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Rainfed agroecosystem resilience in the Palestinian West Bank, 1918–2017

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ABSTRACT

Research has shown that rai-fed (*Baʿlī*) cultivation provides a resilient agroecological structure. Recent work in agroecology has refined our understanding of agroecosystem resilience, but both temporal and geographical scales are often limited. Due to largely inaccessible and dwindling water resources, an examination of change at the scale of an agroecological landscape is required to better understand how rainfed agroecosystems remain resilient over an extensive period of time. Our article examines the relationship between agroecological landscape change and resilience in the face of powerful social-economic transformations. Our study combines the novel approach of geospatial, field and interview data in order to understand the long-term resilience of an entire agroecological landscape in the Palestinian West Bank. We argue that the study area has experienced a high level of resilience for over 70 years, perhaps for as long as 100 years, and this resilience is attributed not to a stability in production practices, but to a dynamism in practices that have enabled cultivators to adapt to broader political-economic shifts. In doing so, the paper calls for attention within agroecology and food systems research to the dynamism and resilience found within rainfed agroecosystems.

KEYWORDS

Agroecology; geospatial; landscape; resilience; Palestinian

Introduction

At face value, the continued presence of rainfed farming in Palestine might seem something of an anachronism. These practices have often been considered a remainder of the past. In parallel with most of the world, the Palestinian West Bank has witnessed a massive decline in the importance of small-scale agricultural production over the past 50 years. The decline has been concurrent with a series of challenges unique to the Palestinian situation, especially a lack of control over borders, movement, and economy due to Israeli government restrictions. Agricultural marketing, development, and research have been greatly hampered by these restrictions since 1967.

Despite these challenges, rainfed agriculture which has a long history in Palestine, has persisted. Rainfed or *baʿlī* (as it is known in the vernacular)

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agriculture is a suite of planting, tillage, and plant protection strategies that exploits soil moisture for growing crops without irrigation. While rainfed production is the modern technical term, the local term, *baʿlī*, is a suite of strategies that reflects a way of life. It also uses water harvesting techniques such as cisterns and terraces to capture water during the rainy season for watering crops in dry months. Rainfed farming plays an essential role in the economic growth of the West Bank and the livelihoods of its people. The vast majority of the agricultural land area of the West Bank is rainfed (Assaf 2010) with the exception of a handful of cash crops like cucumbers and tomatoes grown under cover and irrigation. This study is motivated by a drive to analyze the historical evolution of rainfed farming in a specific site in a hill region village in the central Palestinian West Bank, where it continues to be practiced. We aim to better understand its persistence in light of the myriad challenges, some of which are unique to the Palestinian context.

Drawing on a geo-spatial and qualitative examination of the case of the Palestinian village Dayr Ballūṭ where it continues to be practiced, we illustrate how key factors which have enabled the persistence of rainfed farming have been shifts in the cropping system and social composition that characterize it, in order to adapt to the constraints of the political-economic situation and Israeli restrictions. Research has shown that Palestinian *baʿlī* (dryland/rainfed) agroecosystems may provide a resilient agroecological structure (Assaf 2010; Awartani 1982; Daiq 2005). In contrast to a belief that Palestinian *baʿlī* agriculture is a remnant of ancient cultivation practices that are little changed (Arnon 1992), our results suggest that agroecosystem resilience depends upon changes in the cropping system and labor structure. However, due to largely inaccessible and dwindling water resources, an examination of change at the scale of an extensive agroecological landscape is required to better understand how rainfed agroecosystems remain resilient over an extensive period of time.

Rainfed production has seen a drastic decline in its share of the Palestinian agricultural economy. Rainfed farming is seen either as a remnant of the past or, at best, as an underdeveloped cultivation practice in need of modernization. However, it is not just a remainder of a more primitive agricultural system or a last resort; people in Dayr Ballūṭ chose an increasingly diversified and changing *baʿlī* agroecosystem in order to successfully withstand economic and political transformations that have taken place in Palestine in recent time. More specifically, our research shows that crop diversity within the agroecosystem increased by more than 130 per cent since 1950 during a time of massive Israeli restrictions on water resources, mobility of people and goods, and agricultural inputs.

Our study combines geospatial and qualitative data in order to understand the resilience of this agroecosystem. We argue that the study area has experienced a high level of resilience for over 75 years, and this resilience

is attributed not to a stability in production practices, but rather to a dynamism in practices that have enabled cultivators to adapt to broader political-economic shifts, environmental conditions, including such variables as rainfall, chemical and physical soil structure and topography. Our paper seeks to further examine this trend, by illustrating a case where a rainfed system has exhibited long-term resiliency and how this resilience has been underpinned by dynamism in practices in order for the system to align with – or remain viable in the face of broader shifts. We are one of the first research groups to conduct a detailed case study in Palestine that demonstrates the agroecological structure of resilience over an extensive period of time.

The next section provides a brief review of the literature on rainfed systems, their relative attributes and advantages, and their use in the Middle East and Palestine to set the context for a further analysis of the factors underpinning its persistence. This is followed by a discussion of methodology. The third section is the main substantive discussion of study findings. A concluding section highlights key contributions of this study to work on rainfed systems, and avenues for further research.

