WATER SECURITY IN REFUGEE HOST COMMUNITIES:
SYRIAN REFUGEES IN JORDAN

BY

BRETT R. BARKLEY

THESIS

Submitted in partial fulfillment of the requirements
for the degree of Master of Science in Agricultural and Applied Economics
in the Graduate College of the
University of Illinois at Urbana-Champaign, 2015

Urbana, Illinois

Master's Committee:

Associate Professor Nicholas Brozović, Chair
Associate Professor Arnab Chakraborty
Professor Alex Winter-Nelson

Abstract

Previous research has suggested that host communities experience positive welfare effects following a large refugee influx, with local agricultural producers receiving the largest benefits. However, this may not occur in host communities where production inputs such as water are scarce. I adapt a dynamic economic model of groundwater extraction to analyze the environmental impact of the Syrian refugee influx from 2013 onward on the Amman Wadi As-Sir aquifer in the northern region of Jordan. I then show that, given model assumptions, agricultural producers in the Jordanian Highlands experience negative welfare effects as the resource is allocated away from producing sectors of the economy in order to provide for the refugee population. The extent of this effect varies given different scenarios of repatriation or resettlement, and is long-lived as the aquifer is depleted. Finally, I discuss policy implications for increasing water security in Jordan, focusing on two fronts: long-term capacity (e.g. wastewater reuse, infrastructure rehabilitation, and/or desalination) and local capacity (e.g. community water projects). It is left for future research to test the effectiveness of specific policies.

Acknowledgements

I would like to express my deepest gratitude to everyone who provided support and guidance during my graduate studies and completion of this thesis. My adviser, Professor Nicholas Brozović, helped focus my research in its early stages, encouraged me to travel to Jordan, and has been there for me every step of the way. I am also thankful to my committee members, Professor Arnab Chakraborty and Professor Alex Winter-Nelson, for their time and feedback throughout this process.

My field research in Jordan would not have been possible without the ACES Office of International Programs and support from the Arlys Conrad Endowment fund. Equally important to the success of my time in Jordan was the assistance of graduate student Dominique Gilbert and undergraduate honors student Peter Whitney, who also received support from the James Scholar fund. I am grateful to have shared that experience with them. Of course, I am greatly indebted to the many government and NGO officials who agreed to meet with me and share their knowledge on water and the refugee situation. I am also thankful to the Center for Global Studies and the European Union Center at the University of Illinois for believing in me and funding my graduate studies through the Foreign Language and Area Studies (FLAS) fellowship.

Finally, none of this would have been possible without my wife, Emily Cernoia Barkley, who, despite ongoing personal health problems since moving with me to Champaign, has provided unwavering support. I am forever grateful and hope that I have been able to provide just as much support to her during these difficult times.

Table of Contents

1. Introduction

There are more displaced persons across the globe today than at any time since World War II, when statistics were first collected by the United Nations High Commissioner for Refugees (UNHCR 2014).[1] In the past year, approximately 51.2 million forced migrants—internally displaced persons (IDPs) and refugees—have been stripped of their livelihoods and driven from their homes, some never to return. Over two-thirds of refugees will remain in exile for at least five years, considered a protracted refugee crisis (World Bank 2010). While efforts to ensure the human rights of refugees under international law should only be reinforced, it is also important to consider the impacts felt by the countries hosting them. Refugees can have profound impacts, both good and bad, upon arrival in their new countries depending on the economic base of the host population as well as local environmental conditions in the host community. In fact, an increasing body of literature in refugee studies cites water as a significant source of tension between refugee and host communities (Card 1990; Borton, Brusset, and Hallam 1996; Whitaker 1999; Landau 2002; Cortes 2005; Lach 2007; World Bank 2011; Farishta 2014). However, there is a lack of research in this area in the field of economics.

The Middle East and North Africa[2] region hosts the largest number of refugees registered by UNHCR at just over 4 million (UNHCR 2014). This does not include an additional 2.8 million exiled Palestinians registered in Jordan and Lebanon under mandate of the UN Relief and Works Agency (UNRWA). With persistent and unfortunate conflict a reality in Syria and now again in Iraq, as well as general political instability across much of the region since the Arab Spring of

---

[1] According to the most recent estimates, end-year 2013.

[2] Includes the 22 Arab League nations, minus Sudan and Somalia, plus Turkey, Iran, and Israel.

2011, the large refugee population in the Middle East does not promise to abate any time soon. Moreover, host communities in the Middle East, home to nearly 75% of the world's arid and extremely arid lands, are especially vulnerable to refugee-host tensions over water and are worth further study (IALC 2013).

The primary research questions considered in this thesis are: 1) Do local environmental conditions increase or decrease the economic benefits experienced by a host community in the wake of a refugee crisis and 2) How would this externality on the host population be spread across time? Previous research in economics suggests that host communities experience net benefits from a refugee influx, with agricultural producers and other owners of capital often receiving the largest benefits via increased demand for their goods and falling wages for labor. This may not occur, however, if water is scarce and must be diverted away from production to provide for water consumption of refugees in cities and camps. This thesis, therefore, contributes to the literature by considering how host welfare outcomes might change when host communities face pre-existing water scarcity. I use as a case study the Amman-Zarqa basin in the north of Jordan sometimes called the Jordanian Highlands (Figure 1), location to one of the largest populations of Syrian refugees and Jordan's most important groundwater aquifer.

Water resource economists have explored the implications of shocks to groundwater supply under scenarios of catastrophic environmental events and climate change (Tsur and Zemel 2004; Brozovic and Schenkler 2011; Cachorro et al. 2014). It is plausible that such shocks could also be caused by sudden increased water consumption due to large population movements—e.g. a forced migration shock—especially if population movements are permanent or semi-permanent as in protracted refugee crises. I, therefore, adapt a dynamic economic model of groundwater extraction to analyze the expected rate of resource use and water table decline from 2013 onward in the Amman-Zarqa basin. By comparing a base scenario, pre-refugee influx, with scenarios given varying levels of refugees, I establish the resulting impact on water resources in the Jordanian Highlands. Results show that groundwater in the Amman-Zarqa basin could be completely depleted by 2039—two decades ahead of previous forecasts conducted before the Syrian refugee crisis (USGS 2011)—accompanied by large monetary losses and economic restructuring as irrigated agricultural production declines over time and becomes unfeasible in the near future.

This thesis is organized as follows. Section 2 reviews the relevant literature. Section 3 provides the contextual background of Syrian refugees in Jordan. Section 4 details the model development. Section 5 describes the data used, and Section 6 implements an empirical application to analyze host welfare impacts in the Amman-Zarqa basin. I discuss policy implications in Section 7 and, finally, Section 8 concludes with suggestions for future research.

2. Literature Review

A growing literature exists across various academic fields that analyzes the impacts of forced migration on host communities. This section discusses research from refugee studies and economics. While the latter primarily focuses on quantitative price and income effects for goods and households in host communities (Alix-Garcia and Saah 2009; Alix-Garcia et al. 2011; Alix-Garcia et al. 2012; Maystadt and Duranton 2014), the former offers more qualitative insight into the environmental impacts on water resources potentially exacerbated by a large refugee influx (Card 1990; Borton, Brusset, and Hallam 1996; Whitaker 1999; Landau 2002; Cortes 2005; Lach 2007). I first review the most relevant work from the extensive refugee studies literature and then the young but emergent line of research on forced migration from economics.

Qualitative Studies

Jacobsen (1997) has a very nice discussion on how refugee hosting strategies and settlement patterns can produce different environmental impacts. She argues that local integration of refugees would alleviate many of the problems associated with deforestation and soil degradation common in camp environments. Assuming existing water sanitation infrastructure in the host community can absorb refugee populations, integration may also alleviate water pollution often exacerbated near camps. On the other hand, in dry areas, integration can increase competition over scarce water resources as non-camp refugees tend to consume more water per capita than they are able to in relatively primitive camps; in some cases, in fact, integration has exacerbated urban crises and led to surges in violence (Zetter and Deikun 2010). Crisp (2002) identifies additional concerns with so-called refugee "warehousing" in geographically isolated camps: local markets are small or nonexistent, information about markets that do exist but are not necessarily nearby is hard to obtain, and high transportation costs prevail. Such obscure and remote conditions can lead to refugee populations feeling neglected and frustrated, making them prime recruits for armed groups and potentially exacerbating local and regional stability (Czaika 2005). As an agency created to protect human rights, UNHCR promotes freedom of movement and thus local integration into host society over refugee camps, but host governments often do not favor local integration because, according to international law, it implies permanent asylum, residency status, and eventual citizenship.[3] Despite this resistance by host governments, nearly half of the global refugee population now reside in cities and towns (World Bank 2010).

Unsustainable groundwater extraction and declining recharge rates have been reported in both non-camp and camp settings (Black 1994). In Darfur, IDP camps primarily receive water from several deep boreholes, 30 to 40 meters, often dug by non-governmental organizations (NGOs) (UNEP 2007). The Abu Shouk camp, with a peak population of 80,000 IDPs needing a water supply of more than 1,000 cubic meters per day (m^3/d), had five of its twelve boreholes run dry in 2006. Economic sectors established in relief economies can also increase stress on water use. For example, brick-making has become an important source of income for many displaced persons in Darfur, which, in addition to water, requires large amounts of wood sourced from nearby forests to fire kilns used in the brickmaking process. Halting such economic activities is typically not an option, as it is a source of livelihood for IDPs—and NGOs use the bricks to construct walls around the camps required by international security standards.

---

[3] Article 34 of the 1951 Refugee Convention (cited in Jacobsen 2001).

Berry (2008) cites overuse of water sources as one of the major negative environmental impacts due to Burundian and Rwandan refugee populations in Tanzania, in addition to cutting of trees and bushfires. Berry reports that environmental degradation would be much greater if not for NGO implemented environmental management projects, which include tree plantings, environmental education, provision of wood-saving stoves, sustainable farming practices, and water source rehabilitation. In field interviews and focus groups, many Tanzanians cited water resource depletion and blockage of streams by refugees, though one NGO employee questioned whether such overuse was more due to local communities' agricultural and land use practices. Such blaming of refugees for environmental problems that they don't necessarily cause has been cited elsewhere, for example, regarding Afghan refugees in Pakistan (Allan 1987).

