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Envisioning perennial agroecosystems in Palestine

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ABSTRACT

Climatic change will seriously impact Mediterranean areas. Palestine, which has given forth annual grain based agriculture, is particularly vulnerable given its political and economic situation. Research is needed to build climate adaptation and resilience into agroecosystems within the same landscape that gave forth agriculture. A primary step in achieving that adaptation is to develop polycultures composed of perennial crops to protect and rebuild the soil. Our preliminary research shows that agrobiodiversity and genetic material for this deep adaptation is already present within the landscape, and if developed could produce the new crops used to build perennial polycultures.

Although it is one of world's oldest agricultural areas which has provided a basis for sustenance and livelihood for millennia, a critical issue for Palestine today is the possibility to maintain and expand its agrobiodiversity. The focus of this study is to examine the potential for conservation of local agrobiodiversity and development of accompanying perennial agroecosystems.

One of the most important support structures for Palestinians is the agroecosystem. Yet agroecosystems of Palestinians are tenuous given their political and economic dependency and the particular climatic, geologic, hydrological, and biological characteristics of the land. Soil health in particular is crucial to the functioning of persistent and productive agroecosystems. Tillage and other agricultural practices have a negative impact on soil health (Crews and Rumsey, 2017). Like many Mediterranean areas around the world, Palestine faces a daunting future as climates shift. Climate change will introduce more variability into rain patterns (Giorgi and Lionello, 2008). Palestine's wet-dry rainfall patterns and temperature seasonality are highly sensitive to climatic changes, which challenge arid agroecosystems in the Mediterranean basin, South Africa, Chile, Australia, among others. Moreover, the nearly five million Palestinians in the West Bank and Gaza have little control over their borders, airspace, economy, communications, or energy infrastructure and are vulnerable to climate-induced disruptions. These restrictions, imposed by more than forty years of Israeli military occupation amplify these vulnerabilities.

1. Palestine as a unique research site

Though Palestinians are increasingly dependent on food imports, their agroecosystems continue to be built upon assets provided by the landscape itself, namely a significant biodiversity of potentially useful food, fuel, and fiber plants. The landscape of Palestine has an impressive array of plants that have lead to one of the highest concentrations of agrobiodiversity in the world. The landscape of Palestine gave the wild pulses, grains, woody plants, and trees that humans first began to modify and domesticate about 12,000 years ago. This landscape—which developed to encompass human culture and society, and includes one of the longest durations of settled human cultivation in the world—remains a center of diversity for the Neolithic founder crops as well as many important legume species.

These crops now provide the basis of life for millions of humans around the world. Many of the major founder crops (wheat, barley, bitter vetch, chickpea, lentil, flax, and oat) originate in Palestine and surrounding the areas (Zohary et al., 2012). Evidence of the use and propagation of many other species including fava bean, olive, grape, and pistachio are found in early Epipaleolithic sites in Palestine (Snir et al., 2015; Weiss and Zohary, 2011). With the exception of the tree crops (olive, almond, grape, and pistachio), all of these main domesticated crops were annual crops, requiring tillage and replanting each year. Our work seeks to draw on this agrobiodiversity and build perennial polycultures from within the center of origin of the first crop domestications. The research takes place within the same

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agroecological context: geologic, soils, climate, valleys, outcroppings, and agroecological context as the ancient cultivators. Thus, Palestine presents a unique opportunity given that the same wide agrobiodiversity that was originally used to develop annual plow-based agriculture can be leveraged to explore new crops in mixtures.

As with many parts of the world, small scale agriculture in Palestine has declined greatly (Altieri, 2002; Altieri et al., 2012). The most persistent Palestinian crops remain greenhouse cash crops of peppers, cucumbers, zucchini, and tomatoes, and tree fruit and nut horticulture, namely olive, almond, and grape (Assaf, 2010). The massive decline of small grains of wheat, barley, and pulses like lentil, chickpea is quite striking given that Palestine is the center of origin and cultivation of those staple crops. Palestinian small-scale agriculture declined largely as a result of worldwide economic liberalization and the move to wage labor in the Israeli economy, and Israeli occupation policies which restrict Palestinian access to the means of production namely, land, water, and import/export markets (Tamari, 1981; Tesdell, 2013).

The most persistent small-scale, economically viable, locally-controlled of those crops in the olive. In a modern anomaly, nearly all the olive oil used in Palestine is picked by hand by families, locally processed, and distributed through informal relationships. It provides a vital income source and food source for Palestinians with few other remaining widespread crops. It not coincidental that the most resilient crop today in Palestine is also a perennial crop which require few inputs and water and is highly adapted to the local environment. Olive production has not only persisted but the cultivation area has greatly expanded (Assaf, 2010; Tesdell et al., 2019). For this reason and others, our research group seeks to explore the viability of perennial agroecosystems from within the existing infrastructure of olive production.