Literature review

Studies of rainfed farming have illustrated its importance given that it covers 80 per cent of the agricultural land area in the world and produces the majority of the world's staple foods (Rockström and Karlberg 2009). Furthermore, the ability of rainfed agroecosystems to withstand climatic changes, and economic and social shifts is documented (Shideed 2017; Wani, Rockström, and Oweis 2009). Studies have employed various data including historical surveys, archival photographs, maps, archeological studies, ethnographies and other materials to reconstruct agroecosystems over varying periods of time (Bewley et al. 2010; ; Hritz 2014; Lincoln and Ladefoged 2014; Lincoln, Chadwick, and Vitousek 2014; Manzano Agugliaro, Martínez García, and San Antonio Gomez 2012; Palmer 1994; Rautio et al. 2015; Schaffer and Levin 2015, 2016; Zhang et al. 2010).

In the Middle East, studies have shown the centrality of sustainable water management (Rockström et al. 2010) and the importance of rainfed production to food security (van Ginkel et al. 2013; Haddad et al. 2011). A better understanding of rainfed cultivation in the Middle East is needed due to the anticipated shifts due to climatic change. Moreover, gender remains a central analytic to understand the resilience of rainfed agricultural production in the Middle East (Abdelali-Martini et al. 2008). In the context of Palestine, the gender and social structure of agricultural labor has been greatly underexplored in research. The case has been made that Palestinian rainfed farming provides an effective guard against further deterioration of agricultural

production (Daiq 2005). In the early 1980s, studies emphasized 'benefits' and the economic importance of rainfed farming for the continued persistence of Palestinian agriculture in the West Bank in the wake of the transformations of the 1970s that required less time and labor (Awartani 1982; Tamari 1981, 1990). Studies in the 1990s focused on the development of the rainfed agricultural sector, bringing in the concept of sustainability to the topic (Isaac and Gasteyer 1997) and (Isaac et al. 1994). In rainfed farming, Palestinians shifted from field crops to olives (Butterfield et al. 2000).

We believe that the term *baʿlī* is a reference to the Canaanite title for master god Baal, who was associated with *Hadad*, the Canaanite god of rain and agriculture. The word remains in common usage today. Palestinians use *baʿlī* or *baʿal* as an adjective to describe fields, crops, or fruits that rely only on rain and dew for water (Tesdell 2015; Tesdell and Issa 2017). *Baʿlī* vegetables elicit higher prices and are prized for their superior taste, believed to be a result of slower growth. Indeed, rainfed production has been the basis of agriculture in Palestine for generations owing to the wet-dry Mediterranean seasonality and lack of freshwater, and *baʿlī* developed through highly localized practices of cultivation and by extension landrace development. Rainfed agriculture is not necessarily synonymous with *baʿlī* lifeways because the latter derives from a cosmology based in layered and syncretic religious traditions.

In modern agricultural science, technical specialists of several generations were given to over-generalization about the decline of rainfed production. Arnon (1992) stated in his foundational agronomic work on dryland agriculture, "The dry lands of a great number of countries are now usually vast empty areas. A large proportion is desert, and its contribution to food production is minimal. Other vast areas, on the fringes of the deserts, in Africa and Asia, with a rainfall that is just sufficient or even adequate to grow a single adapted crop, are still cultivated by primitive methods that have not changed since biblical days - with resultant low yields" (Arnon 1992, p. vi). To claim that rainfed agriculture remained unchanged over a span of time, in the case of Arnon, of 2,000 years, requires critical examination. Most of this literature emphasizes the "primitive" practices of cultivators and sometimes extends into the primitive nature of the cultivators themselves (Davis 2016). Within the case of Palestine, which has been the site of a steady modern settler-colonization for over 100 years, this belief remains widespread. For example, when discussing the technological innovations brought by European Jewish settlement, a leading environmental historian of Israel stated, "In practice, the new century did little to change the traditional, subsistence farming practices of the locals" (Tal 2002, p. 49). The belief that Palestinian agricultural rainfed agricultural practices remained unchanged for centuries, if not more, remains pervasive. However, our results suggest that the technical details of the cropping system itself require

a more sophisticated explanation. Rather than a focus on economic or societal deterioration, the case of the Dayr Ballūṭ agroecosystem offers an example of long-term persistence.

The study addresses the following central question: How did the Dayr Ballūṭ agroecosystem develop and persist over this time period? We hypothesize that in contrast predominantly to deterministic and static approaches to rainfed agroecosystem persistence, adherence to dynamic rainfed agroecosystem (*baʿlī*) cropping systems enabled local families to maintain small-scale farming profitable and viable in the face of massive economic and political shifts in the 1970s. More specifically, the increasing diversity of the cropping system, especially the move from melons and tomatoes to Armenian cucumber (*Cucumis melo* var. *flexuosus*), coupled with the changing social structure of labor to include women, enabled farmers to transform and adapt the agroecosystem for continued resilience.

