AGROFORESTRY FOR PALESTINE

GOOD TREES FOR A BETTER FUTURE

by

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Table of Contents

AGROFORESTRY FOR PALESTINE 1

Preface 8

CHAPTER I 10

An historical overview: Our relationship with trees in Palestine 10

CHAPTER II 26

What can trees do for you? The ecology of woodlands 26

Perennial vs. ephemeral plants - Why plant trees not vegetables? 26

Woody vs. herbaceous perennial plants 27

Nutrient cycling in a woodland ecosystem 28

Nitrogen fixation 28

Mineral mining 28

Biomass accumulation 29

The value of ecosystem diversity 29

Diversity = Choice 29

Diversity = Resilience and Continuity 29

Temporal diversity: Phenology 30

CHAPTER III 32

Design Methodologies and Cultivation Techniques 32

Permaculture design methodology 32

What is Permaculture? 32

Observation 32

Zonation 33

Structural elements of agroforestry systems 34

Swale 34

Terrace 38

Gabion 39

Roads 40

Mulch 40

Agroforestry techniques 42

Propagation 43

Grafting - vegetable alchemy 46

Alley cropping 49

Food forests....49
CHAPTER IV....53
Design templates....53
West Bank citys' altitudes and annual rainfall....53
1. Food forest for the highlands....54
Sketch of design template for a highland food forest....61
Tree species list for the highland food forest....62
2. Food forest for the lowlands....69
Sketch of design template for a lowland food forest....69
List of tree and vine species for a lowland food forest....70
3. Foresting the desert: ecological restoration of a landscape....78
How to hold back the desert....82
Sketch of design template for a desertification resistant forest....90
List of tree species recommended to reverse desertification....90
4. Phytoremediation for poor quality water sources: sewage, salt, greywater....94
Greywater Irrigation....94
Sewage and urban runoff irrigation....95
Saline springs....96
Desalinating species for Palestine....97
CHAPTER V....99
Tree Species Profiles and Illustrative Plates....99
Featured Tree Species....99
Key to featured species profiles....99
***Acacia tortilis* - Umbrella Thorn**....101
Balanites aegyptiaca - Desert Soapfruit....103
Ceratonia siliqua - Carob tree....105
Crataegus azarolus – Azarole....107
Faidherbia Albida - Winter Thorn....109
Leucaena leucocephala - Leucaena....111
Moringa peregrina - Palestinian Moringa....113
Pistacia palaestina - Terebinth....115
Quercus calliprinos - Kermes Oak....117
Tree Species' Profiles....119

Acacia nilotica......119
Acacia raddiana......119
Acacia tortilis......119
Albizia lebbeck - Lebbeck......119
Arbutus andrachne......120
Atriplex halimus - Sea orache......120
Balanites aegyptiaca......120
Bauhinia purpurea......120
Calotropis procera - Dead Sea fruit......120
Carya illinoinensis - Pecan......120
Cassia fistula - Cassia......121
Casuarina cunninghamiana - River She-oak......121
Casuarina equisetifolia......121
Casuarina glauca......121
Ceratonia siliqua......121
Chamaecytisus palmensis - Tree Lucerne......121
Citrus x limon - Lemon......121
Citrus maxima - Pomelo......122
Commiphora gileadensis......122
Commiphora myrrha......122
Cordia sinensis......122
Crataegus aronia......122
Crataegus azarolus – Hawthorn......123
Cupressus sempervirens......123
Cydonia oblonga - Quince......123
Cytisus proliferus......123
Dalbergia sissoo......123
Delonix regia - Flame tree......123
Diospyros kaki - Persimmon......123
Eriobotrya japonica - Loquat......124
Faidherbia albida......124
Feijoa sellowiana aka Acca sellowiana......124
Ficus carica - Fig......124

Geoffroea decorticans ... 124
Grevillea robusta aka Southern Silky Oak ... 124
Gleditsia triacanthos inermis aka Thornless Honey Locust ... 125
Jacaranda mimosifolia ... 125
Jasminum officinale - Jasmine ... 125
Juglans regia - Walnut ... 125
Leucaena leucocephala - Leucaena ... 125
Macadamia tetraphylla - Macadamia ... 125
Malus domestica - Apple ... 126
Mangifera indica - Mango ... 126
Moringa oleifera ... 126
Moringa peregrina ... 126
Morus alba; M. nigra; M. rubra - Mulberry ... 126
Musa acuminate - Banana ... 127
Nicotiana glauca ... 127
Olea europaea - Olive ... 127
Persea Americana - Avocado ... 127
Phoenix dactylifera - Date ... 127
Pinus pinea - Pine ... 127
Pistacia atlantica - Mastic tree ... 127
Pistacia lentiscus - Mastic tree ... 128
Pistacia palaestina ... 128
Pistacia vera - Pistachio ... 128
Portulaca oleracea - Purslane ... 128
Prosopis juliflora ... 128
Prosopis nigra ... 129
Prosopis alba ... 129
Prosopis juliflora ... 129
Prosopis tamarugo ... 129
Prunus armeniaca - Apricot ... 129
Prunus avium - Wild cherry ... 130
Prunus domestica - Plum ... 130
Prunus dulcis - Almond ... 130

Prunus persica - Peach....130
Prunus persica nucipersica - Nectarine....130
Punica granatum - Pomegranate....130
Psidium guajava - Guava....130
Pyrus communis sativa - Pear....131
Pyrus persica....131
Quercus calliprinos....131
Rosa x damascena - Damask rose....131
Salicornia bigelovii - Dwarf glasswort....131
Sclerocarya birrea ssp. caffra - Marula tree....131
Salvadora persica....131
Styrax officinalis....132
Tamarix aphylla....132
Tecoma stans - Tecoma....132
Terminalia catappa - Bastard almond....132
Tipuana tipu....132
Vitis vinifera – Grape Vine....132
Ziziphus jujuba....133
Ziziphus lotus....133
Ziziphus spina-christi....133
Acacia nilotica....134
Acacia raddiana....134
Bauhinia purpurea....136
Cslotropis procera....137
Crataegus aronia....140
Delonix regia....141
Ficus carica....142
Geoffroea decorticans....143
Jacaranda mimosifolia....144
Morus ruba....145
Olea europaea....146
Persea americana....147
Phoenix dactylifera....148

Pistacia vera 149
Prosopis juliflora..........150
Prunus armeniaca..........151
Prunus amygdalus 152
Punica granatum..........153
Salvadora persica 154
Styrax officinalis..........155
Tamarix aphylla..........156
Tipuana tipu 158
Vitis vinifera 159
Ziziphus lotus..........160
Ziziphus spina-christi 161
Glossary of terms 162

Preface

Offering shelter, food and fuel, trees have always provided our species with essential resources and continue to do so today. The history of the management of trees in the Palestinian landscape began as soon as *Homo sapiens* first set foot on the soil: forest clearance - first with fire and later with stone axes - began the inexorable change to the face of the land, and subsequent herding, farming, urbanisation, and industry accelerated the decline of forest cover, exposing the soil to erosion. As the resource-rich forests were transformed into desert, communities became poorer, eventually abandoning their homes - people were forced to move on to find the resources they needed to survive.

Understanding the consequences of **deforestation**, and that the application of informed management could restore the abundance of the forest, laws were enforced to prohibit cutting and farmers began to plant trees in their gardens. The diversity of trees in cultivation has increased over the millennia as trade relations brought cultivated species from Africa and other parts of Eurasia. Olive was the first species to be farmed extensively and, with the vine, continues to be economically significant. The selection of fruit characteristics by generations of farmers gave rise to a diversity of fruit varieties from the same wild genetic stock and, with the application of hydro-engineering during the Classical and Islamic periods, the area of cultivated orchards extended from the mountains into the dryer lowlands. Up to thirty different fruiting species were in cultivation in a single orchard.

The twentieth century witnessed a collapse of agricultural production in Palestine, especially in **agroforestry**. With the notable exceptions of the British, Jordanian, and Israeli **reafforestation** of the hills around Jerusalem (mostly pine), the orchards and fragments of surviving woodland have been declining, with the hills and valleys reverting to desert and steppe as herders again replace farmers, denuding the land.

Today, agroforestry as a tool for landscape regeneration holds the potential to stop the decline and restore the vitality of the land of Palestine. Simple techniques and appropriate species selection allow us to protect the quality of the environment and improve food and water security, with effects reaching far into the future. There exists no technical nor ecological impediment to reviving the Palestinian agricultural sector with valuable tree crops.

Agroforestry had long been the backbone of the national economy and is the only regenerative form of agriculture. A return to agroforestry practices promises a prosperous future for all. This booklet aims to promote the utility of trees for people today: to provide motivation to protect and extend orchards and woodlands, in order to stabilise the ecology and climate of Palestine for the benefit of its people.


Photo: Orchards of Battir, Palestine

CHAPTER I

An historical overview: Our relationship with trees in Palestine

In Palestine, the earliest evidence of the controlled use of fire comes from excavations at Qesem Cave near Jaffa, where 380,000-year-old fragments of charred bone were discovered around heated soil "hearths". Even before the arrival of *Homo sapiens* and long before the domestication of animals, fire was used by other hominins to engineer favourable environmental conditions, opening forests and maintaining grasslands to nourish herds of gazelle, ibex, auroch (wild cattle), and rabbit to be hunted for food. The controlled use of fire, first innovated by *Homo erectus* between 1 and 1.6 million years ago, continued to transform the structure of vegetation throughout human history.

Homo sapiens first radiated out of Africa into Palestine between 100,000 and 60,000 years ago along the Great Rift Valley, a corridor of familiar African flora and fauna which still extends as far north as the Sea of Galilee. The River Jordan and the Dead Sea lie in this valley. At first, little adaptation was necessary, as the hunting and gathering skills developed in Africa were transferable to the *Acacia* savannah and riparian forests of Palestine.

Photo: Rift valley ecosystem with *Acacia* and *Ibex*

Just like other *Hominins* before them, *Homo sapiens* migrated up and out of the Great Rift Valley and into Eurasia, continuing as far as Australia and eventually reaching the Americas. The altitudinal migration from the rift valley to the highlands of Palestine brought these ancient humans into alien forests of Oak (*Quercus*), Terebinth (*Pistacia*), Carob (*Ceratonia*), Almond

(*Prunus*), and Pine (*Pinus*). Leaving the familiar plants of the Great Rift Valley behind, they familiarised themselves with the flora of the Mediterranean zone where wild pigs thrived and the **pearctic** bird migration provided a regular seasonal glut. For at least 50,000 years our ancestors hunted boar, deer, and auroch in the forests, gazelle and honerger on the steppe, ibex, hyrax, and rabbit in the desert, and fish and waterfowl on the River Jordan. Meat and fish were the major dietary components, but these hunter-gatherers also ate herbs, seeds, and especially tree fruits and nuts. Here they found olive, vine, pistachio, almond, pine nut, jujube, hawthorn, carob, walnut, and a superb diversity of edible herbaceous plants including fruits such as melon and squash.

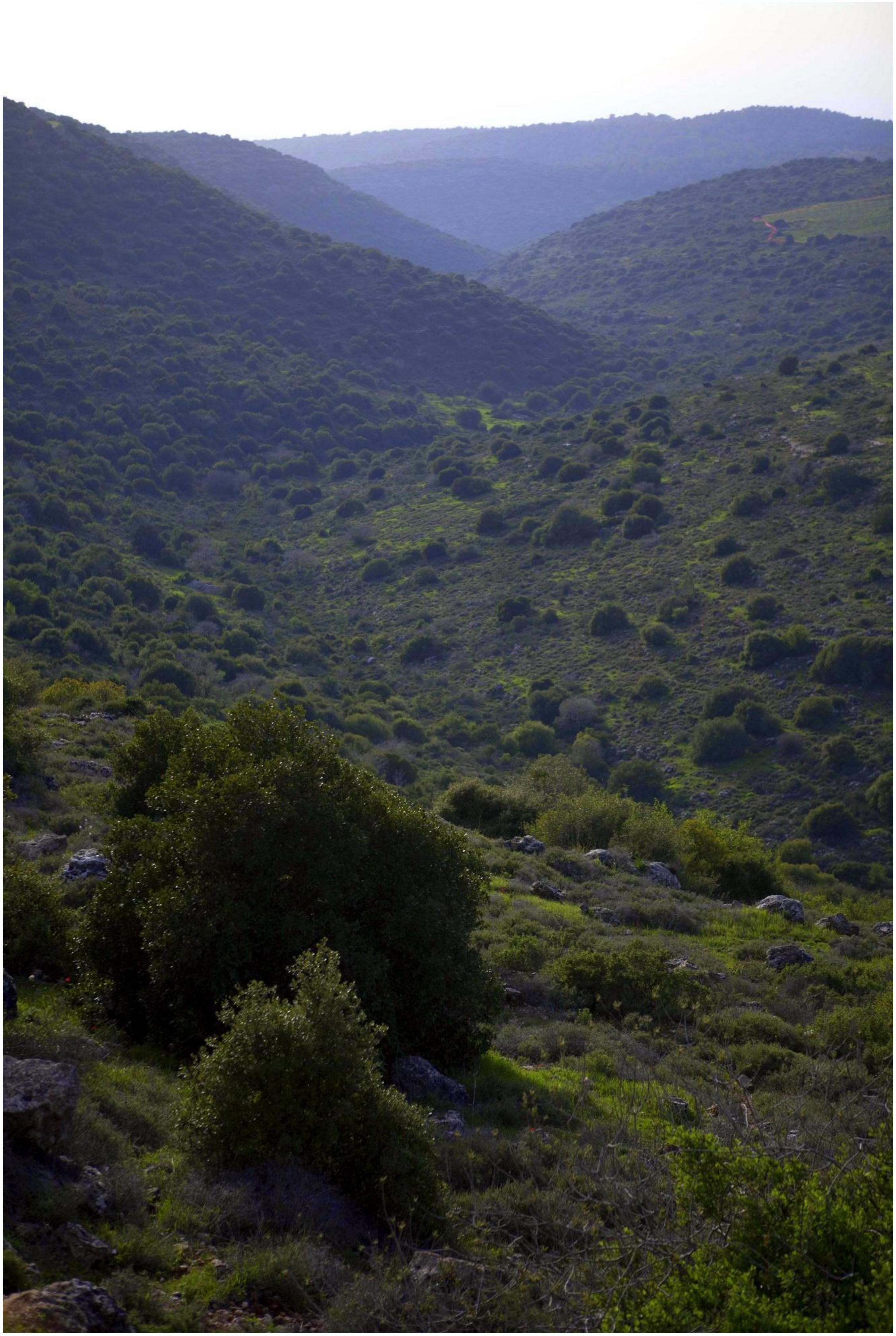


Photo: Oak woodland, *Quercus calliprinos*

The steep altitudinal gradient from the Central Mountain Ridge to the Jordan Valley creates an ecological gradient exaggerated by rain shadow effect. The rainfall sharply decreases from the humid mountains to the arid environmental conditions down in the Rift Valley, halving every couple of kilometres east of the mountain ridge. Because of the global geographic location of Palestine at the meeting of the three continents of Europe, Asia, and Africa, four plant communities of discrete global distribution each occupy an altitudinal range between the mountains and the Rift Valley. Uniquely in Palestine, in a day's walk (35 km) starting on the ridge (from Bethlehem, for example), one can descend through the Mediterranean forests of the Atlantic flora group, through the Irano-Turanian flora of the eastern slope of the West Bank, through the Central Asian steppe flora of the Judean desert and lower slopes of the Jordan Valley, and finally down to the Dead Sea and the flora of the Sudanese penetration zone, a submarine **promontory** of flora of otherwise Northeast African distribution. Each plant group is very diverse, and their close proximity offered a great variety of resources to our ancestors.

