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The Importance of Urban Eco-gardens for Biodiversity and Human Sustainability: A Case Study from Palestine

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The situation in Palestine is of concern where global threats of climate change, overexploitation, habitat destruction, invasive species, and pollution are compounded by occupation and conflict. Thus, almost 1/3rd of vascular plant species are rare and over 50 are listed as endangered or rare based on their abundance and presence in grids studied earlier. Here, we describe the development of a conservation botanic garden that works via research, education, and direct in situ and ex situ conservation of plant species. The garden now boasts 381 species of vascular plants (63 are rare). The team scientifically and selectively introduced some rare and endemic species, developed educational modules, and engaged the community in all aspects of planning and growth of this garden. It has acted as a model for threatened and protected areas in the state of Palestine, as well as becoming a national oasis for both wildlife and humans. The lessons learned from this experience include: 1) principles of minimal intervention in eco-friendly ways producing zones of permaculture and gardening towards conservation (ex situ and in situ conservation), while allowing botanic garden functionality, 2) involvement of staff, volunteers, experts, and community in education and conservation efforts, 3) value of research in plants and animals for integrated ecosystem management. The outcome of this work is a maximally utilitarian garden for areas like education, direct conservation, research, and human satisfaction whilst ensuring long-term sustainability in a nascent state in the midst of a difficult political situation.

Keywords

In Situ conservation, Ex Situ conservation, Urban gardens, Developing countries

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1. INTRODUCTION

The decline of the world's environment and biodiversity is accelerating due to the increasing threats of climate change, pollution, overexploitation, invasive species, and habitat destruction (McNeill 2016; Urban 2015). The UN's Sustainable Development Goals (SDGs), the Convention on Biological Diversity (CBD), and five other related conventions highlight our fragile global and local ecosystems (Herkenrath 2012; Turnhout, Dewulf and Hulme 2016) and failure to meet targets of conservation (CBD 2021; Xu et al. 2021). Meeting such global obligations like the new, post-2020, CBD framework is more difficult in developing countries (Hagerman and Pelai 2016). The state of Palestine entrusted our institute (Palestine Institute for Biodiversity and Sustainability) to do the reporting for CBD (See EQA 2021) and create a new National Biodiversity Strategy and Action Plan (NBSAP). In producing the results, consideration was taken into account of the unique situation of the country and its needs for additional infrastructure including botanic gardens. Developing countries (those with lower socioeconomic development than the Western Countries; see Verdirame 1996) face significant challenges due to their limited resources and history of being exploited for raw material used by developed countries in ways that harm the global environment (Baatz 2013; Hansen and Sato 2016). For example, the Arab world (the region referred to at MENA- Middle East and North Africa) faces significant environmental challenges while it is politically and structurally in a vulnerable position (Waha 2017). The nascent state of Palestine is specifically challenged; because of several reasons: 1) it signed the CBD in 2015 and only started working on these issues more intensely afterwards, (but it was denied funding by pressure from the US – See Qumsiyeh and Albaradeiya 2022). 2) The Palestinian state in the making is still living under Israeli occupation which carries attendant environmental challenges and inability to meet them including lack of sovereignty over resources, impact of settler and military activity among others (see Qumsiyeh, Zavala and Amr 2014; Qumsiyeh and Albaradeiya 2022; Tal 2002). Our own report from Palestine (https://chm.cbd.int/database/record?documentID=257520) shows limited progress and currently the PIBS team is leading in building the National Biodiversity Strategy and Action Plan which will be in line with the post-2020 CBD targets (CBD 2021) and national circumstances. The aspects that have been completed both identify challenges and display opportunities; also, they go further in proposing mitigation and adaptation strategies. Key challenges identified above require interventions in line with the enormity of the threats. This is especially true in urban areas where most of our population reside like in many other countries (UN-DESA 2007).