Methods

Study area

The study was conducted in a highly diverse agricultural plain landscape of the Wadi Dayr Ballūṭ valley. The valley (32° 3′ N and 35° 1′ E) is located on the lower slopes of the West Bank hill ridge at 260 m. (853 ft.) above sea level in the district of Salfit of Palestine (*see Figure 1)*. The 2014 Corine-based land use/land cover analysis has established the land area of the Dayr Ballūṭ plain at 727 dunams (179 acres), which is a medium-large agricultural plain by West Bank hill standards. Dayr Ballūṭ village included 3873 inhabitants in

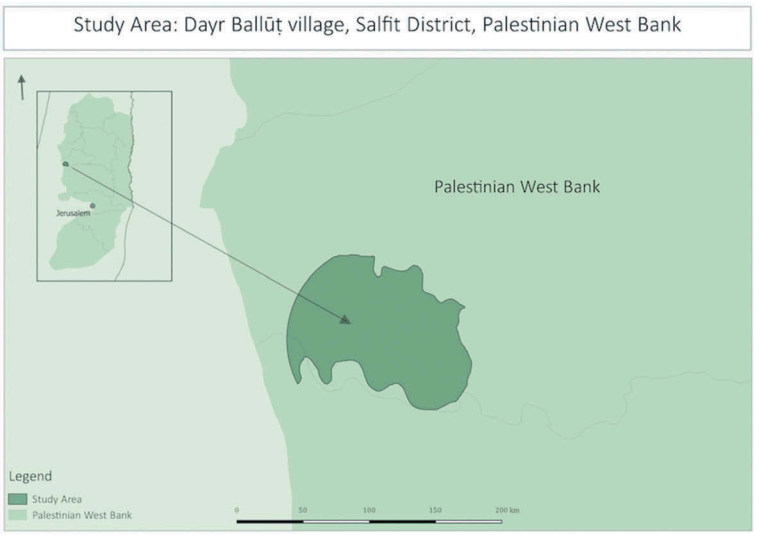

Figure 1. Study area, Dayr Ballūṭ, Salfit district, Palestinian West Bank

2017. At the same time, a complex of Israeli government restrictions pins in village lands. Israeli settlements hem it in to the east, south, and north; an Israeli-imposed nature reserve borders on the south; the separation wall stands to the west (UN-OCHA 2009).

The study area experiences a Mediterranean climate with two main seasons: a winter rain season (November to March) and a summer dry season (April-October). It receives a mean annual rainfall of 569.9 mm. (22 in.). The plain lies above Wadi Dayr Ballūṭ valley, which snakes down to the coast from an elevation of 500 meters (1,640 feet) in the hill range south of the city of Nablus. The plain area is composed of a rich complex of colluvial-alluvial soils classified traditionally as Mediterranean Brown Forest Soils, or Mollic Leptosols in the WRB classification (Singer 2007). The area surrounding the agricultural plain has broadly defined Terra Rossa soils or Epileptic Luvisols in the WRB system.

The agricultural plain (or *marj* as it is known in the vernacular) of the West Bank village of Dayr Ballūt, in the Salfit Governorate, offers a unique insight into the relations of the endurance of *baʿlī* cultivation. The *marj* area is host to one of the most diverse agro-ecosystems found in Palestine today. In the past, rainfed (*baʿlī*) systems produced wheat, barley, sesame, and lentils, in addition to vegetables like faqqūs (*Cucumis melo* var. *flexuosus*, or Armenian cucumber) across Palestine. These highly diversified agro-ecosystems have declined drastically since the 1960s for a suite of reasons, ranging from changes in labor and social structure to economic shifts to Israeli government restrictions on trade and farmland. Within this context, the Dayr Ballūṭ cultivated plain stands out as a rare, living example of the rainfed agroecological systems that have supported Palestinians for generations.

Dayr Ballūṭ valley was subject to significant pressures that have had a direct bearing on the agroecosystems. Economic shifts similar to those that have affected small-scale cultivation around the world began to influence the village agroecosystem in the 1970s. With military and political control of the West Bank by Israel beginning in 1967, a massive labor market opened in Israel, primarily in construction (Tamari 1981). Men from the village, given their close proximity to major metropolitan regions in Israel, quickly entered the wage-labor force, rendering cultivation a secondary source of income. The labor transition resulted in a massive transformation of the agroecological landscape from extensive small grains and legumes to wide planting of olive trees and a highly diversified, intensive rainfed vegetable agroecosystem practiced nearly exclusively by women.

Despite the opportunity to implement drip irrigation and plastic cover for crops, the women farmers in Dayr Ballūṭ chose to shift to rainfed vegetables instead. They cited numerous times in interviews that rainfed crops allowed them much greater freedom as it did not require the purchasing of chemical

inputs and irrigation equipment; it used minimal labor and brought a good price during its short season.

Quantification of land use land cover change

Archival aerial photographs of the Dayr Ballūṭ valley were used to evaluate the status of cultivation and vegetation cover of the study area over about 75 years. Historical aerial photographs from 1918 and 1944 as well as high-resolution aerial photographs from 1997 and 2014 years were geo-referenced using the World Geodetic System (WGS84). The 1944, 1997 and 2014 images were digitized in accordance with the CORINE land cover standards to produce a land cover information system (CORINE Land Cover 1995). Geo-referencing and digitization were conducted using a non-proprietary GIS software package, QGIS. Nine field transects were conducted across late 2015, 2016 and early 2017 in order to field check the digitization of the historical aerial photographs, for the identification of wild gathered food plants, food crops and other landscape features (Tesdell, et. al., 2018). A food plant and crop inventory was conducted over two growing seasons (2015–2016 and 2016–2017) to establish the baseline of the current agroecosystem structure. Primary food crops grown in the Dayr Ballūṭ plain were surveyed and added to the research engine. Wild-gathered food plants were also surveyed and added to the research engine. These data were used to create an agroecological research engine that allows the manipulation and visualization of data for research.