Photo: Orchards suddenly give way to desert on the Eastern Slope of the Mountains of Bethlehem. The interface between the Farmer and the Nomad.

It was here in the Jordan Valley and Wadi il-Araba that, for the first time in history, humans ceased migrating and gradually settled in permanent 'villages'. Migration was resource-driven, which is to say people were compelled to move because they were running out of some resource that could not (or would not) live without. Any journey exposes the travellers to dislocation, danger, and fatigue; the likelihood of locating that which is sought is as great as their resource-tracking ability, thus the English proverb "a bird in the hand is worth two in the bush". People would resist unnecessary migration. The proximity and uniquely diverse set of **ecozones** on the eastern slope of the West Bank offered our ancestors, for the first time, the opportunity to gather resources from these four **ecozones** in one sortie. The seasonal abundance of the **boreal ecozones** of the highland valleys combined with dependable springs and the refuge of the mild winter climate of the Jordan Valley allowed for the first sedentary lifestyle in history: about 12,000 years ago, the people known today as the Natufians began to settle in the Jordan Valley. However, a rapid climatic deterioration and cold and dry conditions lasting over a thousand years (the Younger-Dryas) forced a return to a more mobile, subsistence lifestyle.

An end to the drought is thought to have contributed to the increasingly widespread practice of rye cultivation. The earliest evidence of agriculture, around 11,050 BCE, comes from Tell Abu Hureya on the banks of the Euphrates in Syria, where excavations revealed grains of rye and stone-bladed sickles. Extensive evidence of charcoal-making strongly supports the idea that that trees were utilised for fuel as well as for constructing dwellings, and of course fruits and nuts were harvested for food. Consequently, Natufian settlement favoured wooded areas for their abundance of resources.

As herding and agriculture spread and populations grew, the carrying capacity of the land decreased due to anthropogenic degradation. The clearing of woodland with stone axes (first used about five thousand years ago) for timber and fuel, followed by the denudation of the land by burning, ill-managed grazing herds, and the expansion of agricultural practices of soil destabilisation, resulted in massive soil erosion, loss of fertility, and desertification. Even in the Neolithic, populous villages like Ayn il-Ghazzal near Amman show impoverishment leading to abandonment soon after the nearby woodland was cleared, overgrazing denuded the hills, and the soil eroded down into the valleys. However, not until the rudimentary industry and population densities of the Chalcolithic Period did anthropogenic environmental stress become the principal agent of the collapse of entire civilizations. Hitherto communities migrated along resource gradients to relocate in a region of more intact woodland **ecosystems**.

Technological innovation and the associated cultural changes brought an ever-increasing demand for tree resources. Not only were population densities increasing as the carrying capacity of the land was decreasing, but farming produced a surplus which allowed the first craftsmen (and women) to specialise in particular industries. Industry requires fuel, and from the Late Neolithic onwards the fuel demand per capita increased over millennia. The trees supplied the fuel. The manufacture of house plaster required fuelwood and charcoal to fire the lime kilns. It is estimated that eight times the quantity of wood used structurally in the home was required to fuel the making of plaster.

The water demand of populations in urban centres continued to grow. The short winter rainy season followed by a seven- or eight-month-long dry summer, necessitated the harvesting and storage of rainwater in plastered cisterns and pools. The Natufians constructed reservoirs beside dry river channels which filled when the river flooded. Examples can still be seen in the Wadi il-Khreitun near Bethlehem. During the Neolithic, about 6,000 years ago, villagers constructed lime plastered cisterns under each dwelling, as are found at Ramad and Lebwe. The first cities or "land-use-zoned villages" like Tell Be'er Sheva (the ancient settlement of Birsebah) in the northern Naqab Desert constructed massive communal rainwater storage cisterns cut from the rock and lined with lime plaster from about 6,000 years ago. The stored water served domestic sanitation and cooking, but also extended the farming season in this arid region.

Although ceramic technologies date back 27,000 years, pottery as cooking vessels do not appear in the archaeological record until sedentary settlement patterns are adopted. In the Levant the earliest pottery dates from about 9,000 years ago - contemporary with the proliferation of agriculture. Demand for the high temperatures required for firing pottery in a kiln added to the existing demand for wood for warmth, construction and cooking.

The metallurgical industries were necessarily located in the remaining forested areas to exploit the convenient source of fuelwood. However, harvesting the wood from the trees without allowing for regeneration resulted in an unsustainable demand for fuel. The forests near the industry were gradually cut back, for example *Acacia* from Wadi Faynan in the Araba Valley and Timna on the Red Sea where the fragile arid **ecosystems** of the Rift Valley were especially vulnerable due to their slow regeneration rate. This resulted in the fuelwood having to be transported over ever-greater distances, incurring ever-increasing costs. Finally, either the cost of transporting the fuelwood or the total exhaustion of the regional forests lead to the abandonment and relocation of many ancient industrial centres. The decline was catalysed by the increasing value of the remaining fuelwood, which economically incentivised the exploitation of more remote forests in a positive feedback loop toward total **deforestation**.

The regeneration of the forests was largely prevented by the grazing of herds, especially goats, whose mouths and grazing habits remove even the spiniest vegetation. The ancient practice of burning to maintain and extend spring grasslands for grazing herds, first wild and later domesticated sheep, goats, and cattle, reinforced the grassland/savannah/desert disclimax **ecology**. The continued expansion of cereal agriculture driven by population growth, and arguably facilitated by climate change, demanded a greater area of land be brought into cultivation.

Photo: Herd of goats and sheep Arab Al-Zuweidin, Palestine

The Eastern Mediterranean, Western Asia and North Africa had become so extensively deforested by the Mid Bronze Age, between 5,000-4,000 years ago, that timber became a strategically-important commodity traded between kingdoms over thousands of kilometres. The remaining Levantine forests were plundered by the Sumerians from Mesopotamia around 2700-2500 BCE to fuel the growth of cities (as related in the Epic of Gilgamesh). Understanding that deforestation was the cause of land degradation and impoverishment of the kingdom, Hammurabi King of Babylon introduced laws, around 1750 BCE, which carried the death penalty for unauthorized felling of trees. These are the earliest known efforts to conserve the forest resources.

The arid climate of North Africa exacerbated the rapid overexploitation of forest resources, resulting in a shortage in supply of timber and fuelwood in the area. From about 5,000 years ago the early Egyptian kings of the Nile extended their influence over the Eastern Mediterranean Sea - having exhausted the forests of Egypt, the Ancient Egyptians depended on imported timber traded from the Levantine port of Byblos to build a navy whose dominance of maritime trade in the Mediterranean lasted a thousand years.

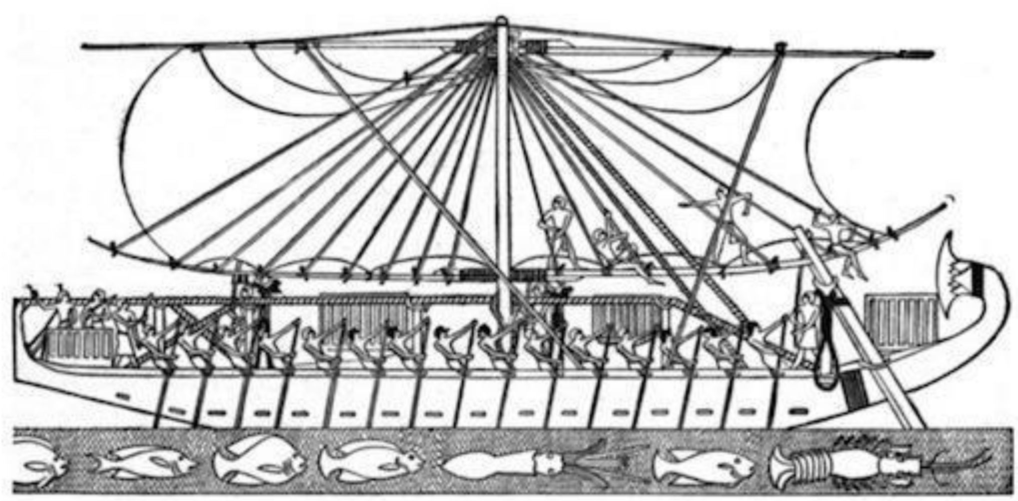


Image: Drawing of an ancient Egyptian naval vessel


Photo: ancient olive tree, near Jenin

Already, long before the Classical Period of history, the land of Palestine was mostly denuded of vegetation. The resulting soil erosion and drying of the climate degraded the environment. Tree pollen analysis of the sediments of the Sea of Galilee and the Dead Sea show a significant reduction in all trees in the landscape except for the olive tree (*Olea*), which became more common around 3,500 years ago. This is interpreted as the first evidence of olive cultivation to substitute the products of the lost forests, and is direct evidence of the earliest practice of agroforestry in Palestine, although it may have originated much earlier. Carbon dating has aged ancient olives growing in Palestine today as being between 1,600 and 5,000 years old. The upper age estimates are not corroborated by all ageing techniques and so are still questionably accurate. Some trees, or at least their **rootstock**, may even be survivors of the wild olive trees of the Mediterranean forests. As well as being the first cultivated tree crop in Palestine, the olive remains the most economically significant up to the present.

In the lowlands the date palm became an important tree crop. 7000 year old date palm seeds are found in the archaeological record In Iran, Egypt and Pakistan but these are thought to originate from wild plants. There is evidence of date palm cultivation in today's Iraq from 4000BCE. When the date palm was first cultivated in Palestine is unknown but by 2500BCE the Palestinian lowlands were renouned for their date palm industry.

Photo: Date palm, Jordan Valley

The Bible's Old Testament describes the status of the environment in the Iron Age and includes much information on the agricultural and pastoral customs of that period, including details of agroforestry products traded internationally. The main themes are:

- the previous wealth of the land and its subsequent degradation
- sustainable exploitation and over grazing
- the understanding that humans are the driving force of this “defilement” of the natural bounty of the forests is explicit

“I brought you into a fertile land to eat its fruit and rich produce. But you came and defiled my land and made my inheritance detestable.” (Jeremiah 2:7)

"Hurt not the earth, neither the seas nor the trees" (Rev. 7:3)

“God will destroy those who destroy the earth" (Rev. 11:18)

"If not for the trees, human life could not exist" (Midrash Sifre to Deut. 20:19)

“He heweth him down cedars, and taketh the cypress and the oak, which he strengtheneth for himself among the trees of the forest: he planteth an ash, and the rain doth nourish it.”
(Isaiah 44:14)

“Howl, fir tree; for the cedar is fallen; because the mighty are spoiled: howl, O ye oaks of Bashan; for the forest of the vintage is come down.” (Zechariah 11:2)

“And a letter unto Asaph the keeper of the king's forest, that he may give me timber to make beams for the gates of the palace which appertained to the house, and for the wall of the city, and for the house that I shall enter into. And the king granted me, according to the good hand of my God upon me.” (Nehemiah 2:8)

“Moreover he built cities in the mountains of Judah, and in the forests he built castles and towers.” (Two Chronicles 27:4)

“By thy servants hast thou reproached the Lord, and hast said, By the multitude of my chariots am I come up to the height of the mountains, to the sides of Lebanon; and I will cut down the tall cedars thereof, and the choice fir trees thereof: and I will enter into the height of his border, and the forest of his Carmel.” (Isaiah 37:24)

“The land is mine and you are but aliens and my tenants. Throughout the country that you hold as a possession, you must provide for the redemption of the land.”(Lev. 25:23-24)

“The earth dries up and withers, the world languishes and withers, the exalted of the earth languish. The earth lies under its inhabitants; for they have transgressed the laws, violated the statutes, and broken the everlasting covenant. Therefore a curse consumes the earth; its people must bear their guilt.” (Isaiah 24:4-6)

“As they sat down to eat their meal, they looked up and saw a caravan of Ishmaelites coming from Gilead. Their camels were loaded with spices, balm and myrrh, and they were on their way to take them down to Egypt.” (Genesis 37:25)

This latter quote refers to the products of *Commiphora gileadensis* (balsam) and *Commiphora myrrhensis*.

The ecological disaster, precipitated by the deforestation in the Late Bronze Age, continues to influence the **ecology** of the region. The flooding and massive soil erosion from the hills caused the silting of coastal ports and cities throughout the Iron Age and into the Classical Period. Terraces and gabions were constructed to stabilise the soil on the slopes and along the course of ephemeral streams. In Roman times rainwater harvesting and storage technologies were applied on a scale never before witnessed in Palestine, comprising channels, aqueducts, reservoirs and domestic cisterns. The reign of Herod the Great around the year zero is noted for scientific innovations in waterproof plaster and the inverted siphon. A network of rainwater harvesting channels, springs, and aqueducts supplied the population centres. Roman rule brought relative peace to this region, or at least fewer destructive wars and invasions. Agroforestry diversified into novel crops and spread into more marginal areas, becoming the most economically significant activity.

Cultural continuity and economic stability were maintained during the transition from the Roman into the Byzantine period. This stability increased as the region found itself closer to the centre of the empire, which by this time was Constantinople. The adoption of Christianity as the official imperial religion also focused more imperial resources and attention on the “Holylands” as the setting of the events reported in the Bible. Byzantine rule encouraged population growth and trade, and wealth generated by agroforestry was reinvested into the landscape as the cultivable zone was further extended down into the deserts by application of rainwater harvesting and **soil humidity** conservation techniques. Tax breaks were designed to encourage the landowners to improve marginal land, especially olive cultivation on terraces. Land was taxed according to the soil fertility and annual rainfall: those cultivating the poorest, driest soils paid the lowest (or even no) taxes.