Based on survey research, Whitaker (2002) attempted to explain the impacts of refugees on agricultural production and economic activity in Tanzania. While the former, in particular, would be thought to have implications for water resource use, she does not mention water. Findings, however, provide evidence of positive economic impacts due to an enlarged consumer market and new source of cheap labor—in some cases, doubling farm production in communities nearest to camps. But among local inhabitants not in agricultural production, the uneducated and poor appeared to fare much worse than the educated Tanzanians who faced less competition for employment. Refugees are not always unskilled, though. Over one-third of Iraqi refugees in Jordan, as of 2008, had university or professional degrees and were successful finding jobs in universities and hospitals (Crisp et al. 2009).

Gentry (2009) also studied the economic and environmental impacts of Burundian refugees in Tanzania. At the time of the study, there were still nearly 200,000 Burundian refugees in Tanzania. Interviews and focus groups conducted with refugees, host community members, and staff from NGOs found that coordination between relief aid and development aid can have significant positive effects on both refugee and host communities. The presence of NGOs in the local economy created employment for many Tanzanians, and farmers also benefited from the World Food Programme's (WFP) local purchase policy, which requires a purchase quota of locally grown foods for refugee operations. Tanzanians also benefited from free healthcare accessible to them in the refugee camps. Environmental impacts according to Gentry, however, were negative, presenting evidence of significant vegetation loss in immediately surrounding areas of the camps using satellite data. Reforestation efforts by NGOs usually were not enough to offset losses. Several villages were also negatively affected by water pollution in early stages of refugee influx—around 49,000 people or 20% of the local population experienced water quality degradation. Though in a few villages, new wells and boreholes were constructed, which increased access to safe drinking water for some Tanzanians. Over-poaching of bush meat also proved to be very harmful with possible repercussions for the local economy into the future.

Quantitative Studies

While the economics literature on voluntary migration is relatively robust, that of forced migration is still in its infancy—nearly all studies having been completed since 2008 (Ruiz and Vargas-Silva 2013). Moreover, most of this research focuses on outcomes of IDPs or refugees, not the hosts, and all employ econometric techniques. Research on host outcomes in developing countries to date has considered forced migration shocks in Tanzania, South Sudan, and Columbia. They are reviewed below.

Alix-Garcia and Saah (2009) presented evidence that host communities in Tanzania likely experienced overall net benefits in the wake of crises in Burundi and Rwanda during the 1990s, which displaced over 700,000 refugees. However, they found that urban households likely experienced net welfare losses. These conclusions are based on estimated price effects of food aid and non-aid food items and subsequent changes in household wealth indicators over the study period. In two follow-up articles, focusing on IDP camps near the town of Nyala in Darfur, the authors found similar price effects after also accounting for housing rents (Alix-Garcia et al. 2011). They also extended previous analysis to more environmental factors with satellite data from 2001-2007, finding evidence of significant vegetation loss due to small-scale farming and construction of houses and businesses—especially surrounding IDP camps near urban centers which afford better market access and increased security (Alix-Garcia et al. 2012).

In Columbia, Calderon and Ibanez (2009) found that an exogenous shock to the labor supply—in this case the result of IDPs fleeing violence in rural areas between 1998 and 2008 to more secure urban centers of the country—had negative impacts on wages for all workers in the cities that received them. While the migration itself was driven by exogenous factors, to account for potential non-random location decisions of the forced migrants, an instrumental variable approach was used that interacts the number of civilians killed by illegal armed groups in the place of origin with the distance to destination municipalities. Negative labor market outcomes for the host community were found to be greater among less skilled workers and in the informal sector, where a 10% increase in the share of IDPs reduced hourly wages up to 2.4% and 3%, respectively. This is compared to 1.4% wage reduction for all workers. In both the formal and informal sectors, female workers tended to suffer a slightly larger wage reduction by about 0.5 percentage points.

Considering the case of Tanzania again, Baez (2011) focused on both short- and long-term health and human capital impacts for an especially vulnerable subset of the host population: children. Using data from the Kagera Health and Demographic Survey (1991-2004) conducted by the World Bank in areas of Tanzania affected and unaffected by the Burundian and Rwandan refugee crises, this study presented discouraging evidence that in the short-term children under five in affected areas suffered from impaired anthropometric development, a 15 to 20 percentage point increase in the incidence of infectious disease, and a 7 percentage point drop in mortality. In the long-term, it was found that such childhood exposure reduced height in early adulthood by 1.2%, years of schooling by 7.1%, and literacy by 8.6%. Unlike Calderon and Ibanez (2009), Baez was able to do without an instrumental variable approach by exploiting the presence of natural geographic barriers between western and eastern Kagera, which made the location decision of refugees random regarding the outcomes of interest.

Also using data from the Kagera Health and Demographic Survey (1991-2004), Maystadt and Verwimp (2011) tested hypotheses related to economic consumption per adult equivalent of Tanzanian households in affected areas of Kagera both before and after the refugee crises. Other household characteristics are held constant, including size, primary occupation, landed assets, literacy, and individuals who have migrated out of or into the household to or from other regions. Consistent with Alix-Garcia and Saah (2009), they found supporting evidence of net consumption increases. In this case, even non-agricultural workers experience welfare gains in addition to self-employed farmers. However, agricultural laborers still suffered losses due to increased labor market competition and increasing prices for many consumption goods.

Maystadt and Duranton (2014) extend this analysis with updated data from the Kagera Health and Demographic Survey through 2010, conceivably allowing them to test for "long-term” economic impacts. Results were similar, showing that areas that hosted higher populations of Burundian and Rwandan refugees experienced net increases in consumption per adult equivalent. The authors use this follow-up article to discuss at greater length the potential modes of transmission for this growth, such as agglomeration economies, existences of multiple equilibrium, increased provision of local public goods, or enhanced trade with neighboring countries after repatriation. They conclude that estimated economic gains are likely due to reduced trade costs given improved transportation infrastructure constructed in response to the crisis by the international relief community and the Tanzanian government.

Contribution to the Literature

Based on findings from the existing literature, welfare outcomes of host communities can either be positive or negative, and even when hosts benefit overall, there are always winners and losers. Of the studies reviewed above, producers whether in the agricultural or urban setting tend to be the primary recipients of welfare gains via increased production, rising prices for their goods, and reduced wages for employed labor. This, of course, means that consumers and wage laborers are usually on the losing side. Children are another particularly vulnerable segment of the population and are found to experience negative impacts as measured by health and education outcomes. Despite some of these findings, economic gains have exceeded losses in the two host communities—Kagera, Tanzania and Darfur, South Sudan—where net welfare has been assessed.

Such welfare measures, however, do not consider environmental impacts or how potential resource shortages could alter host welfare. Alix-Garcia et al. (2012) studied vegetation loss in Darfur but did not attempt to show how this affected economic outcomes. Economic outcomes are, indeed, intertwined with environmental outcomes, and ideally should be studied together when appropriate. Agricultural producers, for one, greatly depend upon water as an input and need more of it to increase production or at least as much of it to maintain production. In Tanzania, agricultural production was an important factor in capturing the potential benefits of a refugee influx via expanded output and increasing prices, but under different local environmental conditions where water is scarce, economic gains may be precluded.

The analysis in this thesis contributes to the forced migration literature by assessing environmental and economic outcomes in concert, though narrowly defined. This will help researchers better understand the environmental implications of a refugee influx and how, in turn, that could alter the economic benefits experienced by host communities.

3. Syrian Refugees in Jordan

During fieldwork in Jordan during May 2014, I met with relevant government agencies and NGOs to learn more about the host country's challenges in providing for the growing Syrian refugee population. Conversations with officials focused largely on the issue of water supply in the northern region of Jordan, where the non-camp refugee population is highest, as well as in the Zaatari refugee camp—one of the largest refugee settlements in the world. Field interviews were conducted in Amman, the Zaatari camp in Mafraq, and at Yarmouk Water Company's (YWC) offices in Irbid (Table 1).

Hosting refugees is nothing new for Jordan. This country of 6 million (as of 2011) received approximately 2 million Palestinian refugees in the 1940s and 60s, most of whom still live in Jordan, and more recently hundreds of thousand Iraqi refugees in the 1990s and 2000s. However, the ongoing influx of Syrians escaping the brutal civil war in their home country is likely to be the most concentrated flow of refugees over time in Jordan's history. The most reliable estimates of registered and un-registered Syrian refugees are between 1.4 and 1.8 million as of the end of 2014 (UNHCR 2014; MWI 2013).

Water scarcity is also nothing new for Jordan. An official from the Ministry of Water and Irrigation (MWI) noted that there was already a water crisis in Jordan before the Syrian refugees arrived (MWI, pers. comm., 2014). Water supply is the greatest challenge for the daily operations of the Zaatari Camp, where tankers deliver approximately 1 million gallons/day—amounting to approximately 1.38 million cubic meters/year (MCM/y). According to UNHCR, the camp had a peak population of 202,993 in April 2013. For the one-million-plus refugees outside of camps, consumption is much more difficult to monitor. The water, sanitation, and hygiene (WASH) division of the United Nations Children's Fund (UNICEF), which oversees all water and sanitation policies related to refugees in Jordan, operates under the assumption that refugees in cities and towns consume approximately 80 liters per capita per day (l/cap/d) (UNICEF, pers. comm. 2014). In total, Syrians could be consuming as much as 8-15% of Jordan's annual renewable groundwater resources (Farishta 2014).

This has created great tension between Jordanians and Syrians and between considerations of economic livelihood and environmental sustainability. Jordan must provide water for Syrians but, at the same time, is concerned about how long current supplies will last and how that would impact the country's economy moving forward. The recently completed Disi project, which mines water from a 2,000-year-old aquifer along the border with Saudi Arabia and pumps it over 200 miles to Amman, was supposed to provide water through 2022 but has since been revised to 2016 (MWI, pers. comm., 2014). Regarding extraction from the primary aquifer in the Amman-Zarqa basin, the WASH coordinator at UNICEF noted that it is also more like water mining at this point because of low recharge; officials are now realizing the potential of complete water exhaustion (UNICEF, pers. comm., 2014). Immediate impacts have already been absorbed by increased rationing of water at the household level, especially in Mafraq City and Irbid. Whereas water was previously delivered to households once per week, now it might be delivered only once or twice per month. In such circumstances, households increasingly depend on often unreliable private water trucks.

