several factors as outlined in this report.

ES.27. The simplest hydroponic systems, such as the deep-water culture, Kratky Method and wicking bed systems, do not require electricity or land and need a fraction of the water required in open field agriculture. Hydroponic systems can grow a wide variety of fruits and vegetables, especially leafy greens—they grow fast and provide leaves within a few weeks—that help address the Vitamin A deficiency.

ES.28. If the primary priority is to address food insecurity among refugees and host communities, households can be trained on how to maintain the simplest hydroponic systems using basic materials such as buckets and local rocks, whereas if the overarching goal is to increase economic activity among refugees to increase incomes, a large NFT system can be constructed at the community level where households may consume from the production and the surplus can be sold in the local market or beyond.

ES.29. Refugees are in all contexts among the poorest and their livelihoods are vulnerable. About 88 percent of refugees in Jordan are poor or vulnerable to poverty, this figure is between 71 and 80 percent in Lebanon. A large share of refugees has a background working in food and agriculture, those that earn income receive a very low salary that is insufficient to take them out of poverty.

ES.30. The refugee women working in agriculture and as housekeepers are those with the lowest cash incomes. Per capita income of forcibly displaced women is significantly lower than that of their male counterparts. About 44 percent of female PAs reported no income. The figure for female PAs with non-agricultural occupations was 65.5 percent and for housekeepers it was reported that 69.5 percent had no cash income. In Lebanon, only 7 percent of refugee women reported income in 2016 compared to 70 percent of men. The majority of women are not engaged in paid work in Lebanon and Jordan. In Djibouti, women and girls, from both refugee and host communities, face constraints to economic opportunities. In all locations, private sector jobs and incomes from work can provide the resources to purchase food and other necessities. These need to be created and launching support for a new subsector is one possible solution. This includes hydroponics.

ES.31. Hydroponics provides an opportunity to promote entrepreneurship. There is also potential for production that exceeds individual needs, which could lead to the creation of local markets for such produce and additional jobs. The revenue generated by selling excess production could turn into an important source of income for refugees and allow them to meet other basic needs. Other entrepreneurial opportunities not directly related to hydroponics may arise, especially when the refugees can combine other skills with their training on these systems.

ES.32. Refugees in Lebanon and Jordan are younger and the share of female household heads is larger than that in the host country. Those households have a lower level of education attainment than other households. Female refugees in Jordan are from poorer areas, have less education than the hosts, often come from rural areas, have mainly undertaken home-based work and have not been employed on farms. In Jordan, more than 86 percent of female PAs have less than 12 years of education. In addition, 93 percent of all female PAs were housekeepers, from which about 30 percent had less than 6 years of education and 52 percent had between 6 and 11 years of education. Enhancing skills are key to increase access to jobs, improve livelihoods and expand the private sector.

ES.33. The transferability of knowledge is a key byproduct of hydroponic projects. Refugees who return to their origin communities or relocate to other countries will bring the practical knowledge with them and could potentially start hydroponic operations at their destinations. This is particularly important for refugees who return to Syria, a country with a war-torn infrastructure (e.g. irrigation systems, electric grid, and roads) that may limit activities in traditional agriculture. Additionally, the training process and increase in human capital may empower refugees to find or create employment or other income-generating opportunities, whether related to hydroponics or not.

ES.34. Research demonstrates that working with plants and gardening can be therapeutic and positively affects mental health. Gardening, especially in community or family settings, provides a sense of responsibility, allows for nurturing and can be a relaxing activity, especially for refugees that have experienced stressful events and trauma.

ES.35. Hydroponics is a technology with several types of systems and variations of those systems, which can be customized and adapted according to priorities, objectives and local conditions. The systems vary from mainly using recycled materials to high tech versions.

ES.36. While advanced hydroponic systems may be appropriate for some regions, this study has examined simplified hydroponic systems that are feasible with training and a small initial investment. Though the yields from these simplified systems are lower than advanced systems, these low-tech systems outperform conventional farming methods and use at least 80 percent less water. Initially, a need assessment should be conducted at the local community level, or individual level, to identify and rank the priorities and objectives in order to select and design an adequate hydroponic system. Regardless of the system chosen, this technology can provide important social, economic, and nutritional benefits, especially for the poor and vulnerable, including the forcibly displaced people.

ES.37. As a starting point, a flexible decision matrix can be used as a tool to determine which type of system would be suitable depending on the local conditions of the growing site. The decision matrix in Table ES.1 is an attempt to systematically identify, analyze, prioritize and compare different systems that are being considered for implementation in frontier agriculture. The below decision matrix presents all of the technologies discussed in this report and ranks them using a Likert-type scale on a variety of attributes: water use, energy use, technological complexity, maintenance, startup costs, financial sustainability, and mobility. Given that each situation requires a different set of social, ecological, and economic considerations, there may not be one single best technology for all applications, but many hybrids can be constructed to specific needs of people, enterprises, and communities.

Table ES.1 Decision matrix for water saving technologies

TECHNOLOGY	FOOD	WATER USE*	ENERGY USE	TECHNOLOGICAL COMPLEXITY	MAINTENANCE	START-UP COSTS	FINANCIALLY SELF-SUSTAINING	MOBILITY
WICK SYSTEMS	CROPS	LOW	NONE	SIMPLE	HIGH	LOW	HIGH	LOW-HIGH
DEEP WATER CULTURE	CROPS	LOW	MEDIUM	MEDIUM	LOW	MED-HIGH	MEDIUM	LOW
EBB & FLOW	CROPS	LOW	LOW-HIGH	COMPLEX	HIGH	MED-HIGH	LOW	LOW
DRIP METHOD	CROPS	LOW	HIGH	COMPLEX	LOW	MED-HIGH	LOW	LOW
NUTRIENT FILM TECHNIQUE	CROPS	LOW	HIGH	COMPLEX	MED-HIGH	HIGH	MEDIUM	LOW
AQUAPONICS	CROPS, FISH	LOW	LOW-HIGH**	COMPLEX	HIGH	MED-HIGH	LOW	LOW
AEROPONICS	CROPS	LOW	HIGH	COMPLEX	HIGH	HIGH	HIGH	LOW

Source: Developed by Report Team.

* Open systems recirculate water, closed systems do not recirculate water.

** Depending upon pump size and heating requirements. Aquaponics requires a constant electrical source or backup energy (battery, generator).

ES.38. Interventions aiming at promoting frontier agriculture among refugees need to develop practical criteria that align technical requirements to engage in hydroponics (or other *ponics*) to

socio-economic conditions of the target population and host communities. The data and discussion presented in this report suggest that a matching process should consider, among other factors, a refugee's (or refugee group's) background in agriculture, potential fit and skills to engage in frontier agriculture (e.g. education, reservation wage, and entrepreneurial spirit), needs (food insecurity, work close to home, and other needs), and availability of water, which is a basic input for hydroponics. The availability of basic inputs and overall economic conditions within the host community must also be assessed together with the refugees' background.

ES.39. There is an urgency to engage with and support refugee livelihoods. Previous experiences suggest that pilot or small-scale hydroponic projects targeting vulnerable populations can be implemented rather quickly and produce meaningful results in a short period.

ES.40. Considerations regarding the viability of hydroponic projects for refugee and host populations should be based on an expanded view of cost-benefits and take into account both the economic and social returns on investment. This technology is constantly becoming less expensive and the challenges of cost and scalability will be overcome. In addition, community-based technical support can be obtained from local organizations, universities, and extension services and trust funds can be utilized for financing pilot projects.

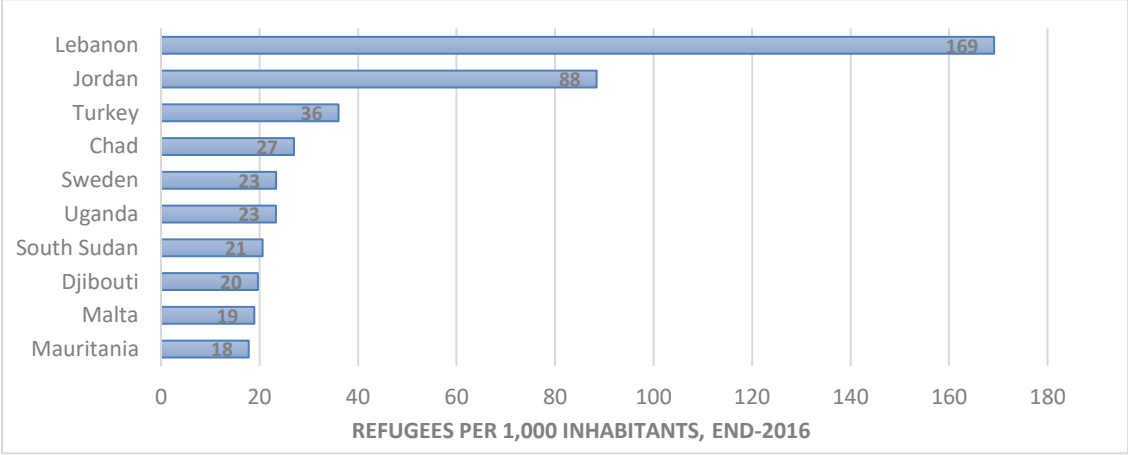
1. Introduction

1.1. Rationale

1.1. The Middle East and North Africa (MENA) is experiencing unprecedented levels of forced displacement. According to UNHCR, as many as 65.6 million people worldwide were forcibly displaced at the end of 2016.[1] UNHCR further reports that approximately 18.2 million people, were living in refugee-like situations, out of which 12 million were registered as Internally Displaced People (IDPs) by the end of 2016.[2] Syria is the number one source country of refugees worldwide; 5.5 million Syrians are registered refugees according to UNHCR, with approximately 2.8 million in Turkey, 1 million in Lebanon, 650,000 in Jordan, 231,000 in Iraq, and 116,000 in Egypt.[3] Other major forcibly displaced populations in MENA include Iraq (5.6 million) and Yemen (3 million).[4]

1.2. Four countries in the World Bank's MENA region are within the top ten countries worldwide with the largest number of refugees per 1,000 inhabitants; namely Lebanon, Jordan, Djibouti, and Malta (see Figure 1.1). In Djibouti, Jordan, Lebanon, Morocco, and other countries in MENA, host countries and communities have been generous despite the number of refugees and the pressure on public services caused by the refugee crises. Turkey is the largest refugee receiving country in the world.[5]

Figure 1.1 Number of refugees per 1,000 inhabitants (end of 2016)



Source: UNHCR (2017) Global Trends: Forced Displacement in 2016.

[1] UNHCR (2017, p. 16) http://www.unhcr.org/globaltrends2016/.
[2] UNHCR (2017, p. 70). The UNHCR Global Trends Report presents data from UNHCR Middle East and North Africa Bureaux, i.e. the following countries: Algeria, Bahrain, Egypt, Israel, Iraq, Jordan, Kuwait, Lebanon, Libya, Mauretania, Morocco, Syria, Saudi Arabia, Tunisia, UAE, Yemen, Qatar, Western Sahara. This report uses UNHCR data. The World Bank's MENA Region overlaps to a considerable degree but, includes Djibouti and Malta and excludes Mauretania.
[3] UNHCR (2017, p. 16).
[4] UNHCR (2017, p. 70).
[5] UNHCR (2017, p. 3).

1.3. MENA is the most water-scarce region in the world, and more than 60 percent of the region's population lives in areas with high or very high surface water stress. This 60 percent compares to the global average of approximately 35 percent. In the MENA region, water challenges are not a new phenomenon, and with the current rate of population growth, there is a "growing range and intensity of water-related risks [and] water governance issues [are] added to the broader and related challenges of climate change and conflict".[6] Over 70 percent of the region's GDP is generated in areas with high to very high surface-water stress, compared to the global average of 22 percent.[7] The economic effects are potentially large as the region is likely to experience climate-related water scarcity: the losses account for 6−14 percent of GDP by 2050.[8]

1.4. The water crisis, coupled with fragility, may fuel more migration and place more pressure on scarce water resources and land according to a recent report (World Bank, 2017c).[9] This report finds that at the household level, water crises may compromise coping capacities and force families to move. In this context, large influxes of forcibly displaced can act as risk multipliers in fragile contexts.[10] For example if host communities and/or IDPs move, or refugees undergo secondary movement in order to have access to land with better water resources, arable land may come under more pressure and potentially lead to disputes over access and rights, This, in turn, could spark local conflicts, furthering the cycle of displacement.

1.5. The rapid and large influx of refugees adds additional pressure to the host countries' water resources, which amplifies the need for more climate-smart and sustainable food production.[11] Currently, agriculture uses nearly 85 percent of the water in the region.[12] While many farmers have implemented drip irrigation and other water-saving technologies in recent decades, more is needed to increase access to nutritious food and improve water efficiency and productivity. The International Labor Organization (ILO) notes that the closed markets of Iraq and Syria and the complication in transport routes due to conflicts have caused a decline in exports and a decrease in prices of traditional crops.[13] The productivity growth rate is the lowest in the world; 0.9 percent in MENA compared to 2.2 percent globally.[14]

1.6. Climate-smart, nutrition sensitive, and sustainable agriculture is important to achieve nutritious food security and increase income-generating activities while improving farmers resilience to shocks including drought, flooding, markets, etc. Many refugee and host populations are food insecure and poor, including in MENA. In Syria, the UNICEF screened 2.3 million children and pregnant and lactating women for acute malnutrition.[15] In Jordan, approximately half

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[6] World Bank (2017d): Beyond Scarcity: *Beyond Scarcity:Water Security in the Middle East and North Africa*. Conference edition.
[7] Ibid.
[8] Ibid.
[9] Ward and Ruckstuhl (2017) argue that it is water scarcity that is the most binding constraint for agricultural development in the region.
[10] World Bank (2017c), Water Management in fragile Systems, *Building Resilience to Shocks and Protracted Crises in the Middle East and North Africa.*
[11] Unpublished document by GFADR World Bank to World Humanitarian Summit, May 2016: Agriculture and Forced Displacement.
[12] World Bank: Water Sector Brief. Siteresources.worldbank.org.
[13] ILO (2017).
[14] Arab Sustainable Development Report (2015) Figure 3.7, p. 53.
[15] UNICEF (2017). https://www.unicef.org/appeals/syria.html.

of the refugee households have reported reducing the quantity and quality of food and skipping meals.[16] In Lebanon, only 7 percent of refugees are living with acceptable levels of food security (see Chapter 2).[17]

1.7. Creating climate smart livelihoods and engaging in inclusive economic activities in the new environment is a key challenge for those who have been displaced. Besides contributing to food security, water-saving technologies and innovations in agriculture can provide jobs and livelihoods along with skills and human and social capital upgrading for both host communities and forcibly displaced populations. In Jordan, for example, a recent ILO study found that there are 1.3 million Syrians living in the country, which is double the number for people officially registered with UNHCR (685,200 were registered at end of 2016). Almost 80 percent of the Syrian refugees live outside of camps in urban and peri-urban areas and depend on short-term, insecure and informal employment.[18] According to ILO (2017), refugees, unlike migrants, often come with families and are therefore less able to move around for seasonal work, such as working in agriculture in the summer and in construction in the winter, which is a common labor market dynamic.[19] The Jordanian Government is seeking to alleviate the constraints faced by refugees and ease their entry into the labor market by giving priority to employment and waiving fees for permits for Syrian refugees and temporarily restricting the entry of migrant workers.[20] *Valid* work permits held by Syrian refugees in Jordan were in August 28,117, i.e. 25,913 men and 2,064 women.[21] The Jordanian Ministry of Labour data show cumulative figures for work permits and note that out of 58,290 permits issued between January 2016 and August 2017 about one third were for work in the agriculture sector.[22] This calls for new ways of increasing livelihoods and creating jobs that can increase the well-being of the refugees in Jordan and beyond.

1.8. Water and agriculture are key to stabilization and ultimately to peacebuilding through producing and selling food, generating income and employment, rebuilding household-level food security, supplying drinking water, and rebuilding social cohesion and institutions from the bottom up in MENA. Building resilience in water and agricultural systems in fragile and conflict-affected systems requires both the short- and long term to be considered in planning, bridging the humanitarian-development divide. Actions that restore water services to farmers and households, refugees and host, are among the first steps to building this resilience.[23] World Bank (2017c) also found that "when water quality and quantity are reduced, water for irrigation may be curtailed, leading to conditions that can breed fragility, such as rural unemployment, rural-urban migration, job competition and price inflation in urban areas, and consequent instability. Regions where a

[16] Team's analysis using the UNHCR PGHV-C dataset; see Chapter 2.
[17] Saiid et al (2016, p. 97). Vulnerability Assessment of Syrian Refugees in Lebanon 2016. World Food Programme, UN Children's Fund, UN High Commissioner for Refugees. Published December 16, 2016. Available at http://data.unhcr.org/syrianrefugees/download.php?id=12482.
[18] ILO (2017). Discussed inter alia on p. 40 and p. 127.
[19] Ibid.
[20] Ibid.
[21] Information provided by UNHCR Jordan, based on Ministry of Labour and Ministry of Planning Data.
[22] The cumulative figure does not reflect that a number of the permits issued are no longer valid. The purpose of the cumulative figure is to indicate the proportion of permits issued for agriculture employment versus other occupations. Source: Ministry of Labour, Department for Syrian Refugees, ppt August 2017.
[23] World Bank (2017c), Water Management in fragile Systems, *Building Resilience to Shocks and Protracted Crises in the Middle East and North Africa.* p. 59.

large portion of employment and livelihoods depend on irrigated and rainfed (in a climate prone region like MENA) agriculture are particularly exposed to these types of risks.

1.9. The first settlements in the world—farming communities (and cities)—began in the Middle-East region, and all of them have changed in response to the variable climate. For thousands of years the people of the Middle-East have coped with the challenges of climate variability and other shocks by adapting their survival strategies to changes in rainfall and conflicts, for example when the shift from agriculture to pastoralism took place. They have evolved their farming practices and shifted livelihood strategies to ensure food security. This report proposes to facilitate another transformational shift: to harness the power of agriculture to provide climate smart sustainable support for displaced populations and their host communities.

Box 1.1 Frontier agriculture

"Frontier agriculture" is a term for climate smart and water saving agriculture technologies that comprises horticulture production applying hydroponic systems, hence growing vegetables with significantly reduced water usage (80-95 percent), minimal land area, and less inputs compared to traditional farming.

There are different types of hydroponic systems ranging from simple to high-tech systems, including open and closed circulation systems. The most common systems are water culture, drip system, and nutrient film technique (NFT). Hydroponics can be installed in urban, peri-urban, and rural locations. The systems can be small, portable, and easy to manage and can be installed in homes, on roofs, and other small private and public spaces. People that have limited or no access to land and who cannot use traditional farming methods can be provided with opportunities to produce climate smart nutritious food with hydroponics.

Currently, hydroponics is mainly used to grow tomatoes, cucumbers, peppers, leafy greens, and a variety of specialty herbs and crops. Plants use equal amounts of water in hydroponics and conventional soil methods, however, a hydroponic system delivers water more efficiently to plant roots so overall water use is significantly reduced. Since the systems support production of fresh vegetables, and herbs, it is expected to have a positive impact both on household members' nutrition and household incomes through sales of fresh produce. See Chapter 3 for a detailed analysis of frontier agriculture technologies.

Source: Team Compilation.

1.10. This report explores the idea that frontier agriculture (see Box 1.1) can contribute to an improvement in well-being, including nutritional status, for groups of people that are less integrated in the labor market. In MENA, this includes women, youth and those who are forcibly displaced. Additionally, new and improved livelihoods, increased employment and inclusion, and expanding markets can potentially reduce the burden of hosting a large number of refugees on host communities and countries while simultaneously providing opportunities for vulnerable host communities.[24] There is evidence from ongoing initiatives of low and high-tech hydroponics that

[24] MENA is facing an enormous youth bulge, and strategies are needed for integrating youth in the economy. OECD (2016) report notes "youth shares in MENA countries are typically higher than global averages, both as share among the total population and the working age population. Yemen and Palestinian Authorities have much higher youth shares in the latter category with more than 26 percent of the working-age population between ages of 15-24, compared to a global average of 19 percent." Moreover, as of 2016 only approximately one fifth of females over 15-years old is

this activity not only contributes to increasing skills and knowledge and improving livelihoods, it can also assist in building communities and recover from the loss of assets and trauma of fleeing from conflict.[25]

1.11. The rationale for mapping and analyzing the potential of "matching" frontier agriculture technologies with the needs of refugees and host populations in MENA is fourfold:

i. The food-water-energy nexus is important for recovery and stabilization of countries and communities. The core of this nexus is the need to establish food security for all individuals. These emerging agriculture technologies can potentially make an important contribution to reduce water use in agriculture (more crops per drop, better water efficiency and productivity) and to increase well-being, food security, and resilience of vulnerable people, while also reducing multi-dimensional poverty. Moreover, agriculture is the first sector to recover from conflict situations because production inputs can be rapidly mobilized, including seeds, tools and water.

ii. Poor refugees and vulnerable host communities are economically insecure and spend a large amount of their time trying to meet their basic needs, in particular food. The returns to skills from prior occupations and education is often low.[26] Policy simulations show that typical development policies that invest in skills, education, and employability are unlikely to succeed in improving welfare unless they are accompanied by more comprehensive measures aimed at creating adequate economic opportunities.[27]

iii. There is an urgent need to bridge the humanitarian development divide and assist displaced populations to rebuild their active lives through concerted development efforts while also supporting host communities. When forcibly displaced populations do not have access to economic opportunities, their human and social capital deplete, and they survive on short-term and sometime negative coping strategies, which include putting children to work, marrying off girls at a very young age, survival sex, and disposing of their few assets.[28]

iv. The humanitarian system is under pressure and underfunded. The large-scale emergencies continue to drive increases in humanitarian assistance needs. Multi-sector requirements in UN appeals have increased thirteen-fold between 2005 and 2015.[29] The pace of growth slowed between 2015 and 2016, with a 6 percent increase and appeals reaching US$27.3 billion in 2016, of which the UN-coordinated appeals accounted for US$20.5 billion and

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in the labor force, implying that women's labor force inclusion in MENA is the lowest in the world (World Development Indicators, 2016 World Bank).

[25] See https://www.weforum.org/agenda/authors/dorte-verner and www.enosh.org.il on an example of community building through hydroponics. World Bank (2017): Forcibly Displaced. Towards a Development Approach Supporting Refugees, the Internally Displaced, and their Hosts. Overview, *notes (p1), "development actors should help reduce –even eliminate vulnerabilities. The forcibly displaced have often acquired vulnerabilities that are specific to them, such as catastrophic losses of assets and trauma.* The issue is further discussed on p.8 of the aforementioned report.

[26] World Bank (2016), and this report team using data from the UNHCR PGHV-C dataset.

[27] World Bank (2016) p. 15.

[28] World Bank (2017 a).

[29] Development Initiatives (2016): Global Humanitarian Assistance Report (2016) http://devinit.org/wp-content/uploads/2016/06/Global-Humanitarian-Assistance-Report-2016_Chapter-3.pdf.

40 percent of the requested amount remained unfunded. Several sectors are particularly underfunded, such as agriculture, education, and security. Moreover, there is a need to advance not only the social side, but also the economic and productive sectors, while shifting from providing humanitarian assistance to development assistance.[30]

1.12. Within the broader frameworks above, this report analyses the potential of frontier agriculture, and more specifically hydroponics for innovation and for development engagement that have a positive impact on the lives of refugees and host communities in the MENA region.

1.2. Objective, Scope, and Audience

1.13. The main objective of this report is to increase the knowledge of water-saving, soilless, climate-smart food and agriculture technologies that can potentially increase nutrition and food security, economic engagement, and livelihoods and skills for disadvantaged refugee groups and their host communities. In the medium run, these technologies can potentially promote entrepreneurship for refugees and host communities in the MENA region.

1.14. The report aims to enhance the knowledge, understanding, and applicability of climate-smart, water- and land-saving agriculture technologies as well as refugee needs. This study covers the spectrum from low-tech hydroponics to medium- and higher-tech variations of hydroponics, such as aquaponics. The report will also explore how to match these climate-smart agriculture technologies to the needs of host and refugee communities in their specific contexts. This should move the needle from a humanitarian to a development path, as the technologies can improve livelihoods for increased nutritious food security and employment of vulnerable populations. The main forcibly displaced crises of Syrian, Iraq and Yemen are not temporarily, therefore requiring more traditional development responses. While refugees and displaced populations do not expect or plan to remain displaced for long, the reality is that the average length of time that a refugee/displaced person remains outside his home community is about 10-17 years. It is beyond the scope of this report to address water desalination and renewable energy as sources of water and energy. It is well understood that these are important technologies to consider and explore further as water scarcity increases.