Photo: Byzantine rainwater storage cistern

Between 400 CE and 700 CE, 78 monasteries were built in the Judean, Naqab, and Sinai deserts. Practising dryland farming of drought resistant tree crops and trading craft items for saltfish, these monasteries survived in harsh arid environments for centuries: The Monastery of St. Sabas (Mar Saba) has been continuously inhabited for over 1,500 years. In most cases, these monastic communities were gradually abandoned, never to be revived as Byzantium declined and the region became a frontier territory once again.

Photo Monastery of St. Sabas (Mar Saba), near Bethlehem

The Naqab Desert saw the rise of a civilisation of farmers and traders called the Nabateans. Nabatea comprised a network of long-distance trade routes along which camel caravans travelled from fortified city to fortified city, bringing valuable commodities like spices and especially incense from *Felix Arabia* to the port of Gaza, where they traded with Rome and Ptolemaic Egypt.

Photo: Central reservoir of the Nabatean city of Sobeita

Out of necessity, the Nabateans devised a dryland agriculture of trees and cereals in a region with no oases or rivers and only 50 to 120 mm/msq/yr rainfall. Orchards were established in the fertile valleys where the **runoff** was augmented by a series of channels harvesting rainfall from the desert slopes, each orchard harvesting rain from an area eighty times the area of cultivation. The urban space was also planned to harvest and conserve rainwater, with a radial network of channels supplying a central reservoir. In the city of Sobeita archaeologists have discovered evidence that taxes could be paid in goods or in hours spent labouring to maintain the city's rainwater harvesting infrastructure. This period (Late Classical) is considered the apogee of agroforestry in Palestine. Agricultural productivity and international trade supported rural population densities exceeding today's.

Photo: Nabatean Desert Orchard, Shivta (Sobeita)

The Islamic Period was a time of relative instability after the Classical Period. Many dryland agricultural communities were finally abandoned. The Roman and Byzantine periods' urban infrastructures were maintained and even enhanced, but the continuing practice of degenerative agricultural practices like ploughing and burning, combined with overgrazing, further impoverished the land.

In the twenty-first century we are better equipped to deal with environmental resource management than ever before. Food and water security are integral to building an economy of resistance; **reafforestation** of the land will conserve species, soil, and water, and allow a gradual regeneration of the **ecosystems** upon which we depend. Ultimately, all wealth is derived from the **landbase**. Today, as often in the history of this land, military occupation and the abuse of colonial power accelerate the rate of environmental degradation - however, harvesting and growing resources *in situ* is a practical way to respond to the coercive potential of the alien control of vital infrastructure. Rainwater harvesting and vibrant orchards and woodlands hold the potential to supply for all our physical needs, and more besides.


Photo: Contemporary food forest

CHAPTER II

What can trees do for you? The ecology of woodlands

Woodland ecosystems are a diverse community of plants, fungi and animals. Each species has a role to play. As a woodland ecosystem matures the community changes demographically and becomes more diverse. The microclimate is transformed as the trees slow the wind, provide shade and increase humidity. Woodlands play host to great diversity of plant growth forms including herbaceous plants and bulbs in the ground layer, shrubs and small trees under the tall canopy trees. A variety of herbaceous and woody vines climb through the shrubs and trees. This variety of plants provides opportunity harvest multiple products in the same area of land. The diverse crops and high productivity of tree farming as long been exploited arid areas, including Palestine but modern agriculture is increasingly dominated by few vegetable crops ill-suited to this environment. Costly and unsustainable agricultural practises are accelerating the degradation of the Palestinian environment and contribute to the decline of Palestinian farming.
In this chapter the intrinsic characteristics of woodlands are contrasted with vegetable, cereal and pasture cultivations. The advantages and opportunities of including trees in farm and garden design recommend agroforestry for regenerating the landscape and recovering the vitality of the agricultural economy of Palestine.

Perennial vs. ephemeral plants - Why plant trees not vegetables?

Many **perennial** plants will live as long as a human life, and many much longer. Long-lived plants invest in their environment: they are selfishly interested in building a comfortable environment around them (cp. nitrogen-fixing trees). This is why **perennials** invest their resources into trapping **humidity**, enriching soil and ameliorating the **microclimate**. **Perennial** species achieve this by forming mutually-beneficial relationships with other organisms in their **ecosystem**. The net result is a gradual accumulation of resources and increased environmental stability. We can use this characteristic of **perennial** species and work with them to gather a wealth of resources around us and our homes. By contrast, **ephemerals** are exploitative of their environment and in competition with their neighbours. The **ephemerals** are adapted to enter **ecosystems** by taking advantage of environmental disturbances such as fire, landslides, river erosion, and tree falls. They need to live fast and die young, spreading their seed as widely as possible to have a chance of reaching a freshly-disturbed area. They are racing against recolonisation of the disturbed area by the next biological community in the **ecological succession**. They have no “choice” but to grab what they can and move on before they are squeezed out by species adapted to out-compete them. They do not invest their resources in their environment because they will not be there long enough to reap benefits. All cereals, almost all vegetables and a few short-lived trees (*Nicotiana glauca, Ailanthus altissima*) are exploitative, requiring a farmer to maintain a destabilised ecosystem of diminishing resources for their cultivation (eg. ploughing, clearing, and burning). Over eight thousand years of expanding agricultural practice, the entire West Bank has been converted into a degenerate landscape, haemorrhaging water, soil, and **biodiversity**. As agricultural practices, now powered by fossil fuels, have become more extensive and mechanised, so has the rate of environmental degradation - of these only **perennial** plants can restore the wealth of the **landbase**. This is not an argument for the exclusion of **ephemerals** but, on the contrary, for their inclusion within an integral community of **perennial** plants, especially trees.

Woody vs. herbaceous perennial plants

Woody plants reinforce their cellulose structural tissues with **lignin**, making wood; herbaceous plants do not. In Palestine many herbaceous plants retreat underground to endure the long dry summer months, abandoning their aerial parts to **herbivory** (eg. A*sphodelus*). These aestivating species are often poisonous. Fewer, better-defended herbaceous plants rest underground during the short, cold winter months, producing new growth in the Spring, replete with spines and thorns to fend off hungry mouths (eg. Capparis). Because, structurally, herbaceous species are usually smaller and simpler (produce no trunks or branches), they tend to provide fewer **ecological niches** for exploitation. Cultivations of herbaceous **perennials** like pasture fields or asparagus plots sustain simpler, poorer **ecosystems** than do orchards or forests.

The main functional difference between woody and herbaceous plants is the microclimatic services they provide:

- Winter Rainfall Interception and Infiltration

  The three-dimensional complexity of the trunks, branches, and leaves of woody plants mediates the interception of falling rain, slowing the rate at which water reaches the soil. This is very significant because any soil has a maximum water infiltration rate. When this is exceeded by the rate at which water arrives at the soil, **runoff** occurs. The amount of **runoff** is the difference between water arrival rate and the soil infiltration rate multiplied by the duration of the rainfall. Woody plants intercept the rainfall so the water takes longer to reach the soil. Therefore the soil infiltration rate is less likely to be exceeded - and, if exceeded, it is for a shorter duration. The result is a significant or complete reduction of **runoff**, compared to areas where no interception occurs. The more complex the woody structure of the **ecosystem**, the higher proportion of the rainfall enters the soil to be stored as **soil humidity** for the following summer season.

- Summer Water Conservation

  The woody plants slow and diffuse the wind and reduce the velocity of air currents through crops and over the surface of soil. Herbaceous crops provide much less friction to reduce wind speeds. This is significant not only to prevent structural damage to the crop but also because wind is drying - slower wind speeds mean a slower rate of desiccation, of both plants and soil. A litter layer of fallen leaves, flowers etc. from these woody plants also covers the surface of the soil under trees; this litter layer provides a physical barrier to the evaporation of **soil humidity** either due to wind desiccation or heat from the sun. Furthermore, the shade cast by trees and vines protects the plants and soil beneath the trees directly from the heating effect of the sun, reducing the **transpiration** and evaporation rates and, therefore, conserving **soil humidity**.

In summary, trees, shrubs and vines are much better at harvesting and conserving water in an ecosystem than are herbaceous perennials or ephemerals.

Nutrient cycling in a woodland ecosystem

As well as harvesting energy from the sun trees play a key role in nutrient and mineral cycling. Because of their size and longevity more nutrients flow through trees than any other group of organisms in woodland. Powered by the sun and recycled by the decomposer microbes trees share their nutrient pool when their tissues decay to build soil. Essential nutrient cycles performed by trees include:

Nitrogen fixation

One of the most important features of trees in building a comfortable environment around them is the fixation of atmospheric nitrogen, N_2. Nitrogen fixation is the conversion of N_2, unusable to plants, to nitrate (NO_3^-), which plants can uptake and utilise, by nitrogen-fixing bacteria – particularly the **Rhizobia**. These form symbioses with certain trees in return for sugars and a stable growth environment inside their **nodulated** roots. NO_3^- is highly mobile in the soil, and thus is easily lost. It is often a limiting factor of plant growth, particularly in the old and relatively static soils of Palestine , and therefore nitrogen fixation, facilitated by these trees, is crucial for high crop yields.

Most soils used in agriculture worldwide are fertilised with synthetically fixed nitrogen to achieve higher yields. These fertilisers are expensive, and their production requires a huge amount of energy and generates a huge amount of waste. Through the planting of nitrogen-fixing tree species, the soil can be improved in an environmentally sustainable way, and the purchase of additional fertilizers can be reduced significantly or even become redundant.

Mineral mining

Mineral mining, when referring to an agroforestry system, describes the process of bringing minerals to the surface of the soil. Deep-rooted trees gather minerals from deep soil layers to sustain their growth. Through the decomposition of dead plant material, other plants can profit from these mineral-mining trees.

Biomass accumulation

Nitrogen fixation and mineral mining both depend on biomass accumulation. Fast-growing trees produce a higher amount of biomass containing nitrogen and minerals from deep soil layers. In contrast, slow growing species, even if they are deep-rooted or nitrogen-fixing, contribute much less to creating or maintaining nutrient-rich soils. Therefore, a high rate of biomass accumulation is just as important as the ability of a tree to mine minerals or to facilitate nitrogen fixation.

The value of ecosystem diversity

Diversity = Choice

- The inclusion of trees into a farm system presents the farmer with many options: beyond selecting the varieties of tree to plant, the farmer can choose the varieties of vine to grow up the trees and the varieties of **sub-canopy** trees and shrubs to be planted in the shade created by the trees. Only by including all growth forms of tree (root crops, salads, vegetables, shrubs, vines, trees, and palms) can the high productivity of the **stratified ecosystems** of the natural forests be achieved, where layer upon layer of specialised communities of plants and animals share the soil's resources and the sunlight. Those adapted to survive at the top receive most light but are far from the soil moisture, whereas **shade plants** beneath enjoy **humidity** stability but are adapted to receive less the sunlight filtered through the leafy **strata** above.

- Wooded **ecosystems** offer a greater diversity of **ecological niches** than any other land **ecosystem**; agriculturally, these niches represent opportunities to diversify the farm's crop production. The more crops a farm produces the more **ecologically** stable and resilient the farm will be. An efficient and resilient cropping system is also an economically stable and resilient farm system. Only through the inclusion of new or rediscovered marketable species will farmers gain the experience required to discern between suitable varieties and gain skills of cultivation, harvesting, and marketing. Because woodlands and orchards are both physically and biologically more **heterogeneous** than herbaceous crops they offer a wide range of **ecological niches** in which to trial a new crop. Observation of the new crop's performance in a number of different circumstances will direct the farmer to the best planting conditions she can offer it on the farm - a comparison not available to the vegetable or monoculture farmer. Monocultures offer one or very few distinct niches for crop plants.

Diversity = Resilience and Continuity

High structural and biological redundancy means having many elements or species to perform each key function. For example, if the farm relied economically on the success of a single crop, then failure of that crop (due to weather or disease or, in a good year, due to the flooding of the market) will bring an economic crisis to the farm. A farm with two or more key crops will be less prone to economic stress. Likewise a farm system with only one strategy to access water, for example a connection to the local piped water provider, is vulnerable to any disruption to the service. A farm designed to harvest and store rainwater has reserves to fall back on when piped water access is interrupted or withdrawn. This same principle applies to all the **ecological** relationships functionally supporting the farm's productivity.

Temporal diversity: Phenology

Phenology is the study of the patterns of plant behaviour. Most, but not all, plants produce leaves, flower, fruit, and drop their leaves in rhythm with the year's seasons. Some flower do so only once and then die, but that lifespan varies from as little as a few weeks (mustard), to a few decades (*Agave*). There are **deciduous** species like the almond and **evergreen** species like the carob. There are winter **deciduous** species like the fig and summer **deciduous** species like the *Moringa*. Most plants flower seasonally, mostly once a year in the spring or in the autumn (*Uringea maritima*), and others flower continuously while conditions allow (*Passiflora*), while still others flower repeatedly in a cycle lasting only weeks (for example *Leucaena* flowers and fruits six times a year in Bethlehem).

Knowledge of the pattern and rhythm of each species' behaviour helps the farmer to select species to assemble communities of crop plants which will do what she wants them to when she wants them to. For example, in order to ensure that the desired winter rainfall interception occurs, species which are in leaf during the rainy season (November to March) are planted in sufficient number. Conversely, if summer **transpiration** needs to be mitigated to avoid dry soil conditions then species of a summer **deciduous** character are selected for inclusion on the farm. Where a continuous supply of food from the farm to the table is desired then a range of varieties ripening and readying for harvest in succession through all twelve months of the year are chosen for planting. By planning for continuous production with fall-back options, a lean season is avoided.

Where trees are to be integrated into a vegetable production system, the patterns of light intensity require consideration. Winter vegetables require minimal shade as daylight intensity is lowest during the winter months. Conversely, summer crops benefit from the sheltering shade cast by trees, protecting them from the powerful summer sunshine. A winter **deciduous** tree or vine meets both criteria for inclusion with vegetables.

In mixed farming systems, animal forage production is often a farm priority. Where the animals are sedentary and remain part of the farm system all year, then fresh food can be produced for them all year, eliminating the requirement and economic burden of purchasing fodder crops. By including a great variety of species, especially continuous and repeat flowering species, a small farm can also achieve a continuous and uninterrupted supply of nectar and pollen to feed bee colonies every day of the year.