Jordan's water system also suffers from high rates of leakage, or non-revenue water, due to aging infrastructure and illegal connections (Mercy Corps, pers. comm., 2014). It's not just that pipes are old, either. Jordan has experienced unprecedented rates of urbanization in recent decades; 80% of the population is now urban (UNICEF, pers. comm., 2014). Pipes were built for 20-year population projections, which were reached more quickly than expected. Add the refugee population to the equation, and the problem is compounded. Official leakage rates are around 50% (MOPIC 2013) but some believe it could be as high as 75% (Mercy Corps, pers. comm., 2014). While such high rates are quite alarming, they do represent an opportunity to significantly increase capacity without actually tapping additional resources. For this reason, officials strongly support rehabilitation over digging new wells, at least in principle. Indeed, several pump stations have been rehabbed, but the interconnectedness of the piped system makes it difficult to upgrade the network piecewise. So, digging new wells is the easiest short-term solution no matter how unsustainable. Engineers at YWC, the water utility responsible for most of the Highlands, have drilled as many as 10 new wells or boreholes since Syrian refugees began arriving. They realize groundwater is being depleted but explain, understandably, that there is simply no choice in order to keep pace with increased demand (YWC, pers. comm., 2014). The new wells have increased capacity 350-500 m^3/hour. A second phase of expansion and rehab is expected to increase capacity by another 500 m^3/hour.

Apart from the Jordan Valley on the northwest border of Jordan, the Highlands and the rest of the country depend on groundwater. Previous studies have found that the water table in the Amman-Zarqa basin drops on average 1.08 meters/year and is projected to be depleted as early as 2060 (Goode et al. 2013, data pre-2011). With Jordan's water resources dwindling, it is unclear how the country's largest consumer—irrigated agriculture—fits into the picture moving forward. Agriculture consumes approximately 66% of water resources in Jordan and the specific area of study (MWI 2013).

In an attempt to help preserve the primary aquifer in the basin, block prices have been in place for domestic water use for many years but policy measures like irrigation pricing have only been passed relatively recently. In the domestic sector, the average Jordanian household pays approximately \$0.73/m^3 to consume 57 cubic meters of water each quarter (water is billed on a quarterly basis) while the average refugee household pays approximately \$0.28/m^3 to consume 36 cubic meters each quarter (WAJ 2015).[4] But water policy in agriculture is a very delicate issue in Jordan given both the spiritual importance of water in traditional Muslim culture and the serious implications such measures could have for the livelihood of farmers. The number of large well-capitalized farms in the Highlands has been growing over the previous decade, but many farmers still live below the poverty line. Most poorer farmers belong to Bedouin tribes, who, though poor, collectively possess significant political influence. Perhaps for these reasons, the block structure eventually introduced by the Groundwater Control Bylaw No. (85) in 2002 was much less effective than originally envisioned. According to the law, water fees are only levied on farmers for extraction over 150,000 m^3/y, and nearly 70% of the approximately 500 irrigation wells in the basin don't exceed this threshold (Venot et al. 2007). For extraction between 151,000-200,000 m^3/y, the law was reformed in 2004 to reduce fees from \$0.035/m^3 to \$0.007/m^3, and extraction over 200,000 m^3/y is charged \$0.085/m^3.

Previous studies have suggested that the bylaw even had the contradictory impact of causing well-capitalized farmers to intensify agricultural production to take advantage of better profit margins at larger scales (Venot et al. 2007). Gross irrigated area in the Highlands indeed increased by 40% from 2004-2010, though it was growing at about the same pace in the years

---

[4] This assumes Jordanians consume 128 l/cap/d and refugees consume 80 l/cap/d. As a comparison, the average price of water in the US is approximately \$0.40/m^3 (FWA 2015).

preceding passage of the new bylaw (USAID 2012). Given this strong growth, the Highlands is now the largest producer of irrigated agriculture in Jordan but still secondary to the Jordan River Valley in terms of total production—both irrigated and rainfed.

Together, agriculture production in these two regions only comprise a small portion (2-3%) of Jordan's gross domestic product (GDP) and total employment, but 28% of Jordan's economy is considered to be agricultural dependent given strong upstream and downstream linkages (IFAD 2001). So, dynamics in the agricultural sector could still have significant repercussions for the rest of the economy in general. This may be especially true for households in the Highlands where half the population lives in rural areas and are engaged in farming at higher rates than the rest of the country (IFAD 2007). Moreover, the region's household income levels are considerably lower than the Jordanian average. While Jordan is considered a non-fragile non-OECD lower middle income country, Mafraq and Zarqa—with household income levels 17% and 12% below the national average—more closely resemble characteristics of fragile low-income countries (i.e., a place with a Country Policy and Institutional Assessment (CPIA) rating below 3.2 and per capita income of 975 USD or less) (World Bank 2010). Because of these characteristics, the impact of Syrian refugees, a curtailment of irrigation water, or both are likely to be most acute here.

Next, I present a general economic model in order to more precisely identify the potential welfare implications for agricultural producers in refugee host communities under conditions of resource scarcity.

4. Model Description

In this section, I describe a well-known modeling framework within water resource economics most popularly conceptualized by Gisser and Sanchez (1980) and later modified by many others (Noel et al. 1980; Lee et al. 1981; Feinerman and Knapp 1983; Allen and Gisser 1984; Nieswiadomy 1985; Kim et al. 1989; Brill and Burness 1994; Koundouri and Christou 2000; Tsur and Zemel 2004; Esteban and Albiac 2012; Cachorro et al. 2014). The model establishes certain economic relationships and integrates them with fundamental hydrological functions describing a single-cell aquifer in order to show how the decisions of water users might affect groundwater resources over time and, as such, determine extraction rate(s) that would maximize the economic value of the aquifer (or, that is, the social welfare of its users). While the original model makes several restrictions—e.g. infinite hydraulic conductivity, constant return flow and recharge, a time-independent linear water demand function, and fixed irrigation technology—its general insights, in most cases, have held up even after relaxing many of these assumptions (Koundouri 2004). Below, I present the model, noting modifications made by the author, and explaining important analytical intuition in order to understand how a migration shock would be expected to affect groundwater resources.

Assuming that demand for water is

$$W = a - bp, \tag{1}$$

where *p* is the price of water and *a* and *b* are coefficients of the demand function. Costs are linear such that

$$\bar{C} = z - cG, \tag{2}$$

where *c* is the slope of the cost function and *z* is defined as the product of the irrigation surface level (S_L) and unit pumping costs (*c'*), i.e. the increased costs per MCM of water pumped per meter decline in the water table. Dynamics of the aquifer,

$$\dot{G} = -(1-\propto)W + r, \tag{3}$$

are a function of the recharge rate (*r*), return flow coefficient (α), and demand for water (*W*). Rearranging equation (1) to express *p* as an explicit function of *W*, then subtracting total costs (2), gives net benefits from water:

$$\left(\frac{a}{b}\right)W - \left(\frac{1}{2b}\right)W^2 - (z - cG)W. \tag{4}$$

Equation (4) is critical to the decision of how much water to pump, which is determined by maximizing the present value of future benefit streams, given some discount rate (*ρ*), the dynamics of the aquifer (3), and initial conditions (G_0):

$$\max_{W(.)} \int_0^\infty \left[\left(\frac{a}{b}\right)W - \left(\frac{1}{2b}\right)W^2 - (z - cG)W\right] e^{-\rho t} dt, \qquad (5)$$

where

$$\dot{G} = -(1-\propto)W + r,$$

$$G(0) = G_0 \quad \text{given,}$$

$$W \geq 0 \quad G \geq 0.$$

The above constitutes an optimal control problem, with the dynamics of the aquifer (3) as the governing differential equation, the water stock *G(t)* as the state variable, and water pumped *W(t)* as the control variable. From the performance criterion (5), the Hamiltonian is written as

$$\mathcal{H} = \left[\left(\frac{a}{b}\right)W - \left(\frac{1}{2b}\right)W^2 - (z - cG)W\right] e^{\rho t} + \lambda(-(1-\alpha)W + r), \qquad (6)$$

in which the adjoint variable, λ, can be interpreted as the scarcity value of water. For this version of the model, Chachorro et al. (2014) show via the maximum principle that the following system of two differential equations can be established:

$$\dot{G} = r - (1-\alpha)(a - zb) - cb(1-\alpha)G + \lambda b(1-\alpha)^2, \qquad (7)$$

$$\dot{\lambda} = c(a - zb) - c^2bG + (cb(1 - \alpha) + \rho)\lambda, \tag{8}$$

which are then solved simultaneously to, first, find the steady state solutions,

$$W_\infty = \frac{r}{1-\propto}, \tag{9}$$

$$G_\infty = \frac{r}{cb(1-\propto)} + \frac{r}{\rho} - \frac{a}{cb} + \frac{z}{c}. \tag{10}$$

Finally, the extraction and stock paths that maximize the present value of future benefit streams are given by

$$W^*(t) = \frac{r}{1-\propto} - \frac{\rho_2}{1-\alpha} e^{\rho_2 t}(G_0 - G_\infty), \tag{11}$$

$$G^*(t) = e^{\rho_2 t}(G_0 - G_\infty) + G_\infty, \tag{12}$$

where $G(0) = G_0$ and ρ_2 is the negative root of the characteristic polynomial:

$$\rho_2 = \frac{\rho - \sqrt{\rho^2 + 4cb(1-\propto)\rho}}{2}. \tag{13}$$

This thesis does not offer comment on the model's original use by Gisser and Sanchez (1980), which was to compare the above forward-looking model solution, (11) and (12), to that of myopic water extraction, in which water users decide how much water to pump each year by equating the marginal cost of pumping with the marginal physical product of water—i.e. without accounting for the scarcity value of water.[5] Rather, the current research is concerned with how the aquifer system, as defined above, responds to shocks to the resource and how such could be expected to impact welfare as defined by equation (5).

This is similar to Chachorro et al.'s (2014) use of the model, except, where they were concerned with supply-side shocks (e.g. climate change, etc.), I am concerned with the effect of a demand-side shock, namely, a large refugee influx. In either case, it is plausible for the resource shock to enter the model via a change in the recharge rate, though, given the demand shock considered, the adjustment of the recharge rate in the model should technically be interpreted as natural recharge, net of refugee water consumption. Thus, the model is constructed in the same way as in Chachorro et al. (2014) but motivated differently; and by incorporating repatriation or resettlement into the model, I also consider a reversal of the shock. Specifically, I adapt the so-called "non-adaptation" version of the model in which the date of the shock is unknown. It is implemented using the original specification above, except equation (5) is solved twice, first, such that

---

[5] By equating $\bar{C} = z - cG$ with p from water demand function, one finds that $W = a - bz - bcG$, which is said to govern myopic groundwater use. Gisser and Sanchez (1980) show analytically and empirically that in large enough aquifers, the discount rate practically disappears from the solution to the optimal control problem and thus is not significantly different from the myopic, or "competitive", solution. The so-called Gisser-Sanchez effect, then, warrants that little benefit results from public management of the aquifer. For the full resolution of this problem, see Gisser and Sanchez (1980).

$$\dot{G} = -(1-\propto)W + r_1 \qquad \text{and,} \tag{14}$$

$$G(0) = G_0,$$

then, such that

$$\dot{G} = -(1-\propto)W + r_2 \qquad \text{and,} \tag{15}$$

$$G(t_a) = G_0,$$

where the initial stock level in (15), $G(t_a) = G_0$, is equal to the stock level in year t_a in (14). The model solutions are then combined for when $t \leq t_a$ such that $r = r_1$ and when year $t > t_a$ such that $r = r_2$.