Globally, urban garden are critical components in biodiversity conservation, for recreation, and community health (Sadler et al. 2010; Schwarz et al. 2014; Hand et al. 2017). The nascent state of Palestine has started to address the need of public spaces like museums and gardens for these reasons (Qumsiyeh 2017; Qumsiyeh et al. 2017). Palestine is part of the Fertile Crescent, the cradle of agriculture and civilization. It is located at the intersection of continents and harbors five phytogeographical zones (Irano-Turanian, Saharo-Arabian, Mediterranean, Coastal, and Sudanese). Threats to natural and cultural heritage range from; the collection of plants and flowers as souvenirs or spices, to Israeli settlement activities, to increased Palestinian urbanization as detailed elsewhere (Qumsiyeh, Zavala and Amr 2014; Qumsiyeh and Albaradeiya 2022). It is not inevitable that urbanization leads to biodiversity decline and habitat loss (Hudson et al. 2021; Lovell 2010; Sperling and Lortie 2010; Westwood et al. 2021). Urban gardening in Palestine carries great promise (Heywood 2017; Qumsiyeh et al. 2017; Renu 2018).

The present study examines the establishment of an integrated botanic garden at the Palestine Institute for Biodiversity and Sustainability (PIBS) in terms of its utility for sustainability of humans and of biodiversity in a developing country under sociopolitical pressures and draw lessons from this experience.

2. MATERIALS AND METHODS

Bethlehem University has a main campus and a side campus called Mar Andrea. Two buildings in the latter campus were used as dormitories but were mostly abandoned. The 12-dunum (3.212 acres) land was partly planted with olive and almond trees in the 1970s, and used to store construction and maintenance items. In late 2014, the area was examined and found to have great potential as an urban garden, a permaculture facility, and a botanic garden. PIBS team took two years (from late 2014 to 2016) to observe where plants grew and thus where habitats need to be preserved. During this period, the only projects executed in the garden were: 1) repair stone terraces already found on site, 2) create a pond in the lowest part of the property to harvest rainwater that was already accumulating there and had resulted in significant erosion of rich soil to the neighboring lands (see Figure 1 where the artificial wetland was created in area 8), and 3) repair the old storage building and extend it with a cage to make it a functioning animal room for rehabilitation of wildlife and also to keep domestic birds (#16 in Figure 1).

Figure 1. The botanic garden areas discussed in text are divided into the following areas: 1 Wild plants 2 rare plants, 3 orchids, 4 irises, 5 bird watching, 6 bee hives, 7 tortoises, 8 wetland and rain harvesting, 9 greenhouse 1, 10 animal rehabilitation, 11 Community garden, 12 exploration playground, 13 nurseries, 14 greenhouse with aquaponics, 15 compost, 16 green wall, 17 herbarium (in building), 18 rest areas, 19 amphitheater, 20 biogas, 21 tortoise area, 22 biogas and kitchen and tool areas.

While some data was collected in 2015 and 2016, most of the data discussed in the results were collected in the past 5 years (2017-2021). These included plant phenology and mapping in the garden using traditional plant transect and observation methods. They also included year-round observation of fauna by use of methods unique to each group of animals: a) Sherman live traps for small mammals, b) echolocation recordings for bats, c) camera traps and direct observation for large mammals and birds, d) invertebrate collection methods (Gibb and Oseto 2019).

Methods for in situ conservation: Data collected on site in terms of presence of species in each square meter of the land were used to determine what and where to conserve existing plants. For example, one area of the garden was noted to have a population of hundreds of small-fruit pheasant's-eye *(Adonis microcarpa)* otherwise uncommon in the Bethlehem region. The area was marked and maintained and a sign for the plant was introduced. Visitors enjoyed this red carpet that comes in late February and early march. The same of the few (dispersed) orchids in the garden (six sites with four in situ conserved species). Further interventions on site included building new stone terraces with minimal disruption in the areas of the garden that had wild plant diversity to be maintained, and creating different areas in the garden with the aim of introducing new species to them.

Methods for ex situ conservation: Literature on plants gathered in the past and supplemented it with data gathered since in our area were reviewed (see Al Sheikh and Mahassneh 2017; Al Sheikh and Qumsiyeh 2021a, 2021b; Pahl and Qumsiyeh 2021). Guiding principles for translocations were followed (Guerrant Jr, Havens and Vitt 2014; Heywood et al. 2018). The selection of families like orchids and irises for ex-situ conservation was done based on analysis of need for protection (Al Sheikh and Qumsiyeh 2021a). Some native Palestinian trees (carob- *Ceratonia siliqua*, hawthorn- *Crataegus aronia*, oaks- *Quercus coccifera*, mastic tree- *Pistacia lentiscus*) were planted. Wild trees were cultivated between existing olive trees because there is evidence of enrichment of biodiversity around olive groves (Awad and Attum 2017). Significant increase in olive production was noted (30% increase from 2015 to 2023) because olive orchards were not well maintained prior to 2014.