Photo: Honey bee foraging from a Mesquite (*Prosopis juliflora*) flower.

Cows, sheep, and goats can also enjoy a diet of fresh forage continuously produced by selecting species which produce new growth sequentially through the calendar. Because of the great range of climate zones and soil types in Palestine a single species' phenology varies with geographic location (for example grapes ripen in June in the Jordan Valley and in October in Bethlehem). Only through observation of the species' behaviour in the local area or by planting and observing *in situ* can we know how to expect the plant to behave on our land.

CHAPTER III

Design Methodologies and Cultivation Techniques

Permaculture design methodology

What is Permaculture?

Permaculture is a methodology for consciously designing regenerative systems. The relationship between humans and their environment is central to permaculture design. By observing how we use our resources we can design systems that increase the efficiency with which resources are transformed into yields at the same time as increasing future resource abundance. Applied to agroforestry, permaculture provides a step by step methodology for creating living systems to provide ourselves and our communities with, water, food, fuel and building materials as well as mitigating the risk of wildfire and disease. In implementing a permaculture design we start small and develop the design over time never requiring more resource than is at our disposal at any time. A well designed system will grow, gaining in wealth and efficiency with time.

Observation

Of primary importance to the **permaculture** design methodology is a long and protracted observation of flows both on and influencing the site. Flows are defined as external energetic forces and material flows into, out of, and through a system which inform, support, constrain, influence and damage the metasystem of the design project and its aims. We can focus, amplify and **ameliorate** these flows by spatial and conceptual design responses.

Designer's checklist for site analysis

- Elevation
- Temperature: winter minimum and summer maximum
- Rainfall: annual average and variability
- Soil type: use maps or test kit - generally the darker the soil the better it is
- Soil depth

- Aspect (only if there is a slope)
- Plant communities: any trees, and if so which?

Sector analysis

An area's sectors are defined as those **psychical** areas in which particular flows' periods, frequency, strength, and influence are felt:

- Fire: direction and intensity of hazard
- Water: rainfall, **runoff**, **soil humidity**, water storage volumes, external water resources (piped ground water)
- Access: entrance and exit nodes, vehicular access, pedestrian circulation and demonstration stations
- Sun: seasonal and diurnal variation in period intensity and the shifting extent of shade and shadows
- Wind: seasonality, direction, temperature and desiccation
- Landforms: aspect, orientation drainage, geology and soil types
- Wildlife: attractors (eg. flowers which attract pollinating insects) and hazards (eg. wild boar foraging activity)

Sectors are mapped on the site according to the direction or area from which a flow moves onto the site. Sector analysis allows us to know how to:

- determine the correct placement of elements
- understand how different flows relate
- organize information

Zonation

The **permaculture** design methodology uses a model of concentric zones, where areas requiring more labour and oversight, such as the dwelling centre, are located in or near zone 1, and areas requiring fewer resources, such as the food forest, are located farther away. In combination with sector mapping, zoning places the elements of the farm a way that allows for the most efficient use of energy and matter flowing through the site. This design minimizes the use of resources while maximizing harvest yields, **biodiversity**, and resource recycling. Any service building serves as the organizational hub of the farm's design.

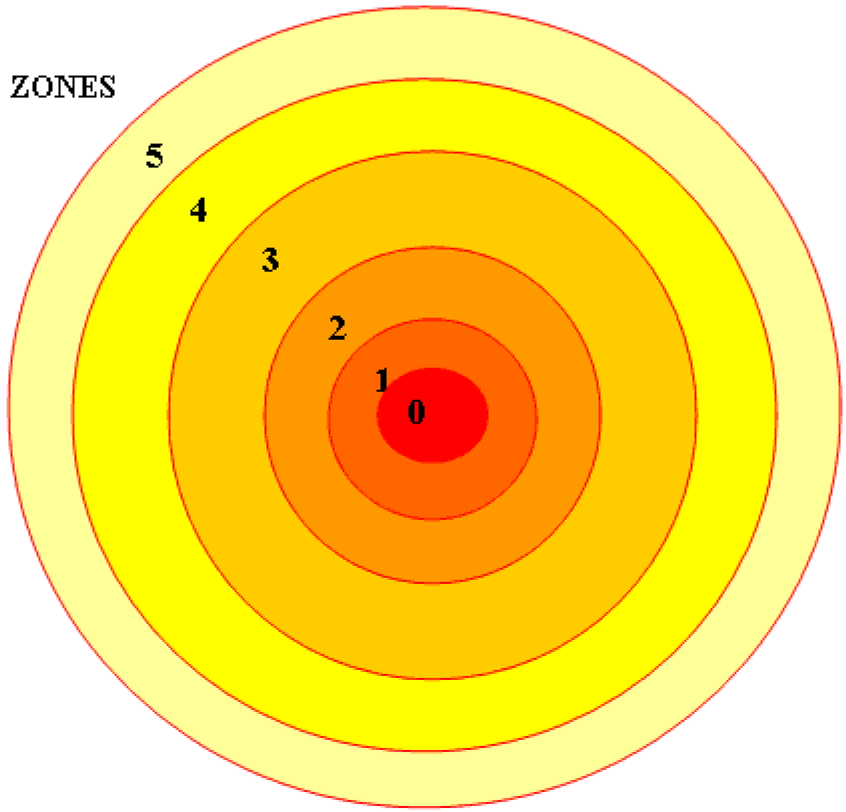


Diagram of conceptual zonation model

Structural elements of agroforestry systems

Mapping the sectors onto a base map of the site helps to select the right placement of structural elements. These elements are constructed with the available materials to affect the way a sector is influencing the site. For example, where rainfall results in runoff, water and eroded soil are lost from the site. To conserve the rainwater as soil humidity, accessible to the crops the runoff can be harvested by physical structures placed in its path (see swale, terrace and gabion below).

Swale

- Superficial earthwork, cheap and easy to implement

1. Swale slows and spreads **runoff** to be sunk into the soil, preventing soil erosion.
2. The retained, still **runoff** deposits its suspended load of organic matter and silt, eroded from areas of higher altitude.
3. The harvested rainwater infiltrates the soil along the whole length of the swale, greatly increasing the **soil humidity**!


Photo: Swale ditch retaining water after rain

Photo: Thousands of tonnes of rainwater are harvested above a single swale, Bustan Qaraaqa, Beit Sahour

Photo: Eroded soil harvested and deposited above a swale

Terrace

- A dry stone wall backfilled with soil, constructed on a contour parallel to the course of the *wadi* drainage; importantly, the wall is permeable to prevent soil water saturation, which causes walls to collapse after storms
- Usually taking advantage of the naturally-occurring stepped slope profile, the consequence of a geology in which the resistant limestone rock **strata** alternate with softer chalk or marl
- Slope gradation increases the area of cultivable soil by creating horizontal or gently-sloping shelves where the rainfall will infiltrate the soil instead of flowing perpendicular to the contour as **runoff**

Photo: Terraced slope, Beit Jala

Photo: Olives cultivated on a terraced slope, Ayn il-Hawiyah, Husan

Gabion

- A low stone wall, constructed across the floodplain perpendicular to the course of drainage
- A series gabions creates a graduated profile of horizontal areas descending the wadi
- The gabion spreads and slows the **runoff** flowing down the wadi and diffuses the erosive force of the flow from the channel across the width of the floodplain


Photo: Gabions constructed in the Wadi il-kelb, 1600 years ago have resisted erosion, conserving the soil. Khirbet Il-Deir, Judean Desert

Roads

- On contour (or as close as possible!)
- Permeable (e.g. crushed rock, not asphalt or concrete)
- Where existing roads create **runoff** and focus the erosive force of the flowing water, the **runoff** should be directed into infiltration basins and swales implemented beside the road from high to low at regular intervals

Mulch

Mulch is essential for a healthy, abundant **ecosystem**. A mulch is made by spreading a thick layer of (ideally) organic material over the surface of the soil. The mulch protects the soil, much like our clothes protect our skin, forming a physical barrier to the heat and UV rays of sunlight and the desiccating contact of wind, retaining moisture in shallow soils and allowing life to thrive in what would otherwise be dry, barren earth. In time, trees will produce their own mulch of leaf litter but, until then, all planting requires the application of a thick mulch. Ideally, all the soil area on the farm should be protected by a covering mulch layer. Sandwich mulches of alternating material density are the best.

The Perfect Mulch: Manure sandwich sheet mulch

1. Start collecting materials and don’t stop - little and often is best. You will need cardboard boxes, manure (must be rotted - cow/sheep/goat is better than chicken but anything will do), straw/hay, or any vegetable matter.

2. Cover the soil with a thin layer of manure.
3. Cover the manure with a thick layer of overlapping cardboard sheets.
4. Apply another sparse layer of manure.
5. Apply another thick layer of overlapping cardboard sheets.
6. Finish with a thick interlocking mat of straw, palm leaves, weeds, exhausted vegetable crops etc. This will improve the overall appearance and prevent the mulch from blowing away in the wind. The addition of small rocks or earth sods may be a sensible precaution.
7. Repeat annually, ideally in the spring to pre-empt the emergence of weeds.


Photo: Mulching a newly planted tree

Sheet mulch vs. point mulch

It is always better to mulch a small area thoroughly than a large area inadequately. If the available materials are insufficient to cover the whole area of exposed soil, then point mulches laid around a tree or group of trees are the next best thing. Where trees are receiving irrigation then a mulch is especially effective at saving time and water by reducing the required irrigation frequency. The mulch should be laid to a minimum radius of 1.5 metres around a sapling, and to the radius of the crown of a mature tree - the more extensive the mulch, the more effective it will be.

Sheet mulches are more effective at conserving soil moisture and building soil fertility. A sheet mulch, seasonally applied, is a sure way to tackle tenacious **perennial** weeds and prevent spiny weed growth. Sheet mulches laid on bare rock will decay into soil, allowing the cultivation of *Opuntia ficus indica*, banana, melons, cucumbers and tomatoes in one year (bananas will require support or they fall over!).

A thick sheet mulch laid in a newly planted orchard will halve the time and, therefore, the labour and water, required to establish the trees. Mulched orchards will establish in one year, whereas ploughed orchards require irrigation for the first two summers.

Rock mulch

In the absence of any organic material or as a cover to a cardboard sheet mulch, rocks are useful for mulching. Fist-sized stones are best, laid in a layer two stones deep. A single layer of stone will simply conduct heat straight from the sun to the soil. At night the stones will lose heat faster than the surrounding soil, becoming cooler than the surrounding air and causing condensation of water vapour on spring nights: dew. The dew will run down under the stones infiltrating the soil. When the sun rises, the **soil humidity** will be retained in the shade of the covering rock mulch.

Other mulches

Protective fertilising mulches

> Wood chips, wood shavings, olive *jif*, sheep fleece, old clothes, woollen blankets, and cotton or wool stuffed mattresses all make excellent mulches.

Protective non-fertilising mulches

> Plasterboard, sheet iron, plastic sacks/bags, carpets, and rocks are all better than nothing.

REMEMBER: *EXPOSED SOIL IS DEAD SOIL*

Agroforestry techniques

Few techniques are needed to produce healthy and productive trees and their crops. Learning successful techniques for propagation and establishment will save time and money and increase the number of crops available. Diverse woodlands can be created on a very low budget. Other techniques like grafting enable us to increase the diversity, quantity and quality of crops per square meter of land. The following basic techniques are recommended to produced orchards and woodlands in Palestine.

Propagation

Seed collection

Ideally, seed should be harvested from local wild populations to preserve and exploit the geographically-structured genetic diversity of the **metapopulation**. Each species has its harvest season, which varies throughout the year depending on altitude and that year's weather. Fruits ripen from May to December. Seed should be collected from as many individual trees as possible to maximise the genetic diversity in the resulting nursery stock.

Seed storage

Extract the seed from the fruit before dry storage:

- Label the seed with:
  - **Location** - collection site (most important)
  - **Date** - date of collection
  - **Name** - if you don't know a name make one up! The Latin binomial is best.
- Store in a plastic container (for example in a spice pot or screw-top bottle), not in a bag, to exclude predatory beetles.
- All seeds should be sown as soon as possible as **viability** diminishes with storage.

Pre-treatment

The purpose of seed pre-treatment is to break **seed dormancy**, inducing a prompt and synchronous germination. This saves nursery resources, thus making propagation more economical and manageable. Pre-treatment is essential for most dryland species whose seeds remain dormant in the environment for years or even decades. Some Palestinian species' seeds have been proven still viable after even thousands of years!

Scarification :

- Physical: clipping and sanding the seed coat makes it permeable to water, but this is a time-consuming technique and therefore only suitable for small batches of seed.

OR

- Chemical: immersing the dry seed in a small volume of concentrated hydrochloric acid weakens the seed coat, making it permeable to water. Seeds should be thoroughly washed, then soaked for 24 hours before sowing.

Stratification

- A successive regime of periods of refrigeration and warm storage simulates the passage of the seasons. Most seeds germinate in the spring following winter **dormancy** in a process known as **vernalisation**.

Soaking

- All but the smallest seeds respond to 24 hours' soaking in clean warm water with higher germination rates.

Seed Sowing

Mix ratio by volume: 6:1:4:2 of compost, manure, soil, and sand respectively.

Container: Sow in a seven litre pot or bag, longer than it is wide.

Sowing: Cover seed to a depth of twice the length of the seed's B axis (A=length, B=width, C=depth; the C and B axes are often the same).

Irrigation: Water daily, keep moist but not wet - rainwater is always best. No fertigation required.

Recruitment: Germination occurs commonly between 3 and 6 weeks but takes much longer in winter. In summer, shading will aid recruitment but is not essential.

Remove trees aged 12 to 20 months from the nursery for immediate transplantation.