Interviews

Twenty-three (23) in-depth interviews were conducted from August 2015–May 2017. Interviews were conducted in the homes and fields with farmers of the Dayr Ballūṭ plain and in order to achieve historical depth. All interviewees were women over the age of 70. Vernacular place names were documented. Three field transects were conducted with women farmers once in February 2017 and twice in March 2017 in order to understand more the topography and plant associations of the village. Finally, a general meeting was conducted with 20 women farmers using a participatory approach to hear from them and to discuss the main issues related to *baʿlī* farming.

Results and discussion

Persistence of rainfed (baʿlī) agroecosystems in the Dayr Ballūt valley

GIS analysis documented the persistence of cultivation of the Dayr Ballūṭ

agricultural plain from 1918 to 2017, specifically, analysis of December 1918 aerial photographs allowed us to determine the same southern border and many of the agricultural parcels existing in 2017 have done so for nearly 100 years. The stable southern border and many land tenure plots illustrate the enduring importance of intensive cultivation of the plain despite the many upheavals and challenges facing Palestinian farmers during the period of study. The 1944 images give a complete aerial image of the study area and allows determination of the extent of cultivation at that moment in time, but it is not possible to determine the crops grown from the photographs. However oral histories with elderly farmers were used to make a partial reconstruction of the cropping system during that time.

This *baʿlī* agroecosystem has been retained from 1944 until today based on a geospatial analysis and oral history interviews. However, based on partial coverage of the agricultural plain (21%), we are able to infer with that the agricultural plain was farmed in this way from 1918 due to the unchanged borders of the farmed plain area. The geospatial analysis of 2014 aerial imagery showed that the agricultural plain included 514 individual parcels and fields (*see Figure 2).* The area of these parcels averaged 1,354 square meters. The largest parcel was 11,069 square meters and the smallest parcel area was 303 square meters. Several acres are located within what local people call the *bālūʿ*, or seasonal wetland area. It floods with the winter rains and remains wetter than other parts of the plain throughout the year. According to our geospatial analysis of archival aerial photography, the area and shape of the agricultural plain remained largely unchanged from 1944 to 2014 (*see Table 1*). This indicates that despite massive olive tree expansion, village built-up area expansion, and drip irrigation

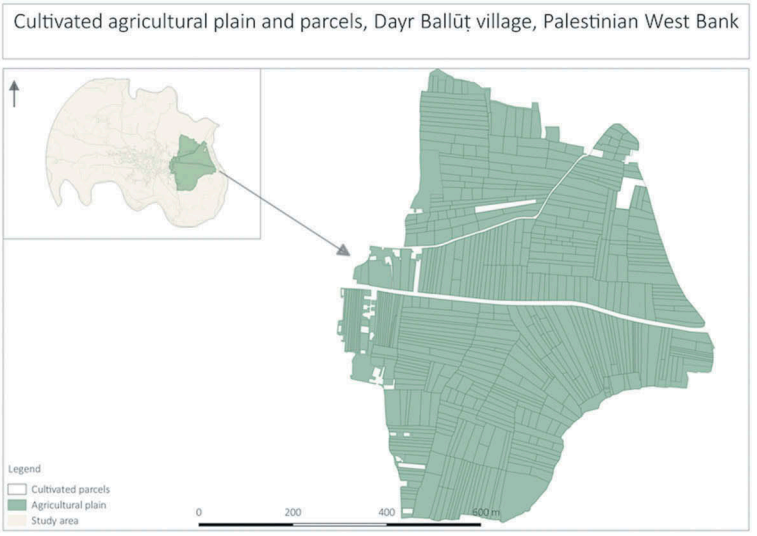

Figure 2. Cultivated agricultural plain, Dayr Ballūṭ, Salfit district, Palestinian West Bank

Table 1. Area of cultivated agricultural plain (marj) in Dayr Ballūṭ, Palestinian West Bank, 1944–2014.

	1944	1997	2014
Area of Agricultural Plain (m^2)	726,761	705,081	688,456

Source: Makaneyyat Research Engine based on digitization of aerial photography.

introduction over the same period, Dayr Ballūṭ villagers actively preserved the land area of the agricultural plain. In addition, the same census showed that areas cultivated with uncovered rainfed vegetables crops made up 80 per cent of the Salfit Governorate, and the area with most cultivated uncovered rainfed vegetables was Dayr Ballūt, with 59.7 per cent of its area (PCBS 2012).

Resilience through political-economic transformations

According to oral histories with farmers over the age of 70, two major transition points were identified. First, in 1948 a major political upheaval and the creation of the State of Israel promoted an influx of refugees from the coastal areas to the village.

Dayr Ballūṭ, in addition to neighboring villages, had previously depended on the western coastal cities of Jaffa, Al-Lydd, Ramle to market their crops and livestock. However, refugees from the coast did bring vegetable seeds and expertise to the village. Second, most of the men in the village left small-scale agriculture and entered the Israeli wage labor market following the Israeli occupation of the Palestinian West Bank in 1967. From subsistence cultivation, they suddenly entered the wage-labor market. They began to earn 500 to 1000 Israeli Shekels (ILS) per month in the mid-1970s. In 2017, the monthly wage in construction is 5,000–6,000 ILS. The exit of men from the agricultural labor pool resulted in the reorganization of the agroecosystems, continued adherence to *baʿlī* system, and the increased role of women in the agroecosystem. According to Khadija and Zaina, after men left Dayr Ballūṭ village to work in Israel, from 1967 until the present, women cultivated the *marj* (interview, farmer, 2016).