3. RESULTS

3.1 Biodiversity in Palestine and in the garden

Surveys highlight a rise in the number of species in our plant-rich region (Al Sheikh and Qumsiyeh 2021b; Pahl and Qumsiyeh 2021). A preliminary meta-analysis in the West Bank identified 600 plant species including 187 endangered, 171 very rare, 238 rare, and four already extinct (Al Sheikh and Qumsiyeh 2021a). The fieldwork done here allowed us to compare data from Mediterranean areas nearby to data on plants found in the garden as well as build our herbarium collection. An intensive study of the plants of the garden gave us a list of 432 confirmed species of which 59 were introduced by us and 63 are rare (PIBS 2022a). This is very high for an area of this size (12 dunum), at this latitude and located inside an urban area. Selected species were introduced into the garden for either education or for conservation value, including: Pink Butterfly Orchid- *Anacamptis papilionacea*, Pyramidal Orchid- *Anacamptis pyramidalis*, Strawberry Tree- *Arbutus andrachne*, Spiny Broom-*Calicotome villosa*, Spotted Golden Thistle- *Scolymus maculatus*, Bay Tree- *Laurus nobilis*, Myrtle- *Myrtus communis*, Common Narcissus- *Narcissus tazetta*, Three-toothed Orchid- *Orchis tridentata*, Yellow Bee Orchid- *Ophrys lutea*, Carmel Bee-

orchid- *Ophrys umbilcata*, Anatolian Orchid- *Orchis anatolica*, Small-flowered Pancratium- *Vagaria parviflora*, Three-lobed Sage- *Salvia fruticosa*, Snowdrop Bush- *Stryax officinalis.*

In addition to the plants, the garden boasts diversity within its species of mushrooms (*Coprinellus micaceus, Omphalotus olearius, Psathyrella bipellis, Suillus collinitus, Trametes hirsute, Volvopluteus gloiocephalus*) and rich **animal diversity**. Visitors especially enjoy two groups, butterflies and birds. A total of twenty-nine species of butterflies were documented belonging to five families (Papilionidae, Pieridae, Lycaenidae, Hesperiinae and Nymphalinae). Three species are noted year-round while most appear from late February to Early May (Abusarhan et al. 2016). The garden has rich invertebrate biodiversity with over 1500 species.

Reptiles observed include *Testudo graeca, Eiresnis decemlineatus, Eirenis rothi, Platyceps collaris, Dolichophis jugularis, Hemorrhois nummifer, Typhlops vermicularis, Chalcides ocellatus, Heremites vittatus, Ablepharus rueppellii, Ophisops elegans, Phoenicolacerta laevis, Chamaeleo chamaeleon, Stellagama stellio, Hemidactylus turcicus, Mediodactylus kotschyi, Ptuodactylus guttatus, Mauremys rivulata.* 49 species of birds have already been recorded in the garden (PIBS 2022b) including: resident, winter visitors, and migratory species (many of the latter were noted after introduction of the artificial pond discussed above. Breeding species in this small area include: doves, bulbuls, Palestine sunbirds, house sparrows, hooded crow, and the Syrian woodpecker. Unfortunately, the invasive and damaging Myna bird *Acridotheres tristis* is also nesting here (Handal and Qumsiyeh 2021).

The only resident **amphibian** of the garden was the common *Bufotes sitibundus.* However, when the aquatic rain-harvesting ecosystem was built, two more species, *Hyla savygnyi and Pelophylax bedriagae* were introduced. A native fish species was also introduced (*Garra rufa* from Wadi Qana). Mammals observed here include: rodents (*Acomys cahirinus, Apodemus mystacinus, Mus musculus*), shrews (*Crocidura Leucodon*), red foxes (*Vulpes vulpes*), mole rat (*Spalax leucodon*), and four species of bats (*Pipistrellus kuhli, Pipistrellus savi, Rhinopoma hardwiki, Tadaria teniotis).*

3.2 Structure and outputs of the garden

The garden project fits within the mission of PIBS to preserve the natural and cultural heritage of Palestine by research, education, and actions of conservation. The structure for PIBS and for its garden was developed collectively with volunteer and expert participation. A desktop study was followed by meetings with people concerned and input from visits to more than 15 global botanic gardens in both developed and developing countries. Also, two of the authors attended an in person online management program held by The International Association of Botanic Gardens held in Shanghai, China. These extensive consultations were distilled in the general goals of the garden:

1) Develop applied research that guides policy.