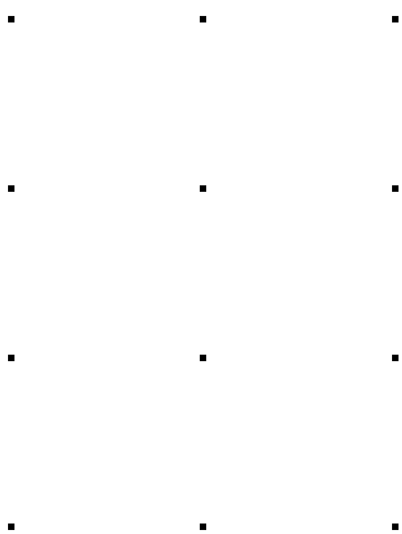
Photo: Tree nursery at Bustan Qaraaqa, Palestine

Tree planting and establishment

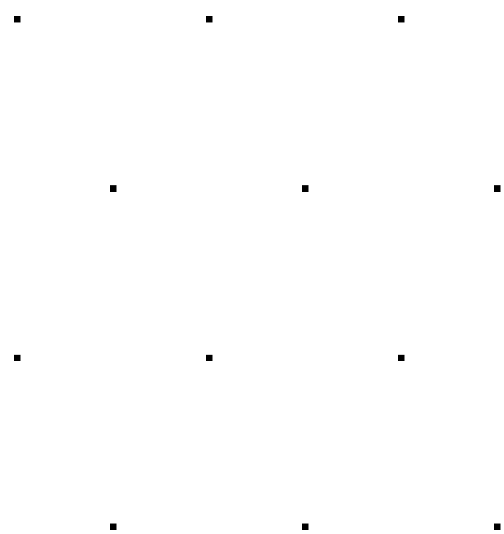
Factors to consider:

Spacing: An initial plantation requires three metres between trees for establishment, with a long-term aim of increasing the average distance to five metres after 10 years. Trees can be removed (killed) or coppiced to manage the emerging **demography** in response to system feedback.

Patterns: An offset or triangular (isometric) grid pattern results in a higher stocking density, whilst maintaining the same distance between neighbours.



square grid pattern



isometric grid pattern

Integration: With reference to other elements of the design, the species and varieties are located along resource gradients. For example, those species like *Citrus* and avocado (*Persea*), which will always require irrigation, are placed close to the water source. Trees that need no post-establishment irrigation are placed further from the water source to conserve energy in the future. Likewise, those species that respond well to attentive care are located at nodes of activity and along the access track and paths. Trees like the olive that need visiting just once a year are placed mainly in the areas of the farm furthest from the central zone of activity.

Grafting - vegetable alchemy

Planning to cultivate trees should not only be influenced by factors like the climate or soil type, but also by the plants that already grow on the land. Clearing the land from old, established trees or shrubs is rarely the right approach. These **perennial** plants may, at first glance, not seem to be of any use, since most of them do not produce valuable fruits or timber - however, the benefit hides under the surface. Due to overgrazing, most of these trees' or shrubs' visible over ground growth underplay the extent of their massive root systems.

Through grafting, these structures can be used to speed up the growth and increase the yield of valuable products for the market. Species like *Crataegus azarolus*, *Pistacia palaestina,* or *Pyrus persica* are well adapted to the climatic conditions in and around Palestine, and this adaptation can be capitalised to grow more valuable fruits or nuts on their **rootstock**. So, having these established yet economically "inferior" species will, in the end, increase the robustness and yield of your fruit garden and reduce the period of economic latency before you can begin to harvest. Furthermore, grafting enables you to grow different varieties of fruit on the same tree - especially where space is a limiting factor, this technique can diversify the products you harvest in your garden.

The following list shows you possible grafting partners for the fruit trees (**bold**) mentioned in this book.

- **Pecan** *(Carya illinoinensis)*
    - only on other trees of the *Carya* genus
- **Lemon** *(Citrus x limon)*
    - on any other tree of the *Citrus* genus
- **Pomelo** *(Citrus maxima)*
    - on any other tree of the *Citrus* genus
- **Quince** *(Cydonia oblonga)*
    - *Pyrus persica*
    - Loquat *(Eriobotrya japonica)*
    - Hawthorn *(Crataegus azarolus)*
- **Persimmon** (*Diospyros kaki*)
    - only on Diospyros kaki born of seed
- **Loquat** *(Eriobotrya japonica)*
    - Hawthorn *(Crataegus azarolus)*
- **Fig** *(Ficus carica)*
    - only on other fig trees and wild figs
- **Walnut** *(Juglans regia)*
    - on *Juglans regia* from seed and on the black walnut *(Juglans nigra)*
- **Macadamia** *(Macadamia tetraphylla)*
    - on any *Macadamia tetraphylla* from seed and M. integrifolia
- **Apple** *(Malus domestica)*
    - Hawthorn *(Crataegus azarolus)*
    - on all other trees of the *Malus* genus which locally is Malus trilobata
- **Mango** *(Mangifera indica)*
    - only on other mango trees
- **Mulberry** *(Morus alba; M. nigra; M. rubra)*
    - on other trees of the *Morus* genus of which Morus nigra is indiginous
- **Olive** *(Olea europaea)*
    - on other olive variations (*Olea europea var. europea* and *Olea europea var. sylvestris*)
- **Avocado** *(Persea americana)*
    - only on other trees of the *Persea* genus
- **Pistachio** *(Pistacia vera)*
    - *Pistacia vera male can be grafted onto one windward branch of a female tree for wind pollination of her flowers without planting male trees*
    - *Pistacia palaestina*

    - *Pistacia atlantica*
    - *Pistacia terebinthus*
    - *Pistacia lentiscus*
- **Apricot** *(Prunus armeniaca)*
    - Almond *(Prunus dulcis)*
    - Peach *(Prunus persica)*
    - Nectarine *(Prunus persica nucipersica)*
    - on several other trees of the *Prunus* genus
- **Cherry** *(Prunus avium)*
    - only on other cherry trees (*P. avium* grown from seed or *P. cerasus*)
- **Almond** *(Prunus dulcis)*
    - on wild almond trees which mostly produce bitter nuts
    - Peach *(Prunus persica)*
    - Nectarine *(Prunus persica nucipersica)*
    - Apricot *(Prunus armeniaca)*
- **Peach** *(Prunus persica)*
    - Apricot *(Prunus armeniaca)*
    - Almond *(Prunus dulcis)*
    - Nectarine *(Prunus persica nucipersica)*
    - on several other trees of the *Prunus* genus
- **Nectarine** *(Prunus persica nucipersica)*
    - Apricot *(Prunus armeniaca)*
    - Almond *(Prunus dulcis)*
    - Peach *(Prunus persica)*
    - on several other trees of the *Prunus* genus
- **Pomegranate** *(Punica granatum)*
    - on wild or self-sown pomegranate trees
- **Pear** *(Pyrus communis)*
    - *Pyrus persica*
    - Hawthorn *(Crataegus azarolus)*
    - Loquat *(Eriobotrya japonica)*
    - Quince *(Cydonia oblonga*)
    - Asian pear *(Pyrus pyrifolia)*
- **Pine** *(Pinus pinea)*
    - on **rootstocks** of other pine trees to speed up and increase nut production
- **Vine** *(Vitis vinifera)*
    - on other vine **rootstocks** to grow a preferable variety

Alley cropping

In an agroforestry system, trees are often planted in alleys intercropped with vegetable crops. This alternative planting scheme is called “alley cropping”, and increases total biomass yield, in addition to diversifying (and thus making more resilient) the range of economically valuable crops produced.

The tree crop (a single suitable species to minimise labour input) should be planted in alleys of a width no less than 5m. During cropping season, the trees should be pruned continuously down to 1m. *Leucaena leucocephala,* for example, can be grown as a hedge species whereas some of the trees may be used for forage and others, which are not pruned down to 1m, for pole production. Since the competition from *Leucaena* hedgerows would extend up to 3m into the crop area and have a negative effect on yield, a root barrier should be installed: dig a narrow trench about 30cm wide and 50cm deep and use a layer of polythene sheet. This root barrier may reduce both height and girth of the poles but has a positive effect on the crop. Other good hedge species are *Moringa oleifera* and *Moringa peregrina* which should be planted 3m apart in rows 10m wide.

Planting trees in rows facilitates mechanical harvesting and thus enables farmers to produce cereal crops. Alley cropping therefore makes it possible to grow monoculture crops in a system mixed with trees which provide services such as erosion control, wind- or firebreak. Additionally, forage from **coppicing** and timber can be grown, which diversifies the product line and decreases dependency on the price or demand of one product.

Photo of alley cropping with rows *Leaucaena leucochephala*

Food forests

Food forests intensively integrate trees, vines, shrubs and vegetables in imitation of natural ecosystem structure. They are extremely productive per unit area and provide a great range of yields including both products and services. Food forests stabilise the ecosystem and accumulate resources. The diverse community of plants and animals they comprise provides the individual crop species with all their needs, or in other words the forest does the work to the farmer has no need to. Significant food forest yields include:

- Harvested rainwater

- Harvested soil eroded from elsewhere

Food forest products

- **Edible products**
    - Direct
        - fruits
        - nuts
        - seeds
        - leaves
        - flowers
        - oil
        - gum
    - Indirect:
        - Foliage and bark for cow, sheep and goat forage and fodder for meat and dairy produce
        - Nectar and pollen for bees for honey production
- **Non-food products**
    - Gums and resins
    - fuelwood
    - charcoal
    - timber
    - oil for fuel or lubrication
    - fibres
    - soap from fruits and bark

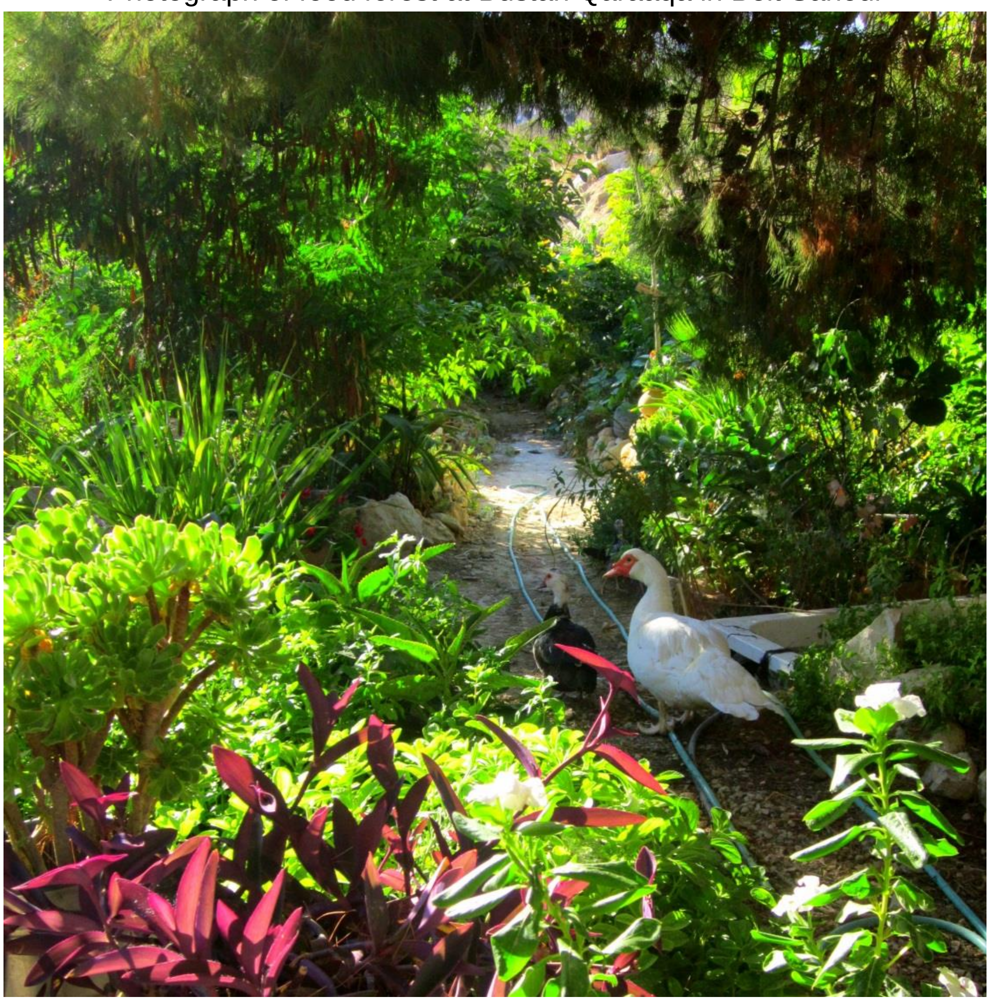
Food Forest Services

- Rainwater harvesting increases **soil humidity**
- Soil stabilisation/erosion prevention
- Building soil structure and fertility
- Climatic amelioration:
    - reduced seasonal and diurnal temperature range for warmer winter nights and cooler summer days
    - reduced insolation decreases UV irradiation
    - increased air humidity
    - increased rainfall and reduced evaporation from soil
    - slower air currents preventing storm damage and wind desiccation

- Extends the season of the forest's crop production and service provision to 12 months of the year
- Increased crop diversity
    - Reduced occurrence of pests and disease, and inhibition of contagion within the species (prevention is better than cure!)
    - Insurance that crop failure or the low market price of a single crop doesn't stress the farmer and his budget, because there are always other crops soon to be harvested

Photograph of food forest at Bustan Qaraaqa in Beit Sahour

Photograph of food forest at Bustan Qaraaqa in Beit Sahour



Photograph of food forest at Bustan Qaraaqa in Beit Sahour

CHAPTER IV

Design templates

This chapter aims to provide the reader with all she needs to get started planting trees at home or at work. Four common and widespread situations are described and recommendations are given for getting the greatest benefit from appropriate agroforestry designs. A shortlist of suitable tree and vine species are provided for each of the four situations. Whilst the design templates could be replicated, it is the author's hope they will inspire design innovations as each reader adapts the principle to their circumstances. Each design template is a detailed example of an agroforestry community's species' composition and structure to maximise productivity, safety and resilience and to minimise labour. In order to select the appropriate design template for a site the elevation and amount rainfall must be found out.

West Bank citys' altitudes and annual rainfall

Designing woodland requires information on climatic and geographical conditions which includes altitude, rainfall and temperature. Generally, the climate in the West Bank is relatively arid, and the mean annual rainfall doesn't exceed 500 mm/year in much of the area. However, a general description of the climate in the West Bank is impossible, due to huge differences of the landscape. The following table contains the most important data on the climate and altitude of the largest cities in the West Bank, and is meant to help landowners to estimate the rainfall, temperature range, and altitude of their lands.