Political economic transformations

Until the 1948 influx of Palestinian refugees from the coastal areas, wheat, barley, and livestock grazing had been the primary crops cultivated by both men and women. The plain and hill areas of the village were planted with two local wheats (known as "*dibbiyyeh*" and "*fāshī*"), sorghum, sesame, tobacco, *Vicia sativa* (known as "*beka*"), *Vicia palaestina* (known as "*kirsenneh*"), lentils and with small groves of ancient olive trees. These trees are known as *Rūmī* olive trees in the vernacular in reference to the Byzantine period, regardless of whether they date from that period. Sheep and goats

played a major role in the agrarian economy for meat, ghee and dried milk products.

Following the inclusion of new techniques and crops, women in the village describe cultivating new crops such as okra, tomato, onion, garlic, watermelon and cantaloupe. As Abdel Rahman stated, "They are the ones who taught us to plant vegetables, even the watermelon, they are the ones who brought it. Their lands were vegetable lands and we didn't know much but wheat and sorghum" (interview, farmer, 2016) According to Maryam "when we came to Dayr Ballūṭ in 1948 they used to cultivate only wheat and sorghum so they learned from to us how to cultivate the terraces, and to cultivate vegetables" (interview, farmer, 2016). The transition indicates a large increase in agro-biodiversity from 9 primary crops to 17 primary crops after 1950 to 21 major crops after 1970 (*see Table 2*). However, after the 1970s economic shift, vegetables and olive trees began to take on more importance. Women farmers in Dayr Ballūṭ currently grow a suite of 21 crops. Other primary crops planted in the agricultural plain mostly for village and home consumption include wheat, garlic, onions and okra. Crops of lesser importance include sesame, chickpea, vetch, fava bean and pea. This increase illustrates an important diversification process.

Table 2. Changes in crop diversity in cultivated agricultural plain (marj) in Dayr Ballūṭ, Palestinian West Bank, 1944–2014.

Before 1950	1950–1970	1970–2016
(1) *Triticum aestivum* ("Dibbeyyeh")	(1) *Triticum aestivum* ("Dibbeyyeh")	(1) *Triticum aestivum* ("Dibbeyyeh")
(2) *Triticum aestivum* ("Fasheyyeh")	(2) *Triticum aestivum* ("Fasheyyeh")	(2) *Triticum aestivum* ("Fasheyyeh")
(3) *Nicotiana tabacum*	(3) *Nicotiana tabacum*	(3) *Nicotiana tabacum*
(4) "Beeka"	(4) "Beeka"	(4) "Beeka"
(5) *Vicia ervillia* Willd	(5) *Vicia Ervillia* Willd	(5) *Vicia Ervillia* Willd
(6) *Lens asculenta*	(6) *Lens asculenta*	(6) *Lens asculenta*
(7) *Sorghum vulgare*	(7) *Sorghum vulgare*	(7) *Cucumis melo* var. *flexuosus*
(8) *Sesamum indicum*	(8) *Sesamum indicum*	(8) *Sorghum vulgare*
(9) *Hordium sativum*	(9) *Hordium sativum*	(9) *Sesamum indicum*
(10) *Olea europeaea*	(10) *Abelmoschus esculentus*	(10) *Hordium sativum*
	(11) *Allium cepa*	(11) *Abelmoschus esculentus*
	(12) *Allium sativum*	(12) *Allium cepa*
	(13) *Solanum tuberosum*	(13) *Allium sativum*
	(14) *Cicer arietium*	(14) *Solanum tuberosum*
	(15) *Cucumis melo* var. *flexuosus*	(15) *Cicer arietium*
	(16) *Cucumis melo* var. *cantalupensis*	(16) *Pisum sativum*
	(17) *Solanum lycopersicum*	(17) *Vigana sinensis*
	(18) *Olea europeaea*	(18) *Sesamum indicum*
		(19) *Helian annus*
		(20) *Curcuma longa*
		(21) *Persea Americana*
		(22) *Olea europeaea*

Source: Makaneyyat Research based on fieldwork, field transects, and in-depth interviews conducted from August 2015–May 2017.

After 1967, drip irrigation technology and plastic greenhouses became available to Palestinian farmers at a high initial cost. However, they did not take up irrigated production of vegetables. Choosing rainfed production because of its lack of upfront investment and much lower cost of production, women farmers in Dayr Ballūṭ transitioned to an exclusively wide array of rainfed crops, mostly for village and household consumption. With the entrance of men into the Israeli labor force, in contrast to many surrounding villages, women in the village assumed responsibility for farming the plain.

Enabled by the proximity of fields to the village built up area, women farmers (1) planted the surrounding hillsides with olive trees where there had been small grains and (2) significantly shifted the crops grown in the plain area from small grains to vegetables. The women farmers currently control the entire agroecosystem including seed management, planting, weeding, harvesting and marketing (see Figure 4). The only extensive involvement of men came with plowing with a tractor and transportation of the product to the central market. A nearly complete transformation in the gender structure of agricultural labor took place. Wild-gathered food plants also remain an important part of the diet during the winter/spring rain reason from December through end of April. Wild-gathered vegetables provide a consistent dimension of the agroecosystem in times of low productivity, off-season and otherwise, and are often excluded from consideration of system resilience. Our field survey resulted in an inventory of 33 food plants that are wild-gathered (Tesdell et. al., 2018). They are often eaten fresh, sautéed, or in some cases, wrapped and stuffed with rice.