Let us now consider more closely the role the recharge rate (*r*) plays in the above model. First, it is observed that the steady state solutions are increasing monotonic functions of *r* given that $\propto -1$ is always negative:

$$\frac{\partial W_\infty}{\partial r} = \frac{-1}{\propto - 1}, \tag{16}$$

$$\frac{\partial G_\infty}{\partial r} = \frac{1}{\rho} - \frac{1}{bc(\alpha - 1)}. \tag{17}$$

This, of course, makes sense; the more water entering aquifer, the more one will be able to pump in the long run and the greater the stock of the resource will be. Since the extraction rate is still governed by the dynamics of the aquifer, it follows that the amount of water pumped in $t = \infty$ in response to an increase in *r* does not increase to the extent that the long run stock of the resource drops or stays the same—it should always increase, as well. Alternatively, the lower the value of *r*, the lower the steady state of extractions and stock of the resource. To be clear, a larger shock to the resource means less water will be available in the long run.

I also note the obvious conclusion, based on equations (9) and (10), that the date of the resource shock, t_a, has no effect on the steady state extraction and stock solutions, such that

$$\frac{\partial W_\infty}{\partial t_a} = 0, \tag{18}$$

$$\frac{\partial G_\infty}{\partial t_a} = 0. \tag{19}$$

This follows given that water users do not know the date of the shock and cannot account for it in their pumping decisions. Only the magnitude of the shock, all else equal, will determine long-run adaptation.

Analyses performed with the model

In Section 6, I present the results of three different analyses based on the model just described. First, I perform a sensitivity analysis to understand how the economic parameters can be expected to affect model outcomes. Second, based on data presented in Section 5, I proceed with an empirical application for the Amman-Zarqa basin in Jordan, initially assuming that the refugee influx is permanent and occurs in $t = t_a = 0$.[6] Finally, I consider the possibility of repatriation or resettlement of refugees (i.e. the influx is not permanent) where a reversal of the shock, at least in part, occurs in $t_{rep} \neq 0$. For each of the empirical applications, a post-optimality analysis is conducted in which water is allocated between the domestic and agricultural sectors based on expected consumption, respectively, in each scenario. More specifically, I assume one water demand function that represents both sectors. Once the model is solved, I allocate annual water availability, first, to domestic use and, second, to irrigation use and compare associated welfare estimates and how they evolve through time according to whether the refugee influx is permanent or not. Calibration of scenarios is described in more detail in the next section.

---

[6] In the case that $t_a = 0$, the model need only to be solved once according to dynamics of the aquifer (15) such that $G(t_a) = G(0) = G_0$.

5. Data

I collected data from a variety of sources. Values of model parameters for the Amman Wadi As-Sir aquifer, or the B2-A7 formation, in the Amman-Zarqa basin are given in Table 2. Description of economic and hydrological data, as well as calibration of scenarios, for the empirical application in Section 6 follows in order.

Fitch (2001), as part of a USAID study, conducted a survey of 156 farms in the Jordanian Highlands; based on the average energy costs and depth to water table, unit pumping costs in US Dollars (USD) per MCM per meter of lift were found to be around 450 USD/MCM m.[7] This is used to calculate the linear cost function (2). Unfortunately, an estimate of the demand for water equation (1) for either the domestic or agricultural sectors across the entire Amman-Zarqa basin is not available. Tabieh et al. (2012) estimated a household water demand function for Zarqa City, which is located between Amman and Mafraq City. They found demand for water to be almost perfectly inelastic; a 10% increase in the price of water only caused a 0.04% decrease in demand. According to a meta-analysis of the literature, demand for irrigation water at low price levels is also often very inelastic (FAO 2004). Venot and Molle (2008), though they didn't estimate a demand equation, did present evidence that an increase in the price of water in the Jordanian Highlands does very little to curtail irrigation water use below all but very cost-prohibitive price thresholds. Based on these findings, I use demand parameters that imply a highly inelastic response to the price of water. Such assumptions are also consistent with demand

---

[7] Energy costs for electricity varied from 30 fils/m^3 to 130 fils/m^3, depending on the depth of the well. A small number of farmers instead of electricity use diesel fuel, which is about 20% higher than the cost of electricity. Average pumping depth in Fitch's (2001) study was 191 meters. A fils equals 1/1000 of a Jordanian Dinar (JD) and 1 JD equals 1.41 USD.

parameters used elsewhere in the water resource economics literature (e.g. by Chacorro et al. (2014) and Esteban & Albiac (2012) in their study of the Western La Mancha aquifer in Spain).

Hydrological parameters are drawn from technical reports published by the government of Jordan and academic researchers. Surface level (660 m) and initial water table (510 m) are from MWI (2013). Al Muhamid (2005) reports that the annual recharge is 56 MCM and area of the aquifer is 4,710 km^2. Finally, Venot et al. (2009) estimate the return flow coefficient to be 0.25. I assume a discount rate of 0.05.

Four scenarios are calibrated for the empirical application. Scenarios 1a and 1b are based on UNHCR refugee population figures for year-end 2014 (UNHCR 2014), while 2a and 2b use less conservative estimates produced by the government of Jordan (MWI 2013) (Table 3). Figures are adjusted given that approximately 65% of Syrian refugees reside in the northern governorates of Mafraq, Irbid, Jerash, Aljoun, and Zarqa, which receive their domestic water supply from the B2-A7 aquifer in the Amman-Zarqa basin (UNHCR 2014).[8] Scenarios also take into account that Amman receives 19% of its water from the same aquifer. Each scenario is calibrated under two different assumptions about water consumption patterns for refugees inside and outside of camps. Water consumption in the Zaatari camp is approximately 32 l/cap/d (UNICEF 2014). UNICEF estimates that refugee consumption outside of camps is approximately 80 l/cap/d (UNICEF, pers. comm. 2014). However, it is widely perceived that Syrians are not accustomed to conserving water to the extent that Jordanians are—and thus consume more water than the average Jordanian (MWI, pers. comm. 2014). The Jordanian government and international donors are even funding an extensive communications campaign to raise awareness among

---

[8] For Zarqa, only refugees residing in Zarqa City are considered. The Al-Azraq refugee camp, which is in the eastern part of the Zarqa governorate is not in the Amman-Zarqa basin.

Syrian refugees about Jordan’s acute water shortage and to encourage them to adopt water-saving practices (GIZ, pers. comm. 2014). So, it is reasonable to assume for an upper bound that Syrians outside of camps could be consuming at least as much as the average Jordanian or 128 l/cap/d.

6. Results

In this section, I first present results of the sensitivity analysis. Then, I proceed with the empirial application for the Amman-Zarqa basin in order to determine the welfare impacts due to a large refugee influx, with specific focus on the welfare of agricultural households in the host community.

Sensitivity Analysis

Before applying the model to the specific area of study, it is useful to perform a sensitivity analysis on the economic parameters in order to gain a better understanding of how the model works and how results of the empirical application might change under different assumptions. I follow Nieswiadomy (1985) and Feinerman and Knapp (1983) in designing the sensitivity analysis and selecting the parameters of focus. Also, the demand slope, demand intercept, and unit costs of pumping are likely more subject to measurement error compared to other model parameters and, therefore, warrant special consideration before interpreting results.

Table 4 details alternative values for each parameter in the analysis and the associated welfare calculations. It is observed that benefits from groundwater extraction decrease as either the demand slope or unit pumping costs increase. At least in the latter case, the reason is relatively straightforward: as pumping costs increase, individuals must use less water or use the same amount at higher cost. On the other hand, it is observed that benefits from groundwater extraction increase as the demand curve shifts up (i.e. the intercept increases). Again, this makes sense as it means that individuals are able to use more water or that water can be allocated to more individuals at the same unit cost. These findings are, of course, consistent with what we would expect.

I also report calculated arc elasticities for each parameter in Table 4. This measures the percentage change in welfare from a one percent change in the parameter value. It is observed that results are quite sensitive (i.e. elasticity > $|1|$) to changes in the economic parameters of the model, with unit pumping costs causing the largest change, then the intercept and slope in respective order. This is consistent with previous findings in the literature (Nieswiadomy 1985; Feinerman and Knapp 1983) and should be considered when interpreting results of the empirical application.[9]

Empirical Application

Taking $t = 0$ as the first full year of significant refugee influx, 2013, and based on the given parameters (Table 2), results for the base scenario show initial extraction levels at approximately 168 MCM/year, which is within current estimates of actual extraction (Figure 2) (Venot & Molle 2008; Farishta 2014). The aquifer reaches a steady state of pumping (W_∞) at approximately 75 MCM/year by 2048, and the welfare of all water users (5) is just over 11 million USD (Table 5).

---

[9] As an additional note, Feinerman and Knapp (1983) test additional parameters and find that results are also relatively sensitive to area times storativity and the discount rate (with inverse relationships) but are insensitive to other parameters.

Under the most conservative assumptions of the Syrian refugee population and associated water consumption patterns (Scenario 1a), W_∞ falls to 40 MCM/year and total welfare is reduced by approximately 25%. In this scenario, water can no longer be allocated to agriculture as of 2029. According to the worst case scenario (Scenario 2b), a steady state is not reached and the B2-A7 aquifer will be entirely depleted by 2040—a full 20 years ahead of previous forecasts.[10] Given the new demand for water by refugees and the decreasing amount of water pumped, agriculture can no longer receive water allocations after 2020. In this scenario, total welfare is reduced by 52% and by 71% for agricultural producers. While the nominal welfare values are relatively small, they, of course, only include the direct benefits from water in the production process—not from associated agricultural productivity and other closely linked sectors. The direction of the change in welfare as it relates to extraction rates and the water table level is what is most important for my purposes. Given the predominantly rural and agricultural livelihood of households in this region of Jordan, we would expect the overall monetary losses due to decreased agricultural productivity to be quite large. And implications would likely stretch far beyond monetary losses, perhaps quickening the pace of urbanization and the societal tensions thereof.