2) Conserving plant species that are rare and threatened in Palestine by in situ and ex situ conservation.

3) Provide the public, researchers, and decision makers greater information on plant diversity in Palestine, making it a more mainstream subject.

4) The garden acts as an oasis of tranquility in an area of conflict and increased urbanization.

Figure 2. Rainwater harvesting pond in foreground and museum building in background.

Human interventions were planned and applied in a way that enhances the existing biodiversity while maximizing use of space:

1) The horticultural work in the garden is rooted in both permaculture and utilitarian principles (e.g. using swales/trenches and enhancing stone terracing**)**. Almost 60% of food for the average 6-10 volunteers accommodated weekly on site is now a product of the garden (olive oil, eggs, pickled olives, vegetables, jams, fruits, fish etc.) and this is increasing every year.

2) As a reaction to the limited availability of water and space a greenhouse with **aquaponics and hydroponic systems** was built**.** One graduate student from Switzerland used our system to conduct master thesis on the subject (Kessens 2016).

3) In order to enhance the number of pollinating insect species and individuals, **insect hotels and local beehives** were introduced.

4) **Ex-situ conservations**: Palestine has endemics and large number of rare and endangered species and most are impacted by habitat destruction. Some (especially from the orchidaceae family and the iridaceae family) were translocated into the garden after significant research about methodologies helped identify importance of transplant season and including soil content (fungus that supports orchids for example Fig. 3).

Figure 3. Proper stage and amount of surrounding soil used for transfer of orchids.

5) The rain harvesting **aquatic ecosystem** was built in 2014 in the lowest area of the land. As noted above (3.1) this attracted migrating birds and this was enriched by the introduction of aquatic plants and animals.

6) **Medicinal and herbal plant areas** were developed and are popular with visitors (as biocultural heritage and ecosystem service).

7) ***Hugelkultur* systems and community gardens** were developed to provide agricultural space for 30 families from three refugee camps and city residents from the surrounding area. These people are trained here on the principles of environmental-friendly plant production and benefit from the production of their own vegetables. Organic waste forms a large part of the outcome of managing gardens and farms. The proper disposal of such material is often neglected and done in an environmentally unfriendly way, thrown into the environment, thereby reducing the area of agricultural land or area for the botanical garden. To avoid such situations in future. visitors were educated on the proper disposal of organic waste and its use in sustainable production as fertilizer.

8) The c**ompost and vermiculture areas** are critical educational and utilitarian tools in our botanic garden. Organic waste in Palestine constitutes 60-65% of the generated waste (ARIJ 2016). Increasingly, visitors, schools, and university groups are adopting these methods for home and institutional use.

9) The **exploration playground** was constructed using recycled materials like tires and olive oil press mats. It provides space for children to play and learn about biodiversity and agriculture. The space is popular especially in light of the shortage of such spaces for children in urban areas of Palestine.

10) Our garden introduces the development and use of **sustainable energy (solar power and biogas).** That system provides on one hand energy for the garden and on the other hand it also serves educational purposes. Motors for the hydroponic and aquaponics systems as well as the pumps of the wells are powered by solar energy. Biogas is sporadically used by volunteers when cooking.

Other amenities for visitors, researchers and workers of the garden include storage for work equipment of the staff (tool shed)**,** bathrooms (including a compost toilet)**,** molecular laboratories**,** herbarium**,** and three greenhouses. The **pathways** serve as the underlying structure of the garden and are planned to preserve biodiversity while being utilitarian. The garden plan, its design and the subsequent construction of pathways facilitates the movement of staff, volunteers and visitors. Seven **rest areas** provide space for visitors and volunteers to sit during their visits or work-sessions in the garden while at the same time enjoying the scenery and the surrounding biodiversity. During the COVID19 lockdowns, a video was produced and shared on social media and with our large email list (nearly 50,000 emails). You can see this at https://youtu.be/7cBil5ahC6o

4. DISCUSSION

4.1 Lessons Learned

Many lessons were learned by establishing and maintaining gardens:

1) Conducting a survey on the wild flora of the garden for two years prior to decisions about necessary interventions allowed us to decide what areas had key species (defined as those uncommon in the Bethlehem region and need to be conserved) growing and that aided the planning for paths and amenities.