Resilience in face of political-economic transformations

The persistence of the borders and field parcels in the agricultural plain over the study period does not indicate constancy of the agroecosystem itself. In contrast to a belief that Palestinian agriculture is a remnant of ancient cultivation practices that have little changed (Arnon 1992), our results suggest that agroecosystem resilience depends upon dynamic change. Based on our results, there are three central axes upon which the dynamism and persistence of this agroecosystem resilience pivots.

First, the agroecosystem became more, not less diverse in terms of species and field crop diversity as time went on. Interviews indicate that 21 crop species were grown in 2017 in the Dayr Ballūṭ agricultural plain. Interviewees say that they try new crops each year in order to test their viability and the market demand. As Maryam stated, “they brought *faqqūs* from Ramallah and it worked well so we kept planting it” (interview, farmer, 2016). The increase in crop diversity conflicts with prevailing trends within Palestinian agriculture and within the Middle East more broadly (Khoury et al. 2014). Moreover, crops grown by farmers in Dayr Ballūṭ are nearly all highly adapted for rainfed production. Common cash-crop vegetables such as

tomato and cucumber that are grown under irrigation in hothouses are virtually absent.

The faqqūs" grown by women farmers in Dayr Ballūṭ is *Cucumis melo* var. *flexuosus*, which is known as *faqqūs* in local dialect and Armenian cucumber in English. The long slender cucumber-like melon is planted in February and March after the last winter rains and harvested in May. It is a prized local spring crop and either eaten fresh or pickled like cucumbers. Interviewees noted that the varieties of *faqqūs* grown in Palestine are so well adapted to chemical-free rainfed cultivation that the plant will not bear fruit if irrigated. It is said that under irrigation, it will have impressive vegetative growth, but for unclear reasons, the plant will not give fruit. In the case of the hybrid greenhouse cucumber, a major cash crop, the parthenocarpic reproduction without fertilization and its chemical inputs negatively affects the flavor and texture. In this sense, open-pollinated rainfed crops like the *faqqūs* have a distinctive and lucrative market advantage. The most surprising result from our study was that *Cucumis melo var. flexuosus* was not grown in Dayr Ballūṭ until the 1970s. Interviews and fieldwork suggest that the highly-adapted nature of the crop to rainfed production led to its selection and popularity. As one farmer, Mariam, explained as to the suitability of *Cucumis melo var. flexuosus* "if they were to plant *faqqūs* on irrigation, it wouldn't work, it doesn't give good fruit" (interview, farmer, 2016).

Second, a major increase in the land area of olive trees suggests the shift is not only indicative of a change of crops. In the shift seen in the 1944 map from rainfed small grains and legumes (primarily wheat, barley, lentils and chickpeas) to rainfed olive trees in 1997 and 2014, is another important shift from annual to perennial crops (*see Figure 3, 4, and 5).* The increase in land area of olive trees indicates that the perenniality of olive trees as a crop affords at least three primary benefits. Firstly, the perenniality of olive trees provides all-year, permanent presence on the landscape in a context of fragile land tenure both due to Israeli government restrictions for Palestinians and economic disadvantages faced by small-scale farmers, especially women. Next, as Khadija stated, they planted olives, "to make oil, because it was productive. Before we used to plant wheat where the olives are now but the wheat doesn't produce like before" (interview, farmer, 2016). Aside from two to three plowings per year, harvest in October, and minimal pruning and fertilizing with manure, olives are more forgiving of part-time farmers. Finally, the increase in land area of olives suggests their importance as a secondary crop as a buffer with the uncertainties of vegetable production in the agricultural plain. The high value, storability and large market for olive oil allow the women farmers a larger margin for market and climatic fluctuations in their main enterprise, which is vegetable production.

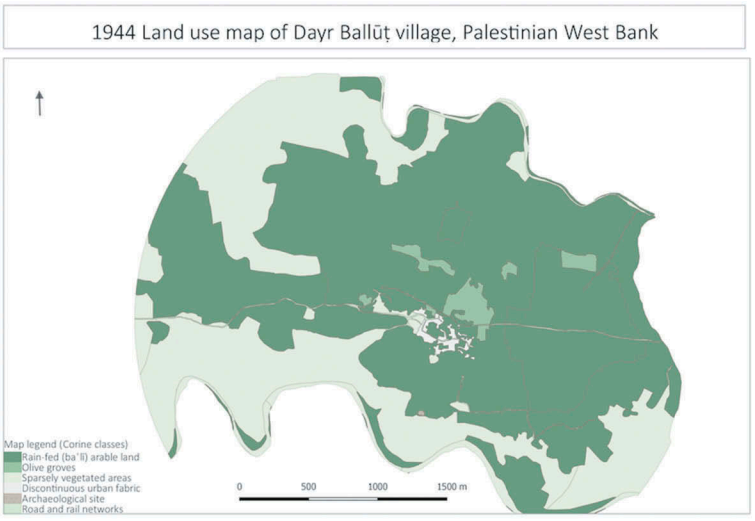

Figure 3. Land use of cultivated agricultural plain in 1944, Dayr Ballūṭ, Salfit district, Palestinian West Bank