Results reported in Table 5 assume that Syrian refugees will permanently remain in Jordan. While this would not be unprecedented, it is unlikely. Palestinian refugees, almost all of whom have remained in Jordan since arriving over 50 years ago, represent a very unique case. Perhaps more comparable is the situation of Afghani refugees in Pakistan, who, despite some returning within the past ten years, have remained in large numbers in Pakistan since fleeing their country

---

[10] According to USGS study by Good et al. (2013) conducted before the Syrian refugee crisis began, the B2-A7 aquifer will be depleted by 2060 if trends were extrapolated.

beginning in 1978. Still, optimism would have that the war in Syria will eventually resolve and Syrians will be able to return to their home. This is the stated desire of most Syrians in Jordan, and repatriation under stable conditions or a “just return” is a primary objective of UNHCR (UNHCR pers. comm. 2014). There is, however, hesitation in assuming full repatriation; between 1998 and 2007, only 11.4 million refugees worldwide repatriated with far fewer receiving resettlement in a third country (Megan 2013). The fate of refugees—repatriation, resettlement, or local integration in the country of first asylum—is a complex issue, the determinants of which are unique to each refugee crisis and are outside the scope of this study. For the purposes of the following simulations, though, an 80% repatriation rate is assumed.

As described in Section 4, to model the impact if repatriation occurs in year $t_{rep} = 10$, I increase r from year t_{rep} onward by the amount that water consumption is expected to decrease as a result of the refugee population returning to their home country. Consistent with expectations, social welfare of agricultural households will increase relative to the scenarios discussed above, though it will still be lower than in the base scenario (Table 6). Once repatriation occurs, the extraction path shifts so that W_∞ will be the same as if the new higher recharge rate were always the norm, which conforms to previously discussed theoretical conclusions based on the partial derivative $\frac{\partial W_\infty}{\partial r}$. This means that the welfare externality might only be temporary and accumulate only during the period between initial influx and eventual repatriation. However, if the refugee influx is large enough and refugees stay long enough, repatriation may be too late.

In scenarios 2a and 2b, while the aquifer is never depleted, the respective extraction paths fall below levels capable of sustaining agricultural activity. For the latter case, extraction levels are too low to maintain agriculture for the final three years of the influx period, then, once repatriation occurs, it is able to resume at a lessened capacity until 2036 when it becomes permanently unsustainable. The aquifer will only be depleted in the case that $t_{rep} \geq t_{dep}$, where t_{dep} is the year of aquifer depletion. Thus, for example, if $t_{rep} = 30$, scenario 2b will be identical to the same scenario in the original specification (Table 5), as the aquifer is depleted before repatriation occurs (Table 8).[11] Results reported in Table 8 assume that once the aquifer is depleted, i.e. $W^*(t) = 0$, water can no longer be extracted and therefore does not contribute to welfare beyond that point—in this case, after 2040. It is possible that water could again be extracted when repatriation occurs and *r* returns to previous levels. However, given that such high extraction rates have already occurred and that the aquifer stock would be at relatively low levels, it is plausible that salinity may render the aquifer obsolete for agricultural purposes even after repatriation.[12] This suggests that the externality on welfare could be long-lived, with the host community feeling the effects long after refugees are gone.

---

[11] For model results if repatriation occurs in $t_{rep} = 20$, see Figure 4 and Table 6.

[12] For simplicity, this study assumes that water in sector *i* has a constant value at any positive extraction rate, regardless of the salinity level.

7. Policy Discussion

When considering policy solutions that would alleviate impacts on the host population in Jordan, welfare estimates in this analysis should probably be treated as upper bounds. This is the case for a few reasons.

First, the demand for water function in the model treats agricultural producers and domestic users identically and makes strict assumptions about how water users respond to rising prices. By using an inelastic linear demand curve, the model will not accurately reflect the potential rationing behavior of water users at high price levels under strong assumptions of water conservation. However, this is perhaps not as far from reality in Jordan as one may think. Domestic water consumption is already at relatively low levels in Jordan, levels that are more likely to be concomitant with inelastic portions of the water demand curve. Moreover, as mentioned previously, nearly 70% of irrigation wells in the Amman-Zarqa basin operate at levels for which no water fees are charged.

Secondly, when interpreting results, one should also keep in mind that the model does not consider the possibility for adaptive irrigation technology in the agricultural sector. This means that farmers are treated as unable to recover any of their production losses, for example, by adopting less water intensive crops, improving water application efficiencies, or merely switching to rainfed agriculture. Assuming farmers increasingly engage in any of these activities in the face of water scarcity and assuming such are profitable, even in the least, would lessen negative welfare impacts. Previous studies suggest that most vegetable farmers in the Amman-Zarqa basin over-irrigate their crops (though orchard farms are under-irrigated) (Venot et al.

2007). Given such conditions, overall efficiency of water use is at 62%. Helping farmers use water more efficiently and implement other potential adaptive measures could be a policy solution of itself.

Finally, the analysis does not consider the potential welfare-increasing dynamics of price effects. Since the Syrian crisis began in 2011, there has been clear upward pressure on the food Consumer Price Index (CPI) in Jordan, especially for items largely produced in domestic markets such as vegetables, dairy, eggs, and meat products and less so for items that are mostly imported like cereals and legumes (UNDP 2013). The overall food CPI has increased in the range of 12-20% between 2011 and 2013. However, it should be noted that the prices of production inputs in the agricultural sector have also risen given the disruption of regional supply chains since the Syrian crisis began. So, the net welfare effect of price changes on farmers is unclear. Insofar as they are positive, the results of the above analysis likely represent welfare losses that in this respect as well should be considered upper bounds.

With these considerations in mind, any set of solutions intended to alleviate the acute welfare impact on Jordanian households corroborated by the model in this paper needs to address the largest current water user: agriculture. Agriculture is the predominant livelihood for households throughout the northern governorates. A sharp decline of agriculture in the Highlands could potentially devastate the region—already one of the poorest in Jordan—and potentially send a ripple-effect throughout the national economy, not a desirable situation for a stable country which to this point has survived the tremors of the Arab Spring. Policy solutions should include the following.

As observed in my field research, water infrastructure in Jordan suffers from high leakage rates, and while the sentiment to focus on rehabilitation is present, it is often easier to increase water supply by simply digging new wells. Though the water network serves domestic use, it could have significant alleviating effects on the agricultural sector, as well, since water savings in the former would mean less allocations away from the latter. Consider, for example, the Tabaqet Fahel pump station which was rehabilitated for a cost of 250,000 USD and increased utilization by 1.840 MCM/y or 80 liters per day for 63,000 people (Mercy Corps 2014). In addition, the Zabdah reservoir project reduced leaks by 0.788 MCM/y at a cost of 530,000 USD. On average, these two projects cost 0.29 USD per cubic meter of water without increasing actual extraction rates. Construction of two new wells at the Zaatari camp cost about the same amount or 0.32 USD per cubic meter—but increased extraction by 1.4 MCM/y. Thus, at least, for isolated infrastructure like wells and reservoirs, rehabilitation seems to be more cost effective than digging new wells, even without considering the opportunity cost of water. Rehabilitation of subsurface pipes throughout the water network is likely to pose greater difficulty. Even so, it is worth consideration, particularly if reality is closer to assumptions of the more conservative scenarios (1a and 1b). That is, if the shock from refugees is large but not catastrophic, solutions that might appear expensive under normal circumstances might be worthwhile under conditions of significant water scarcity as they could preserve the life of the aquifer and offset the shock. However, if the aquifer would be depleted regardless of infrastructure improvements, the cost of reducing leakage would be in vain and merely add to welfare losses.

Other policy solutions that should be considered regard alternative water sources. Currently, an estimated 100 MCM/y of treated wastewater is produced in the Amman-Zarqa basin, but essentially all of it is conveyed to the Jordan Valley for cultivation of higher value crops (Seder

& Abdel-Jabbar 2010). It is unlikely that current allocations would be redirected, but plans have been produced recommending that nearly 25 MCM/y in future new allocations be utilized for either agriculture or industry in the Highlands (MWI 2001). Implementation of such a plan could ensure that t_{ag} does not arrive, or if it does, that Jordan is better prepared to make that transition. While desalination projects, namely the Red Sea-Dead Sea Canal, could also serve as an important source of water supply in the future, as currently planned it is intended primarily to provide domestic water to Amman and small amounts of irrigation water to the Jordan River Valley—not the Highlands (MWI, pers. comm. 2014). Thus, such a project would only help the current situation to the extent the City of Amman's demand for water on the Amman-Zarqa basin is reduced, which presumably could be the case if desalination was implemented.

A more bottom-up approach to increase water supply via alternative sources is by household level water management projects, such as the rainwater cistern program operated by the local Jordanian community based organization (CBO), Jerasia. Dating back to before the Syrian crisis began, this micro but potentially effective strategy has provided 54 Jordanian and refugee households in Jerash with loans of 1,400 USD to install a rainwater catchment and cistern system capable of collecting 60-90 cubic meters of water per year, which can provide 25-50% of water needs for a five-person household (Mercy Corps 2014; Author's calculations). For an initial investment equivalent to the cost of rehabilitating or digging two wells, such a program could potentially provide thousands of households with water. Operationalizing to this scale, however, would take about 10-15 years based on the length of current loan cycles (i.e. about three years). Despite the limited scope and drawbacks of such projects, they have the potential to build local capacity and give households—both Jordanian and Syrian—increased water security, reducing refugee-host tensions over water. Such community water projects can complement large scale efforts to increase infrastructure capacity, especially in times of heightened crisis when network deliveries don’t materialize and water trucks are fewer and farther between.

8. Conclusion

Though natural resource impacts are often cited as a primary source of tension between refugee and host communities, there is a lack of economic research in this area—particularly in regard to water. Therefore, this thesis conducted a dynamic economic analysis of the impacts of refugee communities on host water security, focusing on the case of Syrian refugees in Jordan.

It was shown that, in countries suffering from pre-existing water scarcity, the welfare of agricultural households is likely to decrease, contrary to previous research in the economics literature. This is important because previous studies have found that, in host communities experiencing overall net benefits from a refugee influx, agricultural producers accounted for the largest welfare gain among host households. Thus, if agricultural producers, in fact, do not experience such gains, it is more likely that a refugee influx could impose a net loss on hosts. Moreover, it was found that a shock to water resources due to forced migration could cause a long-lived externality in host communities by shifting the extraction path so that the aquifer is depleted before a steady state is reached. However, if repatriation occurs before aquifer depletion, increased recharge should allow extraction to return to higher levels. In this case, externalities could still be long-lived; depending on extraction levels that occurred during the influx phase, agriculture may no longer be viable even after repatriation.