2) Our area is located in the Mediterranean vegetation zone. Yet, desertification is already encroaching from the east due to climate change and other anthropogenic factors (Qumsiyeh et al. 2014). Thus, a rain harvesting system was introduced (the eco-pond), trees were planted to mitigate the effects of reduced rainfall, and measures to reduce soil erosion were implemented (see above).

3) Native plants were protected as well as the overall biodiversity by ceasing plowing in the olive orchards. Instead, a sickle and grass-cutting tools were used to reduce grasses which tended to outcompete the desired dicotyledonous plants in certain areas.

4) Volunteers were recruited from abroad using platforms like *Workaway* and *Volunteermatch* and locally including via community service programs. The total number of volunteers from abroad who joined for periods of three weeks to three months totaled over 220 from 45 countries. Volunteers helped in the Herbarium, in the regular maintenance work of the garden especially in cultivated areas, and in guiding visitors.

5) The community garden experiment was relatively successful as evidenced by feedback from users (e.g. via questions asked to them or their comments on Facebook page, see https://www.facebook.com/PIBS.PMNH) including from the nearby refugee camp and by the annual increase in its production (over 40% annual increase between 2018 to 2021).

A negative experience: A visitor brought an invasive freshwater snail *Planorbella duryi* among the roots of an aquatic plant. This and a leak in the pond forced us to restructure the eco-pond and restock it with the native flora and fauna species. As a result of that situation, a new policy was adapted for the introduction of plants to the garden, where plants are isolated for a minimum of three-months in a greenhouse before their introduction into the garden.

4.2 How does the garden contribute to the UN Sustainable Development Goals?

As a developing country that signed on to the UN agenda for Sustainable Development Goals (SDGs), we should consider how a botanic garden serves these goals. Below are notes on each relevant SDG.

SDG1 (no poverty) and SDG2 (no hunger): The garden acts as an educational center to show people the value of food sovereignty and control of production by using innovative actions like; community gardening, aquaponics, hydroponics, biogas etc. Unlike gardens in more advanced countries, this is very important in our situation because of conflict induced poverty in a developing country.

SDG3 (Good health and wellbeing): The conflict in our region creates numerous stresses both physical and mental. The garden acts as an oasis of tranquility and provides healthy air (among the plants) thus, providing an environment to promote people's health (see also Classens 2015).

SDG4 (Quality Education): PIBS and its garden improves science education and love for exploration and innovation in an area beset by other challenges that would distract from this. This includes education on recycling and upcycling as well as education on how to reduce the use of harmful products. Furthermore, university students (both undergraduate and graduate students) use the garden for their theses and other educational course projects.

SDG5 (Gender Equality): Specific activities for girls and women happen almost on a weekly basis which are important especially in a mostly patriarchal society. With expert female facilitators, we give them space to make their own plans and activities that serve their needs. They decide to get knowledge in different areas such as nutrition, health, and food sovereignty.

SDG6 (Clean water and Sanitation) and SDG 7 (Affordable and Clean Energy): The benefit to visitors to the garden is seeing such projects in operation at the institute (compost toilets, solar energy, biogas production, rain harvesting system).

SDG10 (Reduced inequality): The community garden and other facilities and their associated programs and activities reduce inequality by being open to all people equally but also by specific programs geared to marginalized communities (women, children, refugee camps, remote villages, and poor people). By providing such resources to Palestinians, inequality is reduced.

Figure 4. The museum and institute regularly holds children's activities every Friday with different themes from nature. Thousands have already benefitted from this

SDG11 (Sustainable cities and communities): The garden ensures sustainability of a vulnerable community by providing green infrastructure, including in our case a community garden and other productive permaculture facilities that sustain volunteers and community.

SDG12 (Responsible Consumption and Production): The garden provides over 20 modules and periodic workshops for education and awareness about the sustainable use of food and the reduction of waste and negative effects on nature. From composting to recycling to solar energy and biogas systems, the facilities empower and inspire.