	Altitude (meters above sea level)	Mean annual rainfall (mm/year)	Temperature range (°C)
Jenin	150	530	10-35
Nablus	550	590	8-33, winter frosts
Ramallah	850	600	4-30, winter frosts
East Jerusalem	750	550	6-30, winter frosts
Bethlehem	775	500	6-30, winter frosts
Jericho	-250	120	10-35
Hebron	930	460	1-30, winter frosts

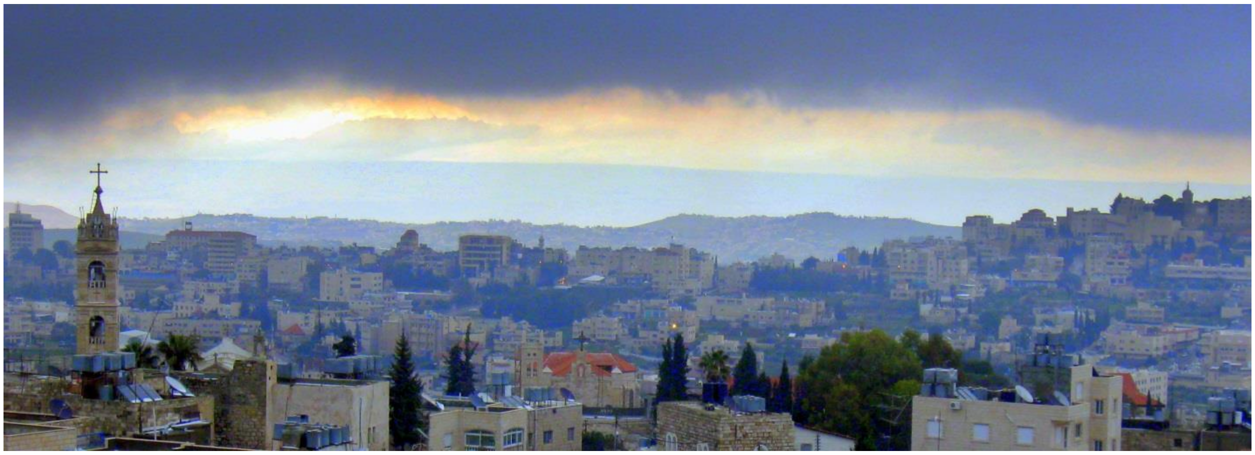


Photo: Rainclouds over Bethlehem

1. Food forest for the highlands

Most people in the West Bank live in the highlands. This design template is suitable for all but the most urban situations. Once established the highland food forest will provide the individual or family with much of their food and energy requirements as well as creating a clean, green environment for recreation and relaxation with year round appeal.

Photo: Highland mixed fruit orchards, Wadi il-Makhrur, Bethlehem District

Geology

The geological spine of Palestine is the ridge of hills running north to south from Jenin to Hebron. This upland region is the tail-end of the Levantine mountain range which, branching from the Taurus mountains in Turkey, runs south parallel to the Mediterranean coast through Syria, Lebanon, and Palestine (peaking at 3,088 metres in Lebanon), terminating abruptly south of Hebron where the Judean and Naqab deserts unite. In the West Bank, the geology is entirely karst. Fine white and pink limestone rock dominates, alternating with thin bedding planes of red, brown, black, and white chert.


Photo: Chert outcrop, Judean Desert

The soil of the highlands of Palestine is very fertile, provided it is maintained humid. The esteemed *terra rosa* soil preferred for quality vine and olive crops surrounds the highland cities of Nablus, Tulkarem, Qalqilyah, Jerusalem, Bethlehem, and Hebron. At lower altitudes there is brown rendzina soil on hard limestones and pale rendzina soils on soft limestones, and marl especially in the valleys.

The highlands of the West Bank are characterised by a Mediterranean climate with long hot dry summers and short winters with occasional frosts and snow, and erratic precipitation between September and April. There may be as much as two months in the winter when no significant rain falls. Damaging Khamesseni wind and sand storms occur usually in April-May and September-October.

Ecology

The highlands of Palestine were covered by Eastern Mediterranean **sclerophyllous** woodland dominated by oak (*Quercus calliprinos*) with terebinth (*Pistacia*), carob (*Certonia*), hawthorn (*Crataegus*) and storax (*Styrax*), pine (*Pinus*), strawberry tree (*Arbutus*), and olive (*Olea*). The woodlands are mainly evergreen in character and exceptionally **biodiverse**.

Traditional agriculture: *il-hadika*, *il-hakura*, and *il-bustan*

Traditionally the whole family was involved in growing and preparing food at home, and today using the land around the house to produce your favourite fruit, vegetables, and herbs is as popular as ever. Vegetables and fruit were grown in the *hadika,* an intensively managed vegetable garden near the kitchen. The *hakura* was a walled orchard of olive, lemon, vines, almond, apricot, fig, mulberry, and pomegranate surrounding the home that provided shade and privacy. Within the walls lay the rock cistern for irrigation with stored winter rainwater. The family's farmland of steep terraced slopes and narrow *wadis* between broad ridges was managed as a *bustan*, a **polyculture** of rainfall irrigated crops and dryland orchards. In this system the more humid soil of the *wadi* is planted with the deep-rooted fruit trees like almond, apricot, peach, fig, and mulberry; the terraces are usually planted with mainly olive but also pomegranate, almond, and apricot; the ridge tops are used for cereal crops such as barley and wheat. All the soil area of the *bustan* is traditionally ploughed two to six times a year. Mules are used to plough the open ridges and the broader *wadis,* and donkeys plough the narrow terraces under the low branches of the orchard trees.

Photo: Traditional *bustan* agroforestry system, Wadi il-Halas, Batir

Photo: Traditional spring-fed bustan agriculture integrating orchards and vegetable cultivation. Ayn il-Hawiyah, Husan

Traditional *bustan* agricultural system integrating olive and cereal cultivation, Ajloon

Photo: Ploughing under olive trees with a donkey, Beit Sahour

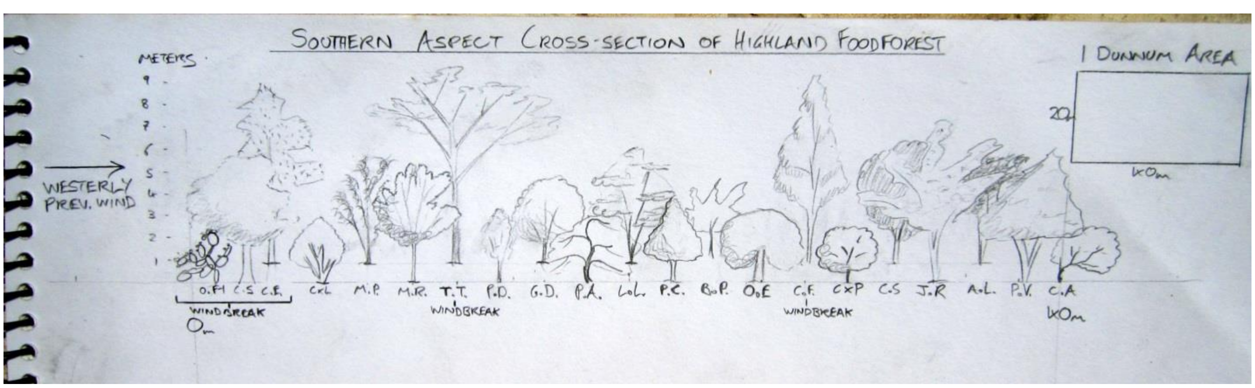
Intense winter rainfall in the mountain area of the West Bank causes extensive damage to structures and roads costing lives every year. The *wadis* are especially vulnerable to damage, as the **runoff** causes the rivers to surge, eroding the banks and washing out bridges. Where road embankments have been constructed across the narrow *wadi* floodplain, extensive flooding can occur and frequently entire roads disappear. On the slopes, terrace walls collapse. The **runoff** erodes the soil from the ridgeline down to the *wadi* with the erosion rate increasing lower in the landscape. On average 100 tonnes of soil per hectare are eroded each year on the eastern slope of the West Bank.

Damage caused by **runoff** and flooding can easily be mitigated by superficial landscaping to maximise rainwater infiltration starting from high in the landscape and working down towards the *wadi*. Swales, terraces, and vegetation will slow, spread, and sink the rain into the soil, minimising **runoff**. Using gravel and mulches instead of asphalt, concrete, and paving stones will increase the area of permeable surfaces, preventing **runoff**. Where **runoff** is inevitable, for example from the house roof, the flow can be directed to swale or an infiltration basin to sink into the soil or into a cistern, reservoir, or water tank for domestic or agricultural use.

Frost damage

On winter nights the coldest air sinks, forming streams of freezing air which flow down the *wadis*. Road embankments and boundary walls can trap pools of the cold dense air creating frost pockets. These pockets need to be "drained" where possible by ventilation of the barrier (for example the addition of a gate in a wall), or the cold air flow can be diverted earlier, higher up in the landscape. A vertical difference of 10 metres can make the difference between life and death for frost intolerant species and can prevent frost damage to tender species. It is, therefore, recommended to avoid planting frost tender varieties in the *wadi*, instead planting them on a south-facing terrace on the valley side with protection from the prevailing westerly wind. Fleece and mulch can be used to insulate frost tender plants during the winter months.

Sketch of design template for a highland food forest



Key to Sketch of highland food forest cross section. From left to right:

Abbreviation	Tree Species
O.P.	*Opuntia ficu-indica*
C.S.	*Ceratonia siliqua*
C.E.	*Casurina equistifolia*
CxL	*Citrus x limon*
M.P.	*Moringa peregrine*
M.R.	*Morus rubra*
T.T.	*Tipuana tipu*
P.D.	*Prunus domestica*
G.D.	*Geofroea decorticans*
P.A.	*Prunus armeniaca*
P.C.	*Pyrus communis*
B.P.	*Bauhinia purpurea*
O.E.	*Olea europea*
C.F.	*Cassia fistula*
CxP	*Citrus x paradise*
C.S.	*Certonia siliqua*
J. R.	*Juglans regia*
A.L.	*Albizia lebbeck*
P.V.	*Pistacia vera*
C.A.	*Crataegus aronia*

Tree species list for the highland food forest

Table of tree species:

Latin Binomial	English Species Name	English Variety Name	Palestinian Arabic Species Name	Palestinian Arabic Variety Name
Acacia nilotica	Arabic gumtree			
*Acacia raddiana**	Umbrella tree		سويد	
*Acacia tortilis**	Umbrella tree		سويد	
Albizia lebbeck	Lebbeck			
Bauhinia purpurea				
Carya illinoinensis	Pecan		امريكي	
Cassia fistula	Cassia			
Casuarina	River She-oak			

cunninghamiana				
Casuarina equisetifolia	Coast Sheoak			
Casuarina glauca				
*Ceratonia siliqua**	Carob		خروب	
	Carob	American	خروب	امريكي
	Carob	Baladi	خروب	بلدي
Chamaecytisus palmensis	Tree Lucerne			
Citrus japonica	Kumquat		برتقال صيني	
Citrus maxima	Pomelo		بوملة	
	Pomelo	White	بوملة	ابيض
Citrus × aurantium	Seville Orange		خشخاش	
Citrus x clementine	Clementine		كلمنتينا	
Citrus x deliciosa	Mandarin		مندلينا	
	Mandarin	Mkhaal	مندلينا	مخال
	Mandarin	Baladi	مندلينا	بلدي
Citrus x limon	Lemon		ليمون	
Citrus x paradisi	Grapefruit		جريب فروت	
	Grapefruit	Ruby Grapefruit	جريب فروت	احمر
Citrus x sinensis	Sweet Orange		برتقال	
	Sweet Orange	Navel (Abu sura)	برتقال	ابو سرة
*Crataegus azarolus**	Hawthorne		زعرور	
*Crataegus aronia**	Hawthorne			
Cupressus				

sempervirens				
Cydonia oblonga	Quince		سفرجل	
Dalbergia sissoo	Indian Rosewood			
Diospyros kaki	Persimmon		كاكي، فرسمونا	
Eriobotrya japonica	Loquat		اسكا دنيا	
*Faidherbia albida**	White Acacia			
Ficus carica	Fig		تين	
	Fig	Sba3i	تين	سباعي
	Fig	Khortmani	تين	خرطماني
	Fig	Darfur	تين	دافور
	Fig	Fkaysi	تين	فقيسي
	Fig	Muazi	تين	موازي
	Fig	7madi	تين	حماضي
Feijoa sellowiana	Pineapple-guava		فريوجا	
Geoffroea decorticans	Palo Verde			
Gleditsia triacanthos inermis	Honey Locust			
Grevillea robusta	Southern Silky-oak			
Jacaranda mimosifolia				
Jasminum officinale	Jasmine			
Juglans regia	Walnut		جوز	
Leucaena leucocephala	Lead tree			

Macadamia integrifolia	Macadamia		مكديميا	
Malus domestica	Apple		تفاح	
	Apple	3ana	تفاح	عانا
	Apple	Sweet	تفاح	سكري
	Apple	Golden	تفاح	جولدن
	Apple	Starting	تفاح	ستارتنك
Moringa oleifera	Indian Moringa			
*Moringa peregrina**	Palestinian Moringa		اليسسر	
Morus alba	White		توت ابيض	
Morus nigra	Black Mulberry		توت اسود	
*Morus rubra**	Red Mulberry		توت احمر	
	Red Mulberry	Baladi	توت احمر	توت بلدب
	Red Mulberry	Iranian (long)	توت احمر	توت ايراني
Olea europea	Olive		زيتون	
	Olive	Baladi	زيتون	بلدي
	Olive	K18	زيتون	
	Olive	Spanish	زيتون	اسباني
	Olive	Manzanilla	زيتون	منزلينو
	Olive	Syrian	زيتون	سوري
Persea Americana	Avocado		ابو كادو	
	Avocado	Has	ابو كادو	هس
	Avocado	Big Has	ابو كادو	هس كبير
	Avocado	Tinker	ابو كادو	تنكر
*Phoenix dactylifera**	Date Palm		فستق حلبي	
*Pinus pinea**	Pine			

*Pistacia atlantica**				
*Pistacia lentiscus**	Mastic Tree			
*Pistacia palaestina**				
Pistacia vera	Pistachio			
Prosopis alba	White Carob			
Prosopis juliflora	Mesquite		السلم	
Prosopis nigra	Black Carob			
Prunus armeniaca	Apricot			
Prunus avium	Wild Cherry			
Prunus domestica	Plum		جرنق	
	Plum	Adicon	جرنق	ادكون
	Plum	Yellow	جرنق	اصفر
	Plum	Black Diamond	جرنق	بلاك دايموند
	Plum	Black	جرنق	اسود
	Plum	Santa Rosa	جرنق	سانتا روزا
	Plum	1200	جرنق	
	Plum	Bullock's Muzzle	جرنق	خشم العجل
*Prunus dulcis**	Almond		لوز	
	Almond	Umm Il-fa7m	لوز	ام الفحم
	Almond	Naba	لوز	نابا
	Almond	Khofa	لوز	جخفا
	Almond	M Daylight	لوز	م ديليت
Prunus persica	Peach		خوخ	
	Peach	Abu Farwa	خوخ	ابو فروة