Conclusions of this thesis are limited on a few fronts. First, I assume irrigated agricultural production is viable for all positive rates of extraction. In reality, if an aquifer is being mined, irrigation water quality (e.g. high salinity levels) is likely to become a prohibiting factor even if extraction is still otherwise economically viable. Second, as mentioned in the policy discussion, I also assume farmers are unable to adapt to reduced water availability, for example, either by switching to improved irrigation technology, engaging in dryland farming, or utilizing alternative water resource supplies—e.g. wastewater reuse or desalination assuming such infrastructure is available to farmers. These are options that, as discussed above, have already been implemented in Jordan in some capacity (wastewater reuse) or have been in advanced planning stages for several years (desalination). Thus, any long-term assessment of Jordan’s water resources should include them. Further research in any of these areas would add value to the analysis presented in this thesis.

Tables and Figures

Table 1: List of Organizations Interviewed

- Deutsche Gesellschaft fur Internationale Zusammenarbeit (GIZ)
  - Bjorn Zimprich - Communications Coordinator, German-Jordan Water Program
- Injaz Jordan
  - Muhammed Qalid - Refugee Program Manager
- Mercy Corps. Jordan
  - Ghazboun Hassan - Chief Water Engineer
- Ministry of Water and Irrigation (MWI)
  - Nisreen Haddadin - Director of Water Demand Management
- Oxfam Jordan
  - Pierre Dassonville - WASH Coordinator
- United Nations Children Fund (UNICEF)
  - Jamaal Shah - WASH Coordinator, Jordan Country Office
  - Habeb Ahmen -WASH Officer, Zaatari Refugee Camp
- United Nations High Commissioner for Refugees (UNHCR)
  - Kilian Kleinschmidt - Camp Director, Zaatari Refugee Camp
  - Tom Cocran - Environmental Specialist, Zaatari Refugee Camp
- University of Jordan
  - Dr. Marwan Raggad - Faculty, Center for Land, Water, and Environment
- Yarmouk Water Company
  - Salameh Mahasneh - Investment Program Manager

Table 2: Values of parameters of Amman Wadi As-Sir (B2-A7) Aquifer

Parameter	Description	Units	Value	Source
b	Water demand slope	(MCM/yr)^2 per $	0.0915	
a	Water demand intercept	MCM/yr	8,425.6	
z	Pumping costs intercept	$/MCM	293,040	c'*S_L
c	Pumping costs slope	$/MCM^2	3.14	c'/A*S
c'	Unit costs of pumping	$/MCM m	444	Fitch, 2001
r	Natural recharge	MCM/yr	56	Al Muhamid, 2005
G_0	Initial stock level	MCM	66,270	H_0*A*S
H_0	Initial water table	Meters	469	MWI, 2013
S_L	Surface elevation	Meters	660	MWI, 2013
A	Aquifer area	Square km	4,710	Al Muhamid, 2005
S	Sorativity coefficient	Unitless	0.03	MWI, 2000
ρ	Social discount rate	Annual	0.05	
α	Return flow coefficient	Unitless	0.25	Venot, 2009

Table 3: Syrian refugee population and estimated water consumption

Scenario	Refugee Population		Refugee Water Consumption			Recharge
			l/cap/d	MCM/y	Total	MCM/y
base						56.0
1a	Camp	88,682	32	1.036	26.640	29.4
	Community	876,840	80	25.604		
1b	Camp	88,682	32	1.036	42.002	14.0
	Community	876,840	128	40.966		
2a	Camp	202,993	32	2.371	51.604	4.4
	Community	1,686,061	80	49.233		
2b	Camp	202,993	32	2.371	81.144	-25.1
	Community	1,686,061	128	78.773		

note: the value of recharge in the model refers to actual recharge, net of refugee water needs

Table 4: Sensitivity analysis using demand slope, intercept, and pumping cost

	Value	Net Benefits (thousand USD)	Elasticity
Demand slope	0.0622	303,190	-2.33
	0.1555	941	
Demand intercept	4,203.5	520	2.59
	9,437.2	48,867	
Unit pumping cost	300	211,030	-2.98
	600	1,383	

Table 5: Net benefits for each scenario

		Net Benefits (thousand USD)		
Scenario		Agriculture	Domestic	Total
base		5,548	5,456	11,003
1a	t_{ag}: 2029	2,981	5,301	8,282
		(-46.3%)	(-2.8%)	(-24.7%)
1b	t_{ag}: 2024	2,402	4,709	7,111
		(-56.7%)	(-13.7%)	(-35.4%)
2a	t_{ag}: 2023	2,150	4,377	6,527
		(-61.2%)	(-19.8%)	(-40.7%)
2b	t_{ag} : 2020	1,636	3,643	5,279
	t_{dev}: 2040	(-70.5%)	(-33.2%)	(-52.0%)

note: t_{ag} is the year water can no longer be allocated to agriculture, and t_{dev} is the date of aquifer depletion. Percent change from base in parentheses.

Table 6: Net benefits if repatriation occurs after 10 years

		Net Benefits (thousand USD)		
Scenario		Agriculture	Domestic	Total
base		5,548	5,456	11,003
1a		4,025	6,152	10,177
		(-27.4%)	(12.8%)	(-7.5%)
1b	$t_{ag}: 2061$	3,283	6,389	9,672
		(-40.8%)	(17.1%)	(-12.1%)
2a	$t_{ag}: 2049$	2,898	6,446	9,344
		(-47.8%)	(18.2%)	(-15.1%)
2b	$t_{ag}: 2020 - 22$ $t_{ag}: 2036$	2,074	6,218	8,292
		(-62.6%)	(14.0%)	(-24.6%)

note: t_{ag} is the year water can no longer be allocated to agriculture. Percent change from base in parentheses.

Table 7: Net benefits if repatriation occurs after 20 years

		Net Benefits (thousand USD)		
Scenario		Agriculture	Domestic	Total
base		5,548	5,456	11,003
1a	$t_{ag}: 2029 - 32$	3,352	6,127	9,479
		(-39.6%)	(12.3%)	(-13.9%)
1b	$t_{ag}: 2024 - 32$ $t_{ag}: 2061$	2,590	6,063	8,653
		(-53.3%)	(11.1%)	(-21.4%)
2a	$t_{ag}: 2023 - 32$ $t_{ag}: 2049$	2,266	5,890	8,156
		(-59.1%)	(8.0%)	(-25.9%)
2b	$t_{ag}: 2020 - 32$ $t_{ag}: 2036$	1,648	5,080	6,729
		(-70.3%)	(-6.9%)	(-38.9%)

note: t_{ag} is the year water can no longer be allocated to agriculture. Percent change from base in parentheses

Table 8: Net benefits if repatriation occurs after 30 years

		Net Benefits (thousand USD)		
Scenario		Agriculture	Domestic	Total
base		5,548	5,456	11,003
1a	t_{ag} : $2029-42$	3,121	5,883	9,004
		(-43.7%)	(7.8%)	(-18.2%)
1b	t_{ag} : $2024-42$	2,436	5,578	8,014
	t_{ag} : 2061	(-56.1%)	(2.2.%)	(-27.2%)
2a	t_{ag}: $2023-42$	2,157	5,298	7,456
	t_{ag}: 2049	(-61.1%)	(-2.9%)	(-32.2%)
2b	t_{ag} : 2020	1,636	3,643	5,279
	t_{dep}: 2040	(-70.5%)	(-33.2%)	(-52.0%)

note: t_{ag} is the year water can no longer be allocated to agricultureand t_{dep} is the date of aquifer depletion. Percent change from base in parentheses.

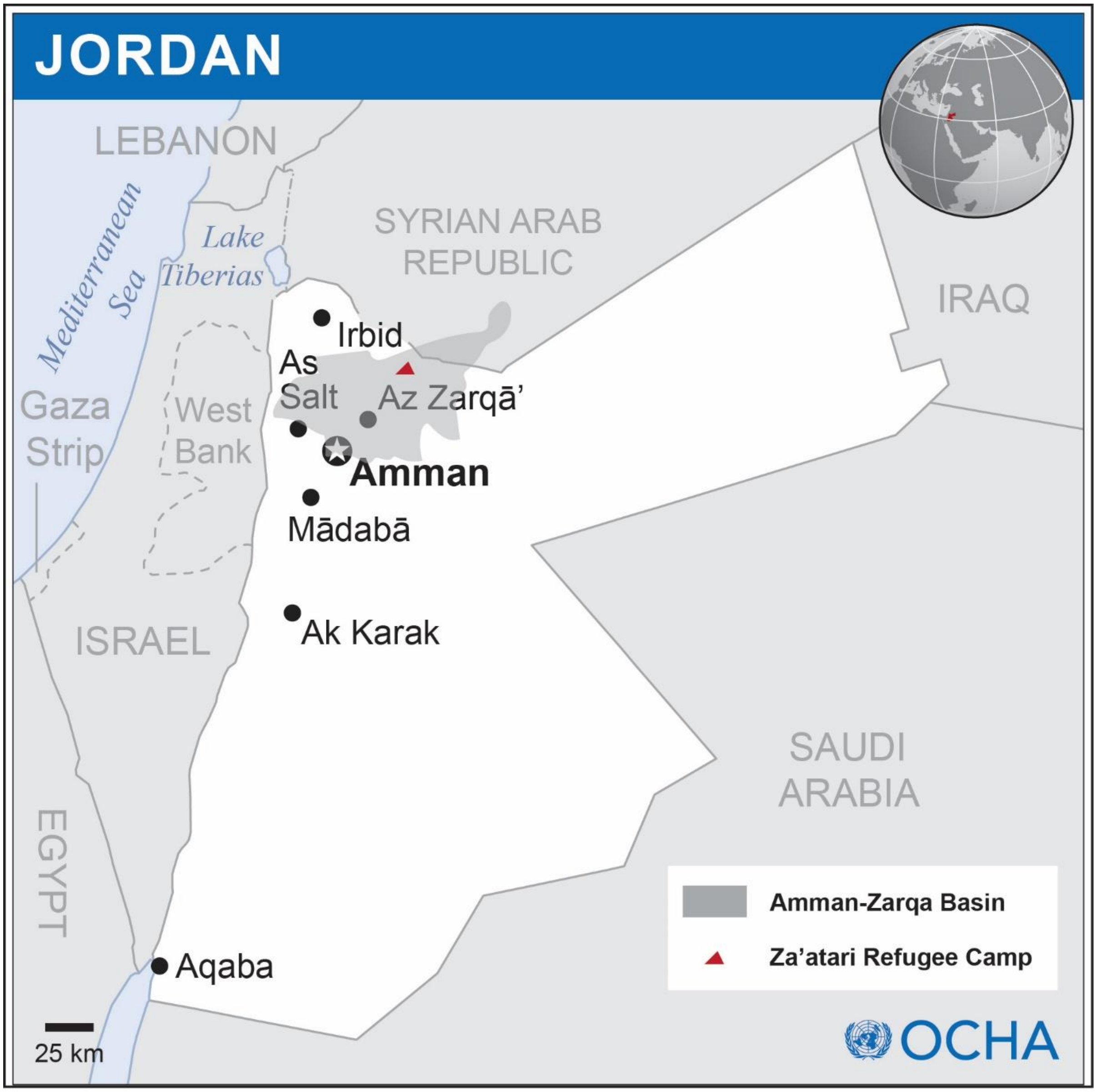

Figure 1: Location map of study area (Source: OCHA 2013; Legend added by author)