1.15. This report analyses situations in the MENA region and focuses specifically on three countries with the largest share of refugees per host population, namely Jordan, Lebanon, and Djibouti.[31] Lebanon and Jordan are middle-income countries and mainly host Syrian refugees. These two countries together were hosting approximately 1.7 million refugees at the end of 2016, and they rank first and second, respectively, in terms of the share of refugees per host population (see Figure 1.1 above). Most emphasis will be on the analysis of refugees and their hosts in these countries, due to the needs described above, magnitude of the refugee population in these countries, and data availability. Djibouti is a lower-middle income country, but more than 23

[30] Development Initiatives (2017): Global Humanitarian Assistance Report (2017). Devinit.org/wp-content/uploads/2017/06/GHA-Report-2017-chapter-2.pdf.

[31] Djibouti has been included in order to provide contrast to Lebanon and Jordan, and show a protracted refugee situation in a poverty stricken and environmentally harsh for both refugees who mainly live in camps and their host communities. Malta is not included in this analysis because of the largely transitory situation of migrants and refugees and the lack of available data to analyze the situation.

percent of the population lives in extreme poverty.[32] There were around 26,000 refugees in Djibouti at the end of 2016, this has risen to 27,600 by July 2017. The majority of the refugees in Djibouti are from Somalia (48.2 percent), Ethiopia (31 percent), and Yemen (16 percent) (UNHCR Fact Sheet, August 2017). In a country with slightly less than 1 million inhabitants, the number of refugees represent a considerable share of the population in the country.

1.16. The audience for the report are development practitioners in a broad sense, including the private sector and civil society organizations. The report serves as an analytical input to the development debate that can potentially inform future operations for refugees and hosts.[33] Therefore, the technologies specifically focus on application as an innovation to development programs in the agricultural sector with development gains. These gains include nutritional improvement, employment and livelihoods, and income, as well as human and social capital upgrading with the potential for entrepreneurship and private sector development targeting the most vulnerable, including women and youth.

1.17. This report builds on the World Bank's Food and Agriculture Strategy. It does so by conducting a mapping and analysis of the potential use of Frontier Agriculture to leverage resources and support refugees so that the food and agriculture sector in the MENA region is climate-smart, improves livelihoods and creates more and better jobs (including jobs for women and youth), boosts agribusiness, and improves food security and produces enough safe, nutritious food for everyone, everywhere, every day.

1.3. Methodology

1.18. The methodology applied in this report includes: (i) a mapping and analysis of various techniques and types of hydroponic and barriers and opportunities for application of water-saving agriculture technologies; (ii) quantitative multivariate data analyses that prove a mapping (based on existing UNHCR refugee registry data from Lebanon and Jordan (2014), which looks at the extent to which refugees in those countries have a background in agriculture as well as their existing livelihood vulnerabilities, needs, opportunities, and other characteristics. This analysis is supplemented with information on livelihood opportunities and constraints for refugees drawing from UNHCR, ILO and other organizations. For Djibouti, the mapping includes WFP and UNHCR data and other data publicly available. Moreover, a mission was undertaken to selected institutions and projects to assess existing applications, including commercial and large private sector initiatives, application and development of technologies in research centers and universities, and small-scale technology implementation by humanitarian and development organizations.

1.19. The rest of the report is structured as follows: Chapter two analyzes food security, economic engagement, and profiles of refugees, particularly in Jordan, Lebanon, and Djibouti. Chapter three introduces hydroponics and discusses the different types and adaptability and the requirements of the technology for different environments. Chapter four summarizes the potential of frontier agriculture technologies to contribute to increased livelihoods and incomes of refugees

[32] www.worldbank.org/en/country/djibouti.

[33] In close collaboration with UNHCR and host governments, the World Bank is planning IDA18 operations under the Refugee Sub-window to address protracted situations in several regions.

and host communities. Finally, three annexes are included. A technical background paper on frontier agriculture is available as a separate document.

2. Refugees and Host Communities

2.1. This chapter presents and discusses characteristics of the refugee population considered relevant for introducing climate-smart agriculture technologies for refugees and hosts in Lebanon, Jordan, and Djibouti. The chapter is not exhaustive, but seeks to identify based on available data: (i) whether the background of refugees is conducive to engage in agriculture-related activities and (ii) identify the most vulnerable populations and assess their characteristics and needs. This chapter also presents information that can be used to develop a socio-economic matrix that can facilitate the matching of refugees to host communities where climate-smart agriculture including hydroponics is likely to work best.[34]

2.1. Refugee Profiles

2.1.1 Poverty

2.2. The refugees in Jordan and Lebanon have similar characteristics, but refugees in Jordan are poorer. About 88 percent of refugees in Jordan are poor or vulnerable to poverty.[35] In Lebanon, 71 percent of the refugees are living in poverty, though in some districts, poverty rates reach 80 percent.[36] Most of the Syrian refugees come from the poorer areas of Syria and have settled in relatively poorer areas of Lebanon and Jordan. The vast majority of Syrians in Jordan live in suboptimal housing conditions and do not have residential permits. As of August 2017, under 20,000 refugees had received permit to work in agriculture, forestry and fishing in Jordan. These conditions limit their well-being and ability to participate in economic activities that would contribute to improve their well-being.

2.1.2. Previous occupation, education and household composition

2.3. A large share of refugees had a background in agriculture in Syrian.[37] In Jordan, 17.2 percent of Principal Applicants (PA) who applied for UNHCR assistance worked in agriculture, 50.8 percent worked in non-agricultural occupations, and 32 percent were housekeepers. In Lebanon, 10.7 percent of PAs worked in agriculture, 66.8 percent in non-agricultural occupations, and 22.5 percent were housekeepers. It is very likely that there is a large amount of underreporting regarding home-based work including in farming, livestock herding, etc.

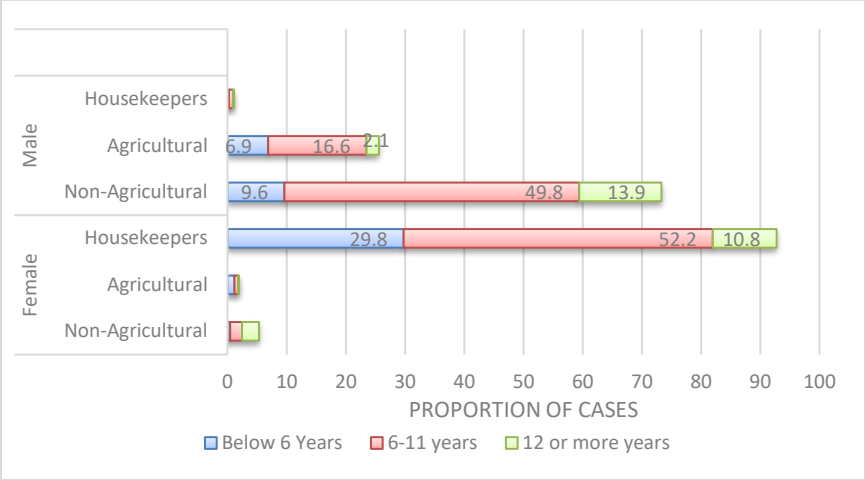
2.4. Refugees are younger and there is a larger share of female PAs than in the host country. The data analyses show that the Syrian refugees in Jordan and Lebanon are on average younger

[34] The analyses are based on the micro-data: the UNHCR PGHV-C dataset
[35] World Bank (2016, p. 111).
[36] Saiid et al. (2016, p. 51).
[37] This study classifies refugees as having had a background in agriculture if they were famers, animal and livestock producers, or worked as laborers in agriculture, forestry, fishery, or mining.

than the host populations. Moreover, there are many female PAs and they have a lower level of education attainment.[38]

2.5. Male PA also have low levels of education, particularly those who had agricultural occupations before leaving Syria**.** In terms of education, 16.7 percent of male PAs have less than 6 years of education, 67.1 percent have between 6 and 11 years of education, and only 16.1 percent have 12 or more years of education (see figure 2.1). Among all male PAs, 23.1 percent were former farmers (or had agricultural occupations) who have less than 12 years of education. Only 2.1 percent of male PAs were individuals who had agricultural occupations and had more than 12 years of education (see figure 2.1).

Figure 2.1 Proportion of cases by former occupation, education, and gender of PA, Jordan 2014, percent



Source: Authors' compilation using the UNHCR PGHV-C dataset.

2.6. Female refugees in Jordan are from poorer areas, have less education than the hosts and often come from rural areas and have mainly undertaken home-based work and have not been employed on farms. In Jordan, more than 86 percent of female PAs)[39] have less than 12 years of education (see Figure 2.1). In addition, 93 percent of all female PAs were housekeepers, from which about 30 percent had less than 6 years of education and 52 percent had between 6 and 11 years of education. Among female PAs, only 1.9 percent had previous jobs in agriculture and 5.3 percent had other non-agricultural occupations. The vast majority of female PAs who had

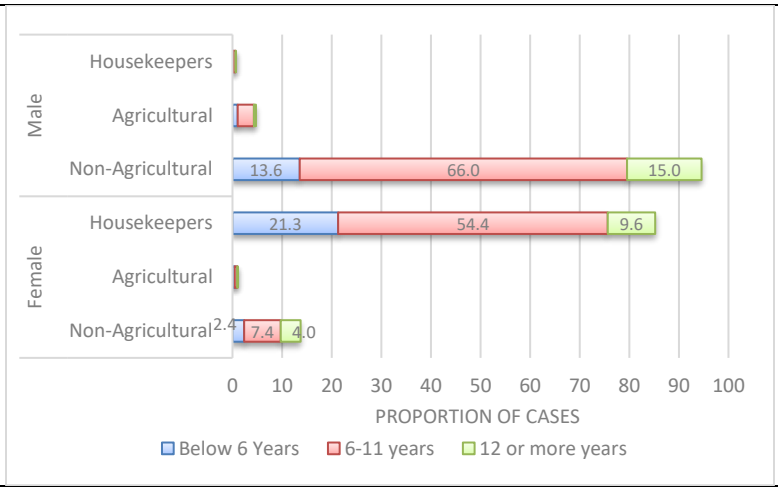
[38] World Bank (2016), p. xv. The unit of observation is the "case" as used by UNHCR: "A processing unit similar to a family headed by a Principal Applicant (PA). It comprises (biological and non-biological) sons and daughter up to the age 18 (or 21) years, but also includes first degree family members emotionally and/or economically dependent and for whom a living on their own and whose ability to function independently in society/ in the community and/or to pursue an occupation is not granted, and/or who require assistance from a caregiver". The UNHCR definition of a "household" differs, this is not a processing unit but a group of persons who live together, pool their resources, make common provisions for food or other essentials for living/surviving and where the members are dependent on each other and all trying to meet their combines sets of needs. Here quoted from (World Bank 2016).

[39] The UNHCR ProGres system refers to a "case" as a unit of observation that is constituted by a Principal Applicant (PA) for refugee status and the family or extended family members with the PA. The PA is the head of the case. The analyses follow Verme et al. (2016) and use case as the unit of reference and analysis in this section of the report.

agricultural occupations had less than 12 years of education. The data also show that 25 percent of female housekeepers had husbands who were farmers.[40]

2.7. In Lebanon, 82 percent of all female PAs are housekeepers, 6 percent had agricultural occupations, and 12 percent had non-agricultural occupations. Among male PAs, 87 percent had non-agricultural occupations, about 12.5 percent had agricultural occupations, 0.5 percent were housekeepers. Figure 2.2, constructed only with observations that had information about educational attainment shows that over 80 percent of female PAs have less than 11 years of education**.** According to Saiid et al (2016, p.11), female heads of household are more likely to be illiterate. Figure 2.2 shows that male PAs also have low levels of education. Approximately 15 percent of male PAs have less than 6 years of education and 60 percent have between 6 and 11 years of education. Only 15 percent of male and 13.6 percent of female heads of households have secondary or tertiary levels of education in Lebanon.[41]

Figure 2.2 Proportion of cases by former occupation, education, and gender of PA, Lebanon, 2014



Source: Authors' compilation using the UNHCR PGHV-C dataset.

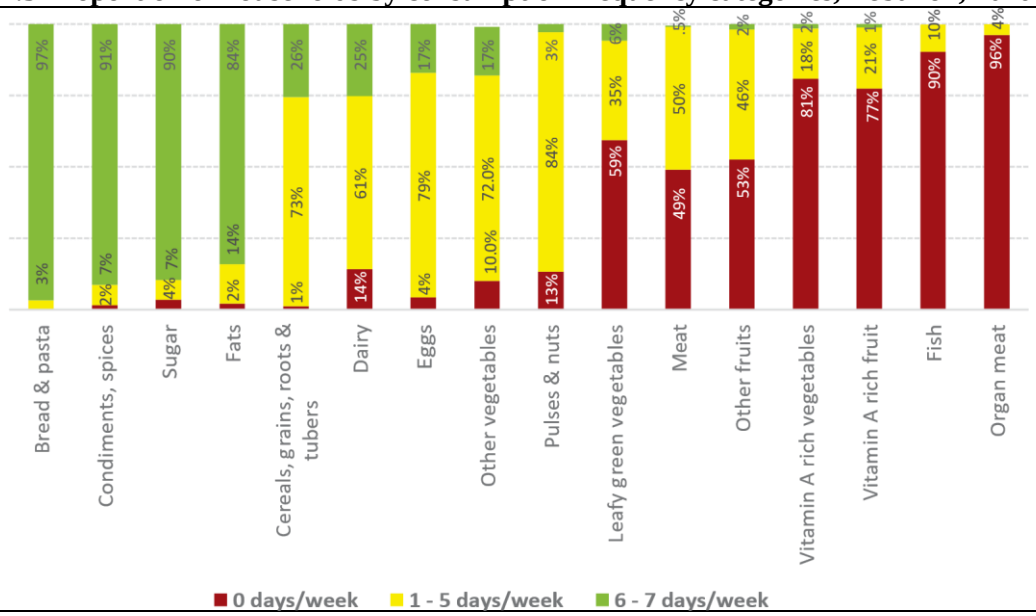
2.1.3. Food and nutrition security

2.8. According to Saiid et al (2016), the vast majority of refugees in Lebanon have no access to animal proteins (fish, organ meat) and fruit and vegetables that are rich in vitamin A (figure 2.3). Their survey shows that only 7 percent of refugees have acceptable levels of access to food and are food secure, while 58 percent are living under mild food insecurity and 35 percent under moderate or severe food insecurity.

[40] Verner (2011).

[41] A 2016 small-scale survey of refugees in Lebanon shows that over three quarters of male and female refugee household heads have primary schooling or lower levels of education. Only 12 percent of male and 10 percent of female head of households have secondary or tertiary levels of education (Saiid et al., 2016, p.11).

Figure 2.3 Proportion of households by consumption frequency categories, Lebanon, 2016



Source: Saiid et al (2016, p. 41).

2.9. A significant share of Syrian refugees in Jordan and Lebanon are not only food insecure, but have recently been faced with deterioration of their dietary quality and reduction in the number of daily meals. In Jordan, 48.7 percent of the PAs reported reducing food quantity, 45.7 percent skip meals, 42.5 percent limit size at meals, 27.2 percent purchase food on debts, and 17.9 percent borrow food or rely on help from friends and/or neighbors. There are no significant differences in food needs based on previous occupation category (see table 2.1). Refugees in Lebanon are also subject to significant food insecurity and Figure 2.5 shows that 89 percent of the PAs reported reducing food quality, 61.4 percent skip meals, 46.2 percent reduced food quantity, 38.7 percent borrow food or rely on help from friends and/or neighbors, and 6.1 percent reported that women in the household eat less than men.

Table 2.1 Access to Food by previous occupation of Principal Applicant, Jordan, 2014, percent

	Non-Agricultural	Agricultural	Housekeepers	Total
	Proportion of cases			
Reducing food quantity	48.4	48.6	49.2	48.7
Borrow food or rely on help from friends &/or neighbors	17.8	19.9	17.2	17.9
Purchase food on debts	28.4	30.7	23.4	27.2
Skip meals	46.5	45.4	44.7	45.7
Limit size at meals	42.7	41.4	42.7	42.5

Source: Authors' compilation using the UNHCR PGHV-C dataset.

2.10. A number of different nutritious food items are not consumed by refugees on a regular basis due to shortages including nutrient-rich foods such as fruits and vegetables, eggs, and meat.

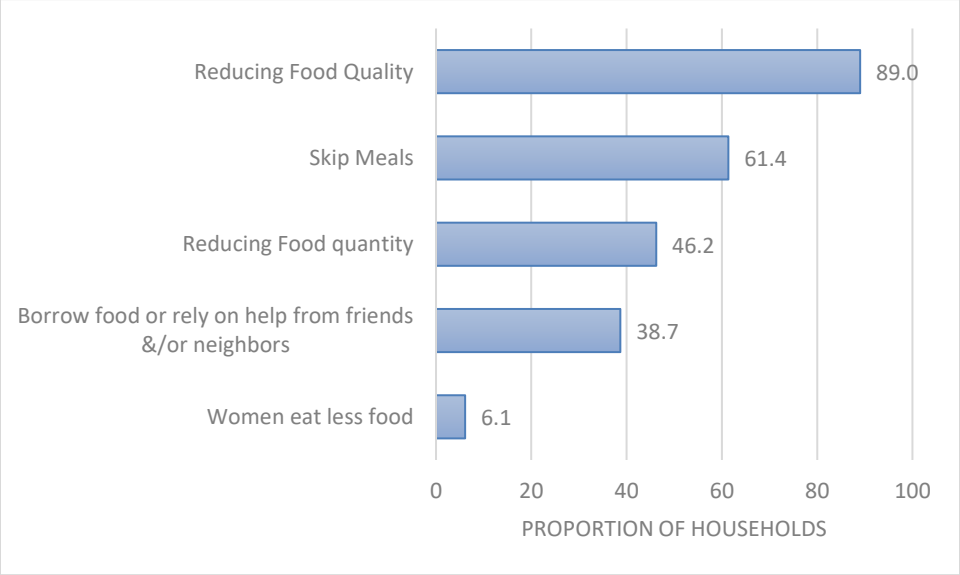
Table 2.2 reports the average number of days per week that refugees in Jordan reported going by without access to specific food items. Refugees were deprived of oils and fats (about 5 days out 7 days), eggs, dairy, cereal, pasta, canned food, and vegetables (about 3 days out of 7 days). It also shows that there is no difference based on the PA's occupational background. The lack of sufficient nutritious food affects refugees' health outcomes and is especially critical for children as it affects their brain and general development that is lasting the rest of a child's life.

Table 2.2 Average number of days per week without food by previous occupation of Principal Applicant

Average number of Days without:	Non-Agricultural	Agricultural	Housekeepers
Oils and Fat	4.8	4.7	5.0
Dairy	3.3	3.2	3.3
Eggs	3.1	3.1	3.1
Cereal and Pasta	3.0	3.1	3.1
Canned Food	3.0	3.2	3.1
Vegetables	2.9	2.9	2.9
Dry Pulses	2.7	2.8	2.8
Meat, Poultry and Fish	1.3	1.3	1.3
Fruits	1.0	0.9	1.0

Source: Authors' compilation using the UNHCR PGHV-C dataset.

Figure 2.4 Access to food, Lebanon, 2014, percent



Source: Authors' compilation using the UNHCR PGHV-C dataset.

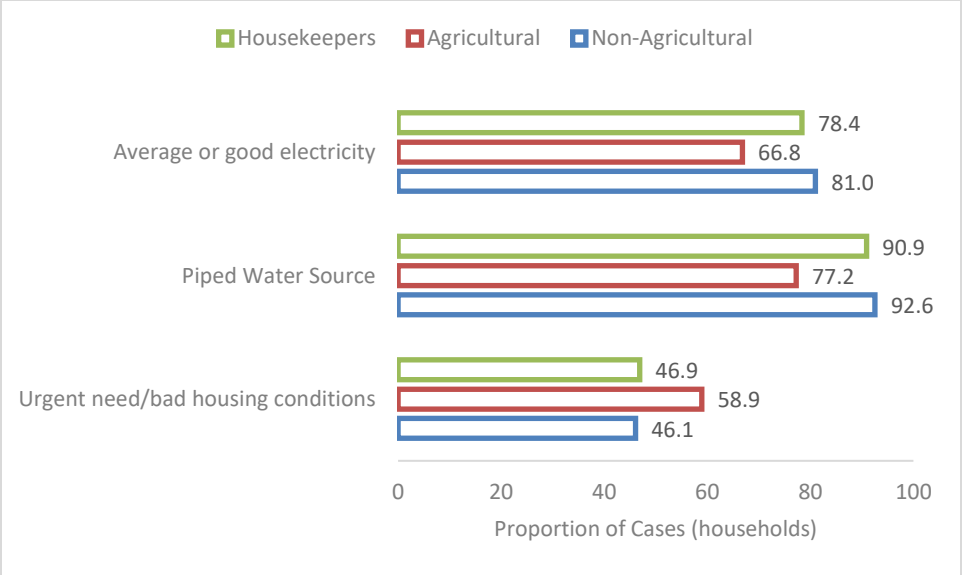
2.11. The data suggest that Syrian refugees in Jordan and Lebanon encounter significant barriers to consumption of nutritious food, which may affect their health and ability to engage in income-generating and other activities that could facilitate social and economic wellbeing. In addition,

children are particularly at risk of long-term development impacts if they remain in food-insecure conditions during their upbringing. Interpreting the data, refugees are in a situation where they need opportunities to alleviate nutrition and food shortages. This situation includes not only those refugees with a background in agriculture, but all groups.

2.1.4. Housing and Water

2.12. In Jordan, 58.9 percent of PAs who worked in agriculture live in places that need urgent repairs or are in bad conditions. This figure contrasts the 46 percent of housekeepers and non-agricultural workers who live in places that need urgent repairs or are in bad conditions (see figure 2.5). Over 90 percent of PAs who were housekeepers or had non-agricultural occupations have access to piped water, compared to 77 percent of PAs who worked in agriculture. In addition, 81 percent of PAs, who had non-agricultural occupations and 78.4 percent of PA housekeepers had access to average or good electricity, compared to 66.8 percent of PAs who worked in agriculture. PAs who worked in agriculture spend JD 8.2 per month to buy water, compared to JD 8.0 for PA with non-agricultural occupations and JD 5.4 for housekeepers. In Jordan, even if the PAs live in houses that need urgent repair, there seems to be access to piped water in the majority of cases, which coupled with access to electricity, offer some of the basic inputs for production of different kinds. There is, however, no information in the data on the quantity and quality of the services.

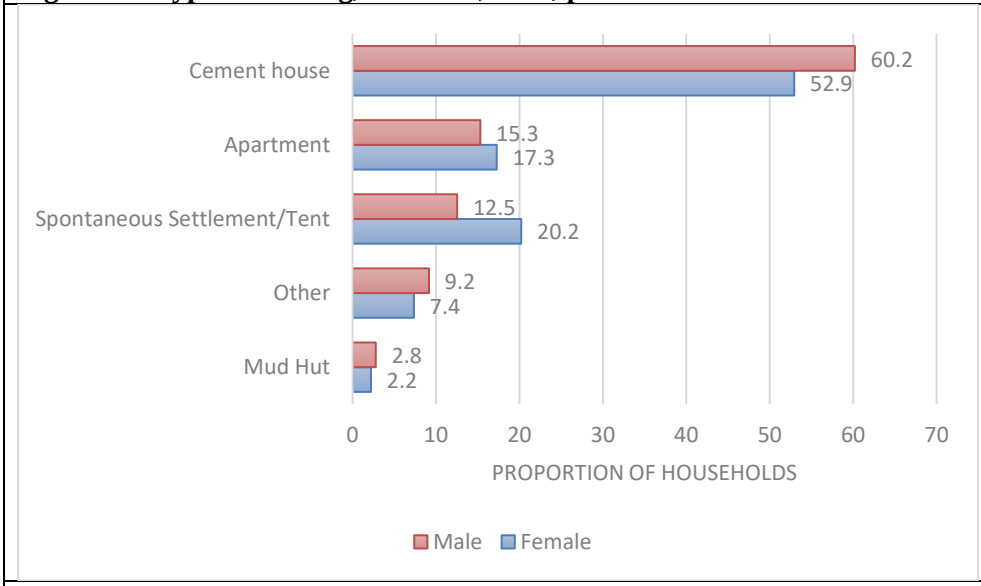
Figure 2.5 Housing conditions and access to water, Jordan, 2014, percent



Source: Authors' compilation using the UNHCR PGHV-C dataset.