SDG13 (Climate action): In addition to what was mentioned under SDG12, there is a special emphasis on climate change mitigation and adaptation. For example, six educational modules were designed and distributed to 14 schools in the Bethlehem and Hebron district in addition to thousands of museum visitors. The well-researched material (example Fig. 4) was later translated into short educational animated videos targeting all social groups (found at https://www.palestinenature.org/education/).

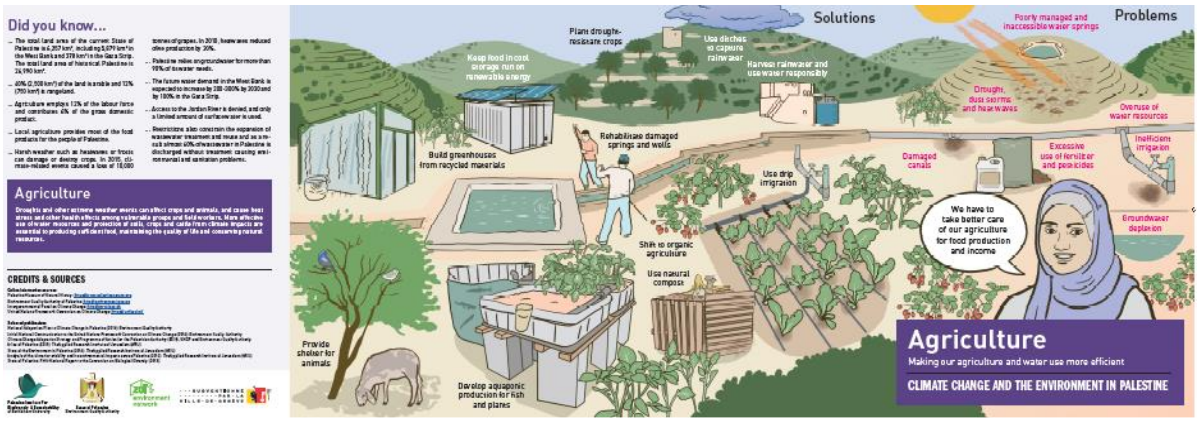

Figure 5. An example of an educational module that is tailored to the local people (available also in Arabic) and based on the work of the garden.

SDG 15 (Life on land): The garden builds a natural oasis for both people and wildlife acting as a small and protected area with 381 wild growing species of plants and many species of vertebrates as well as invertebrates.

SDG 16 (Peace, justice and strong institutions): The garden of PIBS is an attractive place for volunteers and visitors from all over the world, from different cultures and religions (see statistics on https://www.palestinenature.org/annual-reports/). The site thus contributes to mutual understanding and peace. The motto for us is respect: for ourselves, for others, and for nature. The front garden is considered as a peace garden for gatherings as well as for peaceful meditation. Finally, having created this institute on a bedrock of volunteerism and local contribution, it acts as a social incubator with global influence. Tens of thousands of people have already been influenced in directions of peace and sustainability through this facility.

SDG17 (Partnerships for the goals): PIBS and its gardens work in close cooperation with the Environment Quality Authority (EQA) and other governmental and nongovernmental agencies to develop programs that serve sustainability nationally. For example, PIBS was selected to build the new National Biodiversity Strategy and Action Plan 2023-2025 for Palestine and the new Protected Areas Network.

4.3 The garden in local and global context

Museums and their gardens, when developed, can significantly contribute to education about ecosystem services and the awareness of environmental issues in general (Cavender, Smith and Marfleet 2019; Qumsiyeh 2017; Qumsiyeh et al. 2017). Palestine is part of the Fertile Crescent, where the earliest forms of domestication of animals and plants were documented. In this area one can find important and rich genetic diversity of wild species that gave rise to domestic species (e.g. wheat, barley, lentils, and chickpeas). Threats to biodiversity in Palestine are the same threats identified elsewhere by the global community (CBD 2021) with some added ones. The significant global and more restricted local threats are partially addressed via botanic and urban gardens (Fig. 6) and community involvement. Being to the east and at the edge of an encroaching desert with

overall decline in biodiversity, our garden provides a buffer zone and a realistic chance for ex-situ and in-situ conservation.