2. Perennial polycultures old and new

The Palestinian landscape provides a has hosted a long history of polycultures (olive-grape-wheat being the most famous) and plant diversity which can be used to mitigate coming social-ecological climate shifts (Barbera and Cullotta, 2014). These plants and systems can assist humans in protecting and building soils, and in developing climate-resilient agroecosystems that can sustainably feed communities for the long term. Perennial agroecosystems are increasingly seen as a viable alternative to annual plow-based agriculture which results in soil loss and requires significant inputs from fossil fuels (Crews et al., 2016). Soils have degraded over millennia in Palestine as with most of the world. The existing dry stone terraces and tree crops provides a kind of infrastructure from which to rebuild soil and build new polycultures. New crops could be placed into this system to reduce and eliminate tillage and make permanent vegetative cover over the soil.

While polycultures of fruit and nut trees (olive, almond, fig, grape) and field crops (wheat, barley, lentil and vetch) have been present in Palestine for millennia, new permanent perennial polycultures are needed to reduce tillage of field crops. Perennial grains, legumes, and cover crops could be used rebuild soils and provide food fuel and fiber. In hill areas, these perennial crops could be used within the existing terraced olive groves. In flatland areas, such crops could be grown in open fields as alley crops within agroforestry systems to provide greater diversity, economic benefit, and ecosystem services for pollinators and others. Moreover, agroecosystems may be developed to include perennial-annual mixtures.

3. Study methods

In order to explore these concerns, our research group, which is called Makaneyyat, was founded in 2015 to strengthen agrobiodiversity and build perennial polycultures in Palestine. As a result, we began to compile large datasets from archival sources, aerial images, interviews, and fieldwork within an open-source agroecological research engine. The engine allows researchers to manipulate, filter, visualize, and store agroecological data in order to drive their own investigations. The genetic material, geodata, and the ethnobotanical information that we are gathering is not readily available elsewhere, especially to Palestinians who are already food insecure and could rely on these wild plants again in the future. In addition to writing and digitizing this locally held knowledge, we have also been working to make existing botanical knowledge about Palestinian plants available to Palestinians by digitizing primary source floras of Palestine and using an API developed by the team.

Using a transdisciplinary approach to sustainability science (Lang et al., 2012), our development of perennial agro-ecosystems draws on the lived experience and knowledge of local farmers and foragers to co-produce knowledge that is relevant to Palestinian communities and agroecosystems. The focus on perennial agroecosystems within Makaneyyat'soverall vision has been inspired by our relationship with The Land Institute (Kansas, USA), where researchers are developing new perennial grain crops to be grown in diverse mixtures that hold soils and mimic the resiliency of native ecosystems, and leading society into a new perennial agricultural economy that fits within the ecosphere. Plant breeders and ecologists at The Land Institute are enacting strategies for new perennial crop domestication (DeHaan et al., 2016; Schlautman et al., 2018; Van Tassel et al., 2017) and Ecosphere Studies is developing cultural and educational practices to transition human communities toward new perennial food systems and enduring social values (Jackson et al., 2018).

Beginning in 2017, we began to conserve and improve species that contribute to agrobiodiversity in Palestine. Since then, Makaneyyat has collaborated with The Land Institute on research design, candidate selection, and community-based approaches. Central to this collaboration is a shared focus on the use of open science models to build climate adaptation into agriculture. We focus in two central areas of research: first, in-situ and ex-situ conservation of important wild food plants and crops and second, pilot studies on the viability of select species for improving agrobiodiversity, stemming soil loss, and building resiliency for climatic shifts.

4. Research site

Our conservation area and research plots are located at approximately 600–800 m above sea level near the city of Ramallah in the Palestinian West Bank. We currently work in four in-situ sites for the conservation and propagation of key species. The Mediterranean sea coast lies about 30 miles (48 km) at its closest point. Dependable annual rainfall records are not available however we are able to infer that its average annual rainfall stands at approximately 500 mm per year. The Birzeit University weather station located at 800 m above sea level has recorded an average annual rainfall of 659 mm for the period of 2003–2018. The Israel Meteorological Service (IMS) official average annual rainfall for Jerusalem (station located at 815 m above sea level) is 537 mm per year over the years of 1981–2010. It is a strongly Mediterranean climate. Notably, the areas we collect, conserve, and screen candidate species is located within 7 miles (11 km) of one of the first archeologically verifiable site of early domestication 15,000 years ago, the Natuf Valley.

5. Pilot study to test research methods and screen select species

First, a pilot study was conducted at our first research site beginning in August 2017 in order to test research methods and begin screening potential candidate legume crops. The research site sit at a lower elevation of 600 m, likely meaning that it receives lower rainfall amounts than the nearby stations at 800 m. In 2017, accessions were withdrawn from the USDA GRIN genebank in order to begin exploring various crops within the *Medicago (M. coronarium, M. carnosum, M. cancellata, M. prostrata, M. ruthenica, M. falcata, M. arborea), Vicia (V. peregrina), and Trifolium (T. physodes)*. The accessions were divided into 10 small

research plots located on three dry stone terraces among olive trees of approximately 50–70 years of age.