2.13. A large proportion of Syrian refugees in Lebanon live in dire housing condition: 59 percent of male PAs and 57 percent of female PAs reported living in structures in poor conditions. Moreover, figure 2.6 shows that 20.2 percent of female PAs and 12.5 percent of male PAs live in spontaneous settlements or tents and about 10 percent of female PAs and 12 percent of male PAs live in mud huts or in other housing arrangements that include caravans, incomplete structures, or living as guests with host families in Lebanon.

Figure 2.6 Type of housing, Lebanon, 2014, percent



Source: Authors' compilation using the UNHCR PGVS-C dataset.

2.14. In Lebanon, to the contrary, refugees face significant water shortages and have limited access to piped water. According to Saiid et al (2016), only 27 percent of the refugee households reported having access to piped water. The vast majority of the refugees relied on bottled water (42 percent), wells (11 percent), public water taps (5 percent), trucked water (8 percent), and springs (3 percent).[42] Approximately half of the refugee households in Lebanon do not pay for water. Households who must buy drinking water, however, spend an average of US$23 per month. Water spending is particularly high for those who rely on trucked water (US$27/month) compared to households who have access to the public water supply (US$15/month).

2.1.5. Needs by Gender and Generation

2.15. The UNHCR classifies refugee needs in major groups including: [43]

- Child at risk
- Unaccompanied or separated child
- Woman at risk
- Older person at risk
- Single parent or caregiver
- Disability
- Serious medical condition
- Family unity
- Specific legal and physical protection needs
- Torture

[42] Saiid et al (2016, p.24).

[43] For details about this classification, refer to "Guidance on the Use of Standardized Specific Needs Codes (SNCs)" published by the UNHCR. SNCs are utilized to record information into the ProGres system managed by the UNHCR.

2.16. This section refers to an individual who has reported at least one of these needs as an individual "in need." In general, individuals from rural and urban areas have different levels of accumulated human capital and personal endowments (e.g. education, labor market skills, adaptability to different living environments, etc.), thus their needs may also differ significantly.

2.17. In Jordan, 40 percent of those that had a PA who worked in agricultural occupations reported that a member of their case had some need, compared to 35.2 percent of cases of PAs who were employed in non-agricultural occupations, and 52.2 percent of cases of PAs who were housekeepers (Table 2.3)**.** Among those with a previous agricultural occupation, approximately 66 percent of PAs older than 65 years and 56 percent of individuals 18 years or younger reported some form of need in their household, compared to 30 percent of PAs between 19 and 34 years old and 44 percent of PAs between 35 and 59 years old.

2.18. Thirty percent of those cases that had a PA who worked in agricultural occupations reported at least one member with a need, compared to 23.2 percent of cases of PAs who were employed in non-agricultural occupations, and 45 percent of cases of PAs who were housekeepers (Table 2.3)**.** This shows that the vulnerability situation in Lebanon is somewhat comparable to that of Jordan._Younger and older PAs are significantly more likely to report that members of their cases are in need. Six out of ten PAs 18-years old or younger reported some form of need and three quarters of PAs older than 65 years reported needs. In Lebanon, eight out of ten housekeepers older than 65 years old reported needs in their households.

2.19. The data for Jordan and Lebanon show that younger and older individuals are disproportionally more likely to report some form of need regardless of their previous occupation. Regardless of gender, young (18 years and younger) and old (66 years and older) PAs are subject to increased needs compared to other age cohorts (table 2.3). In addition, old PAs are subject to the largest number of needs. The number of children also significantly increases the number of needs. Overall, as the refugee gets older, the needs increase and more rapidly for refugees with an agriculture background than those with a non-agriculture background.

2.20. Single and separated women have more needs than married women and men. The effect of marital status on needs, however, differs by gender. More specifically, female PAs who are married have fewer needs than both single or separated, divorced, and widowed female PAs. On the contrary, male PAs who are married have more needs than single or separated, divorced, and widowed male Pas.

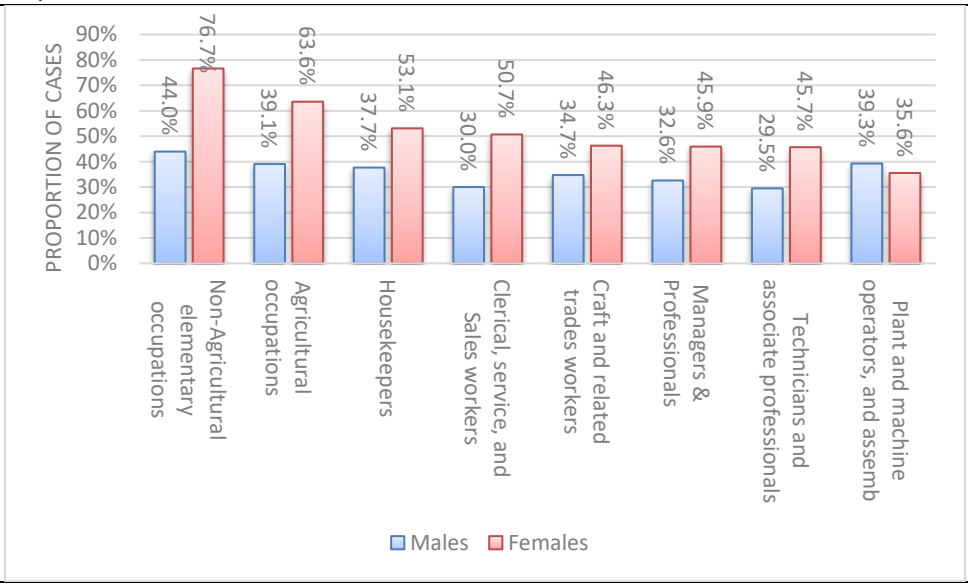
Table 2.3 Share of cases with at least one member reporting need, by age cohort and former occupation, 2014, years

Occupation	Age					
	18 years and Younger	19-34 years	35- 49 years	50-65 years	More 65 years	All age cohorts
Jordan						
Non-Agricultural	51.1	29.0	39.1	44.9	57.6	35.2
Agricultural	56.0	30.2	44.0	52.4	65.7	40
Housekeepers	57.8	43.3	57.2	58.0	68.2	52.6
Lebanon						
Non-Agricultural	47.6	17.2	22.9	45.9	68.3	23.3
Agricultural	66.0	21.9	27.5	43.6	65.3	30.1
Housekeepers	58.4	38.5	45.3	61.3	80.0	45.0

Source: Authors' compilation using the UNHCR PGHV-C dataset.

2.21. Women are significantly more vulnerable than men are, regardless of occupation. Figure 2.7 shows that among cases of PAs who had agricultural occupations before leaving Syria, 64 percent reported having at least one need, compared to 39 percent of cases where the PA was a male. The proportion of male and female PAs with agricultural occupations who reported needs is significantly higher than that of PAs who had non-agricultural occupations, except for those who had non-agricultural elementary occupations.

Figure 2.7 Proportion of cases with at least one member reporting need, by occupation, Jordan, 2014, Percent

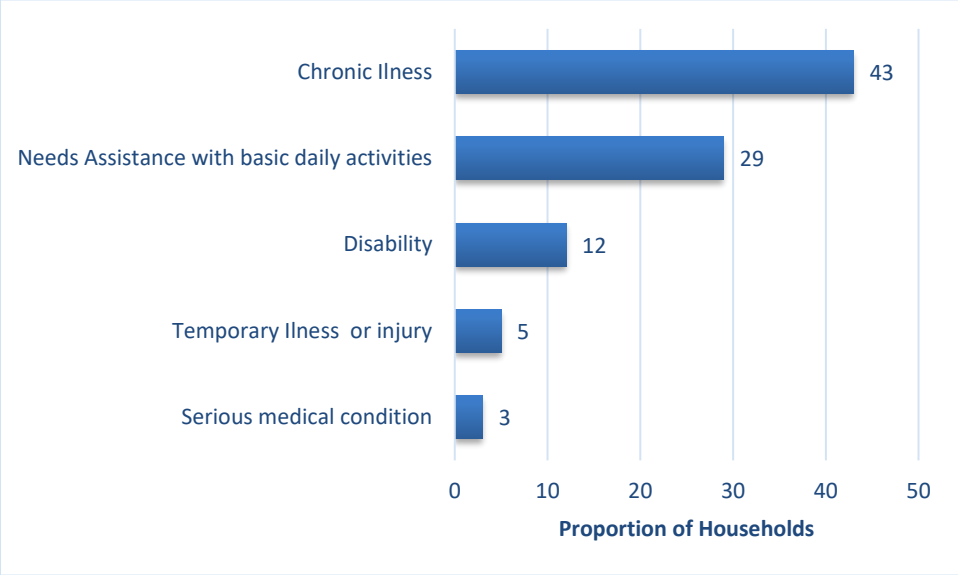


Source: Authors' compilation using the UNHCR PGHV-C dataset.

2.22. In Lebanon, 63 percent of male-headed and female-headed households reported that at least one household member had a specific need in 2016. Chronic diseases (43 percent), assistance with

basic daily activities (29 percent), and mental and physical disabilities (12 percent) are the most prevalent needs among Syrian refugees in Lebanon.

Figure 2.8 Proportion in percent of households with at least one member reporting specific need, Lebanon, 2016



Source: Saiid et al (2016, p. 12).

2.23. A set of multivariate-regression analyses was conducted with micro-data from Jordan to address whether there is evidence that gender, education, and age are correlated with refugees' vulnerability. This section uses the micro-data from Jordan to examine how PA's characteristics including agricultural background affects the odds that a refugee will be vulnerable at the host community. Appendix 1 presents the methodology and reports estimates.

2.24. In Jordan, regardless of gender, young (18 years and younger) and old (66 years and older) PAs are subject to increased needs compared to other age cohorts. In addition, old PAs are subject to the largest number of needs. The number of children also significantly increases the number of needs. The effect of marital status on needs, however, differs by gender. More specifically, female PAs who are married have fewer needs than both single or separated, divorced, and widowed female PAs. On the contrary, male PAs who are married have more needs than single or separated, divorced, and widowed male PAs.

2.25. Educational attainment is inversely related to needs, but its effect is much stronger for women. Compared to women with less than 6 years of education, those who have between 6 and 11 years of education are expected to have 0.2 fewer needs and those who had 12 years or more of education are expected to have 0.3 fewer needs. For males, those who have between 6 and 11 years of education are expected to have 0.03 fewer needs and those who had 12 years or more of education are expected to have 0.09 fewer needs. Previous professional occupation, which is correlated with both education and skills, has a significant effect on needs. Female PAs who worked in agriculture, clerical, services, and sales, and in non-agricultural occupations are expected to have increased needs compared to those in other occupations. For males, those who worked in agriculture, craft and related services, plant and machine operators, and in non-

agricultural occupations are expected to have increased needs compared to those in other occupations (see Box 2.1).

2.26. The overall takeaway of the regression analysis is that female PAs who are either young (18 years and younger) or old (66 years and older), that have worked in agriculture or are less educated, that are single, separated, divorced, or widowed, and that have children, are significantly more likely to have needs as classified by the UNHCR than their counterparts. For male PAs, the profile is similar, except that married men are expected to have more needs and the positive effect of education is significantly smaller. Refugee women do face barriers that make it difficult for them to engage in economic activities outside of their households due to their traditional housekeeping roles. Yet in rural Syria, women play a significant role. According to estimations, approximately 70 percent of all agricultural work is performed by women. Within the agricultural cycle, women carry the obligation of physically planting seeds, weeding, threshing, harvesting, processing, etc. They do most of the harvest while simultaneously sustaining their duties as the family caretaker. Women and children are singularly responsible for fruits and vegetable production, poultry and livestock maintenance (milking, grazing, barn cleaning, nutrition, childcare, birth control, and even health care and sheep infusion).

2.1.6. Income and Economic Integration in Host Communities

2.27. Income is one relevant measure of refugees' economic integration. Figures 2.9 and 2.10 report average per capita income excluding UNHCR assistance for refugees in Jordan and Lebanon respectively. It shows that previous occupations, which are associated with skills, affect income per capita (see also Box 2.1). Regression analysis reported in Appendix 2 shows, however, that the returns to education are negligible, and education seems to play no role in explaining the Syrian refugees' income levels after their relocation. This is consistent with World Bank 2016 (Verme et al.) and implies that traditional policies focused only on human capital accumulation have limited or no effect on Syrian refugees' standard of living. The skills and training acquired in agriculture in Syria seem adaptable to the economic environment in Jordan.

2.28. PAs with agricultural occupations have income lower than those who had non- agricultural occupations or were housekeepers in Jordan (Figure 2.9). For male PAs, those who previously worked in non-agricultural occupations reported JD 66.9 in per capita income, compared to JD 58.2 for those in agriculture, and JD 48.5 for housekeepers. Among female PAs, those who previously worked in non-agricultural occupations reported JD 69.8 in per capita income, compared to JD 44 for those in agriculture, and JD 48.1 for housekeepers. In Jordan women working in agriculture and housekeepers are those with the lowest cash incomes.

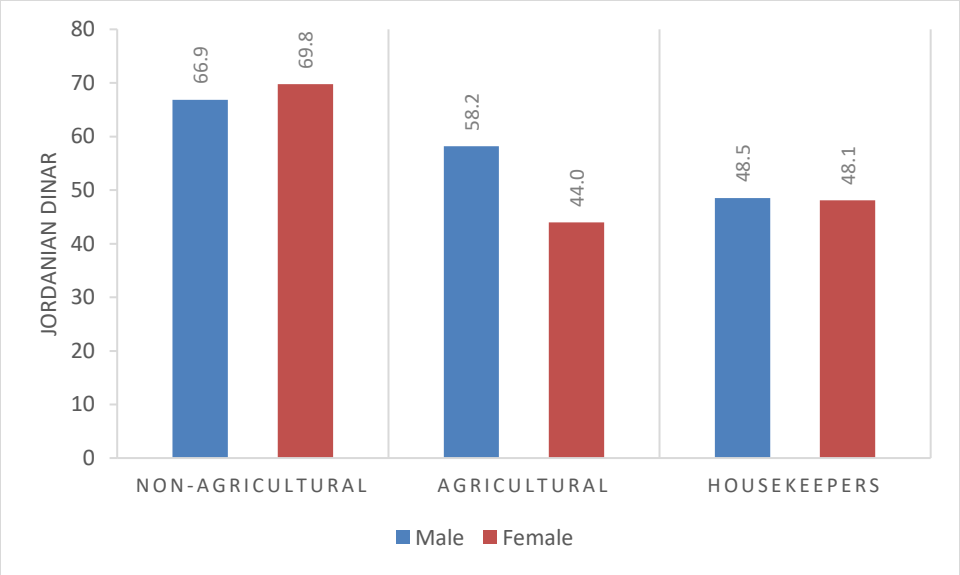
2.29. Controlling for education and other covariates, per capita income of female PAs is significantly lower than that of male PAs in Jordan. The estimates imply that per capita income of female PAs is about JD 13 lower than average per capita income of male PAs. In addition, per capita income of married PAs is also lower than that of single, divorced, or widowed PAs. An interaction between Female and Married PAs – not reported in Table A2–shows that PAs who are female are expected to have per capita income lower than that of PAs who are either married or female, i.e. female PAs who are married face significant barriers to labor market integration and, thus, they may receive further attention to address their particular needs.

2.30. Older individuals face significant barriers to be integrated into the labor market of host communities. The regression analysis also provides evidence that, controlling for other factors, there is no statistically significant differences in per capita income for PAs between 15 to 49 years old. However, per capita income of PAs older than 50 years of age is significantly lower than that of PAs of all other age cohorts. Compared to PAs younger than 50 years, per capita income was approximately JD 9 lower for PAs between 50 and 65 years of age and about JD 18 lower for PAs 66 years and older.

2.31. The length of time since arrival in Jordan is also an important predictor of refugees' per capita income, and thus of economic integration. The coefficient estimates imply that the average per capita income of PAs who have been in Jordan for two years is about JD 15 higher than that of those who arrived in less than a year. In addition, income per capita of those who have arrived 3 or more years ago is JD 19 higher than those who arrived less than a year ago.

2.32. In Lebanon, the average household income per capita (from all sources) was US$60 in 2016. However, several income sources are not sustainable because it includes informal loans (60 percent of HH reported loans) and food vouchers (50 percent of HH). The income from agriculture, construction or informal jobs is not sufficient to meet households' spending needs.[44]

Figure 2.9 Per capita income by previous occupation, Syrian Refugees in Jordan, 2014, Dinars



Source: Authors' compilation using the UNHCR PGHV-C dataset.
Note: The figures above exclude UNHCR Assistance and only include households with income > 0.

2.33. In Jordan, the share of refugees that receive no income is significantly smaller for PAs who had agricultural occupations compared to both PAs with non-agricultural occupations or housekeepers; the differences are remarkably large for female PAs. Figure 2.10 shows that refugees' economic integration can also be measured by the proportion of cases (or PAs) that report

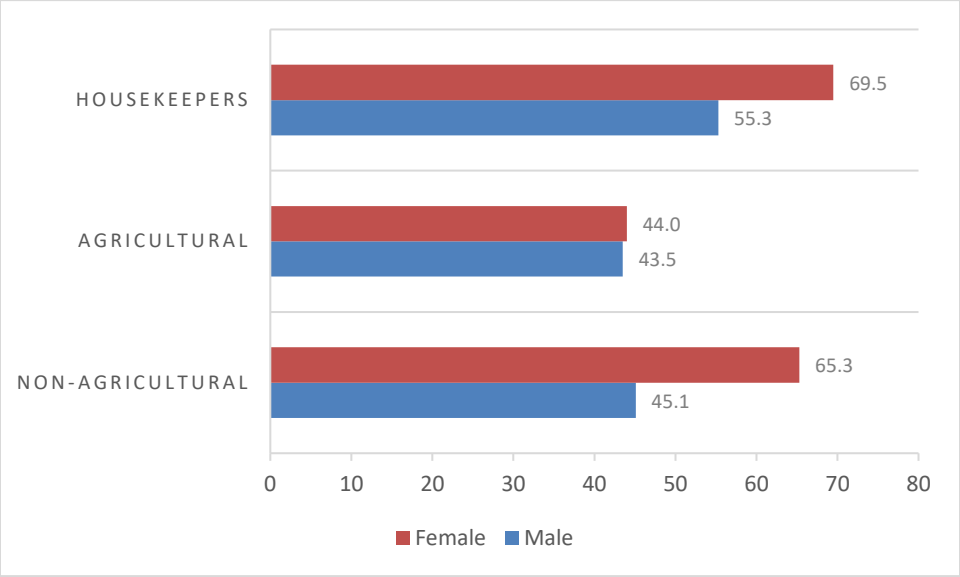
[44] Saiid et al. (2016, p. 60).

income. More than 44 percent of cases with female PAs who worked in agriculture reported no income, compared to 65.3 percent of female PAs who had non-agricultural occupations and 69.5 percent of female PA housekeepers.

2.34. In Lebanon, 70 percent of working-age men and 7 percent of women reported income from work in 2016. Working-age individuals worked an average of 14 days per month and were working mostly in construction (33 percent), agriculture (22 percent), services (26 percent), and in retail and cleaning (12 percent).[45]

2.35. It is important to note that jobs available to Syrian female refugees in agriculture are often daily or seasonal. The strong focus among Syrian women refugees to work in agriculture is based on their previous experience to work in agriculture prior to the conflict. The majority of women are from agricultural Syrian governorates (Daraa & Homs).

Figure 2.10 Proportion of households without income by Previous Occupation, Jordan, 2014, percent



Source: Authors' compilation using the UNHCR PGHV-C dataset.
Note: The figures above exclude UNHCR Assistance.

[45] Saiid et al (2016, p. 60).

Box 2.1 Jordan: The links between professional background, household income at host community and reporting of needs[46]

Previous professional experience has a significant effect on Syrian refugees' income. However, the traditional occupation hierarchy where managers and other professional occupations outperform other occupations in terms of earnings is also not applicable to refugees. Compared to managers and other professional occupations, PAs who had previously worked as technicians, associate professionals, clerical, services, crafts and in agricultural occupations have higher per capita income. Per capita income of PA housekeepers, on the other hand, is lower than that of PAs who were managers or other professionals. Noteworthy, PAs who were previously employed in agricultural occupations had per capita income of about JD8 higher than average per capita income of managers and other professionals.

The model estimates provide evidence that PAs who reported needs are expected to have lower per capita income regardless of their background. Income per capita of PAs who reported needs is approximately JD 5 lower than that of those who reported no needs. This finding reinforces the view that vulnerable individuals face significant hurdles to be integrated in the economy of the host community, and thus they may require additional support to mitigate the extra burden of their background.

Source: Authors' compilation using the UNHCR PGHV-C dataset.

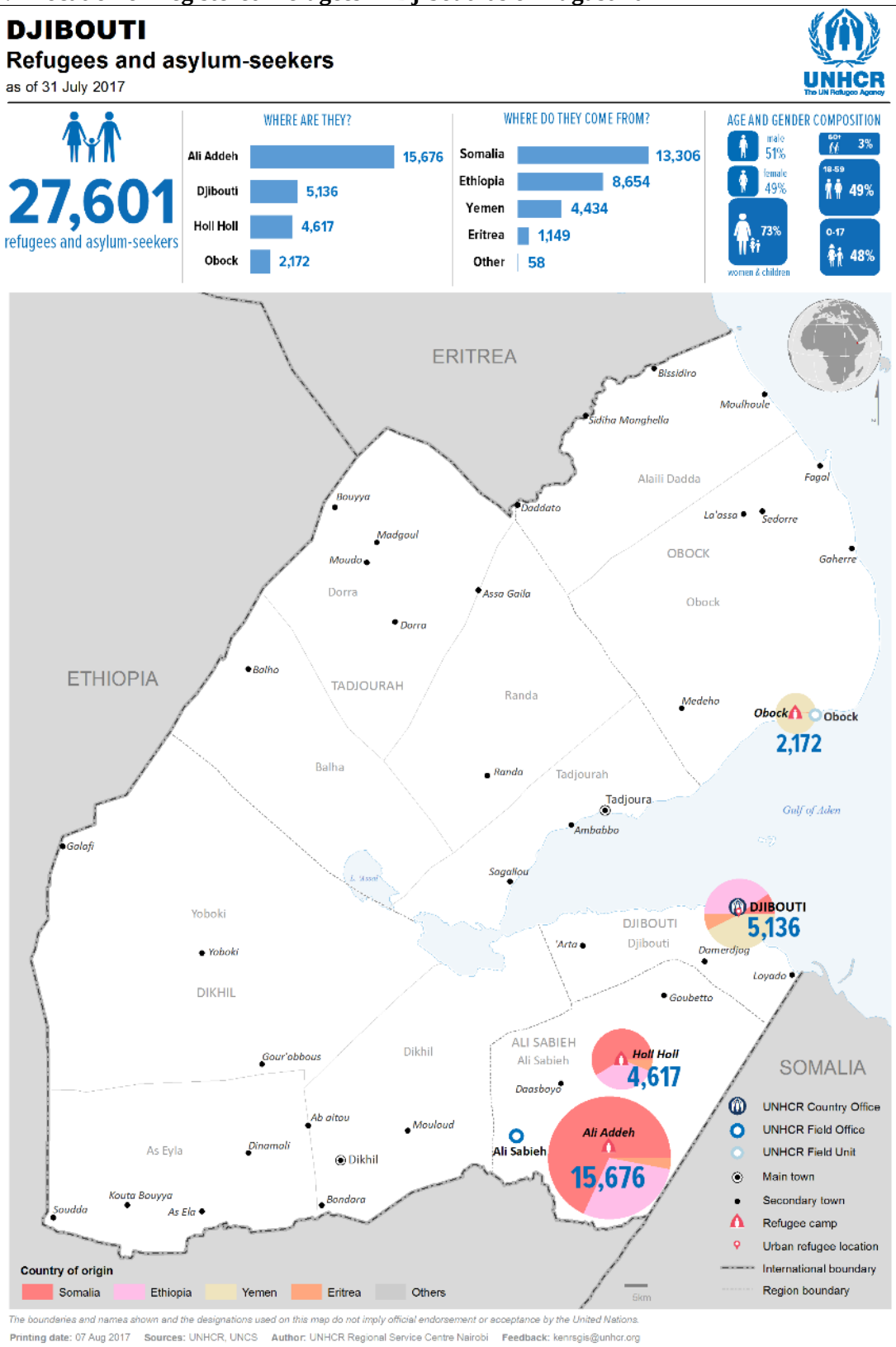
2.2. Refugees and their hosts in Djibouti

2.2.1. Poverty

2.36. Djibouti hosts more than 27,600 registered refugees and asylum seekers mainly from Somalia (13,300), Ethiopia (8,700), Eritrea (1,100) and about 4,400 Yemenis.[47] Seventy-three percent are women and children. More than three quarters live in isolated camps in very poor and isolated regions. About 2,200 of the Yemenis stay in Markazi camp near Obock (harbor), the conditions in the camp are difficult and many therefore leave the camp to go to Djibouti City and the town of Obock. Other nationalities mainly live in the overstretched camps of Holl Holl (4,600) and Ali Addeh (15,700) in the Southern Ali Sabieh region.[48] The Djibouti refugee situation is protracted, with mainly Somalis having been there for more than 20 years. The Djibouti Government has an open-door policy for refugees, and policies and concrete actions are presently underway with assistance from the international community (see Map 2.1.)