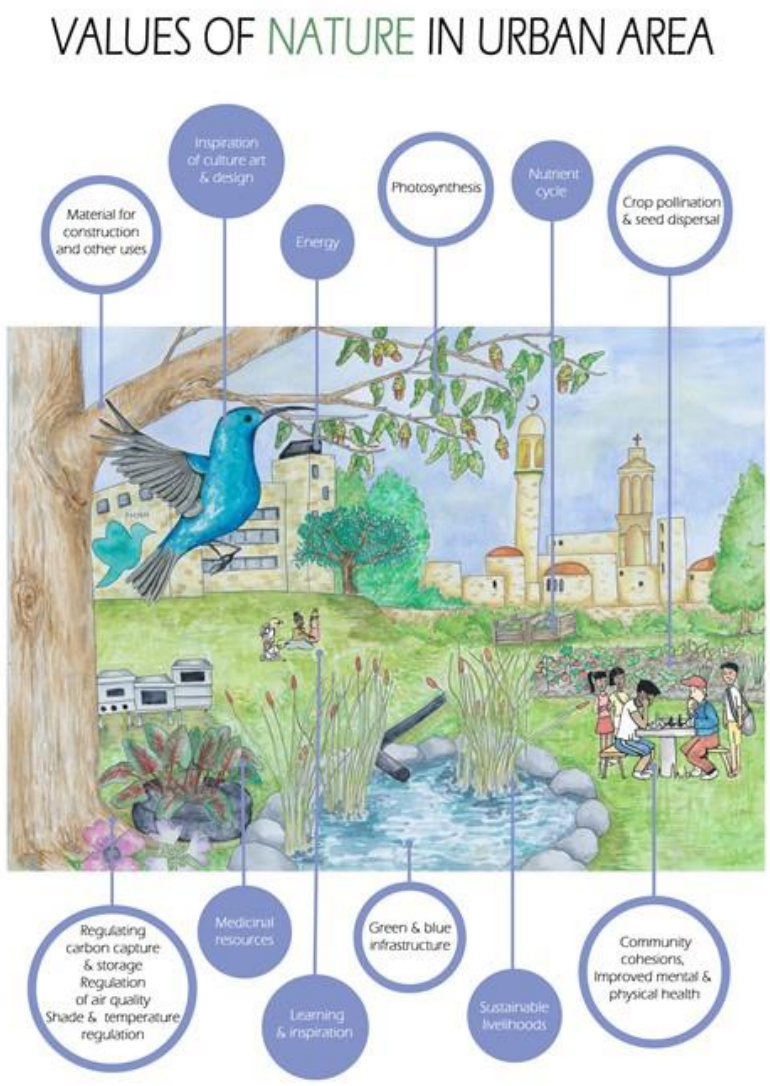

Figure 6. Summary of value of Nature in urban areas.

Urban gardens are important to benefit the local communities (Krasny and Tidball 2009) but can bring back the diversity of fauna and flora into cities, as a consequence it enhances ecosystem services which indicates the value of nature in urban areas (McLain et al. 2012). Yet, some urban gardens enhance biodiversity but many don't (Loreau et al. 2001). In a study of several French urban gardens of similar size to ours (Shwartz et al. 2014) showed significant enhancement of biodiversity in gardens that have some positive interventions. In our case, the data provided above showed significant enhancement to biodiversity in this small garden over the seven years of its establishment with now 432 species which is more than what is recorded in a the nearest protected area with similar habitats (Qumsiyeh et al. 2023). Yet, the involvement of people in our case via having educational modules, a community garden and children exploration playground

was significant, with thousands having already benefited. As noted by others (Mougeot 2006; Pearson, Pearson and Pearson 2010), this creates ecological citizenship, environmental restoration and remediation.

In conclusion, the data support the idea that wildlife/native friendly gardening increase biodiversity including in urban gardens (Pardee and Philpott 2014). The garden rapidly evolved over the past few years and we accumulated data on its uses, not just in terms of an urban and community garden but for in situ and ex situ conservation. The data collected show promise for local authorities and stakeholders' ability to meet international targets, but can also serve as a model for other developing countries especially those facing difficult political and/or socioeconomic circumstances. The lessons learned from it that could be applicable to other communities and countries, and potentiality for replication of successes while learning from mistakes. The future plans for the garden include a section where domesticated varieties are planted next to their ancestral varieties, which emphasizes the development of these varieties. It would also include an expansion of our existing molecular work to include studies of molecular phylogeny of local agrobiodiversity and the potential domestication of other food crops from this Fertile Crescent.

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