Screening has been undertaken in these legumes at the first stage to seek plants with vigor to withstand the Mediterranean dry season from April to November. Field notes were taken with regard to overall vigor, number of stems, color of flower, and the growth habit of the plant.

6. Initial observations from pilot study

Selections were made after cycle one. Sixteen (16) *Medicago* plants were selected from 10 different Alborea half-sib families to be the parents of the progeny for the next generation. Very preliminary observations include: (1) the plant vigor scale is a fairly good predictor of plant survival through the dry season, and (2) stem number seemed to be important for low vigor plants, where seventy percent (70%) of the low vigor plants with more than 2 stems were still surviving in the dry season.

7. In-situ and ex-situ conservation

Second, in-situ field genebanks and an ex-situ seed collection were established to conserve a wide selection of endemic wild plants that have potential uses as components of polycultural systems. The seed collection/genebank is instrumental to establishing a pool of potential candidate crops for perennial polycultural systems adapted to the Mediterranean climate of Palestine. We have first identified wild food plants (the database currently holds about 175 plants identified in through fieldwork, interviews, and secondary literature).

Collecting specimens and seeds from wild populations in Palestine and currently hold them in a basic ex-situ collection with associated database containing passport information. We are also creating an informal network of field genebanks for the conservation of wild populations, located on private land protected from grazing animals, wild boars, tillage, and herbicide use which constitute the main threats to the regeneration of wild plants. These four areas range from 850 m in elevation to 200 m in elevation. Collection began with wild food trees in August 2018 and continued into the rainy season with the annual and perennial spring plants. Special emphasis was placed on leguminous plants as part of the initial goal of developing perennial leguminous cover crops for fruit and nut groves that dominate the hill regions of Palestine and the greater Mediterranean. Palestine serves as an important *in situ* repository of diversity for these crops and their crop wild relatives. Much of this wild germplasm is currently outside the reach of major biodiversity efforts to collect, catalog, and preserve *ex situ and* is available *to* most researchers except Palestinians.

8. Preliminary findings of conservation efforts

As of December 1, 2019, more than 500 accessions from more than 100 species and representing 50 genera have been collected, identified, stored in the ex-situ collection. Geolocations are available for nearly all of the accessions. Collection focused on legumes and wild food trees and shrubs. Collection has thus far taken place at elevations ranging from 200 m to 850 m above sea level within the hill region of the West Bank. In addition to the ex-situ collection, 120 specimens have been preserved, identified, and stored for reference in a basic herbarium.

There is a large diversity of leguminous plants of the *Fabaceae* family. Some of the endemic leguminous plants from the *Vicia*, *Trifolium*, *Medicago*, *Lotus*, *Ononis*, *Onobrychis* genera hold promise as cover crops. They are likely spread via grazing animals and the use of manure from grazing animals. Being leguminous, these plants contain more protein and are preferred by grazing animals. Many crop wild relatives are also part of the collection. These include the wild relatives of cultivated peas (*Pisum*), lentil (Lens), chickpea (Cicer), and Fava bean (*Vicia*). Collection from wild populations adapted to the microclimatic conditions of the Palestinian hill region is critical to our goal of developing new crops for cultivation in Palestine.

9. Future directions

Agrobiodiversity conservation is a crucial avenue of our research. Preliminary results show that several high potential species include *Bituminaria Bituminosa*, *Medicago Arborea cross*, some *Lotus* species, *Cicer*, and *Astragalus* among others. However, the impact on olive oil and olive production as well as other fruit and nut trees remains to be studied. Early observations from the pilot study and the genebanks point to a tremendous diversity from which new cover and grain crops can be developed. Success by Makaneyyat in new crop development would likely have far reaching impacts for agriculture across the Mediterranean region.

One of the central questions revolves around the emphasis on perennial species that might be developed to produce more seed, an edible crop, or grazing forage. However, initial investigations point to the potential use of self-renewing annual species such as many in the *Medicago* and *Trifolium* genera as has been studied in Australia (Hayes et al., 2017; Nichols et al., 2007, 2007). It is more likely that a mix of both annual and perennial species would be part of the research strategy. Our open scientific model, rooted in its social context, is also a promising mode of inquiry for community-based research.

Author contributions

Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Software; Supervision; Validation; Visualization; Roles/Writing - original draft; Writing - review & editing.

Omar Tesdell: Writing - original draft; Writing - review & editing; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration.

Yusra Othman: Investigation.

Yara Dowani: Investigation.

Samir Khraishi: Data curation.

Mary Deeik: Data curation.

Brandon Schlautman: Methodology; Supervision.

Aubrey Streit Krug: Writing - original draft; Writing - review & editing.

David Van Tassel: Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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