[46] We use regression analysis to examine how a refugee's background affects their income from work, a proxy for economic integration in Jordan. The methodology and estimates are reported in Appendix 2.
[47] UNHCR (August 2017), website: reporting.unhcr.org Figures above are rounded.
[48] Ibid.

Map 2.1 Location of Registered Refugees in Djibouti as of August 2017



Source: UNHCR.

2.37. The refugees currently have limited opportunities for economic integration, because of the climatic conditions, as well as the remoteness. The concentration of refugees in a few places heightens the pressure on the environment. Services to refugees are delivered by humanitarian agencies in parallel systems, and refugees actually have better access than host communities, who also live in abject poverty and have limited access to services. According to humanitarian organizations, there is no tension between refugees and host communities at present, however, there is fear that the differential treatment with regard to services, pressure on the fragile environment, and the year-long drought situation could build up tension.

2.38. Twenty-three percent of Djibouti's population lives in extreme poverty.[49] The harsh environment for traditional agriculture is one reason that the population mainly lives in and around Djibouti City[50] (71 percent). Of those living in Djibouti City, up to two-thirds live in slums.[51] The rural population subsists primarily on nomadic herding.

2.2.2. Gender

2.39. The refugee crisis has a significant gender profile. Refugee girls are subject to female genital mutilation (FGM). FGM is also practiced extensively in the host population, and is a major obstacle for girls and women to uphold their sexual and reproductive rights, go to school as adolescents and remain healthy. WFP has a special focus on keeping girls in school. The new refugee law (April 2017) and the implementation of the Comprehensive Refugee Response Framework (CRRF) focusing on health and education for refugees and their hosts will be an important initiative to reduce vulnerabilities (UNHCR and WB are engaged).[52] Organizations also note extensive practices of poverty-related sexual practices: survival sex, GBV, and early marriages.

2.40. Figures for Djibouti (not refugees) show that the literacy rate among young women age 15-24 is only 48 percent. According to UNICEF, no data exist in the global databases consulted on the literacy rate of male youth. Girls' net attendance ratio is 66 percent in primary school and 37 percent in secondary school. The attendance ratio for boys is similar to that of girls (67 percent) in primary school but higher in secondary school (45 percent).

2.41. The labor force participation rate among young women aged 15-24 is 46 percent, while the corresponding percentage for young men is 56 percent. Overall, more than 48 percent of the working-age population is unemployed.[53]

2.2.3. Food insecurity[54]

2.42. WFP and CARE (2013) reported a low asset holding – including livestock – among refugees and hosts and the latter lost most of their livestock and small stock in the consecutive

[49] http://www.worldbank.org/en/country/djibouti.
[50] World Bank, (2016).
[51] Ec.europa.eu/echo/files/aid/countries/factsheets/Djibouti_en.pdf.
[52] http://crrf.unhcr.org/en/
[53] http://www.africaneconomicoutlook.org/en/country-notes/djibouti.
[54] World Food Programme and Care (2013): *Food security, Livelihoods and Markets report for Ali Addeh and Holl*

years of droughts. The report also shows that 37 percent of households (both refugees and hosts) experienced lack of fodder and pasture as the biggest constraint for livestock production, followed by parasites and diseases (32 percent), and scarcity of water (15 percent).[55] Water access and quality in the camps are poor due to limited infrastructure, a large number of unprotected water sources, and a limited capacity to treat water. Fifty-one percent of households in Holl Holl and 30 percent of households in Ali Addeh have below minimum water usage[56] (compared with 35 percent and 61 percent in their respective host communities). Ninety percent of households in Ali Addeh camp and 83 percent of households in Holl Holl have access to latrines (compared to only 57 percent and 24 percent in their respective host communities).[57]

2.43. Around 40 percent of the refugees are food insecure[58] but host populations near the camp areas have considerably higher levels of food insecurity. WFP has found that for those living in refugee camps, food insecurity is largely due to sales of the food rations to meet other non-food needs, sharing of the food, and repayment of loans using food rations. The sales contribute to food rations being insufficient (WFP notes that rations last between 17 and 23 days). Female-headed households and new arrivals are more likely to be food insecure.

2.2.4. Economic activities

2.44. Refugees and host communities have limited access to other income sources. WFP and CARE (2013) found that most of the households, both in camps and host communities, depend on informal income sources, for refugees no particular income source was found to be prominent.[59, 60] The 2013 Joint Assessment Mission found that the vast majority of refugees have access to none or only one source of income (almost one-third of refugees earn income from the sale of food aid, gifts and transfers, about 20 percent from daily/seasonal wages, and 10 percent from informal trade such as the sale of charcoal and firewood). Refugees are frustrated by the limited access to credit, labor opportunities, land for cultivation, livestock and vocational training.[61] Approximately one-third of the host community households in Ali Addeh and Holl Holl rely on informal trade that include charcoal, daily non-agricultural labor and domestic wage respectively.

Holl Refugees and Host Communities. The study surveyed a total of 576 households, interviewed 90 traders and 15 focus group discussions were conducted. WFP and Care carried out a livelihoods and market study for the two refugee camps and host community of Ali Addeh and Holl Holl in Ali Sabieh region in November 2013. CSIS study (April 2017): Stuck in Limbo, Refugees and Migrants and Food Insecure in Djibouti.

[55] WFP and CARE (2013).

[56] Under 20 liters per person per day.

[57] World Bank (2017b) Forced Displacement Strategy Notes, Djibouti Background Paper DRAFT and WFP and UNHCR: Joint Assessment mission – Ali Addeh and Holl Holl Camps, Djibouti November 2013.

[58] WFP and UNHCR Joint Assessment mission – Ali Addeh and Holl Holl Camps, Djibouti November 2013. The assessmnet found 42 percent of HH in Ali Added and 37 percent in Holl Holl are moderately or severely food insecure compared to 66 percent and 44 percent in the respective hos communities.

[59] WFP and UNHCR (2013).

[60] WFP and CARE (2013).

[61] WFP and UNHCR (2013).

2.2.5. Resource scarcity

2.45. The WFP assessment in 2013 found low asset holding including livestock within the camp and host community as the latter lost most of their livestock and small stock in the consecutive years of droughts. Moreover, livestock production in both the host population and refugees is dogged by lack of pasture and fodder. This was reported by 37 percent of households as the biggest constraint; parasites and diseases was reported by 32 percent; and scarcity of water was reported by 15 percent.

2.46. Water access is scarce for both refugees and host communities. There is limited infrastructure and water sources are mainly unprotected. Water access and quality in the camps are poor due to limited infrastructure, a large number of unprotected water sources and a limited capacity to treat water. Fifty-one percent of households in Holl Holl and 30 percent of households in Ali Addeh have below minimum water usage[62] (compared with 35 percent and 61 percent in their respective host communities). Ninety percent of households in Ali Addeh camp and 83 percent of households in Holl Holl have access to latrines (compared to only 57 percent and 24 percent in their respective host communities).[63]

2.47. Overcrowding in refugee households is common and the housing conditions are poor. Shelters are dismal and old clothing and vegetation is used for construction and mending. In the 2013 Joint Assessment Mission, it was noted that overcrowding is a problem with 80 percent of refugee households in Holl Holl, and 51 percent in Ali Addeh reporting that more than three people sharing a room (compared to 65 percent and 83 percent in their respective host communities).[64]

2.48. Organizations are concerned that scarce resources could eventually lead to conflict between the local population and the displaced. Rising food insecurity will likely also cause higher rates of severe acute malnutrition among children under age five. Competition for access to the country's limited natural resources, particularly in areas with large numbers of refugees and migrants, could also increase. The firewood collection (main fuel for cooking) and sales create pressure on the environment around the camps thereby contributing to land degradation already highly challenged by adverse climatic conditions.

2.49. Humanitarian organizations continuously state that availability and access to fresh water is of great concern among both refugee camps and host communities. The increasing population pressure contributes to the reduction of fresh water availability per capita in the camps, posing a high risk of contaminated groundwater reserves. The newly planned freshwater pipeline that will bring water from Ethiopia to Djibouti may change this.

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[62] Under 20 liters per person per day.
[63] World Bank (2017b) Forced Displacement Strategy Notes, Djibouti Background Paper DRAFT and WFP and UNHCR: Joint Assessment mission – Ali Addeh and Holl Holl Camps, Djibouti November 2013.
[64] Ibid.

Box 2.2 Policy towards refugees and migrants

Djibouti is also a main migrant transition point, both for migrants and asylum seekers heading for the Gulf States and beyond. Each year some hundred thousand people, mainly Ethiopians and some Somalis, journey through Djibouti, usually through the port of Obock and then cross over and go through Yemen. Many Yemenis now come the other way because of the conflict in Yemen. They now come as refugees and asylum seekers, but seem to, in many cases, remain unregistered and head for Djibouti City rather than seeking asylum at one of the three refugee camps.

Djibouti has a long tradition of hosting refugees and has maintained an open door policy. At the Leaders Summit for Refugees in New York in September 2016, Djibouti declared that it would take new steps towards inclusion of refugees in local communities, in national education programs and health systems. The recent Refugee Law (promulgated January 2017 to be implemented by decree) will grant refugees access to accredited education (English language curriculum) and legal protection. Djibouti has started to implement the Comprehensive Refugee Response Framework (CRRF) and together with its international partners, steps have been taken to implement refugee management policies that enhance the self-reliance of refugees and host communities. The partners include UNHCR, the World Bank, donors and diplomatic missions in Djibouti.[65]

Organizations working in Djibouti note that more refugee and migrants are likely to continue to pour in, as conflicts in Yemen and the Horn of Africa remain active.

Source: Authors' Compilation Based on Field Meetings.

[65] A joint World Bank/UNHCR mission to Djibouti in April 2017 explored the potential use of the Bank's IDA-18 (International Development Assistance) regional sub-window for refugees and host communities, a financial facility that aims to support low-income countries that host refugees.

3. Frontier Agriculture Technologies

3.1. Traditional farming methods are often difficult in arid areas with little arable land and with populations facing water scarcity and a harsh climate. About 1.1 billion people worldwide lack access to water and 2.7 billion people face water scarcity for at least one month of the year. According to the UN, nearly two-thirds of the world's population may face water shortages by 2025 (UN 2016).

3.2. In MENA, a shift from immediate, reactive responses to a balanced, long-term development approach is necessary to address the water and fragility challenges (World Bank, 2017c). There is a vicious cycle of water and fragility due to their compounding nature. Water scarcity challenges are becoming worse with climate change, rising demands, inter-sectoral competition and urbanization. The water-saving technologies discussed in this section may not only help address food security and other basic needs, but may also help achieve water security through leveraging the opportunities and productive potential of water (World Bank, 2017d).

3.3. Several initiatives have been launched to address challenges of limited arable land and water resources through soil-based farming methods such as small plots, community gardens and drip irrigation gardens. Hydroponics and aquaponics may also be alternatives that have limited implementation, adoption and adaptation in developing countries, including MENA. These technologies require much less water, no soil, and minimal use of land. Hydroponics may be a valid alternative to produce nutritious food while increasing livelihoods in constrained areas that are not rich in natural resources.

3.4. The following sections address climate smart water-saving agriculture technologies, namely different types of hydroponic systems, from the simplest to the most advanced techniques. It covers the inputs and outputs, different aspects of production, and the costs and labor involved in these technologies. There is an emphasis on simplified hydroponics and aquaponics since these types are already being implemented in the region.

3.1. Hydroponics

3.5. Hydroponics is a method of growing plants using a nutrient solution, which is a mixture of water and nutrient salts, without the presence of soil (Gericke 1940; Gericke 1945; Hoagland and Arnon 1950). Hydroponics is not a new phenomenon; early examples of hydroponic growing were the hanging gardens of Babylon, the floating gardens of the Aztecs of Mexico, and in older Chinese cultures (Resh 1995). In 1929, Dr. Gericke of the University of California Berkeley began promoting the growing of plants in a soilless medium and coined the term "hydroponics". In traditional farming, soil is the main input to store the various nutrients required for plant growth. When water saturates the soil, it picks up these nutrients so they can more readily interact with the plant roots (Campbell and Reece 2002) and then move to shoots, leaves, and fruits. In hydroponics, the need for soil is replaced with the use of nutrient solution.

3.6. Hydroponic systems use approximately 80–99 percent less water than open field agriculture (Despommier 2010), the more advanced systems using less water than the simplified

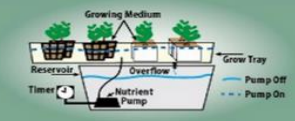
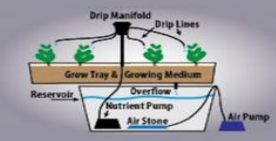
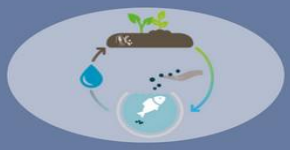
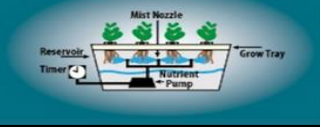
systems. Hydroponic techniques range from simple systems using buckets that do not need electricity to sophisticated systems that are stacked vertically in tall buildings, such as aeroponics. Hydroponic farming is possible across diverse climates and agro-ecological zones, including arid areas (Heredia 2014). Growing in such environments is possible by farming indoors or in greenhouses in a controlled environment. These farming methods separate the production area from the ecosystem and reduce the amount and types of ecosystem services (e.g., biodiversity, habitat, carbon sequestration, building soil, water purification, etc.) compared to traditional agriculture. Thus, hydroponic food production has a positive impact on the environment and on natural resource management.

3.7. Hydroponic farming is being established in both urban and rural areas as consumer demands for fresh produce with high nutritional value increase. In fact, the hydroponic industry in the United States has grown at an annual rate of 3.6 percent in the last five years. Since hydroponic systems do not depend on external conditions, they can be set up almost anywhere. Hydroponic farms have been established in unused or recycled spaces such as parking lots, building rooftops, warehouses, shipping containers and underground tunnels. Producing in urban areas minimizes the distance between the food producer and consumer (Bellows et al 2004). The shorter the supply chain, the less transport, packaging, conservation and labor needed, leading to substantial decreases of resources and energy (e.g., up to 79 percent of the retail price in US conventional food distribution (Wohlgenant 2001). Shortening and simplifying the food supply chains can drastically diminish their environmental impacts, while providing cities and rural areas with fresh, highly nutritious produce.

3.2. Types of Hydroponic Systems

3.8. There is a continuum of at least seven types of hydroponic systems, from the most simplified to the most sophisticated types, that is explored further in this section. From simple to advanced, these systems include: wick systems, deep water culture, ebb and flow, drip method, nutrient film technique, aquaponics, and aeroponics. The type of system chosen depends primarily on the type of plant as well as any limitations of the grower and/or growing space (Jensen 1997). While these system types may share many features, including design, they fundamentally differ in how they manage the nutrient solution. The most popular are water culture, drip system, and NFT (Resh 1995). Figure 3.1 compares the different types of systems and their advantages and disadvantages.

Figure 3.1 Types of hydroponic systems and advantages and disadvantages

Simple & Less Water Saving	Hydroponic Systems	Advantages	Disadvantages
	Wick Systems 	• Affordable • Simple set up • Low maintenance • No nutrient pump or electricity needed	• Limited oxygen access • Slower growth rate • No nutrient recirculation • Prone to algae growth • Less efficient than other hydroponic methods • Salt build-up needs flushing
	Deep Water Culture 	• Inexpensive • Simple set up Low maintenance • No nutrient pump or electricity needed with Kratky Method • Reliable	• Risk of root rot if not cleaned regularly • Slower growth rate • Must top water until roots are long enough to fall into the nutrient solution • Must frequently refill reservoir
	Ebb & Flow 	• Affordable • Low maintenance • Excess nutrient solution recirculates	• Prone to algae growth • Technical malfunctions could result in crop loss
	Drip Method 	• Excess nutrient solution recirculates • Sufficient oxygen flow	• Prone to clogging • Prone to algae growth • Requires regular cleaning
	Nutrient Film Technique 	• Excess nutrient recirculates • Plentiful oxygen flow • Space sufficient	• Prone to clogging • Technical malfunctions could result in crop loss
	Aquaponics 	• Ability to raise fish • Recycles 95%-99% of water • Completely organic • Uses 90% less water than traditional farming • No chemical pesticides	• High startup costs • High risk of system failure • Needs regular monitoring • High energy usage • Needs technical expertise • Needs reliable electricity
Advanced & More Water Saving	**Aeroponics** 	• Maximum nutrient absorption • Excess nutrients recirculate • Plentiful oxygen flow • Space sufficient • Approximately 70% less water than hydroponics	• Prone to clogging • Technical malfunctions could result in crop loss • High-tech • Time intensive • Poorly suited to thick organic-based nutrients and additives

Source: Authors' Compilation.

3.9. Hydroponic systems can generally be delineated into open and closed systems (Abd-Elmoniem et al 2006; Jensen 1997; Nederhoff and Stanghellini 2010). Open systems, also known as "run to waste systems," do not employ water reuse measures and the nutrient solution flows through the system only once and is discarded (Jensen 1997; Nederhoff and Stanghellini 2010). Open systems provide two primary advantages: they eliminate the need for nutrient solution maintenance and reduce the risk of plant pathogens and infection (Jones Jr. 2005). Despite these advantages, open systems are known to waste a large amount of water and nutrients (Nederhoff and Stanghellini 2010) and may not be appropriate for arid regions. On the other hand, closed systems reuse the nutrient solution via recirculation for an unspecified length of time (Lykas et al 2006). More water and nutrients are added instead of replacing the entire solution (Jensen 1997;

Nederhoff and Stanghellini 2010). The nutrient solution is regularly monitored and adjusted to maintain proper nutrient ratios. As a result, closed hydroponic systems use 20-40 percent less water and nutrients than open hydroponic systems, but are more difficult to monitor and maintain. This difficulty arises from ion accumulation as the nutrient solution recirculates (Lykas et al 2006). Also, recirculation requires an infrastructure of reservoirs and pumping systems that have to be monitored and maintained in order to perform optimally, which can make them more susceptible to failure if not managed well (Nederhoff and Stanghellini 2010).

3.2.1 Wick Systems

3.10. Wick systems are non-circulating systems comprising of raised garden beds that have a water reservoir below the plant roots. Water is supplied through a pipe to the water reservoir and the water is drawn upward into the root zone by capillary action, enabling the plants to absorb the amount of water they need. Therefore, there is no need for overhead watering and a lot less water is lost through evaporation. The roots growing in the moist soil have a continuous supply of water, oxygen and nutrients. See Box 3.1 for a system in the Palestine territories.

3.11. The wick system technique works well in dry, water-scarce environments with limited and unreliable technical inputs, such as electricity, and where assistance is not readily available. For example, this technique is currently being used by women in the Palestinian Territories despite the challenges faced by the territories to access materials and inputs (see Box 3.1). The main advantages of using this system are: (i) the unit can be planted 3-5 seasons (times) per year; (ii) it is simple, safe, and easy to manage; (iii) its high acceptance by traditional farmers because the plants are in growing media that is similar to working with soil; and, (iv) the wicking system includes worms that can digest organic kitchen waste into compost to create fertilizer. The main disadvantages of this method are: (i) it does not work well with larger plants with higher water demands; (ii) wicking beds are less efficient than other methods in delivering nutrients to heavy feeders, tomatoes, peppers, etc.; (iii) salt accumulates in the growing media, and weekly flushing should be done to remove excess nutrients from the root zone.

Box 3.1 Wicking bed systems in the Palestinian Territories

In March 2012, the Applied Research Institute Jerusalem (ARIJ), in partnership with the Polish Center for International Aid, piloted a project to adopt NFT and wicking bed production to increase food security, nutrition, women empowerment, income generation and the competitiveness of the agricultural cooperatives sector in Palestine. Thirty-five NFT units and fifty-two wicking bed units were established to benefit marginalized and underprivileged families in remote areas of Bethlehem and Hebron governorates. Education models were also established at Al-Arroub Agricultural School to train students in these technologies. The food produced by the units is consumed by the families and the surplus produce is marketed to generate income and assist collaborating cooperatives in sustaining their social and humanitarian missions.

Each wicking bed unit kit costs $820, which contains four beds with a total area of four square meters and can plant up to 100 seedlings per season for three to four seasons per year. Each wicking bed unit comprises four separate units that can be replanted three to four times a year, yielding the same production capacity as the 5m^2 NFT system, which can hold 128 seedlings per unit. The average annual production is 156 kg with a total market value of $220 for the wick system and 175 kg with a total market value of $245 for the NFT system. The project beneficiaries, which are mostly women, were trained to manage the units, which comprise of water pumps, a pumping regulator, and various fittings, such as pipes and other simple equipment. ARIJ provides training, technical support and follow-up services to the beneficiary families, including a Facebook community for farmers to share experiences and ask questions. ARIJ also connects farmers with specialists from the Ministry of Agriculture to provide additional technical and extension services to the beneficiaries.

Both NFT and wicking bed systems, which are portable, are suitable for urban and rural areas, particularly water-scarce environments, and reduce the usage of irrigation water by 50 percent. In addition to being safe and natural, the systems are conducive to family participation in planting and caring for the plants. These systems enhance food security at the household level in Palestine and the surplus production that is not consumed by the families is often sold to neighbors, thus these systems enable income generation for small farmers.

Source: ARIJ (2016).

3.2.2 Deep Water Culture

3.12. Deep Water Culture (DWC) is one of the simplest hydroponic techniques and is a non-circulating system suitable for areas with little to no electricity. The system requirements are simply a water reservoir to supply nutrients to the plants, a polystyrene platform to float the plants on top of the nutrient solution, and an air pump with air stones attached to supply the roots with oxygen. Water culture systems are highly desirable to grow leafy greens, such as lettuce, because these plants grow fast and consume large amounts of water.

3.13. The Kratky Method is simple to operate, requires little to no maintenance, is inexpensive, and is suitable for inexperienced farmers. It is a type of water culture where the farmer builds or uses a watertight container as a water reservoir, such as five-gallon plastic storage containers or trash bins, filled with the nutrient solution (see Figure 3.2). Plants are grown in net pots on top of the tank cover and are continuously watered since the entire growing medium becomes moistened by capillary action. The roots of the plants are only partially submerged in the water and the top of the plant roots have access to oxygen, creating a moist air. Aside from planting or transplanting, no additional labor is required until harvesting. Electricity and pumps are not needed, so the additional production costs and complexities associated with aeration and circulation in many other hydroponic systems are avoided by this method (Kratky, B.A. 2009).