	Peach	Tunisian	خوخ	تونسي
Prunus persica nucipersica	Nectarine		نكترين	
	Nectarine	Red	نكترين	احمر
	Nectarine	White	نكترين	ابيض
Psidium guajava	Guava		جوافا	
	Guava	Egyptian	جوافا	مصري
	Guava	Bandook	جوافا	بندوق
Punica granatum	Pomegranate		رمان	
	Pomegranate	Sour	رمان	حامض
	Pomegranate	Bullock's Muzzle	رمان	حامض
Pyrus communis sativa	Pear (baladi)		اجاص	
Pyrus persica				
*Quercus calliprinos**	Kerne Oak			
*Rosa x damascene**	Damask Rose			
*Styrax officinalis**	Storax			
Tecoma stans	Tecoma			
Tipuana tipu				
*Ziziphus spina-christi**	Christ's Thorn Jujube		السدر	
Ziziphus jujube	Jujube		عناب	

Table of vine species (دوالي) :

Latin binomial	English Species Name	English Variety Name	Palestinian Arabic Species Name	Palestinian Arabic Variety Name

*Vitis vinifera**	Grape Vine		عنب	
	Grape Vine	Halawani	عنب	حلواني
	Grape Vine	Dabuki	عنب	دابوقي
	Grape Vine	Shami	عنب	شامي
	Grape Vine	Beiruti	عنب	بيروتي
	Grape Vine	Zaini	عنب	زيني
	Grape Vine	SPS	عنب	
	Grape Vine	Jamil	عنب	جيميل
	Grape Vine	Salti	عنب	سلطي
	Grape Vine	Buti	عنب	بيوتي
Passiflora edulis	Passionfruit		بسفلورا	

* *Indigenous Species*

2. Food forest for the lowlands

The Marj il-ibn Amer, Jordan Valley and the Dead Sea basin experience dry and very hot summers but provide the opportunity to grow the greatest variety of crops anywhere on Earth. The winter frosts experienced elsewhere at these latitudes are mitigated but the region's unique submarine elevation. The lack of a cold winter season allows for year round cultivation and the inclusion of tropical crops like banana, avocado and mango. This design template revives the abundant and diverse agroforestry practices of antiquity to provide, cool shade, food and fuel for the individual or the family.

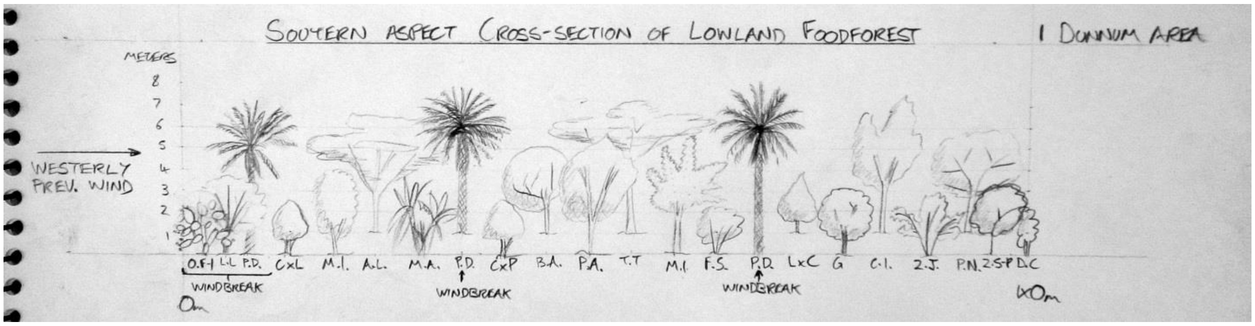
Geography: From springs fed from the mountains of Syria, the Jordan River flows from North to South in and out of the Sea of Galilee at 212 metres below sea level down to the lowest land elevation on Earth, and into the Dead Sea at -400 metres below sea level. The river is dammed and its water diverted to Israel and Jordan; the summer flow is weak and polluted. The river follows the Great Syrian-African Rift Valley, bound by sheer cliffs of bare rock rising one kilometre from the shore of the Dead Sea to the plateau of the Judean Desert. Further north, the valley sides are less steep but rugged. Numerous springs emerge at the edge of the floodplain.

Soil: Deep rich grumusol soil of the *Maraj al-ibn Amer* quickly gives way to brown and pale rendzina soil of the Upper Jordan. The Middle Jordan Valley has fertile alluvial arid brown soil with brown lithosols on the valley sides. In the Lower Jordan the alluvial arid brown soil deteriorates to regosol near the Dead Sea shore as salinity increases and fertility decreases. The soils of the south eastern slope and the Judean Desert are brown lithosols and thin pale rendzina soil on top of the limestone bedrock.

Climate: Hunter-gatherers settled at springs in the Jordan Valley 11,000 years ago, making these the oldest cities on Earth. The mild winter climate and sunshine permit a 12 month growing season for continuous agricultural production. Away from the springs, the extreme summer temperatures make for inhospitable conditions, with long hot dry summers being followed by short warm winters. There are low rainfall totals, ranging from 50 mm/m^2/year in the south to 350 mm/ m^2/year in the north.

Ecology: The Galilee and the *Marj al ibn Amer* were evergreen **sclerophyllous** mediterranean woodlands dominated by *Quercus calliprinos*, *Ceratonia siliqua*, and *Pistacia lentiscus*. The Jordan Valley was wooded with *Ziziphus spina christi, Tamarix spp.*, *Poplar euphrata* (especially along the river banks), and, under springs, *Moringa peregrina*, *Salvadora persica*, and *Ziziphus spina-christi*. Savannah **ecosystems** of the valley floor included *Acacia radiana*, *Acacia tortilis*, *Balanites aegyptiaca*, and *Ziziphus spina Christi*.

Sketch of design template for a lowland food forest



Key to Sketch of lowland foodforest cross section. from left to right:

Abbreviation	Tree Species
O.P.	*Opuntia ficu-indica*
L.L.	*Leucaena leucocephala*
Ph. D.	*Phoenix dactylifera*
CxL	*Citrus x limon*
M.I.	*Mangifera indica*
A.L.	*Albizia lebbeck*
M.A.	*Musa acuminata*
Ph. D.	*Phoenix dactylifera*
CxP	*Citrus x paradise*
B.A.	*Balanites aegyptiaca*
P.A.	*Persea americana*
T.T.	*Tipuana tipu*
M.I.	*Macadamia integrifolia*
F.S.	*Feijoa* sellowiana
Ph. D.	*Phoenix dactylifera*
CxD	*Citrus deliciosa*
G.D.	*Geofroea decorticans*
C.I.	*Carya illinoinensis*
Z.J.	*Ziziphus jujube*
P.N.	*Prosopis nigra*
Z.S-C.	*Zizyphus spina-christi*
D.C.	*Dovyalis caffra*

List of tree and vine species for a lowland food forest

Table of tree species:

Latin Binomial	English Species Name	English Variety Name	Palestinian Arabic Species Name	Palestinian Arabic Variety Name
Acacia nilotica				

*Acacia raddiana**	Umbrella tree		سويد	
*Acacia tortilis**	Umbrella tree		سويد	
Albizia lebbeck	Lebbeck			
*Balanites aegyptiaca**	Soapberry		الزقوم	
Bauhinia purpurea	Butterfly tree			
Calotropis procera	Sodom Apple			
Carya illinoinensis	Pecan		امريكي	
Cassia fistula	Cassia			
Casuarina cunninghamiana	River She-oak			
Casuarina equisetifolia	Coast Sheoak			
Casuarina glauca				
*Ceratonia siliqua**	Carob		خروب	
	Carob	American	خروب	امريكي
	Carob	Baladi	خروب	بلدي
Chamaecytisus palmensis	Tree Lucerne			
Cytisus proliferus	Tagasaste			
Citrus japonica	Kumquat		برتقال صيني	
Citrus maxima	Pomelo		بوملة	
	Pomelo	White	بوملة	ابيض
Citrus × aurantium	Seville Orange		خشخاش	
Citrus x	Clementine		كلمنتينا	

clementina				
Citrus x deliciosa	Mandarin		مندلينا	
	Mandarin	Mkhaal	مندلينا	مخال
	Mandarin	Baladi	مندلينا	بلدي
Citrus x limon	Lemon		ليمون	
Citrus x paradisi	Grapefruit		جريب فروت	
	Grapefruit	Ruby Grapefruit	جريب فروت	احمر
Citrus x sinensis	Sweet Orange		برتقال	
	Sweet Orange	Navel (Abu sura)	برتقال	ابو سرة
Commiphora gileadensis	Balm of Mecca		بلسم	
Commiphora myrrha	Myrrh		لبان	
Cordia sinensis				
*Crataegus azarolus**	Hawthorne		زعرور	
Cupressus sempervirens				
Cydonia oblonga	Quince		سفرجل	
Dalbergia sissoo	Indian Rosewood			
Delonix regia	Royal Poinciana			
Diospyros kaki	Persimmon		كاكي، فرسمونا	
Dovyalis caffra	Kei Apple			
Eriobotrya japonica	Loquat		اسكا دنيا	
*Faidherbia albida**	White Acacia			
Ficus carica	Fig		تين	
	Fig	Sba3i	تين	سباعي

	Fig	Khortmani	تين	خرطماني
	Fig	Darfur	تين	دافور
	Fig	Fkaysi	تين	فقيسي
	Fig	Muazi	تين	موازي
	Fig	7madi	تين	حماضي
Feijoa sellowiana	Pineapple-guava		فريوجا	
Geoffroea decorticans	Palo Verde			
Gleditsia triacanthos inermis	Honey Locust			
Grevillea robusta	Southern Silky-oak			
Jacaranda mimosifolia				
Jasminum officinale	Jasmine			
Leucaena leucocephala	Lead tree			
Macadamia integrifolia	Macadamia		مكديميا	
Malus domestica	Apple		تفاح	
	Apple	3ana	تفاح	عانا
	Apple	Sweet	تفاح	سكري
	Apple	Golden	تفاح	جولدن
	Apple	Starting	تفاح	ستارتنك
Mangifera indica	Mango			
Moringa oleifera	Indian Moringa			
*Moringa peregrina**	Palestinian Moringa		اليسسر	
Morus alba	White		توت ابيض	

Morus nigra	Black Mulberry		توت اسود	
*Morus rubra**	Red Mulberry		توت احمر	
	Red Mulberry	Baladi	توت احمر	توت بلدب
	Red Mulberry	Iranian (long)	توت احمر	توت ايراني
Musa acuminata	Banana			
Olea europea	Olive		زيتون	
	Olive	Baladi	زيتون	بلدي
	Olive	K18	زيتون	
	Olive	Spanish	زيتون	اسباني
	Olive	Manzanilla	زيتون	منزلينو
	Olive	Syrian	زيتون	سوري
Persea Americana	Avocado		ابو كادو	
	Avocado	Has	ابو كادو	هس
	Avocado	Big Has	ابو كادو	هس كبير
	Avocado	Tinker	ابو كادو	تنكر
*Phoenix dactylifera**	Date Palm		فستق حلبي	
*Pistacia atlantica**				
*Pinus pinea**	Pine			
Pistacia vera	Pistachio			
Prosopis alba	White Carob			
Prosopis juliflora	Mesquite		السلم	
Prosopis nigra	Black Carob			
Prunus domestica	Plum		جرنق	
	Plum	Adicon	جرنق	ادكون
	Plum	Yellow	جرنق	اصفر

	Plum	Black Diamond	جرنق	بلاك دايموند
	Plum	Black	جرنق	اسود
	Plum	Santa Rosa	جرنق	سانتا روزا
	Plum	1200	جرنق	
	Plum	Bullock’s Muzzle	جرنق	خشم العجل
*Prunus dulcis**	Almond		لوز	
	Almond	Umm Il-fa7m	لوز	ام الفحم
	Almond	Naba	لوز	نابا
	Almond	Khofa	لوز	جخفا
	Almond	M Daylight	لوز	م ديليت
Prunus persica	Peach		خوخ	
	Peach	Abu Farwa	خوخ	ابو فروة
	Peach	Tunisian	خوخ	تونسي
Prunus persica nucipersica	Nectarine		نكترين	
	Nectarine	Red	نكترين	احمر
	Nectarine	White	نكترين	ابيض
Psidium guajava	Guava		جوافا	
	Guava	Egyptian	جوافا	مصري
	Guava	Bandook	جوافا	بندوق
Punica granatum	Pomegranate		رمان	
	Pomegranate	Sour	رمان	حامض
	Pomegranate	Bullock’s Muzzle	رمان	حامض
Pyrus communis sativa	Pear (baladi)		اجاص	
Pyrus persica				
*Rosa x damascene**	Damask Rose			

*Salvadora persica**	Toothbrush Tree			
Sclerocarya birrea	Marula Tree			
*Tamarix aphylla**	Athel			
Tecoma stans	Tecoma			
Terminalia catappa	Bengal Almond			
Tipuana tipu				
*Ziziphus lotus**				
*Ziziphus spina-christi**	Christ's Thorn Jujube		السدر	
Ziziphus jujube	Jujube		عناب	

Table of vine species (دوالي) :

Latin binomial	**English Species Name**	**English Variety Name**	**Palestinian Arabic Species Name**	**Palestinian Arabic Variety Name**
*Vitis vinifera**	Grape Vine		عنب	
	Grape Vine	Halawani	عنب	حلواني
	Grape Vine	Dabuki	عنب	دابوقي
	Grape Vine	Shami	عنب	شامي
	Grape Vine	Beiruti	عنب	بيروتي
	Grape Vine	Zaini	عنب	زيني
	Grape Vine	SPS	عنب	

	Grape Vine	Jamil	عنب	جيميل
	Grape Vine	Salti	عنب	سلطي
	Grape Vine	Buti	عنب	بيوتي
Passiflora edulis	Passionfruit		بسفلورا	

* *Indigenous Species*

3. Foresting the desert: ecological restoration of a landscape

Palestine's deserts are artificial. Our cultures' land management practices have denuded the eastern slopes of the forests and savannah which once covered them and which built the soils that are still present today. Because the soils have survived (albeit greatly degraded), the option exists to reforest the eastern slopes, Jordan Valley, and Judean Desert. The **ecological** solutions are ready to be applied as soon as the land users decide that woodland is more desirable then desert. This is a serious challenge facing the Palestinian people because the desert is spreading up the eastern slope and the conurbation of cities is moving down the eastern slope, with the narrow altitudinal belt of surviving agricultural land being squeezed, shrinking, in between. In the Bethlehem area, the agricultural belt is only 5km wide and rapidly narrowing. Contemporary agricultural practices of monoculture and ploughing accelerate desertification and have rendered the land between the River Jordan / Dead Sea depression and the mountains barren.