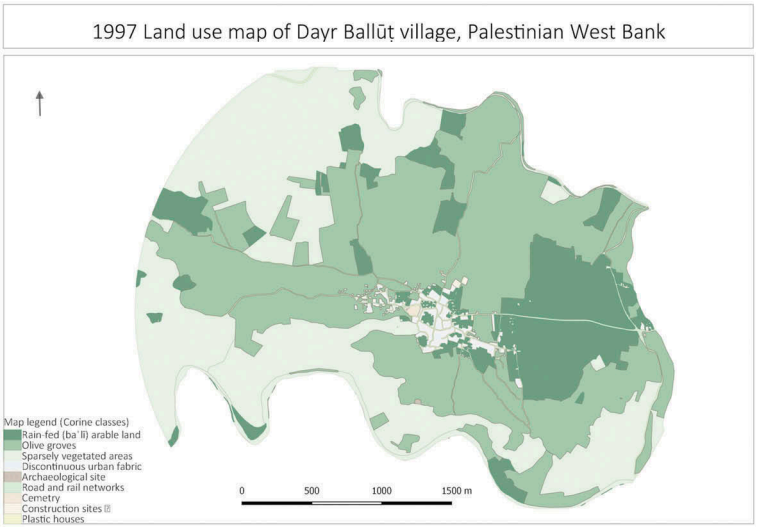

Figure 4. Land use of cultivated agricultural plain in 1997, Dayr Ballūṭ, Salfit district, Palestinian West Bank

Third, and perhaps most importantly, the resilience of the rainfed agroecosystem of Dayr Ballūṭ depended on a restructuring of the agricultural labor of the village (*see Table 3*). Following the exodus of men from agricultural labor in the 1970s to enter the wage labor force within Israel, women in Dayr Ballūṭ assumed control of the entire production process. Previously, they had played a limited role in small grains and legumes production, but they assumed total control of the agroecosystems beginning in the 1970s.

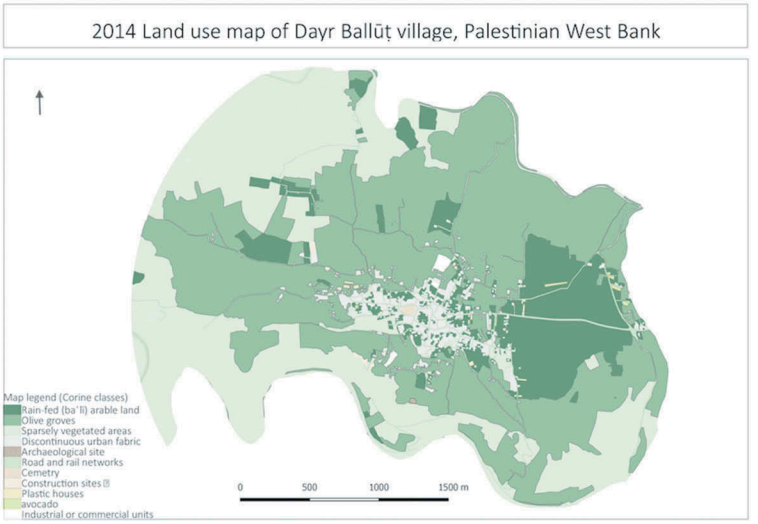

Figure 5. Land use of cultivated agricultural plain in 2014, Dayr Ballūṭ, Salfit district, Palestinian West Bank

Table 3. Changes in cultivation practices before and after 1970 in cultivated agricultural plain (marj) in Dayr Ballūṭ, Palestinian West Bank.

	Before 1970	After 1970
Cultivation primarily by men	• Tilling and preparing ground with draft animals • Harvesting grains by hand • Harvesting vegetables by hand • Threshing grains using draft animals	• Tilling primarily by tractor and some crops with draft animals • Threshing with mechanical thresher • Plant olive trees
Cultivation primarily by women	• Transport and spreading of manure fertilizer • Weeding by hand • Thinning by hand • Assist with harvest • Transport of grain to storage in homes • Seed saving, storage for following season	• Harvesting grains with mechanical harvester • Harvesting vegetables by hand • Planting grains and vegetables • Spraying grains some vegetables with herbicide • Weeding *Cucumis melo var. flexuosus* by hand • Thinning by hand • Seed saving, storage for following season • Watering of olive seedlings

Source: Makaneyyat Research, twenty-three (23) in-depth interviews were conducted from August 2015–May 2017.

Building from the work of Abdelali-Martini et al. (2008), women farmers play a crucial role in the conservation of agro-biodiversity in the Middle East. Interviews in Dayr Ballūṭ indicate that if a group of highly motivated women had not planted the hilly areas with olive trees, and assumed control of the agricultural plain, that the agroecosystem of Dayr Ballūṭ would have followed

a similar path of extensive agrarian deterioration, as with the surrounding villages. More research is needed in order to be able to compare results with villages that did not pursue rainfed production in order to compare the cases. Furthermore, conservation of agro-biodiversity is not the best description of the effect of the labor transition in Dayr Ballūṭ. In fact, according to our findings it was the circumstance that women did not have access to capital for up-front investments in irrigated production that they pursued a suite of new crops that were suited for rainfed production, had a high market value (quality and taste), and allowed the women farmers to remain close to the village core in order to allow more easily for household labor. The farmers of Dayr Ballūṭ plant the wetter (*bālu*ʿ) area of the plain with okra because it thrives on the moist soil conditions. As one farmer, Sarah, noted, "the wet area we plant with okra because it is wet soil, before we used to plant it sesame" (interview, farmer, 2016). Its ability to retain high soil moisture in a wet-dry Mediterranean enables the women farmers of Dayr Ballūṭ to grow crops profitably without the need for expensive resources: water, irrigation equipment, or chemical inputs.