3.14. While there are benefits to the simplicity of the Kratky approach, there are notable disadvantages of the method. When the nutrient solution is stagnant, the mineral salts settle near the bottom and create a nutrient imbalance with very low nutrient concentrations near the surface. This problem can be overcome by inserting an air pump into the water, which keeps the nutrient solution well mixed. The Kratky Method is better suited to short-cycle vegetables, while longer-living plants need larger water containers. Water containers exposed to the sun in areas with hot climates could heat up and lead to oxygen deficiencies and damage to the plants. Furthermore, even though non-circulating systems tend to be cheaper than circulating hydroponic systems, circulating hydroponic systems tend to grow better than non-circulating systems.

Figure 3.2 The Kratky Method bucket system

Source: Authors.

3.2.2.1 Ebb and Flow

3.15. The ebb and flow system, also called flood and drain, is the classic hydroponic setup that is widely used due to its inexpensive cost, dependability and simplicity. This method feeds plants by flooding the plant site with a nutrient solution and allowing that solution to drain back into the reservoir. It uses pots which are filled with inert media and are placed inside a tray or container. During the growing cycle, the tray or container is filled automatically several times a day by a pump that uses a timer.

3.2.2.2 Drip Method

3.16. The drip system is another widely used hydroponic technique with water circulating through the system using drip emitters. The drip emitters drip water rather than spray or run it, which is the case in traditional drip irrigation, and a dripper runs to every plant placed in a growing medium. After the water passes through the cup holding each plant, it goes back into the water reservoir and gets recycled through the system again. Plants can be grown in buckets or trays. The system requires electricity to power a submersible pump to disperse the water and an air stone to mix the water in the reservoir.

3.2.2.3 Nutrient Film Technique

3.17. The Nutrient Film Technique (NFT) places plants in long plastic grow trays with water circulating through the system. Plants are then supported in smaller plastic net cups filled with a growing medium. A water level is set in the tube depending on the maturity of the plants. When the plants are younger, the water level is set higher allowing the roots to reach the water. Once the plant roots mature, the water level is lowered to promote root growth. With this technique, the nutrient solution is pumped past the plant roots allowing the plants to meet their water and nutrient requirements. The drawback of this system is that it is susceptible to power outages and pump failures. Once a failure occurs, the plant roots dry out very rapidly.

3.2.2.4 Aquaponics

3.18. Aquaponics is a method for producing food that combines recirculating aquaculture (raising fish in land-based tanks) with hydroponics (cultivating plants in water). Aquaponics recycles 95 percent to 99 percent of the water introduced in the system and it is this recycling of water that distributes nutrients throughout the system. Aquaponics enables the harvesting of crops as well as fish and other aquatic animals. Please see the Aquaponics section for more detailed information.

3.2.2.5 Aeroponics

3.19. Aeroponics is a relatively new method for growing edible plants and the most advanced method of hydroponics. Aeroponics utilizes a fine mist of nutrient-laden water created by its passage through a pressurized nozzle that is then directed toward the enclosed root system of the plants. Aeroponics uses approximately 70 percent less water than hydroponics, while delivering the same amount of nutrients to the roots. Recent advances in nozzle design have improved the reliability of the system for creating the spray by eliminating clogging, a major issue in earlier models. As a result, more vertical farms are adopting aeroponics as their main growing strategy.

Several configurations of aeroponic growing systems will serve to illustrate the creative process following Stoner's original aeroponic equipment. See Box 3.2 for more information on vertical farming.

Box 3.2 Vertical farming

Vertical farming allows produce to be grown in vertically stacked layers, on vertically inclined surfaces or integrated in other structures, increasing productivity in terms of the amount of produce grown per square meter (Christie 2014). Vertical farms are a space-saving form of controlled environment agriculture and different types of hydroponic systems can be used to grow produce vertically. Vertical farms can range from simple NFT hydroponic systems using recycled materials to multistory buildings using aeroponics, such as Aerofarms in the USA (see photo on right in Figure 3), containing an environment conducive to the growing of fruits, vegetables, and nonedible plants for things such as biofuels, drugs, and vaccines. Today, the leading countries employing vertical farms include Japan, Singapore, Taiwan, China, the United States, and a few countries in Western Europe.

Vertical farming works well for small spaces including in urban settings such as rooftops and unused spaces. It allows for a higher yield to be obtained per square foot and uses less land than traditional farming. Vertical farming is more of a structural technique than an actual system since both hydroponics and other types of water and soil-saving techniques can be set up vertically. For example, vertical hydroponic gardens in Israel utilized NFT with a snake-like structure (top left and top center images in Figure 3.3) while a vertical triangular structure for a hydroponic garden in Palestine utilized NFT but had a lower-tech set up and used lower-cost materials (bottom left image in Figure 3.3). Another vertical garden system in the Palestinian Territories was constructed of recycled large water bottles and soil for production of small plants and herbs (bottom center image in Figure 3.3).

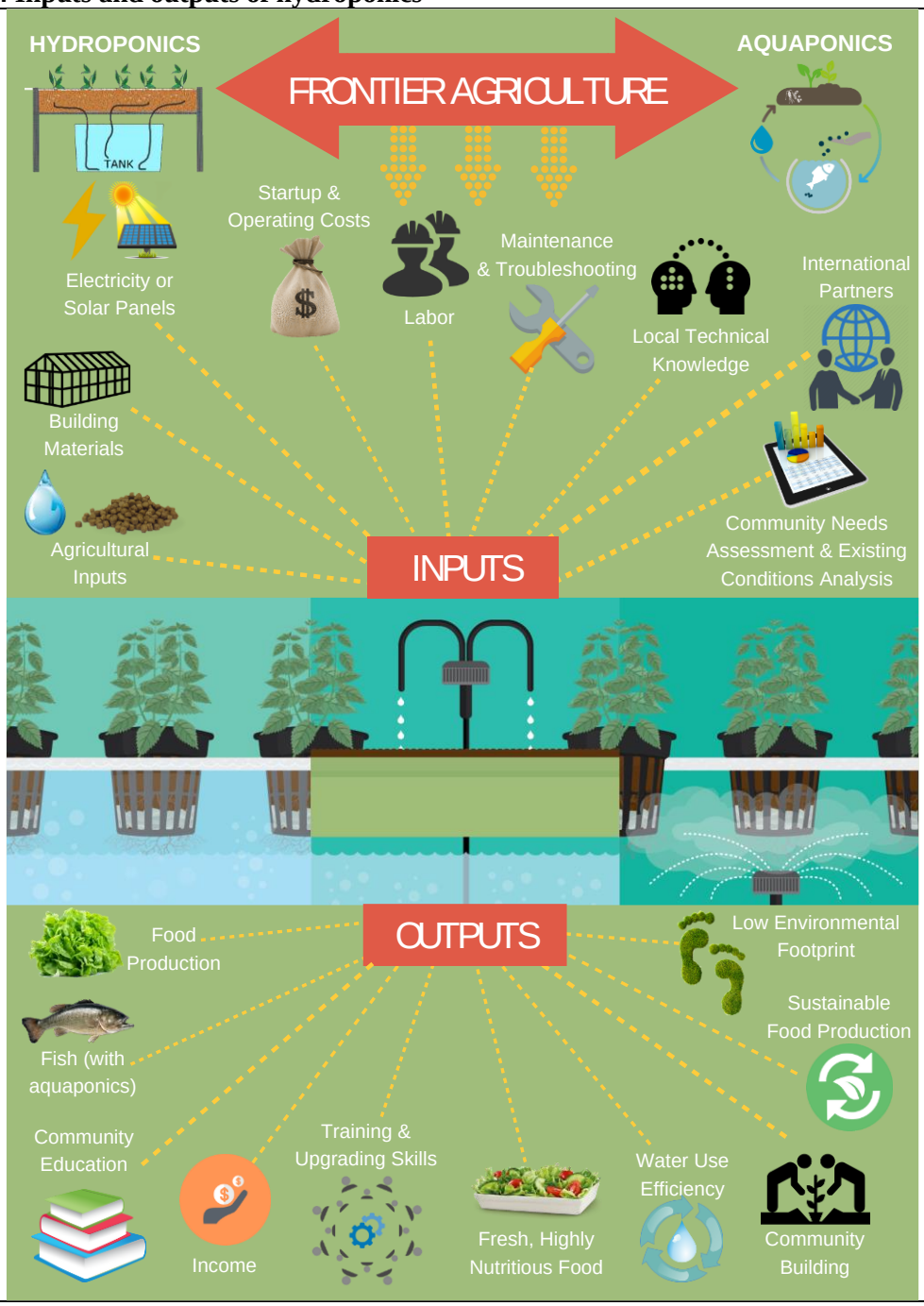
Figure 3.3 Examples of vertical farming approaches

Source: Authors' compilation (left four images) and AeroFarms (right image).

3.3. Inputs

3.20. The main inputs to hydroponics are the seeds or seedlings, nutrient solution, water, growing medium, electricity, and in some cases, lighting. A more thorough demonstration of the inputs and outputs of hydroponics is shown below in Figure 3.4.

Figure 3.4 Inputs and outputs of hydroponics



Source: Authors' compilation.

3.3.1 Types of Seeds and Crops

3.21. A good plant-growing medium should be friable, moderately fertile, of good aeration and well drained. Due to problems of diseases, weed seeds, drainage, aeration and inconsistency in physical conditions, pure topsoil as a seedling and transplant media is not recommended. Unless the farm produces its own seeds or seedlings, the farm will require a continuous supply to operate

the system. Seeds of specific vegetable varieties are needed for given climates, varieties that have multiple resistance to diseases. For example, roma plum tomatoes grow well in hot climates and due to their hardiness, they are less likely to get damaged in the packaging, storing and transportation process. There are many types of plastic trays of various cell sizes for specific vegetable varieties. Fertilization of the transplants is required. There are many methods of watering transplants, either hand watering and mechanically.

3.22. Currently, hydroponics is mainly used to grow leafy greens, tomatoes, cucumbers, peppers, herbs, and several other crops (Spensley 1978; Jenner 1980; Brentlinger 1997; Jensen 1999). A full list of crops is listed in Table 3.1. These crops have demonstrated the revenues required to make a hydroponic operation profitable (Jensen 1999). Vegetables with both a vegetative state (leaf, root production) and a generative state (fruit production) were found to grow much more efficiently in soilless culture.

3.23. The ability to produce certain crops depends on the size of the system. In smaller spaces, such as for domestic use, crops such as leafy greens and herbs are common. These plants grow quickly, can be continuously harvested, and do not require much space to expand. In larger spaces, such as a greenhouse, garage or patio, a more advanced system may be used and voluminous plants can be grown that require trellises and deep root support. In commercial hydroponics, some crops do better than others. Tomatoes, lettuce, bell peppers, and cucumbers do very well in large-scale greenhouse facilities. Herbs and leafy greens do well in warehouse facilities that are vertically-oriented. The quality and amount of crops that are able to be produced will largely determine the viability of the commercial hydroponic operation.

Table 3.1 Crops produced using hydroponics

Vegetables	Fruit	Herbs	Grains
Leafy greens, radishes, celery, cucumbers, potatoes, yams, peppers, wheatgrass, onions, leeks, carrots, parsnips, squash, zucchini, corn, bok choy, kale, swiss chard, arugula, watercress, chives, broccoli, beans, squash, peas, cauliflower, cabbage, carrots, onions, radishes, beets, microgreens	**Tomatoes, watermelon, cantaloupe, strawberries, blackberries, raspberries, blueberries, grapes, dwarf citrus trees (lemons, limes, oranges), dwarf pomegranate tree, bananas**	**Chives, oregano, mint, basil, sage, rosemary**	**Rice, barley**

Source: Authors' compilation.

3.3.2 Nutrient Solution

3.24. The main input in hydroponics, the nutrient solution, is a combination of water and nutrient salts mixed to specific concentrations to meet plant requirements and ensure healthy plants (Hoagland and Arnon 1950; Graves 1980; Jones Jr. 2005; Resh 2013). The nutrient solution is fully controllable and can be delivered to plants on an as needed basis. This makes hydroponics capable of high yields while minimizing water usage and nutrient consumption. These nutrients

are added based on the idea of essentiality, where a nutrient is determined to be essential if its absence will make it impossible for the plant to grow or reproduce and if the nutrient is specifically required by the plant (Arnon and Stout 1939).

3.25. It is crucial to experiment with various nutrient levels for different crops to determine what works as well as different cultivars of plants that may perform better or worse in hydroponics than in soil (Christie 2014). Many, if not all, of the essential nutrients required for plant growth have been identified and are well documented in the scientific literature and horticulture books. These are traditionally split into two groups, macronutrients, each comprising >1,000 mg/kg dry mass, and micronutrients, each comprising <100 mg/kg dry mass (Epstein 1965). The three primary macronutrients are nitrogen (N), phosphorus (P), and potassium (K). Their high level of requirement and physiological importance make N, P, and K the most common nutrient deficiencies and the greatest limiters of plant growth (Campbell and Reece 2002). Furthermore, supplying the plants their necessary macro and micronutrients has an impact on their flavor and nutritive value.

3.26. Nutrient solution maintenance is critical to ensuring optimum plant nutrition. It is important to continuously monitor specific nutrient ion concentrations. However, this is costly for most ions and not currently possible for others since the technology does not yet exist to reliably monitor their concentrations in the solution (Christie 2014).

3.27. In hydroponics, maintaining an optimum pH range between 5 and 7 is essential since there is no soil to act as a pH buffer. Nutrient solution pH is a common parameter used in hydroponic growing. The pH of the root zone effectively determines what nutrients are available to the plant, as plants can only uptake certain ions within a specific pH range (Clark 1982). Since the optimum pH range is identified between 5 and 7, this is the range total maximum ion uptake occurs (Clark 1982; Graves 1983). Soil composition determines the pH of the root zone under soil-based growing conditions and acts as a pH buffer to maintain an adequate range (Campbell and Reece 2002).

3.28. Any pH change will trigger a reaction in the plants since they will not be able to easily control the pH surrounding them (Graves 1983; Jones Jr. 2005; Resh 2013). The only definitive way of determining the concentration of individual ions is through direct measurement. Although ion specific electrodes are available, they are costly and not yet available for every ion of interest within a nutrient solution. Spectrophotometry, a technique that measures light absorbance, can provide a quick method of determining particular nutrient concentrations within the nutrient solution at any given time (Christie 2014).

3.3.3 Water

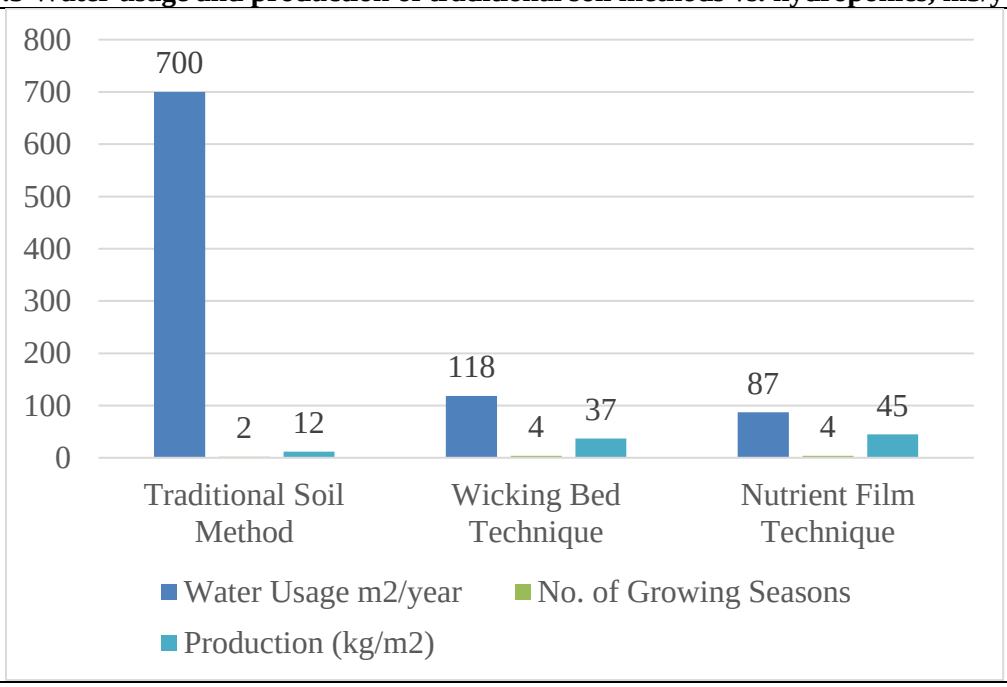
3.29. Water is the primary ingredient in a nutrient solution and therefore the single most important factor to growth (Graves 1983). Most municipal water contains a variety of ions (Spensley et al 1978) or is chemically treated resulting in unusually high amounts of chlorine residuals (Graves 1983). While this may not be immediately detrimental to plant growth, in combination with continuous nutrient solution use, it could contribute to toxic ion buildup over time (Lykas et al 2006) or interference while analyzing certain parameters within the nutrient solution (Resh 2013). Municipal water usually has a pH near or above 7, which can adversely

affect plant nutrient uptake. Utilization of some type of filtration system, such as a reverse osmosis unit, is commonly advised as it removes most impurities from whatever water source is used (Resh 2013).

3.30. Plants consume equal amounts of water in hydroponics and conventional soil methods, however, the hydroponic system delivers the water more efficiently (Sanchez 2007). Hydroponic farming, in closed systems, uses 80-99 percent less water than conventional irrigated farming since the plants only consume the water they need while recycling the unused water back to the reservoir. As noted in Figure 3.1, the nutrient film technique uses less water and produces more than the wicking bed technique, and both these hydroponic methods use much less water and produce much more than soil methods, especially with a doubling in the growing seasons and shorter harvest cycles. For example, the wicking bed unit can be used to plant 2-4 times per year depending on the crops grown, producing an average of 137-177 kg of produce per unit a year. It uses roughly 118 m^3/year or 1/7th of the water used in traditional kitchen gardens (700 m 3 /year); doubles the growing seasons and produces 37 kg versus 12 kg of produce.

3.31. In rain fed agriculture, however, these comparisons become more difficult because rainwater cannot be 'wasted' or 'saved'—it is merely part of the hydrological cycle (e.g., evaporation, condensation and precipitation). When plants are grown indoors or in greenhouses, water is not lost to deep percolation, runoff, and evaporation (Heredia 2014). Other variations and more advanced forms of hydroponics, such as aquaponics and aeroponics, use less water than simpler hydroponic systems (Pantanella et al 2012).

Figure 3.5 Water usage and production of traditional soil methods vs. hydroponics, m3/year



Source: ARIJ (2016).

3.3.4 Growing Mediums

3.32. The most widely used growing medium is rockwool, which is a melted balsamic rock spun into fibers. Due to issues of disposal, once used for growing vegetable crops, the disposal cost in landfills can be excessive as rockwool is biologically non-degradable. A replacement to rockwool that is becoming increasingly common is coconut coir, the husk of coconuts, which is found between the hard, internal shell that contains the coconut meat, and the outer coat of a ripe coconut. It is a 100 percent renewable resource unlike peat moss, which is considered a non-renewable resource. In warmer regions of the world, peat moss breaks down biologically rapidly while coco coir is slow to decompose. Other popular options for growing media are perlite and/or vermiculite, often mixed with peat moss, as a growing medium in the production of greenhouse vegetable crops, especially in the production of vegetable transplants. Sand, gravel and sawdust are also artificial media options. Sand is quite popular in arid/semi-arid regions of the world and sawdust in the forested regions of northern latitudes.

3.3.5 Electricity and Lighting

3.33. Addressing electricity needs is one of the key trials facing the hydroponics industry, particularly in northern latitudes. High-tech hydroponic systems tend to have high energy use since they usually incorporate lighting, pumping, and air moderation systems. Energy use for hydroponics can be part of a renewable energy use strategy for cutting down carbon emissions. Electricity can be sourced from wind or solar systems with a commercial battery to store excess renewable energy when needed. Hydroponic systems also tend to produce food locally, which eliminates much of the energy needed to transport it across long distances (Heredia 2014). One possible way to make commercial hydroponics a more sustainable and suitable alternative to conventional farming would be to locate the greenhouse or indoor farm to an area where there are inexpensive and renewable sources of energy, such as solar, geothermal, or wind power (Barbosa 2015).

3.34. When farming indoors and in greenhouses, most of the energy use in hydroponic farming can be attributed to the heating and cooling loads as well as supplemental artificial lighting. For example, heating is a major component of operational costs for greenhouses in northern Europe and other countries with cold winters. Greenhouses located in more moderate climates, such as climates closer to the greenhouse set point temperature, will experience a lower energy demand. In fact, in certain climates, heating and cooling systems may not be required, but instead replaced by a passive ventilation system, thus reducing the overall energy demand considerably. The feasibility of hydroponic systems is heavily reliant on the climate of farming locations (Barbosa 2015).

3.35. Though lighting increases the energy use, artificial light in indoor environments can make hydroponics feasible in areas with unreliable access to sunlight due to seasonal conditions or the surroundings. Several studies have shown that both light intensity and light quality are important for plant growth and development. Plants use light as an energy source for photosynthesis and as well as an important environmental signal for plant growth and development (Neff 2000, Fukuda et al 2008). When growing indoors, natural light, which is one of the essential elements of growing plants, has been eliminated. Therefore, artificial lighting must be used to supplement the sun. This can be seen in fact as a positive aspect of growing in a controlled environment as many new

artificial lighting technologies actually help produce better quality yields than in traditional outdoor and soil-based agriculture (Christie 2014).

3.4. Production

3.36. The hydroponic system is more productive and efficient than conventional farming as it enables a greater yield, more growing seasons, minimizes the use of pesticides and hydroponic produce can have a higher nutritional value (Resh & Howard 2012). Hydroponics allows for continuous production year-round in many areas and on average, more growing seasons and shorter harvest cycles than soil-based farming methods. The exact number of growing seasons depends on the type of system being used and the temperature of the production area. Also, the yield can be affected by the temperature especially when the system is located outdoors. In addition, hydroponic produce can have a higher nutritional value and more desirable sensory attributes compared to similar cultivars grown in soil (Buchanan & Omaye, 2013; Gichuhi, et al., 2009; Selma et al., 2012; Sgherri et al., 2010).

3.37. Hydroponic farmers have learned to adopt new growing methods and have shifted away from traditional cultivars in order to achieve high yields (Christie 2014). The productivity and hence economics of hydroponic food production continue to be main drivers for expansion. Today, commercial hydroponic farms are capable of producing three to four times the yields compared to soil production while using significantly less water (Ly 2011). These higher yields result from the controlled environmental conditions maintained within the greenhouse or indoor farm, which allow for continuous production year-round. The controlled environment promotes a reduction in the number of days required for each harvest cycle, allowing for multiple crops per year. Also, plants grown hydroponically are generally less stressed than soil-grown plants since the plants are in their optimum growing conditions all the time, and in turn create less waste than conventional farming (Treftz et al 2015).

3.38. Although hydroponic produce can be used as household staples, such as lettuce, tomatoes, herbs, and a variety of vegetables, its high value crops, particularly fruit and specialty vegetables, can be used in value-added products. For example, basil can be processed into pesto, strawberries can be processed into jam while honey can be produced to pollinate strawberries, and blueberries can be dried and sold as an antioxidant snack or mixed into cereals.

3.4.1 Nutrition

3.39. Based on numerous studies, the amounts of key nutrients in hydroponic produce are the same as in conventionally grown produce, and are sometimes even higher. In conventional farming, plants obtain nutrients from soil, whereas in hydroponics, the plants get nutrients from a solution instead. Plants generate their own vitamins; therefore, vitamin levels tend to be similar whether a vegetable is grown in soil or hydroponically. However, the mineral content can vary in hydroponic crops and depends on the fertilizer used. The nutrient levels of a plant can be enhanced by simply adding nutrients to the solution, such as calcium, magnesium, or minor elements such as zinc or iron. Nevertheless, the nutrients and phytochemicals slightly vary for different crops in general, regardless of the growing method. The nutritional profile of each crop depends on the

crop variety, the season it is harvested, the length of time between harvest and consumption, and how the crop is handled and stored during that time. These minor differences in nutrient levels are unlikely to have a significant impact on overall health.