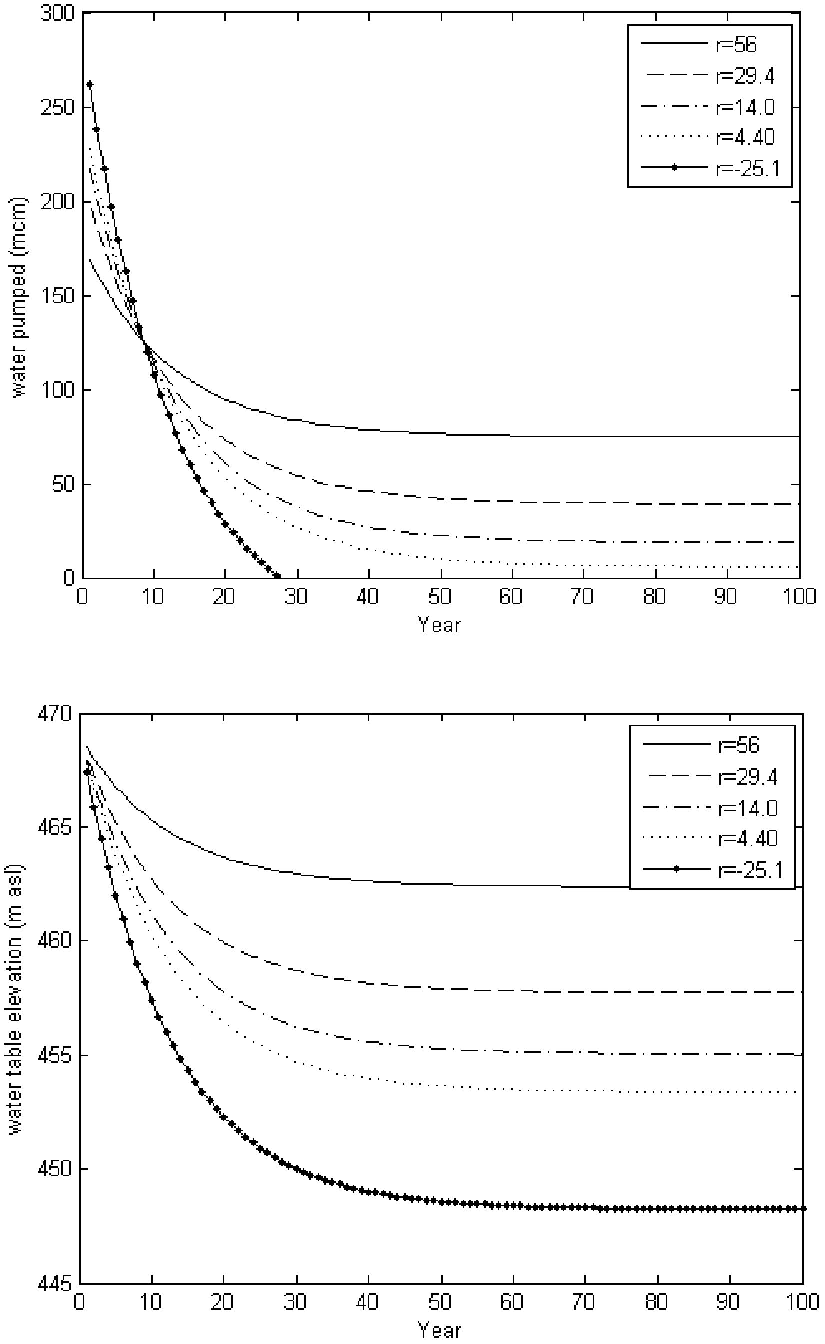

Figure 2: Water pumped, *W*(t),* and water table level, *H*(t),* at different recharge rates, *r.*[13]

---

[13] From equation (5), *H*(t)* can be obtained by dividing *G*(t)* by *A*S*

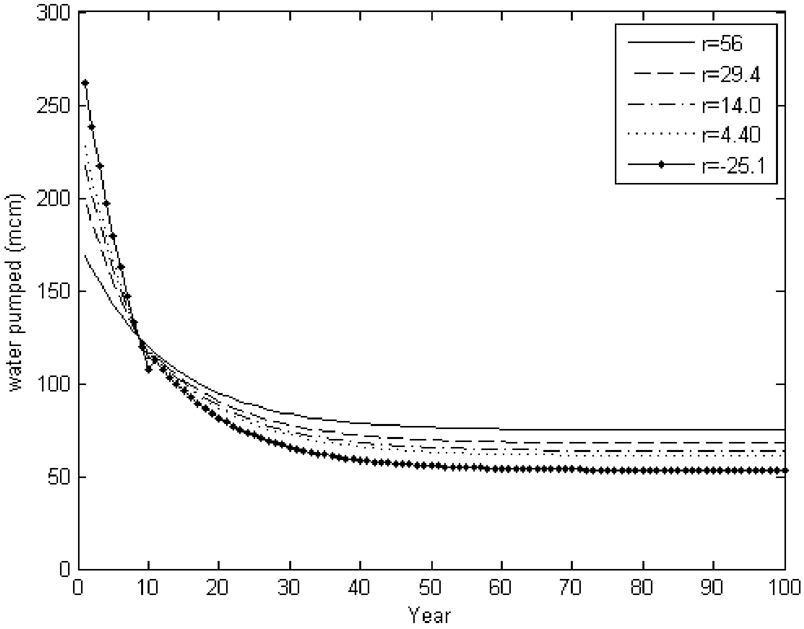

Figure 3: Water pumped, *W*(t),* at different recharge rates, *r,* if repatriation occurs after 10 years

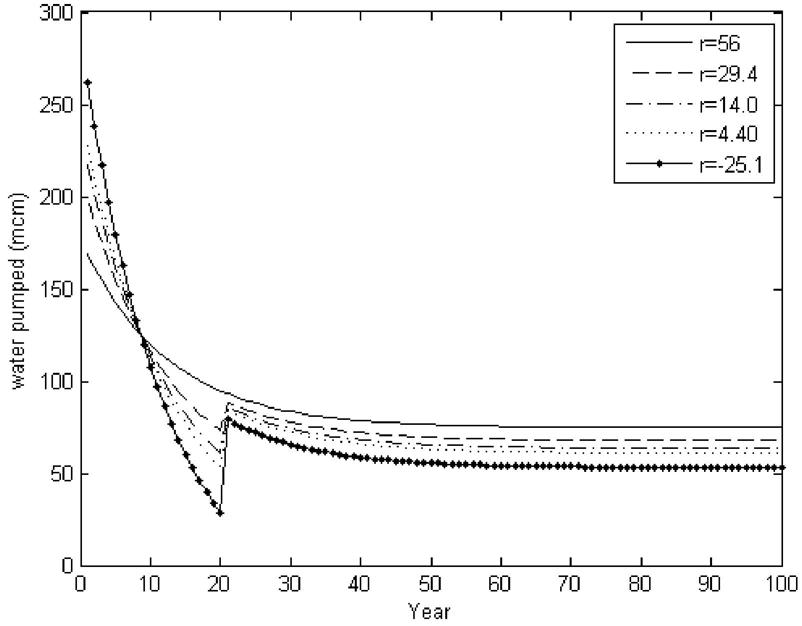

Figure 4: Water pumped, *W*(t),* at different recharge rates, *r,* if repatriation occurs after 20 years

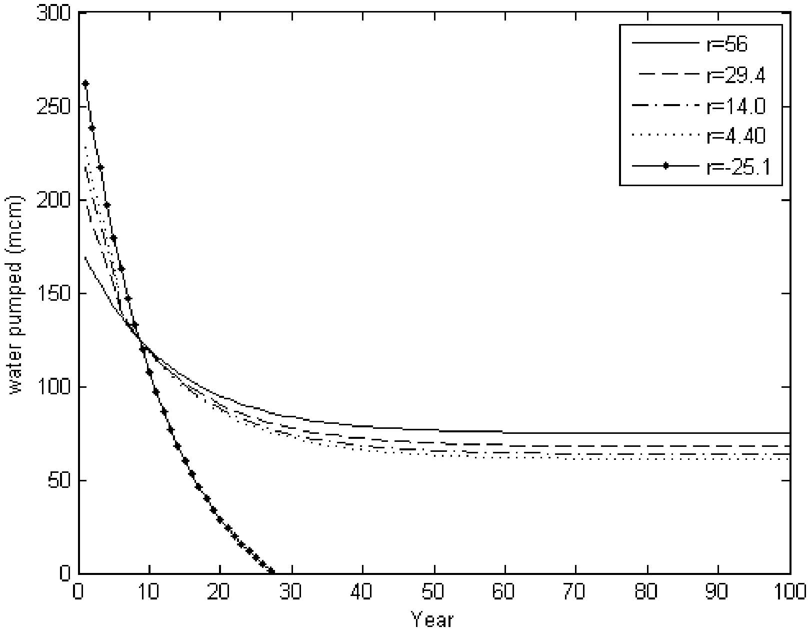

Figure 5: Water pumped, *W*(t),* at different recharge rates, *r,* if repatriation occurs after 30 years

Bibliography

AFD. (2011). *Water Demand Management in Mediterranean countries: Thinking outside the water box!* French Agency of Development (AFD).

Al Mahamid, J. (2005). *Integration of Water Resources of the Upper Aquifer in Amman-Zarqa Basin Based on Mathematical Modeling and GIS, Jordan.* Freiberg: Freiberg Online Geology.