Most of the land is farmed by its owner. During peak times such as planting or harvesting, members of the extended family and older children assist. In contrast to mere conservation, the case study suggests that the agroecosystem was restructured to allow for a more resilient rainfed production system.

To conclude, based on observations, interviews, and field transects, the three axes of the persistence of the *baʿlī* agroecosystem in Dayr Ballūṭ are: (1) increasing agro-biodiversity of crops allows them to spread risk across crops and wild food plant gathering to the diet during the winter and rainy season; (2) rainfed agricultural labor of women who sought to develop their own household economy after the entrance of men into the Israeli wage labor market; and (3) the planting of rainfed olive groves in the 1970s that could provide supplemental income from olive oil and provide protection of land from Israeli confiscation through the planting of trees.

Potential challenges to resilience

Our results indicate that the resilience of rainfed cultivation compared with irrigated production requires further examination. Several potential challenges to resilience have emerged from the study. First, several farmers in Dayr Ballūṭ described their desire in interviews to be able to implement drip irrigation but noted that the Israeli government has classified the agricultural plain as "Area C" according to the 1994 Oslo Peace Accord land classifications which means that construction, irrigation, plastic houses and other modifications of the landscape, are not allowed without permission (UN-OCHA 2009). So far, permission has not been granted.

When asked as to why they would like to implement irrigation, they cited the lack of rains as the primary reason. As Khadija who cultivates a rainfed plot now noted, "Irrigated agriculture is better because it gives results (money) continually, not just seasonally and gives more produce" (interview, farmer, 2016). However, another, Mariam, stated that "rainfed is much better because it doesn't cost like irrigated" (interview, farmer, 2016).

Second, in order to achieve a historical perspective our interviews were limited to those participants over the age of 70. The age of our interviewees has affected the results of the study to suggest that younger generations of farmer women are not interested in continuing to farm in the agricultural plain by hand. The potential effect of age-dynamics requires further examination through interviews with younger farmers in order to ascertain whether age constitutes a challenge to agroecosystem resilience.

Conclusion

Like many parts of the world, the 1970s economic transitions wrought massive changes to the small agricultural systems of Palestine (McMichael 2013). The 1970s transition in the labor market and the rapid modernization of the agricultural regime in the West Bank left a massive gap in the market in the area (Tamari 1990). In the case of the study area and a few other areas in the West Bank, the agroecosystem was able to withstand the massive shift.

Given its plentiful rainfall, its rich soil, its warm climate, and its geomorphological position as a flat plain, the multi-crop farming system does not require costly irrigation or greenhouses. This greatly reduces the overhead costs of production. The resilience of the Dayr Ballūṭ agroecosystem is in part understood by the highly dynamic *baʿlī* cultivation of the women farmers that sustains a low-capital intensive system.

The hilly areas that were formerly planted with wheat and other small grains were planted gradually with olive trees. This provided income during the transition. But more importantly it relieved the women of labor-intensive small grains cultivation. Olive trees by contrast offer an income without the labor-intensive small grains production as well as protecting land from confiscation. Also, there was a lack of livestock, and the grains were in large planted as feed for the livestock. When the livestock farming stopped, the need for small grains went away. Also, olive oil was a highly storable and valuable commodity that could easily be sold in exchange for money, which grew in importance for the people there. The upfront investment required for irrigated production was cost-prohibitive and enabled continued control of the system based on a highly diversified, highly adapted system.

Using geospatial and qualitative methods, we have been able to provide new evidence for the resilience of rainfed agroecosystems in a central West Bank study area. The case study demonstrates the highly dynamic transition

from a field crop system to a vegetable production agroecosystem, which has remained rainfed. It was determined that three central factors facilitated the resilience of the agroecosystem over the study period and area: (1) adherence to rainfed cultivation practices; (2) restructuring of the cropping system to include new and more diverse species; (3) restructuring of agricultural labor with women assuming the major role in cultivation.

Limitations affect our study. The time period of our geospatial analysis was limited by the material available and we have not been able obtain aerial imagery for the entire study area in 1918 and are limited to an extensive analysis only beginning in 1944. Further study is required to explore the market value of each crop and a full agricultural economic analysis of the cost of production in rainfed as compared to irrigated production, for example comparing greenhouse-grown cucumber and the rainfed *Cucumis melo var. flexuosus*. Moreover, the age of our interview participants has provided a strong explanation of agroecosystem resilience in the past within our research study, but it does not provide evidence about the future resilience of the agroecosystem. Interviews with younger farmers would be required for a study on the future of the agroecosystem.

The historical and geographical literature on Palestine long asserted that *Baʿlī* rainfed agro-ecosystems provide a resilient structure. Using a multi-method approach of geospatial and qualitative data, we have been able to provide new evidence to support this claim in a central West Bank study area. The case study demonstrates that the persistence of rainfed farming is underpinned by the highly *dynamic* transition from a male-run rainfed field crop system to a women-run vegetable and olive tree agroecosystem, which has remained rainfed.

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