3.4.2 Pest Management and Plant Survival

3.40. Hydroponically grown plants, though not immune, are usually more pest resistant than plants grown using soil, and do not need chemical herbicides or pesticides. In hydroponics farming, pesticide use is discouraged and usually unnecessary. The plants grown in hydroponics are generally stronger and healthier than their soil grown counterparts since they are fed their exact nutritional requirements in a carefully controlled environment. In addition, natural preventative measures against infestations are implemented in most hydroponics systems. For example, companion planting is one method commonly used in hydroponics where crops are intermixed with plants that act as pest deterrents for the primary crop.

3.41. According to a study that compared hydroponic and soil systems for growing strawberries in a greenhouse, the hydroponic plants had a higher survival rate at 80 percent compared to the soil-grown strawberries, of which less than 50 percent survived. The lower plant survival rates from soil-based farming are attributed to increased pest infections. Although both growing systems received identical integrated pest management treatments, the soil plants suffered more and pests thrived in the soil-grown strawberries, particularly aphids and spider mites. This is due to increased beneficial bacteria and microbes that pests thrive on in soil conditions (Resh & Howard 2012). Although the hydroponic plants were affected by pests, to a lesser extent, the pests were not able to thrive in hydroponic conditions (Treftz et al 2015).

3.42. Pest infections are a large source of economic losses for farmers. Research for improved pest management methods and other natural preventative measures for hydroponic farming is warranted. Furthermore, pesticide usage is a health and environmental concern for many consumers. The results found in the aforementioned study suggest that using hydroponic systems on a large scale has the potential to reduce pesticide usage. Accomplishing this would provide the farmer with higher economic benefits (Treftz et al 2015).

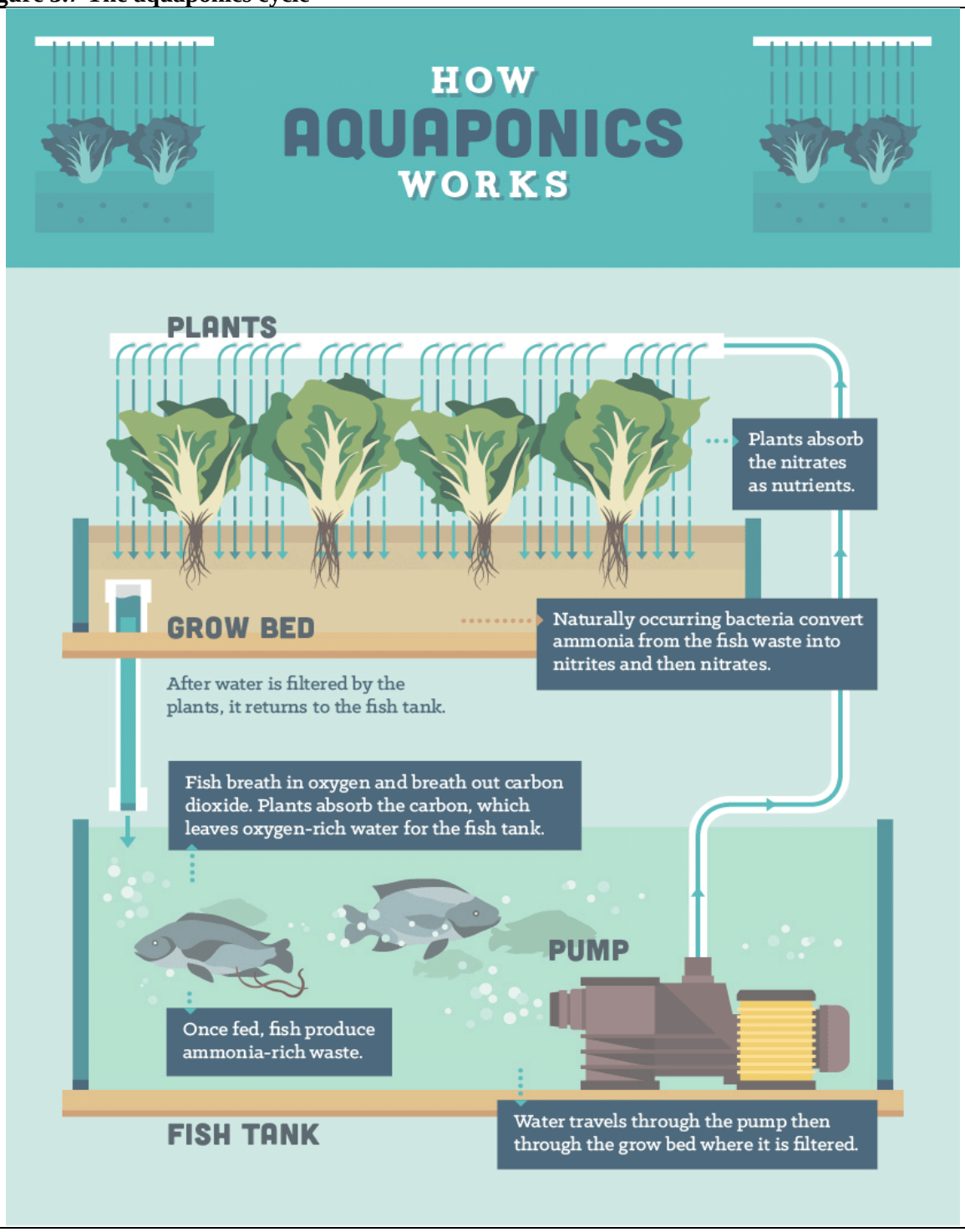
3.5. Aquaponics

3.43. Aquaponics is a method for producing food that combines recirculating aquaculture, raising fish in land-based tanks, with hydroponics, cultivating plants in water. Aquaponics recycles 95 percent to 99 percent of the water introduced in the system and it is this recycling of water that distributes nutrients throughout the system. The same produce with other hydroponic systems can be grown with aquaponics. There is no difference in the productivity of hydroponics and aquaponics in terms of yield, however, aquaponics provides fish as a source of protein. Various types of fish and aquatic animals can be raised in aquaponics as demonstrated in Figure 5. Depending on the type of system, aquaponics often uses less water than other hydroponic systems, with the exclusion of aeroponics. Since fish play a key role in the system and would die with the use of chemical pesticides, aquaponics grows chemical-free, all-natural produce. Figure 6 demonstrates and describes the aquaponics cycle.

Figure 3.6 Types of fish grown using aquaponics

Source: Authors' compilation.

Figure 3.7 The aquaponics cycle



Source: https://www.fix.com/blog/a-guide-to-aquaponics/

3.44. Aquaponics is scalable and adaptable to many different uses. Aquaponics can be used as a small or large-scale commercial farm, a recreational or hobby activity, for community-based projects, as a hands-on teaching tool in the classroom, and it incorporates well with school

curricula. The scale of an operation can be anywhere from a table-top fish tank to a warehouse. The three main types of aquaponic systems include deep water raft culture, media beds, and NFT. Deep water culture is most popular among commercial producers while media beds are most popular among home gardeners. Box 3 demonstrates how aquaponics is used in the Palestinian Territories to increase food consumption, increase livelihoods, empower women and address food security.

Box 3.3 Aquaponics in the Gaza Strip, Palestinian Territories

In response to the crisis in Gaza and given the high number of food insecure female-headed households in urban areas, the FAO has been implementing several small-scale aquaponics projects in partnership with European donors since 2010. In the first phase of their initial project, 119 food insecure female-headed households were provided with innovative vertical rooftop units connected to fish tanks. The objective was to improve the availability of high-quality fresh vegetables for the rural and urban poor and protein in the form of fish while encouraging the sustainable use of scarce resources. With little daily physical effort and in the comfort of carrying out these activities in their own homes, all the beneficiaries increased their household food consumption as a result of the gardens. This enables women to simultaneously improve their food security and income while caring for their homes and children. The project will continue to focus on female producers offering the means for them to secure fresh, nutritious food and potentially generate a supplemental income for their family.

One of the materials and fish suppliers to the FAO, an aquaculturalist based in Beit Lahiya, expanded his small aquaculture farm by integrating a semi-commercial sized plant production component to his operation. By investing his own capital, and using some of the information he acquired from installing units with FAO staff, Iyad Al Attar transformed his livelihood and created the largest aquaponics unit in Gaza. The FAO is closely monitoring his progress and providing technical support when necessary as this initiative sheds light on the potential for vulnerable farmers in Gaza to generate income in semi-commercial aquaponic systems.

Source: FAO.

3.6. Hydroponics: Cost and Labor

3.45. Although the startup cost for hydroponics is usually higher than in traditional farming, hydroponics provides cost savings on water, land, fossil fuel costs, and chemical purchases. The initial cost to set up a hydroponic system depends on the size, location, and complexity of the system being installed and the materials being used, however, the startup costs are usually higher than the cost to set up a soil-growing operation. However, some of the costs of a hydroponic system can be offset due to the system's efficiency in the use of labor, water, fertilizers and pesticides. Also, there tends to be less waste with hydroponics compared to soil-growing operations.

3.46. A hydroponic greenhouse can cost anywhere from 2 to 20 times more than soil agriculture (Mathias 2014) and even more with ultramodern food production methods that are gaining ground, such as aeroponics and agriculture robots. A commercial greenhouse that measures 279 square meters with complete heating, cooling, and ventilation systems would likely cost between US$10,000 and US$30,000 US dollars. Low cost greenhouses, such as hoop houses and attached solar greenhouses, can be constructed for as little as US$500 to US$1,500 (Greer and Diver 2000). A modern greenhouse, excluding the cost of land, was estimated at US$90 to US$100 per square meter when the hydroponics plant growing system was included. Glasshouses can cost as much as US$140 per square meter (Jensen and Malter 1995). In 1998, the cost of greenhouse structure and equipment was estimated to be US$52 per square meter in California (Hickman 1998). In a study done in the San Joaquin Valley of California, equipment and building costs were calculated to be US$95,850 for a 1,860 square meter greenhouse, constructed by metal and double-layer polyethylene covering (Hickman and Klonsky 1993). In Virginia, the construction costs for a pipe-frame greenhouse with heating-ventilating equipment were US$22 per square meter (O'dell 1995). Total and annual investment costs may increase if a more sophisticated control system, different substrate materials, or multiple gutter-connected houses are built. Multiple greenhouses would increase the total expenditure but likely would reduce the cost per square meter because economic gains would be realized and bulk quantity would reduce the price per item (Engindeniz 2009).

3.47. An example of a breakdown of the costs in wicking bed systems and NFT systems in the Palestinian Territories show the simplest systems and cost in an area where imports are expensive and they have managed to use existing materials.

3.48. Commercial hydroponic facilities vary in terms of costs and generally have higher startup costs compared to conventional farming. For commercial hydroponics, a warehouse, greenhouse, or other building is required. Specialized equipment is often necessary for hydroponics, depending on the complexity of the system being used, and hydroponic farming can be costly to operate and maintain. A growing model is needed, and its materials vary upon the type of system and technique selected. Some commercial hydroponic operations also require controllers, computer systems, large-scale lighting fixtures, ventilation and heat recovery systems, irrigation and rainwater harvesting, as well as labor (Pantanella et al 2012).

Box 3.4 Startup costs of wick systems and NFT systems in the Palestinian Territories

In the Palestinian Territories, based on data from ARIJ, the cost of a single wicking bed system is US$820 and covers the following: wicking system (4 beds and fittings); volcanic stone (tuft), compost, organic fertilizer (solid and liquid); shadow net, iron skeleton (protection from sunlight) and agro-plastic sheets to protect units from winter (heavy rain, snow, and frost); seedlings for one season; unit transportation and installation. The average production per season is 34.4 – 44.2 kg per unit, which is approximately US$48 – US$61.80. The average production per year is 137 – 176.8 kg per unit, which is approximately US$191.80 – US$247.50.

Based on the same data, the cost of a NFT hydroponic system is US$1,000 and covers the following: NFT system (PVC pipes and fittings); wicking bed and tools; liquid organic fertilizer; shadow net and iron skeleton (mesh and plastic sheet); seedlings for one season; PH and EC meters, timer, submersible pump; transportation and installation. Each system contains 8 pipes with a 2-inch diameter with a total number of 128 holes. The total capacity per season reaches up to 128 seedlings. The average production per season is 34.7 – 53.2 kg per unit, which is approximately US$54.1 – US$82.90. The average production per year is US$138.30 – US$212 kg per unit, which is approximately US$193.60 – US$296.30.

Source: ARIJ (2016).

3.49. To operate a commercial hydroponic facility, supply and utility costs can be extremely high. In order to lower operating costs and keep them at an even rate, automated technology is crucial at the commercial level. According to the Goucher College report, "Economic Assessment of Hydroponics Lettuce Production", which assumes an hourly wage of $7.50 in Baltimore, Maryland, 90 percent of the production costs of hydroponics are composed of energy (20 percent) and labor (70 percent) costs. Despite its lower energy consumption over traditional productions, its labor costs represent a much larger share than farm labor, which is estimated by the USDA to vary from 17 percent to 40 percent of total operating costs in labor-intensive production (Daly and Fink 2013).

3.50. Although the startup costs for hydroponic farming are higher than producing the same crop in the field, it is difficult to generalize as to how much more expensive. Economic advantages of soilless culture systems include a potentially fast and flexible soilless cropping period, which allows growers to quickly change production to take advantage of market conditions. It is also important to note that the hydroponic systems allow for multiple growing seasons since it is growing in a controlled environment.

3.51. An important factor to consider when choosing a growing system is labor costs. Soil-grown produce is more often cited for having increased labor costs because of weeding, watering, and spraying of pesticides (Resh & Howard 2012). Labor costs depend on several factors depending on the complexity of the system chosen and the amount of trained labor and local technical knowledge. The more sophisticated the system, the more technical expertise is needed to monitor and troubleshoot when problems arise.

3.52. Hydroponics depends on trained labor since any change in plants or in the system can compromise the production. Hydroponic growers must know technical details about the species being produced, plant health problems and how to fix them, symptoms of nutrient deficiency and

toxicity, management of nutrient solution, anticipation of possible power outages and the consequent lack of water circulation in the channels. Therefore, it is necessary to qualify the employee responsible of conducting hydroponics (Correa et al 2012). Examples from Jordan, Palestinian territories, and the UAE show that the required skills and techniques can be rapidly acquired of people with little formal education. Agricultural extensions can play a key role in the adaption of hydroponic growing methods by providing evidence-based educational tools in a clear language to farmers without a formal education. Agricultural extension can also play a vital role in educating business owners on the economic and environmental benefits of growing hydroponically (Treftz 2016).

3.53. The type and amount of employment generated with hydroponics depends on several factors. The factors to be considered include the objectives and priorities; the type of system (e.g. simple systems require less labor than more advanced systems); the size of the system (e.g. small-scale system for domestic use vs. large commercial operation), the level of expertise of the workers (e.g. low-skilled workers performing multiple operations vs. high-skilled workers focusing on their area of expertise), the type of crops (e.g. leafy greens take up less space, have shorter harvest cycles and require more labor than most fruit), the harvesting and marketing process (i.e. whole heads of lettuce packaged in a plastic bag vs. leaves pulled from the lettuce mixed with other lettuce types sold in sealed packages); and the market (e.g. household systems' ability to sell surplus produce informally vs. sufficient demand from upscale markets to purchase from large-scale commercial operations). Based on field observations, the wicking bed systems used by women in Palestine provided one part-time job per unit for self-consumption and the surplus produce is sold to the market. These women only need to work 2-3 hours a day maintaining the system and 2-3 days per week (ARIJ 2017). For larger-scale commercial operations, it is difficult to obtain data on employment, costs etc. as this is private information, however, evidence shows that using a DWC or NFT system to grow leafy greens on one acre of land provides approximately 18-22 full-time jobs, on average (Jensen 2017).

3.54. Although hydroponic food production seems to have a positive overtone because of the numerous benefits, it is important to consider the obstacles that small scale and commercial farmers may encounter. The higher upfront costs needed to develop hydroponic food production solutions is a factor that can slow the farmers' adoption of hydroponics, mostly in developing countries. Nevertheless, lower cost solutions, such as simplified, lower-tech variations of the technology are increasingly being implemented in developing countries, particularly those with an arid landscape and water scarcity, such as Jordan. Further research should investigate economic and crop yields feasibility as determining these factors can provide resources to farmers interested in hydroponic food production.

3.7. Aquaponics: Cost and Labor

3.55. Operating costs for aquaponics are highly variable and depend on factors such as climate, labor costs, and energy requirements and costs, which can vary widely by location as well as over time. Energy prices in particular can vary widely over the course of several years, greatly affecting profitability. Operating costs can include labor, electricity for the pump, electricity for the grow lights, energy for the water heater, water, fish food, seeds and starts, fingerlings, other agricultural materials, replacement costs, operating reserve, marketing, transportation and delivery, insurance,

accounting, tax filing, and real estate taxes (Goodman 2011). An example of calculating operating costs is provided in Table 3.2.

Table 3.2 Example of operating costs for aquaponics

Expense Operating Costs

One 750-gallon 4' x 8' aquaponics starter system with Tilapia and Lettuce

Year	0	1	2	3	4	5	6	7	8	9	10	
	% Total Operating Costs Year 1											% Total Operating Costs Year 10
Labor*	56%	13,650	14,060	14,481	14,916	15,363	15,824	16,299	16,788	17,291	17,810	51%
Electricity for pump	1%	123	136	149	164	180	198	218	240	264	291	1%
Electricity for grow lights	4%	893	982	1,080	1,188	1,307	1,438	1,582	1,740	1,914	2,105	6%
Natural gas for water heater	9%	2,252	2,477	2,725	2,997	3,297	3,627	3,989	4,388	4,827	5,310	15%
Water	0%	68	70	72	74	76	78	81	83	86	88	0%
Fish Food	3%	750	773	796	820	844	869	896	922	950	979	3%
Seeds	0%	120	124	127	131	135	139	143	148	152	157	0%
Fingerlings	2%	375	386	398	410	422	435	448	461	475	489	1%
Other agricultural materials	2%	500	515	530	546	563	580	597	615	633	652	2%
Replacement costs	1%	300	309	318	328	338	348	358	369	380	391	1%
Operating reserve	2%	400	412	424	437	450	464	478	492	507	522	1%
Marketing	3%	700	721	743	765	788	811	836	861	887	913	3%
Transportion & delivery	4%	1,000	1,030	1,061	1,093	1,126	1,159	1,194	1,230	1,267	1,305	4%
Insurance	8%	2000	2,060	2,122	2,185	2,251	2,319	2,388	2,460	2,534	2,610	7%
Accounting	3%	720	742	764	787	810	835	860	886	912	939	3%
Tax filing	2%	400	412	424	437	450	464	478	492	507	522	1%
RE Taxes	0%	0	0	0	0	0	0	0	0	0	0	0%
Total Op. Costs		**24,250**	**25,207**	**26,214**	**27,278**	**28,400**	**29,587**	**30,843**	**32,174**	**33,585**	**35,083**	
Total Costs		**24,250**	**25,207**	**26,214**	**27,278**	**28,400**	**29,587**	**30,843**	**32,174**	**33,585**	**35,083**	

*1 hour per day x $15/hr. x 365 days

Inflation	0.03
Energy Inflation	0.10

Source: Goodman (2011).

3.56. It is challenging to estimate income in an aquaponics system as fish and vegetable production numbers vary greatly from system to system and climate to climate. Further, income is influenced by the type of fish and vegetables that can be grown and local demand. Local food prices may shift dramatically over time, allowing producers to charge more or less for their product (Goodman 2011). Despite these limitations, rough estimates can be made of production numbers to estimate income. It is advisable to use conservative estimates to account for mishaps with the system and unsold produce (Engle 2015). One conservative estimate of the amount of fish produced per liter per year in an aquaponics system is 7 fish per 38 liters of water per year (Goodman 2011), which is used in this example to calculate income from the sale of fish and vegetables (Table 3.3).

Table 3.3 Calculating the income from the sale of tilapia and vegetables over a 10-year period

Income

One 750-gallon 4' x 8' aquaponics starter system with Tilapia and Lettuce

		Year	0	1	2	3	4	5	6	7	8	9	10
# of units	$/unit	Product											
2100	2	Lettuce*		4,200	4,326	4,456	4,589	4,727	4,869	5,015	5,165	5,320	5480
525	6	Tilapia**		3,150	3,245	3,342	3,442	3,545	3,652	3,761	3,874	3,990	4110
32	16	Watercress***		500	515	530	546	563	580	597	615	633	652
		Gross Income		**7,850**	**8,086**	**8,328**	**8,578**	**8,835**	**9,100**	**9,373**	**9,655**	**9,944**	**10,242**

*1 head of lettuce sells for $2

**1 mature tilapia wholesales for about $6/fish live

***Watercress sells for $16/lb.

Source: Goodman (2011).

3.57. Another way to analyze the cost of an aquaponics system is to compare the cost of production to the market price (Goodman 2011). Dr. Carole Engle reviews the cost of production for fish and vegetables and compares this to market prices of fish and vegetables, which is detailed in Table 3.4. However, these production costs do not include startup costs. It is also important to

note that the systems in Table 3.4 are located in Hawaii and the Virgin Islands, both tropical islands where heating costs and greenhouse expenses are minimal and the market price for vegetables is high. Consequently, production costs in other climates may be substantially higher and market price may be lower. Table 3.5 provides the profitability of crops and fish in various aquaponics systems. Engle reports that the costs of producing lettuce and basil were between 30 to 83 percent lower than the market prices reported (Engle 2015). With reference to Table 3.6, another way to analyze the economics of an aquaponics system is to focus on the internal rate of return and the break even point of a system. Extrapolating from the investment cost and annual net return of these seven systems it appears the break even point is roughly five to ten years, with the exception of the catfish system.

Table 3.4 A review of estimated costs of production of plants and fish raised in aquaponics

	Literature source				
	Baker (2010)	Bailey et al. (1998)	Rakocy & Bailey (1998)		Tokunaga et al. (2015)
Location	Hawaii	Virgin Islands	Virgin Islands		Hawaii
Plant type	lettuce	lettuce	lettuce	basil	lettuce
Production cost	$1.50/lb	$11.14–$12.40/case[a]	$6.15/case	$0.75/lb	not calculated
Market price	not reported	$20/case	$20/case	$10.20/lb	$2.15/lb
Fish type	tilapia	tilapia	tilapia	tilapia	tilapia
Production cost	$4.99/lb	$3.17–$3.78/lb	$1.46/lb	$2.50/lb	not calculated
Market price	not reported	$2.50/lb	$1.46/lb	$2.50/lb	$5.00/lb

[a]A case of lettuce typically contains 24 heads of lettuce.

Source: Engle (2015).

Table 3.5 A review of estimated investment costs, profitability and return on investment of selected aquaponics operations

Literature source	Location	Total investment cost ($)	Profitability		
			Annual net returns ($)	Internal rate of return	Modified internal rate of return
Bailey et al. (1998)	Virgin Islands				
Large scale		$1,030,536	$278,038	22%	n.a.
Small scale		$285,134	$30,761	11%	n.a.
Chaves et al.	Scotland	$58,760	$16,701	27%	n.a.
Holliman et al. (2008)	Alabama				
Catfish		$70,640	-$11,579	n.a.	n.a.
Tilapia		$70,640	$4,222	n.a.	n.a.
Rupasinghe and Kennedy (2010)	Australia	n.a.	n.a.	0%–57%	n.a.
Tokunaga et al. (2015)	Hawaii	$217,078	n.a.	n.a.	7.36%

Source: Engle (2015).

3.58. There are several economic benefits to aquaponics when implemented properly, however, the systems can often be finicky, they can fail, and they often are not profitable enterprises. Every location brings a substantial amount of local parameters including availability and cost of

electricity, availability of fish fry and feed, changes in climate and growing seasons, humidity, pest pressure, available local technical knowledge, food prices, other local market factors, availability of building materials, etc. The major inputs in aquaponics tend to be costly, particularly fish food, electricity for pumping the water to provide oxygen to the fish as well as for heating and cooling greenhouses. Income is challenging to estimate in an aquaponics system as fish and vegetable production numbers vary greatly from system to system and climate to climate.