Al-Ansari, N., Al-Oun, S., Hadad, W., & Knutsson, S. (2013). Water loss in Mafraq Governorate, Jordan. *Natural Science, 5*(3), 333-340.

Alix-Garcia, J., & Saah, D. (2009). The Effect of Refugee Inflows on Host Country Populations: Evidence from Tanzania. *World Bank Economic Review, 24*(1), 148-170.

Alix-Garcia, J., Bartlett, A., & Saah, D. (2012). Displaced Populations, Humanitarian Assistance and Hosts: A Framework for Analyzing Impacts on Semi-urban Households. *World Development, 40*(2), 373-386.

Alix-Garcia, J., Bartlett, A., & Saah, D. (2013). The Landscape of Conflict: Forced Migration and Land Use in Darfur. *Journal of Economic Geography, 13*(4), 589-617.

Al-Karablieh, E., Salman, A., & Al-Omari, A. (2007). *The Residential Water Demand Function in Amman-Zarka Basin in Jordan.* Unpublished.

Al-Kuisi, M., & Abdel-Fattah, A. (2010). Groundwater vulnerability to selenium in semi-arid environments: Amman Zarqa Basin, Jordan. *32*, 107-128.

Allan, N. (1987). Impact of Afghan Refugees on the Vegetation Resources of Pakistan's Hindukus-Himalay. *Mountain Research and Development*, 200-204.

Al-Qaisi, B. M. (2010). *Climate Change effects on Water Resources in Amman Zarqa Basin - Jordan.* Amman, JO: MWI.

Baez, J. E. (2011). Civil wars beyond their borders: The human capital and health consequences of hosting refugees. *Journal of Development Economics*, 96(2):391–408.

Berry, L. (2008). *The impact of environmental degradation on refugee-host relations: a case study from Tanzania.* Geneva: UNHCR.

Black, R. (1994). Environmental Change in Refugee-affected Areas of the Third World: the Role of Policy and Research. *Disasters, 18*(2), 107-139.

Brozovic, N., & Schlenker, W. (2011). Optimal management of an ecosystem with an unknown threshold. *Ecological Economics, 70*, 627-640.

Cachorro, J. d., Erdlenbruch, K., & Tidball, M. (2014). Optimal adaptation strategies to face shocks on groundwater resources. *Journal of Economic Dynamics & Control, 40*(10), 134-153.

Calderon, V., & Ibanez, A. M. (2009). Labor Market Effects of Migration-Related Supply Shocks: Evidence from Internal Refugees in Colombia. *Documento CEDE, No.2009-14.* Working Paper No. 14.

Corle, D., Kunen, E., & Haines, M. (2014). *Complex Crises Fund: Jordan, Mid-Cycle Portfolio Review*. USAID.

Crips, J. (2002). *No Solutions in Sight: The Problem of Protracted Refugee Situations in Africa.* The Center for Comparative Immigration.

Crisp, J., Janz, J., Riera, J., & Samy, S. (2009). *Surviving in the City, a Review of UNHCR's Operation for Iraqi Refugees in Urban Areas of Jordan, Lebanon, and Syria.* Geneva: UNHCR.

Czaika, M. (2005). A Refugee Burden Index: Methodology and its application. *Migration Letters, 2*, 101-125.

FAO. (2010). *The Economic Value of Water for Agricultural, Domestic and Industrial Uses: A Global Compilation of Economic Studies and Market Studies.* Rome.

Farishta, A. (2014). *The Impact of Syrian Refugees on Jordan's Water Resources and Water Management Planning.* Thesis presented to the Faculty of Architecture and Planning and Preservation at Columbia University.

Fitch, J. B. (2001). *Curtailment of Groundwater Use for Irrigated Agriculture in the Amman-Zarqa Basin Uplands: An Economic Analysis.* USAID.

Gentry, D. (2009). *Refugee Impacts on Host Communities in Western Tanzania: A GIS and Mixed-Method Geographical Analysis.* Thesis submitted to Department of Geography at Appalachian State University.

Gisser, M., & Sanchez, D. A. (1980). Competition Versus Optimal Control in Groundwater Pumping. *Water Resources Research, 16*(4), 638-642.

Goode, D. J., Senior, L. A., Subah, A., & Jaber, A. (2013). *Groundwater-Level Trends and Forecasts, and Salinity Trends, in the Azraq, Dead Sea, Hammad, Jordan Side Valleys, Yarmouk, and Zarqa Groundwater Basins, Jordan.* New Cumberland, PA: USGS.

Haddadin, M. (2006). *Water Resources in Jordan Evolving Policies for Development, the Environment, and Conflict Resolution.* Washington D.C.: RFF Press.

Harper, A. (2008). Iraq's refugees: ignored and unwanted. *International Review of the Red Cross,* pp. 169-190.

International Fund for Agricultural Devleopment (IFAD). (2001).*The Hashemite Kingdom of Jordan Agricultural Resources Management Project Evaluation Report*. Amman

IFAD. (2007). *Hashemite Kingdom of Jordan: Country strategic opportunities program.* Amman.

Jacobsen, K. (2002). Can Refugees Benefit the State? Refugee Resources and African Statebuilding. *Journal of Modern African Studies, 40,* 577-596.

Khaleq, R. A. (2008). *Water Demand Management in Jordan.* Amman, JO: MWI.

Koundouri, P. (2004). Potential for groundwater management: Gisser-Sanchez effect reconsidered. *Water Resources Research, 40,* W06S16, doi:10.1029/2003WR002164.

Maydstat, J.-F., & Duranton, G. (2014). The Development Push of Refugees: Evidence from Tanzania. *Forthcoming*.

McCormick, P. G., Taha, S. S., & El Nasser, H. (2002). *Planning for reclaimed water in the Amman-Zarqa Basin and Jordan Valley.*

Mercy Corps. (2014). *Tapped Out: Water Scarcity and Refugee Pressures in Jordan.* Portland, OR: Mercy Corps.

Mesnil, A., & Habjoka, N. (2012). *The Azraq Dilemma: Past, Present and Future Groundwater Management.* Amman: GIZ.

MWI. (2000). *Pre-feasibility study water reuse for agriculture and/or forestry in the Amman-Zarqa Highlands.* Amman.

MWI. (2001). *Plan for managing water reuse in the Amman-Zarqa Basin and the Jordan Valley.* Amman.

MWI. (2010). *Plan to reduce over-extraction of groundwater from Amman-Zarqa and Al-Azraq Basins.* Amman.

MWI. (2013). *Cost of Hosting Syrian Refugees on Water Sector of Jordan.*

MWI. (2013). *Structural Benchmark Action Plan to Reduce Water Sector Losses.*

MWI. (2013). High Level Conference on Jordan's Water Crisis.

Nortcliff, S., Carr, G., Potter, R. B., & Darmame, K. (2008). *Jordan's Water Resources: Challenges for the Future*. Reading, UK: University of Reading.

Potter, R. B., Darmame, K., Barham, N., & Nortcliff, S. (2009). "Ever-growing Amman", Jordan: Urban expansion, social polarisation and contemporary urban planning issues. *Habitat International, 33*, 81-92.

Ramirez, O., Beck, R., Ghunaim, A., & Al-Tabini, R. (2008). *Factors Affecting Agriculture Water Use in the Mafraq Basin of Jordan: Quantitative Analyses and Policy Implications.* New Mexico State University.

Ruiz, I. and Vargas-Silva, C. (2013). The economics of forced migration. *The Journal of Development Studies*, 49(6):772–784.

Salman, A., & Al-Karablieh, E. (2005). The Economics of Using Different Qualities of Irrigations Water in Down Stream of Amman-Zarqa Basin. *Unpublished*.

Salman, A., & Al-Karablieh, E. (2006). *Socieconomic Factors Influencing the Household Water Demand Function in Jordan.* Unpublished.

Salman, J. D., Al-Karablieh, E., & Haddadin, M. (2008). Limits of pricing policy in curtailing household water consumption under scarcity conditions. *Water Policy, 10,* 295-304.

Taany, R., Masalha, L., Khresat, S., Ammari, T., & Tahboub, A. (2014). Climate Change Adaptation: a case study in Azraq Basin, Jordan. *International Journal of Current Microbiology and Applied Sciences, 3*(2), 108-122.

Tabieh, M. A. (2007). *An Optimal Irrigation Water Allocation Model: Management and Pricing Policy Implications for the Jordan Valley.* Dissertation.

Tsur, Y., & Zemel, A. (2004). Endangered aquifers: Groundwater management under threats of catastrophic events. *Water Resources Research*.

Tsur, Y., & Zemel, A. (2014). *Dynamic and stochastic analysis of environmental and natural resources.* Discussion Paper No. 1.12, The Hebrew University of Jerusalem.

UNEP. (2007). *Population Displacement and the Environment.* New York: United Nations.

UNICEF. (2014, May). Water Network Studies for Zaatari Camp.

USAID. (2012). *Economic Impacts of Groundwater Drawdown in Jordan.* Washington D.C.

USAID. (2012). *Water Valuation Study - Summary Report: Disaggregated Economic Value of Water in Industry and Irrigated Agriculture in Jordan.* Washington D.C.

Veney, C. (2007). *Forced Migration in Eastern Africa: Democratization, Structural Adjustment, and Refugees.* New York: Palgrave Macmillan.

Venot, J.-P., & Molle, F. (2008). Groundwater Depletion in the Jordan Highlands: Can Pricing Policies Regulate Irrigation Water Use? *Water Resource Management*.

Venot, J. P.; Molle, F.; Hassan, Y. 2007. Irrigated agriculture, water pricing and water savings in the Lower Jordan River Basin (in Jordan). Colombo, Sri Lanka: International Water Management Institute. 61p. (Comprehensive Assessment of Water Management in Agriculture Research Report 18)

Whitaker, B. E. (2002). Refugees in Western Tanzania: The Distribution of Burdens and Benefits Among Hosts. *Journal of Refugee Studies, 15*(4), 339-358.

World Bank. (2010). *The Impacts of Refugees on Neigboring Countries: A Development Challenge.* Washington D.C.

World Bank. (2011). *Study on Impacts and Costs of Forced Displacement: State of the Art Literature Review.* Refugee Studies Center.

Yorke, V. (2013). *Politics matter: Jordan's path to water security lies through political reforms and regional cooperation.* Bern: Swiss National Centre of Competence in Research.

Zetter, R., & Deikun, G. (2010, February). Meeting Humanitarian Challenges in Urban Areas. *Migration Review*(34).