3.59. Aquaponics requires extensive labor, time and knowledge and requires the presence of a technical expert. A technical expert with adequate experience troubleshooting aquaponics systems must be available to deal with common issues, such as managing the pH and alkalinity of the water or issues related to fish health. It is also critical to have a "tinker" as a key participant who buys into the project and participates in its daily maintenance. The tinker does not need to be a technical expert, but be able to fiddle with plumbing, have some construction knowledge, be able to learn about the intricacies of managing water pH, growing fish and plants, and have an experimental attitude. Some members in most communities either possess these skills or can easily learn them, and can be paid or asked to volunteer. Participatory planning processes can strengthen community bonds and make the project worthwhile regardless of the success, failure, or longevity of the aquaponics system itself.

3.60. Many commercial aquaponics systems, specifically those in the United States that have been studied, are not profitable. The many challenges include high start-up costs, highly technical skills and training required to operate a commercial system, and the long lead times between stocking and harvesting fish. For most systems, fish sales cover the cost to raise fish, while hydroponics crops are the main profit center. Catastrophic failures are not uncommon where an entire population of fish dies. Restarting a large system can take several months to ripen filters and increase nutrient levels to the concentrations needed to grow crops. Notwithstanding these challenges, there is a path for profitability, which can involve careful siting, development knowledge and skills, use of alternative revenue streams, and other means (Love et al 2015a). Specifically, alternative business models and creative ways to increase income and reduce expenses can affect cash flow and help a business be profitable.

4. Matching Needs of Refugees and Hosts with Frontier Agriculture Technologies

4.1. The MENA region faces two large challenges. First, the increasingly water-scarce region applies 85 percent of its water in agriculture and second, the recent escalation of the global refugee crisis which, to a large extent, is a MENA crisis. There is a huge need for increased intake of nutritious food, livelihoods, and jobs for a large share of the 18.2 million adult and youth population living in refugee-like situations in MENA. It is necessary for the protracted situation to be addressed through the development lens to provide development solutions that reactivate the lives and skills of the displaced populations. Moreover, the humanitarian system is under pressure and cannot provide sufficient resources to meet the needs of forcibly displaced people in the MENA region and beyond. The remainder of this report attempts to merge two agendas and find solutions through innovative technologies.

4.2. Given that water and arable land are scarce in MENA, one way of increasing food production is through land- and water-saving frontier agriculture. Hydroponics is a climate-smart, innovative, efficient, and effective technology that produces more nutritious food with less water (at least 80 percent) and no arable land. Some hydroponic systems are relatively easy to operate and can be installed for small-scale use for homes and communities to large, commercial farms. The scale depends on the system being used and its design, which depends on the objectives and priorities as well as the local conditions, circumstances and existing skills as well as teachability. There is no single proper enabling environment for hydroponics since different systems can be adapted to different environments. Given the adaptability and flexibility of the technology to most environments, and the outputs including the provision of nutritious food and marketable produce, these technologies are already being employed in some of the most challenging areas in MENA, such as hydroponics and aquaponics in the Palestinian Territories (see Chapter 3). The selection of the type of hydroponic system depends on the access to inputs and the level of creativity to produce, reuse or upcycle inputs. Since the technology is flexible and adaptable to local conditions, the simplest system can start or supplement existing food production, if any. It is a solution that can be brought to areas that previously had no or very limited food production.

4.3. The basic inputs to hydroponics seem to be available or acquirable in all countries in MENA. Hydroponics systems provide high-cost savings on water, land, fossil fuels, and chemical purchases compared to traditional farming. The startup and operating costs entirely depend on the type of system chosen and its level of complexity. The more advanced and complex the system, the higher the startup and operating costs. There also tends to be less waste with hydroponics and overall better resource management. This system allows for more crop cycles in a year than traditional farming and more high-value crops in some areas.

4.4. In Jordan, even if the refugees live in houses that need urgent repair, there seems to be access to piped water in the majority of cases, which coupled with access to electricity from the grid or solar panels offer some of the basic inputs for using soilless and water-saving technologies including hydroponics. For example, private sector farmers that have limited land in the Mafraq desert are already installing hydroponic systems to grow vegetables for the market, despite having

neither piped water nor electricity on the land. They use solar panels and recycle a few cubic meters of water for the production on approximately one hectare of arid desert land. In Djibouti, 80 percent of refugees live in camps and often in dismal tent conditions without access to water and electricity. The new water pipeline that is being built to transport water from Ethiopia to Djibouti may increase options for more productive agriculture away from the micro-vegetable gardens that many refugees cultivate in Djibouti. In Lebanon and Jordan, refugees are not allowed to plant in the soil. The poor housing facilities and the high price of water mean that hydroponic farming and soilless systems that recycle water are among the few ways forward in producing nutritious food.

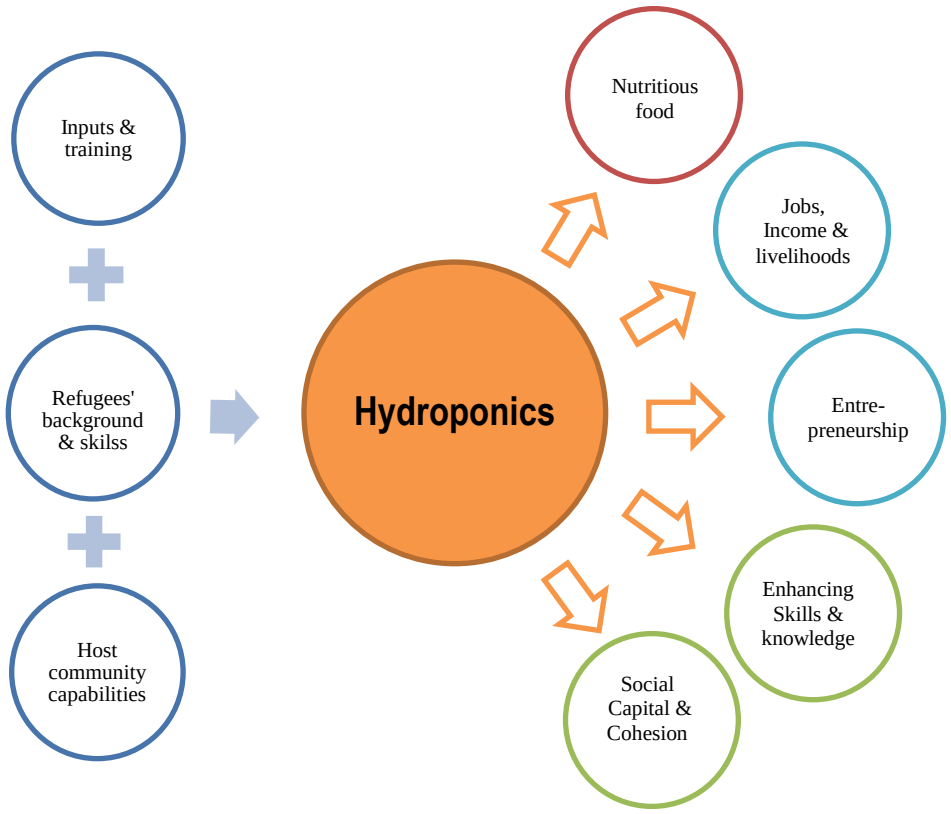
4.5. The following sections present a three-pronged approach to address some of the existing needs by providing opportunities for those forcibly displaced and their hosts with hydroponic farming systems. There are particular groups with more needs than others, these include refugee women in Lebanon and Jordan that previously worked in agriculture and as housekeepers. They are the most food insecure, have the lowest cash incomes, and the vast majority are not engaged in paid work. Social barriers, education, skill matches and household responsibilities seem to prevent many women from participating in the labor markets. Women and girl refugees, and women and girls in host communities in the case of Djibouti, face low education levels, health constraints, and very limited access to economic opportunities.

4.6. Besides contributing to food security, climate smart water-saving agriculture technologies and innovations are ways to improve livelihoods and provide jobs with skills and human capital upgrading for both host and forcibly displaced populations in MENA and in particular those most in need. The report provides a three-prong model to address the needs and focuses on (Figure 4.1):

- Increasing access to nutritious food,
- Improving livelihoods, providing jobs, and entrepreneurship,
- Enhancing skills and building social capital and cohesion.

4.7. Increase access to nutritious food: Most refugees are food insecure and have a Vitamin A deficiency. Less than 10 percent of the refugee population in Lebanon and Jordan are food secure. Female PAs tend to be the most food insecure. The data suggest that refugees in Jordan and Lebanon encounter significant barriers in achieving food security. In Jordan, 45.7 percent of all PAs reported that they skip meals while in Lebanon, 61.4 percent skip meals. Moreover, a number of different nutritious food items (fruits, vegetables, eggs, meat) are not consumed by refugees on a regular basis. In Djibouti, both refugees and rural host communities are food insecure. The WFP and UNHCR assessment in the refugee camps of Holl Holl and Ali Addeh reports figures of 66 percent and 44 percent, respectively. Also the host communities around the two camps are food insecure; 62 percent and 44 percent, respectively. The data for Jordan and Lebanon also show that younger and older individuals in particular are disproportionally more likely to report some form of need (see list in Chapter 2) regardless of their previous occupation in agriculture on non-agricultural sectors. Regardless of gender, the youth and middle-age and elders have unmet needs compared to other age groups.

Figure 4.1: Hydroponics and Refugees' livelihoods



Source: Team Compilation.

4.8. The simplest systems in hydroponics, such as the deep water culture Kratky Method and wicking bed systems, do not require electricity or land and need a fraction of the water required in open field agriculture. As noted chapter 3, hydroponic systems can grow a wide variety of fruits and vegetables, especially leafy greens –they grow fast and provide leaves within a few weeks – that help address the Vitamin A deficiency. If the primary priority is to address food insecurity among refugees and host communities, households can be trained on how to maintain the simplest hydroponic systems using basic materials such as buckets and local rocks, whereas if the overarching goal is to increase economic activity among refugees to increase incomes, a large NFT system can be constructed at the community level where households may consume from the production and the surplus can be sold in the local market or beyond. For example, NFT systems have been implemented in both Lebanon and Jordan and it is easy to replicate the model with refugees in an informal tented settlement.

4.9. Improving livelihoods, and providing jobs and entrepreneurship: Job opportunities need to be created for both displaced populations and host community populations to reduce rampant poverty and vulnerability. Creating economic opportunities can be a game changer for the forcibly displaced populations, host communities and countries. And jobs and livelihoods will reduce the fiscal pressure and burden on the host countries. Creating livelihoods and engaging in economic activities in the new environment is a key challenge for the majority of the forcibly displaced in MENA. The increased population can be an asset to the host countries if they have access to or are provided with economic opportunities to produce and not only rely on humanitarian assistance. Many forcibly displaced and host populations lack jobs and income, which is one of the main

reasons as to why they face nutritious food insecurity and poverty as mentioned above. Hydroponics provides different types of employment and the types and amounts of jobs depend on several factors as outlined in Chapter 3. Based on field observations, the wicking bed systems used by women in Palestine provided one part-time job per unit for self-consumption and the surplus produce is sold to the market. These women only need to work 2-3 hours a day maintaining the system and 2-3 days per week (ARIJ 2017). For larger-scale commercial operations, it is difficult to obtain data on employment, costs, etc. as this is private information, however, evidence shows that using a DWC or NFT system to grow leafy greens on one acre of land provides approximately 18-22 full-time jobs, on average (Jensen 2017).

4.10. Refugees are in all contexts among the poorest and their livelihoods are vulnerable. About 88 percent of refugees in Jordan are poor or vulnerable to poverty, this figure is between 71 and 80 percent in Lebanon. A large share of refugees has a background working in food and agriculture, but according to an analysis based on UNHCR Registry Data (Chapter 2), those that earn income receive a very low salary that is insufficient to take them out of poverty.

4.11. The refugee women working in agriculture and as housekeepers are those with the lowest cash incomes. Per capita income of forcibly displaced women is significantly lower than that of their male counterparts. With regards to economic integration, about 44 percent of female PAs reported no income, the figure for female PAs with non-agricultural occupations was 65.5 percent and for housekeepers it was reported that 69.5 percent had no cash income. In Lebanon, only 7 percent of refugee women reported income in 2016 compared to 70 percent of men. The majority of women are not engaged in paid work in Lebanon and Jordan. In Djibouti, women and girls, from both refugee and host communities face constraints to economic opportunities. In all locations, private sector jobs and incomes from work can provide the resources to purchase food and other necessities. These need to be created and launching support for a new subsector is one possible solution. This includes hydroponics.

4.12. Hydroponics provides an opportunity to promote entrepreneurship. There is also potential for production that exceed individual needs, which could lead to the creation of local markets for such produce and additional jobs. The revenue generated by selling excess production could turn into an important source of income for refugees and allow them to meet other basic needs. Other entrepreneurial opportunities not directly related to hydroponics may arise, especially when the refugees can combine other skills with their training on these systems. For example, they can contribute to a higher level in the value chain, such as producing dried blueberries or essential oils, or create inputs to hydroponics such as upcycling materials or creating hydroponic fertilizer. There are also opportunities for the refugees to collaborate with the host communities. For example, based on field observations in the Palestinian Territories, a set of entrepreneurs had secured contracts with potential restaurant clients before constructing their hydroponics farm in a village near Ramallah.

4.13. Enhance skills: In addition to refugee women being those with housework responsibilities, and the lowest level of education and cash incomes, they also face barriers for economic opportunities and integration. Refugees in Lebanon and Jordan are younger and a larger share of household heads is female than in the host country. Those households have a lower level of education attainment than other households. Female refugees in Jordan are from poorer areas, have

less education than the hosts and often come from rural areas and have mainly undertaken home-based work and have not been employed on farms. The analysis also shows that education is inversely related to needs, but its effect is much stronger for women. In Jordan, more than 86 percent of female PAs have less than 12 years of education. In addition, 93 percent of all female PAs were housekeepers, from which about 30 percent had less than 6 years of education and 52 percent had between 6 and 11 years of education. While education may have a limited role in explaining labor market outcomes immediately after relocation (see Verme et al (2016)), low levels of education limit integration opportunities and professional development in the host country, thus making refugees' economic integration significantly harder and potentially costlier. Enhancing skills are key to increase access to jobs, improve livelihoods and expand the private sector.

4.14. Training and knowledge acquired in hydroponic operations is a way to upgrade human capital, which is transferable to other locations, including to the home country after the conflict recede and reconstruction begins. The transferability of knowledge is a key byproduct of hydroponic projects. Refugees who return to their origin communities or relocate to other countries will bring the practical knowledge with them and could potentially start hydroponics operations at their destinations. This is particularly important for refugees who return to Syria, a country with a war-torn infrastructure (e.g. irrigation systems, electric grid, and roads) that may limit activities in traditional agriculture. Additionally, the training process and increase in human capital may empower refugees to find or create employment or other income generating opportunities, whether related to hydroponics or not. For example, some may choose to work in education in a related field to hydroponic farming and others may choose to work in another part of the value chain, such as producing hydroponic fodder for livestock. Training can also provide social capital to create social enterprises.

4.15. Finally, research demonstrates that working with plants and gardening can be therapeutic and positively affects mental health. Gardening, especially in community or family settings, provides a sense of responsibility, allows for nurturing and can be a relaxing activity, especially for refugees who have experienced stressful events and trauma. For example, in the Dheisheh and Aida refugee camps in the West Bank, which are among the poorest areas in the Palestinian Territories, a project providing rooftop gardens has improved the well-being of several refugees by not only enabling beneficiaries to feel self-reliant, but also reconnect with their land.

4.1. Moving Forward

4.16. Hydroponics is a technology with several types of systems and variations of those systems, which can be customized and adapted according to priorities, objectives and the local conditions. Systems varies from being based on recycled materials to super high tech versions.

4.17. While advanced hydroponic systems may be appropriate for some regions, this study has examined simplified hydroponic systems that are feasible with training and a small initial investment. Though the yields from these simplified systems are lower than advanced systems, these low-tech systems outperform conventional farming methods and use at least 80 percent less water. Initially, ideally a need assessment would be conducted at the local community level, or

individual level to identify and rank the priorities and objectives in order to select an adequate hydroponic system to design the appropriate system. Regardless of the system chosen, this technology can provide an important social, economic, and nutritional benefits, especially for the poor and vulnerable, including the forcibly displaced people.

4.18. As a starting point, a flexible decision matrix can be used as a tool to determine which type of system would be suitable depending on the local conditions of the growing site. The decision matrix in Table 4.1 is an attempt to systematically identify, analyze, prioritize and compare different systems that are being considered for implementation in frontier agriculture. The below decision matrix presents all of the technologies discussed in this chapter and ranks them using a Likert-type scale on a variety of attributes: water use, energy use, technological complexity, maintenance, startup costs, financial sustainability, and mobility. Given that each situation requires a different set of social, ecological, and economic considerations, there may not be one single best technology for all applications, but many hybrids can be constructed to specific needs of people, enterprises, and communities.

Table 4.1 Decision matrix for water saving technologies.

TECHNOLOGY	FOOD	WATER USE*	ENERGY USE	TECHNOLOGICAL COMPLEXITY	MAINTENANCE	START-UP COSTS	FINANCIALLY SELF-SUSTAINING	MOBILITY
WICK SYSTEMS	CROPS	LOW	NONE	SIMPLE	HIGH	LOW	HIGH	LOW-HIGH
DEEP WATER CULTURE	CROPS	LOW	MEDIUM	MEDIUM	LOW	MED-HIGH	MEDIUM	LOW
EBB & FLOW	CROPS	LOW	LOW-HIGH	COMPLEX	HIGH	MED-HIGH	LOW	LOW
DRIP METHOD	CROPS	LOW	HIGH	COMPLEX	LOW	MED-HIGH	LOW	LOW
NUTRIENT FILM TECHNIQUE	CROPS	LOW	HIGH	COMPLEX	MED-HIGH	HIGH	MEDIUM	LOW
AQUAPONICS	CROPS, FISH	LOW	LOW-HIGH**	COMPLEX	HIGH	MED-HIGH	LOW	LOW
AEROPONICS	CROPS	LOW	HIGH	COMPLEX	HIGH	HIGH	HIGH	LOW

Source: Developed by Report Team.

* Open systems recirculate water, closed systems do not recirculate water.

** Depending upon pump size and heating requirements. Aquaponics requires a constant electrical source or backup energy (battery, generator).

4.19. Interventions aiming at promoting frontier agriculture among refugees need to develop practical criteria that align technical requirements to engage in hydroponics (or other *ponics*) to socio-economic conditions of the target population and host communities. The data and discussion presented in this report suggest that a matching process should consider, among other factors, a refugee's (or refugee group's) background in agriculture, potential fit and skills to engage in frontier agriculture (e.g. education, reservation wage, and entrepreneurial spirit), needs (food insecurity, work close to home, and other needs), and availability of water, which is a basic input for hydroponics. The availability of basic inputs and overall economic conditions at the host community must also be assessed together with the refugees' background. An example of a decision matrix to match refugees to host communities is provided in Appendix 3.

4.20. There is an urgency to engage with and support refugee livelihoods. Previous experiences (see Box 3.1 for the case of Palestine territories) suggest that pilot or small-scale hydroponic projects targeting vulnerable populations can be implemented rather quickly and produce meaningful results in a short period.

4.21. Considerations regarding the viability of hydroponic projects for refugee and host populations should be based on an expanded view of cost-benefits and take into account both the economic and social returns on investment. This technology is constantly becoming less expensive and the challenges of cost and scalability will be overcome. In addition, community-based technical support can be obtained from local organizations, universities, and extension services and trust funds can be utilized for financing pilot projects.

References

Abd-Elmoniem, E.M., Abdrabbo, M.A., Farag, A.A., Medany, M.A. 2006. Hydroponics for Food Production: Comparison of Open and Closed Systems on Yield and Consumption of Water and Nutrients. 2nd International Conference on Water Resources and Arid Environments. Riyadh, Saudi Arabia: King Saud University. 1-8.

Albright L.D., Langhans R.W., 1996. Controlled Environmental Agriculture Scoping Study. Controlled Environment Agriculture Program, Cornell University. Accessed November 2014. Available online: http://www.cornellcea.com/attachments/Controlled%20Environment%20Agriculture%20Scoping%20Study%20pdf%20-%20Adobe%20Acrobat%20Professional.pd

Arnon, D.I., Stout, P.R., 1939. The Essentiality of Certain Elements in Minute Quantity for Plants with Special Reference to Copper. Plant Physiology 14, no. 2: 371-375. Bradley, P., and Marulanda, C. 2000. Simplified Hydroponics to Reduce Global Hunger. Acta. Hort. 554: 289-296.

Barbosa G.L., Gadelha F.D.A., Kublik N., Proctor, A., Reichelm, L., Weissinger, E., Wohlleb, G.M., Halden, R.U., 2015. Comparison of Land, Water, and Energy Requirements of Lettuce Grown Using Hydroponic vs. Conventional Agricultural Methods. International Journal of Environmental Research and Public Health. 12(6):6879-6891.

Bellows, A. C., Brown, K., Smit, J., 2004. Health Benefits of Urban Agriculture. Community Food Security Coalition's North American Initiative on Urban Agriculture. Portland, OR. Available online: http://www.co.fresno.ca.us/uploadedfiles/departments/behavioral_health/mhsa/health%20benefits%20of%20urban%20agriculture%20(1-8).pdf

Bohl, M., 1977. Some initial aquaculture experiments in recirculating water systems. Aquaculture 11:323–328.

Both A.J., 1995. Dynamic Simulation of Supplemental Lighting for Greenhouse Hydroponic Lettuce Production. Ph.D. Thesis. Cornell University Libraries; Ithaca, NY, USA:

Brechner M., Both A.J., 2014. Hydroponic Lettuce Handbook. Cornell Controlled Environment Agriculture. Cornell University; (accessed June 2, 2016). Available online: http://www.cornellcea.com/attachments/Cornell%20CEA%20Lettuce%20Handbook%20.pdf

Brentlinger, D., 1997. Status of the Commercial Hydroponic Industry in the United States of America. Acta. Hort. 481: 731-734.

Buchanan, D.N., Omaye, S.T., 2013. Comparative Study of Ascorbic Acid and Tocopherol Concentrations in Hydroponic- and Soil-Grown Lettuces. Food and Nutrition Sciences, 04(10), 1047–1053.

Bugbee, B., 2004. Nutrient Management in Recirculating Hydroponic Culture. Acta Hort.: 99-112.

Bureau of Labor Statistics. 2015. Occupational Outlook Handbook: Agricultural Workers. http://www.bls.gov/ooh/farming-fishing-and-forestry/agricultural-workers.htm#tab-1

Campbell, N.A., Reece. J.B., 2002. Biology. 6th ed. Benjamin Cummings. San Francisco, CA

Carruthers, S., 2002. Hydroponics as an agricultural production system. Practical Hydroponics and Greenhouses. Issue 63

Chen, R., Liu, H.L., Song, S., Sun, G., Chen, R., 2015. Effects of Light Quality on Growth and Quality of Lettuces in Hydroponic. College of Horticulture, South China Agriculture University.

Christie, E., 2014. Water and Nutrient Reuse within Closed Hydroponic Systems. Georgia Southern University.

Collins M, Gratzek J, Shotts Jr E, Dawe D, Campbell L, et al.,1975. Nitrification in an Aquatic Recirculating System. Journal of the Fisheries Research Board of Canada 32: 2025–2031.

Corrêa, R.M., do Carmo Pinto, S.I., Reis, E.S., de Carvalho, V.A.M., 2012. Hydroponic Production of Fruit Tree Seedlings in Brazil: A Standard Methodology for Plant Biological Research, Dr. Toshiki Asao (Ed.) Intechopen.com 11:225-244 Available Online: http://www.intechopen.com/books/hydroponics-a-standard-methodology-for-plant-biologicalresearches/production-of-fruit-seedlings-in-hydroponics

CSIS, 2017. Stuck in Limbo, Refugees and Migrants and Food Insecure in Djibouti.

Cui J., Ma Z., Xu Z., Zhang H., Chang T., Liu H., 2009. Effects of supplemental lighting with different light qualities on growth and physiological characteristics of cucumber, pepper and tomato seedlings Acta Horticulturae Sinica, 36(5):663-670

Daly W., Fink, J., 2013. Economic Assessment of Hydroponic Lettuce Production at Goucher College. Goucher College.

David, P.P., Bonsi, C.K., Trotman, A.A., Douglas, D.Z., 1996. Nutrient Management Effects on Sweet Potato Genotypes Under Controlled Environment. Acta. Hort. 440:65-69.

Despommier, D., 2010. The Vertical Farm: Feeding the World in the 21st Century. New York, NY: St. Martins Press.

Development Initiatives: Global Humanitarian Assistance Report (2016)

Development Initiatives: Global Humanitarian Assistance Report (2017)

Donnell M., Short T., Moore R., Draper C., 2011. Hydroponic Greenhouse Lettuce Enterprise Budget. Hydroponic Program Team, Ohio State University; Ohio, OH, US

Donnan, R. 1994. Nutrient Management - Part 3 - Recirculating Systems. Practical Hydroponics

and Greenhouses, no. 16 (May/June).

Dougher T and Bugbee B., 2004. Long-term blue light effects on the histology of lettuce and soybean leaves and stems, Journal of the American Society for Horticultural Science, 129(4):467-472.

Engle, C. R. July, 2015, July. Economics of Aquaponics. SRAC Publication No. 5006. Southern Regional Aquaculture Center.

Engindeniz, S., 2004. The Economic Analysis of Growing Greenhouse Cucumber with Soilless Culture System: The Case of Turkey, Journal of Sustainable Agriculture, 23(3):5-19

Engle, C., 2015. Economics of Aquaponics. SRAC Publication No. 5006. Southern Regional Aquaculture Center.

ESCWA: Arab Sustainable Development Report (first edition 2015).

Fukuda N., Fujitan M., Ohta Y., Sase S., Nishimura S., Ezura H., 2008. Directional blue light irradiation triggers epidermal cell elongation of abaxial side resulting in inhibition of leaf epinasty in geranium under red light condition," Scientia Horticulturae,115(2)176–182.

Genello, L., Fry, J.P., Frederick, A., Li, X., Love, D.C., 2015. Fish in the Classroom: A Survey of the Use of Aquaponics in Education. European Journal of Health and Biology Education, 4(2):9-20.

Gericke, W.F. 1940. Soilless Gardening. New York, NY: Prentice Hall.

Gericke, W. F. 1945. The Meaning of Hydroponics. Science. 101 (2615):142-143.

Gichuhi, P. N., Mortley, D., Bromfield, E., & BovellBenjamin, A. C. (2009). Nutritional, physical, and sensory evaluation of hydroponic carrots (Daucus carota L.) from different nutrient delivery systems. Journal of Food Science, 74(9), 403–412.

Goodman, E. 2011. Aquaponics: Community and Economic Development. Massachussetts Institute of Technology, Cambridge, MA.

Goodman, E., Okiomah, O.E. 2012. Kenya Deployment Highlights: Accomplishments + Challenges. Kenya Deployment Lessons: Strategies for Next Deployment.

Goodman, E., Okiomah, O.E. 2012. MIT Global Challenge- Exit Interview 2011 Winning Team: Maa-Bara.

Graves, C.J. 1980. The Nutrient Film Technique. Horticultural Reviews 5:1-44.

Hambrey, J. 2013. Aquaponics Research Project: The relevance of aquaponics to the New Zealand aid programme, particularly in the Pacific. New Zealand Aid Programme Ministry of Foreign Affairs and Trade. pp 1-96. Available online: http://www.hambreyconsulting.co.uk/Documents/aquaponics%20final%20report.pdf

Heredia, N.A. 2014. Design, Construction, and Evaluation of a Vertical Hydroponic Tower. California Polytechnic State University. San Luis Obispo.

Hoagland, D.R. and D.I. Arnon. 1950. The Water Culture Method for Growing Plants without Soil. College of Agriculture, University of California, Berkeley, CA v.C347

Holt, S., 2016. Not your dad's farm job: Millenials look to high-tech farms for careers. Civil Eats. Available online: http://civileats.com/2016/01/05/not-your-dads-farm-job-millennials-look-to-high-tech-farms-for-careers/

Hughey, T.W., 2005. Barrel-ponics (a.k.a. Aquaponics in a Barrel). Available online: http://www.aces.edu/dept/fisheries/education/documents/barrel-ponics.pdf

ILO (2017): A Challenging Market becomes more Challenging, Jordanian Workers, Migrant Workers and refugees in the Jordanian Labour market (Author Susan Razzaz et al)

Jensen, M.H. 1997. Hydroponics. HortScience 32(6): 1018-1021.

Jensen, M.H., 1999. Hydroponics Worldwide. Acta Hort. 481(87):719-729.

Jones Jr., J.B., 2005. Hydroponics: A Practical Guide for the Soilless Grower. 2nd ed. Boca Raton, FL: CRC Press.

Lewis, W.M., Yopp, J.H., Schramm, J.H.L., 1978. Use of hydroponics to maintain quality of recirculated water in a fish culture system. Transactions of the American Fisheries Society 107:92–99.

Love, D.C., Fry, J.P., Genello, L., Hill, E.S., Frederick, A., Li, X., Semmens, K., 2014. An international survey of aquaponics practitioners. PLOS One. 9(7): e102662.

Love, D.C., Fry, J.P., Li, X., Hill, E.S., Genello, L., Semmens, K., Thompson, R.E. 2015a. Commercial aquaponics production and profitability: findings from an international survey. Aquaculture 435:67-74

Love, D.C., Genello, L., Li, X., Thompson, R.E., Fry, J.P., 2015b. Production and Consumption of Homegrown Produce and Fish by Noncommercial Aquaponics Gardeners. Journal of Agriculture Food Security and Community Development, Available online: http://dx.doi.org/10.5304/jafscd.2015.061.013

Love, D.C., Uhl, M., Genello, L., 2015c. A Production Model for a Small-Scale Aquaponics System in Baltimore, Maryland, United States. Journal of Aquacultural Engineering 68:19-27.

Lykas, C., N. Katsoulas, P. Giaglaras, Kittas, C. 2006. Electrical Conductivity and pH Prediction in a Recirculated Nutrient Solution of a Greenhouse Soilless Rose Crop. Journal of Plant Nutrition 29:1585-1599.

Ly, H.M. 2011. Converting soil grown production methods to hydroponics in protected cropping. Nuffield International. No 1014.

Martineau V., Lefsrud M., Naznin M.T., Kopsell D.A., 2012. Comparison of light-emitting diode and high-pressure sodium light treatments for hydroponics growth of Boston lettuce. Hortscience, 47:477–482.

Mackowiak C.L., Owens L.P., Hinkle C.R., 1989. Continuous hydroponic wheat production using a recirculating system. National Aeronautics and Space Administration, John F. Kennedy Space Center.

Manifest Mind, 2015. Controlled Environment Agriculture Report and Market Forecast 2015-2023.

Mathias, M.C., 2014. Emerging Hydroponics Industry. Practical Hydroponics & Greenhouses, June Issue, 18-21.

Naegel, L.C.A., 1977. Combined production of fish and plants in recirculating water. Aquaculture 10: 17–24.

Nederhoff, E. and C. Stanghellini., 2010. Water Use Efficiency of Tomatoes in Greenhouses and Hydroponics. Practical Hydroponics and Greenhouses, 115:52-59.

Neff M. M., Fankhauser C., Chory J., 2000. Light: an indicator of time and place, Genes & Development, 14:257–271.

Okiomah, O.E. 2011. Maa-Bara: Catalyzing Change in Nigeria's Niger Delta. Masters Thesis. Massachusetts Institute of Technology. Available online: http://hdl.handle.net/1721.1/63053

Okiomah, O.E. 2012. Maa-Bara Works. Issue 001.

Pantanella, E., Cardarelli, M., Colla, G., Rea, E., Marcucci, A., 2010. Aquaponics vs. Hydroponics: Production and Quality of Lettuce Crop. Università della Tuscia. 927:887-893.

Reynolds, L., 2013. Agriculture and Livestock Remain Major Sources of Greenhouse Gas Emissions. Available online: http://www.worldwatch.org/agriculture-and-livestock-remain-major-sources-greenhouse-gas-emissions-0

Resh, M.H., 1995. Hydroponic Food Production: A Definitive Guidebook of Soilless Food-Growing Methods. 5th Ed.Woodbridge Press Publishing Company, Santa Barbara, California.

Saiid et al, 2016. Vulnerability Assessment of Syrian Refugees in Lebanon, UNHCR, UNICEF, World Food Programme

Samarakoon, U.C., Weerasinghe, P.A., Weerakkody, W.A.P., 2006. Effect of Electrical

Conductivity (EC) of the Nutrient Solution on Nutrient Uptake, Growth, and Yield of

Leaf Lettuce (Lactuca sativa L.) in Stationary Culture. Tropical Agriculture Research 18:13-21.

Samuolienė, G., Urbonavičiūtė, A., Brazaitytė, A., Jankauskienė, J., Duchovskis, P., Bliznikas, Z., Žukauskas, A. 2009. Decrease in Nitrate Concentration in Leafy Vegetables Under a Solid-state Illuminator, HortScience, 44(7):1857-1860.

Sanchez S.V., 2014. Avaliação de alface crespa produzidas em hidropônia tipo NFT em dois ambientes protegidos em Ribeirão Preto (SP). Paulista State University, College of Agricultural and Veterinary Science. (Accessed September 9, 2014)]. Available online: http://www.fcav.unesp.br/download/pgtrabs/pv/m/2802.pdf

Sandall, B., Singh, A., 2011. Using STEM to Investigate Issues In Food Production. Carson Dellosa Publishing LLC.

Selma, M.V., Luna, M.C., Martínez-Sánchez, A., Tudela, J.A., Beltrán, D., Baixauli, C., Gil, M.I., 2012. Sensory quality, bioactive constituents and microbiological quality of green and red fresh-cut lettuces (Lactuca sativa L.) are influenced by soil and soilless agricultural production systems. Postharvest Biology and Technology, 63(1):16–24.

Sgherri, C., Cecconami, S., Pinzino, C., Navari-Izzo, F., Izzo, R., 2010. Levels of antioxidants and nutraceuticals in basil grown in hydroponics and soil. Food Chemistry, 123(2):416–422.

Sneed K., Allen K., Ellis J., 1975. Fish farming and hydroponics. Aquaculture and the Fish Farmer 2:18–20.

Spensley, K., G.W. Winsor, and A.J. Cooper. 1978. Nutrient Film Technique - Crop Culture in Flowing Nutrient Solution. Outlook on Agriculture, 9(6): 299-305.

Stringer, E. T. 2007. Action Research Third Edition. Curtin University of Technology, Australia, Sage Publications.

Tokunaga, K., C. Tamaru, H. Ako, and P.S. Leung. 2015. Economics Of Small-Scale Commercial Aquaponics in Hawaii. Journal of the World Aquaculture Society 46(1):20–32.

Tarantola, A., 2014. The World's Largest LED Hydroponic Farm Used to Be a Sony Factory. Available online: http://gizmodo.com/the-worlds-largest-led-hydroponic-farm-used-to-be-a-son-1603082545

Treftz, C., Omaye, S.T., 2015. Comparison Between Hydroponic and Soil Systems for Growing Strawberries in a Greenhouse. Int. J. Agr. Ext. 3(3):195-200.

UNHCR, 2017: Global Trends: Forced Displacement in 2016.

UN Water, 2012. World Water Day 2012. http://www.unwater.org/wwd12/faqs.html

UNICEF (2017). https://www.unicef.org/appeals/syria.html.

Verner, D., 2012. Adaptation to a Changing Climate in the Arab Countries. A Case for Adaptation Governance and Leadership in Building Climate Resilience. The World Bank.

Verner, D., 2016. Could a livelihood in agriculture be a way for refugees to move from surviving to thriving? World Bank Blog.

Ward, C., Ruckstuhl, S., 2017. Water Scarcity, Climate Change and Conflict in the Middle East and North Africa. I.B.Tauris & Co. Ltd.

WFP and Care, 2013. Food security, Livelihoods and Markets report for Ali Addeh and Holl Holl Refugees and Host Communities.

WFP and UNHCR Joint Assessment mission: Ali Addeh and Holl Holl Camps, Djibouti. November 2013.

Wohlgenant, M.K., 2014. Chapter 16 Marketing Margins: Empirical analysis. Handb. Agric. Econ. 2001(1):933–970.

World Bank, 2016. The Welfare of Syrian Refugees: Evidence from Jordan and Lebanon. (author Paolo Verme, Chiara Gigliarano, Christina Wieser, Kerren Hedlund, Marc Petzoldt, Marco Santacroce.

World Bank, 2017a. Forcibly Displaced. Towards a Development Approach Supporting Refugees, the Internally Displaced, and their Hosts.

World Bank, 2017b. Forced Displacement Strategy Notes, Djibouti Background Paper Draft.

World Bank, 2017c. Water Management in Fragile Systems. Building Resilience to Shocks and Protracted Crises in the Middle East and North Africa. Background Paper.

World Bank, 2017d. Beyond Scarcity. Water Security in the Middle East and North Africa.

World Bank, 2017e. Turbulent Waters: Pursuing Water Security in Fragile Contexts. Working Paper.

World Bank, 2017f. Refugees and Water Saving Agriculture Technologies Workshop. August 17, 2017.

Yorio N. C., Goins G. D., Kagie H. R., Wheeler R. M. and Sager J. C., 2001. Improving spinach, radish, and lettuce growth under red light-emitting diodes LEDs with blue light supplementation, HortScience, 36(2):380-383.

Zhou W.L., Liu W.K., Yang Q.C., 2012. Quality changes in hydroponic lettuce grown under pre-harvest short-duration continuous light of different intensities. J. Hortic. Sci. Biotechnol., 87:429–434.

Appendices

Appendix 1

The UNHCR classifies needs in several categories, thus an individual may have no need or have multiple needs. The dependent variable in our regression analysis is the "number of needs", which is a left-censored variable because a large number of individuals reported that they had no needs as determined by the UNHCR. To address censoring, we use a Tobit specification to estimate the following model:

$$y_i^* = x' \ \ \beta + \varepsilon_i,$$

$$y_i \ \ = \begin{cases} y_i^* & \text{if} \ \ y_i^* > 0 \\ 0 & \text{if} \ \ y_i^* \ \leq 0 \end{cases}$$

where y denotes the number of needs, $y^*$is is latent variable, x is a vector of personal characteristics, and ε is the error term. We estimate Equation (1) using the maximum likelihood method together with robust standard errors. Table A1 reports estimates of marginal effects of the truncated expected value $E(y_i^* | 0 < y_i^*)$, which measures the changes in needs (y_i)with respect to changes in the regressors among the subpopulation for which needs (y_i) is not zero.

Table A.1 Dependent variable: number of needs, marginal effects[1]

	Female		Males	
	1	2	3	4
19 – 34 years	-0.4775	-0.4678	-0.5244	-0.5395
	(0.0299)***	(0.0304)***	(0.0321)***	(0.0334)***
35 – 49 years	-0.2942	-0.3078	-0.5276	-0.5398
	(0.0304)***	(0.0310)***	(0.0325)***	(0.0338)***
50 – 65 Years	-0.0947	-0.1978	-0.2649	-0.2809
	(0.0316)***	(0.0324)***	(0.0335)***	(0.0348)***
65+ years	0.1220	-0.0396	0.2000	0.1547
	(0.0352)***	(0.0362)	(0.0384)***	(0.0397)***
Married	-0.1781	-0.1642	0.0614	0.0610
	(0.0207)***	(0.0209)***	(0.0079)***	(0.0081)***
Separated, Divorced, or Widowed	0.0064	0.0015	0.1854	0.1818
	(0.0217)	(0.0219)	(0.0236)***	(0.0240)***
Number of children	0.0871	0.0858	0.0844	0.0841
	(0.0023)***	(0.0024)***	(0.0014)***	(0.0015)***
6-11 years of Educ.		-0.1798		-0.0295
		(0.0109)***		(0.0068)***
12 + years of Educ.		-0.3243		-0.0863
		(0.0143)***		(0.0090)***
Occupation				
Technicians and associate prof.	-0.0358	-0.0828	-0.0363	-0.0496
	(0.0646)	(0.0705)	(0.0120)***	(0.0127)***
Clerical, service, and Sales	0.0951	-0.0190	0.0000	-0.0195
	(0.0425)**	(0.0452)	(0.0106)	(0.0114)*
Agricultural occupations	0.2759	0.0436	0.0800	0.0498
	(0.0364)***	(0.0402)	(0.0088)***	(0.0100)***
Craft and related trades	-0.0135	-0.1722	0.0687	0.0393
	(0.0497)	(0.0528)***	(0.0087)***	(0.0098)***
Plant & mach. operators, & assemb.	-0.2437	-0.4119	0.0768	0.0496
	(0.1101)**	(0.1130)***	(0.0108)***	(0.0117)***
Non-Agri. elementary occ.	0.4877	0.3007	0.1837	0.1557
	(0.0734)***	(0.0745)***	(0.0143)***	(0.0151)***
Housekeepers	0.0405	-0.1313	0.1742	0.1809
	(0.0247)	(0.0292)***	(0.0206)***	(0.0220)***
N	51,563	50,454	100,083	96,615

* $p<0.1$; ** $p<0.05$; *** $p<0.01$. Robust standard errors are in parenthesis.
Omitted category: 18 years or younger, single, less than 6 years of education, Managers & Professionals.
[1] marginal effects of the truncated expected value $E(y_i^*|0 < y_i^*)$, which measures the changes in y_i with respect to changes in the regressors among the subpopulation for which y_i is not at a boundary.

Appendix 2

This section examines how PAs characteristics affect the odds of labor market success measured by the capacity to create income in the host community. We measure income per capita using the number of people in the case as the denominator. We also examine how PAs who worked in agriculture perform compared to those who worked in other occupations.

In this analysis, the dependent variable is work income per capita (excludes monetary transfers from the UNHCR). The income variable is also left-censored because a large number of cases reported no income. We again utilize a Tobit specification and the maximum likelihood method together with robust standard errors (clustered by age, sex, and education) to estimate the model.

Table A2 in the Appendix reports estimates of marginal effects of the truncated expected value $E(y_i^*|0 < y_i^*)$, which measures the changes in *income* with respect to changes in the regressors among the subpopulation for which *income* is positive.

Table A.2 Dependent variable: work income per capita, marginal effects

	1	2	3	4	5	6
Age Cohorts						
26-34 years	0.4650	-0.6811	-0.8270	-1.2945	-1.0387	-1.0794
	(2.7747)	(2.8435)	(2.8242)	(2.8442)	(2.7685)	(2.8163)
35 49 years	-0.5494	-1.4311	-1.1618	-2.2794	-2.0007	-1.6755
	(3.8525)	(4.0484)	(3.9175)	(4.0183)	(3.9083)	(3.8605)
50-65 years	-10.3337	-9.8925	-9.4237	-10.9000	-10.5947	-9.9809
	(4.1118)**	(4.5068)**	(4.1429)**	(4.3631)**	(4.2471)**	(4.1095)**
65+ years	-19.8292	-19.7745	-19.4191	-19.9243	-19.4885	-18.9504
	(3.9266)***	(4.3290)***	(4.0392)***	(4.2034)***	(4.0817)***	(3.9749)***
Number of children	-1.4617	-1.4770	-1.2900	-1.2464	-1.2798	-1.1377
	(0.6826)**	(0.6405)**	(0.5970)**	(0.6213)**	(0.6145)**	(0.5719)**
Female	-23.8096	-14.7460	-14.5723	-14.2237	-13.9287	-13.7236
	(2.6180)***	(1.7265)***	(1.7574)***	(1.6689)***	(1.6124)***	(1.6009)***
Married	-10.0898	-12.2151	-12.4254	-11.4734	-11.4083	-11.6278
	(2.2852)***	(2.5026)***	(2.4539)***	(2.4743)***	(2.4707)***	(2.4559)***
6-11 years of Educ.	-1.4971		-1.8393	-2.6472	-2.6302	-2.7156
	(2.2102)		(2.0946)	(2.0448)	(2.0176)	(1.9807)
12 + years of Educ.	-4.6631		-2.8480	-3.9347	-3.9535	-4.2167
	(2.1169)**		(2.7194)	(2.6038)	(2.5678)	(2.5580)*
Time since arrival						
1 year	-8.6114	-8.3762	-8.2524	-5.4683	-5.5687	-5.5643
	(1.6640)***	(1.7309)***	(1.7383)***	(1.4660)***	(1.4700)***	(1.4618)***
2 years	-13.7395	-13.0114	-12.6016	-10.0167	-9.7293	-9.6042
	(1.9141)***	(1.9532)***	(1.8752)***	(1.6704)***	(1.6996)***	(1.6174)***
3 or more years	-13.8992	-13.5303	-13.1603	-10.3846	-9.9352	-9.5391
	(2.1883)***	(2.5652)***	(2.5237)***	(2.2801)***	(2.4590)***	(2.3788)***
Occupation						
Technicians & associate prof.		3.0568	2.6818	2.0003	2.0208	1.9361
		(1.4274)**	(1.5085)*	(1.4666)	(1.5347)	(1.5170)
Clerical, service, & sales		5.9851	5.3863	4.7209	4.6570	4.6232
		(1.4686)***	(1.4006)***	(1.2210)***	(1.2601)***	(1.2183)***
Agricultural occupations		7.6712	6.7289	8.0560	7.7658	7.7057
		(1.5723)***	(1.4468)***	(1.4260)***	(1.3929)***	(1.3804)***
Craft and related trades		9.4381	8.5817	8.3814	8.3643	8.2727
		(1.6354)***	(1.3307)***	(1.2929)***	(1.3278)***	(1.3163)***
Plant & mach. operators, &		0.5310	-0.0430	0.5232	0.5520	0.5467
		(1.5554)	(1.3397)	(1.3325)	(1.3641)	(1.3388)
Non-Agri. elementary occ.		4.3862	3.7210	3.8423	3.9721	3.9176
		(1.1416)***	(1.1523)***	(1.1521)***	(1.2248)***	(1.1879)***
Housekeepers		-4.3380	-4.6351	-3.9242	-4.0198	-3.7802
		(1.7808)**	(1.6731)***	(1.6064)**	(1.5835)**	(1.6634)**
City of Destination						
Irbid					-9.9223	-5.1446
					(1.0478)***	(1.0248)***
Mafrag					-18.2812	-14.9110
					(1.9242)***	(1.5592)***
Zarga					-14.4602	-10.9151
					(1.8776)***	(2.0041)***
Other Cities					-2.0680	2.3262
					(0.9026)**	(1.0810)**
Reported Needs			-4.6523			-3.5385
			(1.3843)***			(1.2128)***
Controls for place of origin	No	No	No	Yes	No	Yes
N	53,588	46,818	46,818	46,686	46,818	46,686

* p<0.1; ** p<0.05; *** p<0.01. Robust standard errors (clustered by age, sex, and education) are in parenthesis.
Omitted category: 15-25 years, males, not married, less than 6 years of education, arrived in Jordan in less than a year, Managers & Professionals, and city of destination is Amman.
[1] marginal effects of the truncated expected value $E(y_i^*|0 < y_i^*)$, which measures the changes in y_i with respect to changes in the regressors among the subpopulation for which y_i is not at a boundary.

Appendix 3

Decision Matrix for Matching Refugees to Host communities, Jordan

	Host Community								Refugees							
Host Community	Female LFP	% Rural Population	% Has a Permanent Job, Female	% Has a Permanent Job, Male	% pop with HS or higher level of education	Water Access	Land constraint	% Refugees living in community	% PAs with Background in Agriculture	% Housekeepers	% PA with HS or higher level of education	% Reducing food Quality and/or quantity	Avg. number of days per week without vegetables	Other vulnerabilities	Poverty Status	Water Access
Amman																
Irbid																
Mafrag																
Zarga																
Balga																
Ajloun																
Karak																
Jarash																
Madaba																
Maan																
Tafilah																
Aqabah																

Note: Ordered by % refugee PAs living in city

Color-code cells for matching of hydroponics projects: **Red (poor match); Yellow (has potential) ; Green (most likely to succeed);**

Criteria to color-code: Background in agriculture; access to water; potential fit (education, low reservation wage), need (poverty, food insecurity)

How to populate cells: option 1) raw statistics; option 2) develop group classification for each column (e.g. Female LFP: very low, Low, Med, or High).