Photo: Judean Desert

Once agriculture begins to fail then the herders graze their flocks on the ruins of the farmland. The Judean Desert is stocked with sheep and goats at 900% its carrying capacity. Just one tenth of the food eaten by the flocks and herds actually grows in the Judean Desert - 90% is barley and wheat imported from Canada and the Ukraine. The desert's carrying capacity is so far exceeded that the regeneration of desert plant communities, let alone woodland, is impossible under such a grazing pressure. After thousands of years of overgrazing, even the desert's **soil seed bank** is exhausted. Only fast-growing, short-lived flowering plants and a few tenacious bulbs survive. Without its protective cover of plants, the soil becomes unstable and erodes away with the winter rains and summer winds. As the soil gets thinner the land becomes drier, and the soil is able to absorb and store ever less water from the infrequent rains. Just as global climate fluctuation did before; our modern human culture has loaded the scales of this sensitive region, tipping the balance from verdant abundance to sun-scorched poverty.


Photo: Ayn Jedi

The first agricultural systems to be abandoned were those closest to the Dead Sea, like at Ayn Jedi where an agricultural community thrived in the late Chalcolithic. The Bronze Age fortified cities of the Jordan Valley and Judean Desert were abandoned sequentially from east to west, from low altitude to higher elevations with the highest surviving into the Iron Age. The desert continued to reach higher up the eastern slope, driving a migration of people from the lowlands towards the highlands and the coastal zone throughout the Hellenic, Roman and Byzantine periods.

Photo: Desertification on the Eastern Slope, Bethlehem Governorate

The desert continues to expand, climbing in altitude and latitude, but now for the first time there is no higher land to absorb the displaced farmers. The desert has reached up to 5km from the mountain ridge top and continues to climb. The conurbation of cities radiating and merging from their Bronze Age foundation sites has transformed the landscape from rural to urban. The construction of the Israeli Separation Barrier, comprising walls and fences, confronts this ancient desertification-driven migration, barring passage to greener lands. After its inception in the Fertile Crescent from 11 to 8.5 thousand years ago, our culture of cultivation and city-dwelling has reached maturity. For the first time in the history of the farming people there is nowhere left to run. We must turn around and face the devastation wrought by the degenerative land management so intrinsic to traditional agriculture and civilised culture and ask, “What next?” If we are done running then we must pragmatically tackle desertification where we stand. The good news is that we know how to regenerate the forest and rangeland. As mentioned, the soils are still there, as is a wealth of **biodiversity**. The challenge is how to make marginal agriculture profitable again so that the next generation of farmers might receive the knowledge and skills of this ancient tradition in Palestine. As the conditions have changed, so must the current agricultural methods and crop selection. Globalisation and information technologies facilitate this transition, providing examples of appropriate technologies and crops from around the world, from ancient and contemporary cultures.

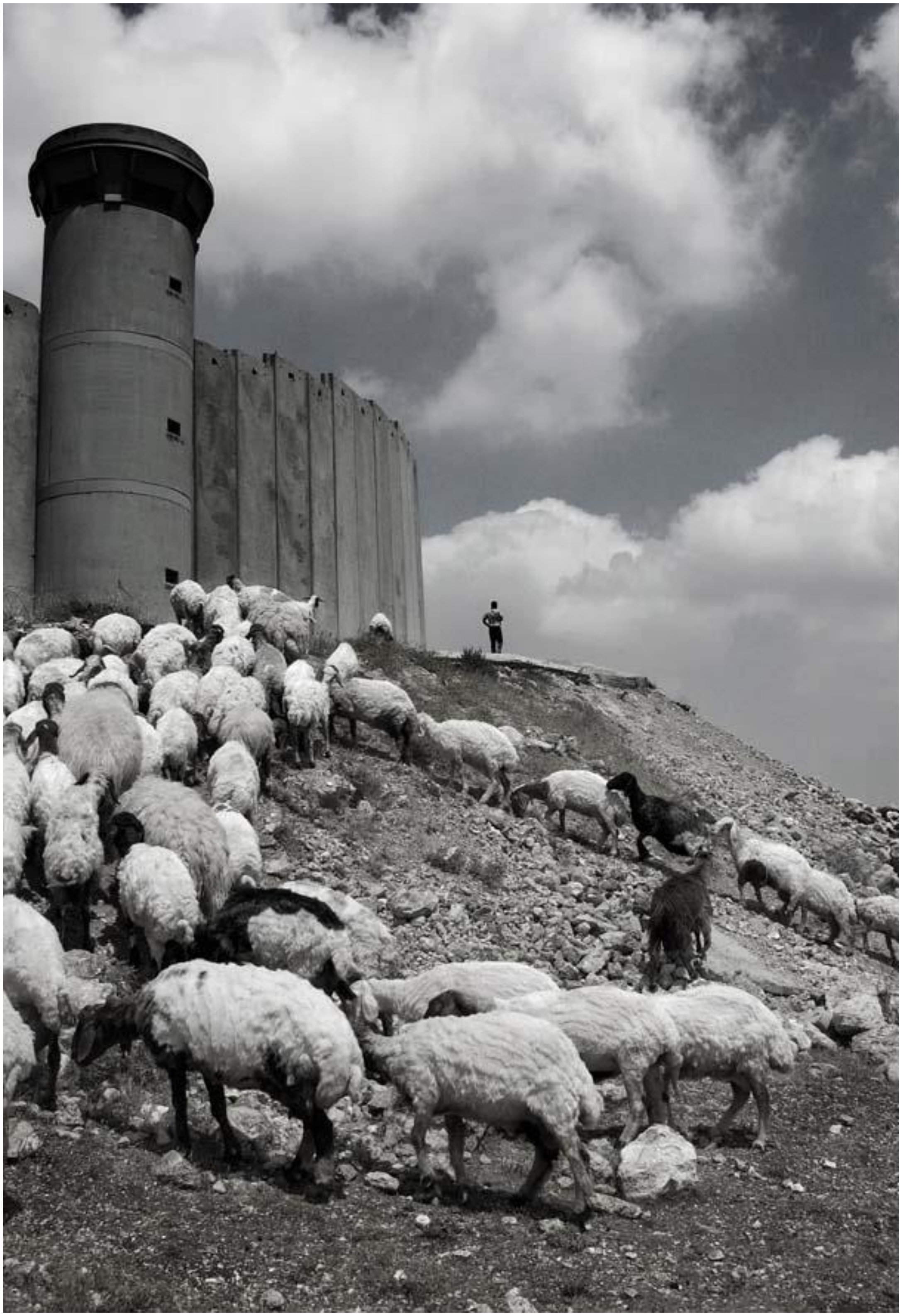


Photo: Separation Wall prevents migration to greener pastures. It is time to turn around and face the challenges of environment resource management. Photo by N. Marcroft

How to hold back the desert

Despite appearances, the Jordan Valley and Judean Desert are botanically diverse. The grazing pressure maintains almost all plants bitten back to the rock and supporting few leaves. A few shrubs like "Rattan" (broom) and *Caparis* (caper) grow from the rocks where the goats can't reach. Higher up the Eastern Slope the richer soils and wetter, colder winters support more diverse communities. An abundance of bulbs, corns, and **ephemerals** create spectacular floral displays in the spring, but by summer only compact spiny shrubs remain (e.g. "Natish" *Sarcopoterium spinosum*).

Photograph: Judean Desert in bloom in the month of March, Wadi an-Nar.


Photograph: *Sarcopoterium spinosum* woven with goat tracks on the Khirbet il-Mird, Judean Desert

If livestock is excluded then the vegetation will grow taller, accumulating biomass and insulating the soil. Gradually, over years, the shrubs will provide cover to nesting birds who will bring seeds of trees from far away. As the ecosystem becomes more stable and humid, the trees will be able to germinate and grow, stunted at first but growing taller as the **soil humidity** increases. The **ecological succession** from graze exposed soil and rock to woodland and savannah takes fifty years or more. This **succession** can be accelerated by identifying and removing the factors limiting the transition from one stage of regeneration to another. Simple farming techniques can produce woodland in just five years in the Judean Desert.

Three steps to abundance:

Step 1: Prevent grazing to protect the vegetation

- Coordinate with shepherds to prevent their flocks from entering a regeneration area
- Exclude the animals with a fence or hedge
  - Fencing
    - Living fence species such as *Geoffroea* and *Tamarix* can be used instead of wire fences and iron posts
    - 10cm poles are cut and hammered into the soil where they take root and resume growth
    - Avoid constructing a fence line down the gradient of the slope as the deflected livestock going up- and downhill will cause hoof erosion which promotes **gullying**

- Hedging
    - A living barrier of spiny plants will protect a regenerating forest effectively. In addition to grazer exclusion, hedges offer a range of products and services a fence does not:
        - Fruits and berries
        - Leaf forage for cows, sheep, and goats
        - Flowers producing nectar and pollen for bees
        - Windbreak
        - Fire break
        - Wildlife habitat supporting pollinators and predators of pests

      Double row hedging is best, with close planting intervals of 30 to 50 cm between plants in a row. The two rows should be staggered making a triangular planting pattern to increase the density of the hedge. Trees and shrubs need to be laid (the trunk is partly severed and bent down to the ground and pegged) to promote thicker, less penetrable growth. Hedges need clipping back to the desired height each winter to maintain their form.

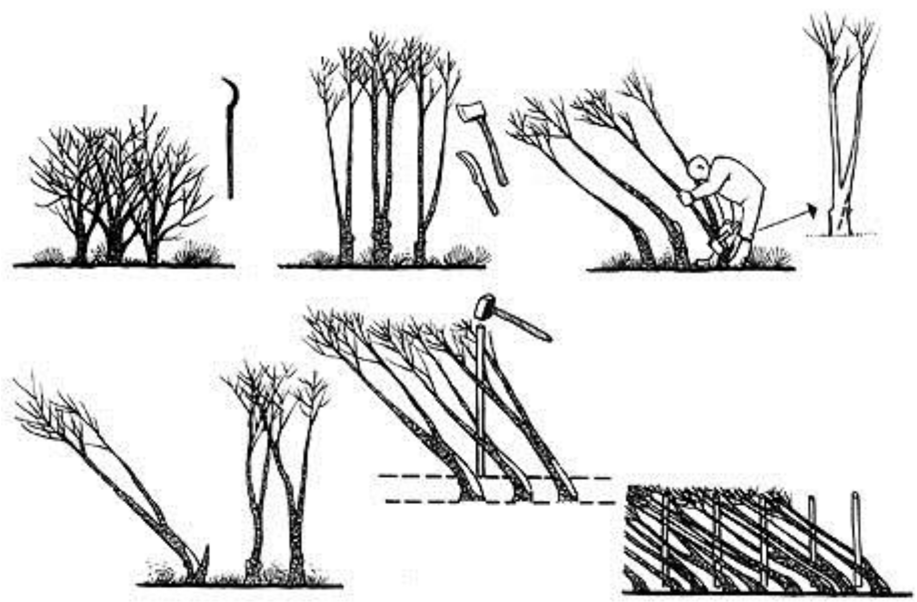
      

      Image: Hedge laying techniques and tools. By Oliver Liebscher

      Good edible spiny hedging species include:
        - *Rhamnus species*
        - *Crataegus azarolus*
        - *Ziziphus lotus*
        - *Agave Americana*
        - *Dovyalis caffra*

- Surround each tree with a protective sheath (translucent plastic tube) to a height of 1.5m, firmly attached to an iron or wooden stake. This method requires no perimeter fence or hedge, but if you plan to plant more trees than fence posts then this method becomes more expensive. The author's personal experience is that the posts (wooden or metal) are vulnerable to theft because they are easily portable. Once unsheathed the sapling will be grazed.

Step 2: Maximise rainwater harvesting

- Plant trees along swales directly under the swale mound:
    - Swales dug on contour stabilise the soil and harvest the winter rain. The most humid location to transplant trees is directly under the swale mound. The trees should be planted at regular intervals - predicted diameter of the tree's crown after five years - along the length of the swale. This depends on the species selection, but an example would be an interval of five meters for a fast-growing species like *Prosopis* and not less than three meters for slow-growing species like *Olea* or *Crataegus.*
- *Media luna* is a crescent-shaped soil-formed feature embracing a tree's planting hole. The open side of the crescent faces up the land gradient. When rainfall results in **runoff** the *media luna* traps a volume of rainwater around the base of the tree, where it infiltrates the soil. The wider the "arms" of the *media luna* the more **runoff** it will collect. *Media lunas* contribute to a rainwater harvesting landscape, and whilst prone to storm damage by erosion they are easily repaired.
- A compost pit beside the planted tree can be dug and filled with compost or any organic material. The pit will allow the rapid infiltration of **runoff**, increasing the subsequent **soil humidity** around the tree's roots and fertilising the tree in time. It is impractical to create compost pits for thousands of trees but this is a recommended technique for small-scale reforestation projects.
- Identify natural drainages in the landscape and plant there first, expanding gradually over years towards the ridges. Water flows downhill, so starting planting in the *wadis* and on the floodplain means planting closest to the water table and therefore in the most humid soil conditions. However, the *wadis* and floodplains are highly erosive environments where overgrazing has removed the vegetation from the slope above. Planting in the drainage channel may be futile due to the violence of the flash floods. It is therefore recommended to start planting where the valley side meets the floodplain, and in the rocky *wadis* leading the floodplain. Swales dug at regular intervals of the slopes and gabions constructed across the *wadis* will reduce the amount of **runoff** and the erosion it causes. Gradually as tree cover extends from the most humid areas to the slopes the landscape will stabilise and the flash floods will be mitigated by increased rainfall interception and infiltration.

  The Nabateans developed a **runoff** irrigated **silvicultural** system about 1700 years ago in the southern deserts of Palestine. In an arid desert landscape already denuded of vegetation by overgrazing, receiving only 50-100mm of rainfall a year, the Nabateans cultivated orchards and cereal crops. They harvested rainfall **runoff** from a large area of desert, directing it with long channels which gently descend to the gardens in the *wadis* (*il-wudian*) graduated by gabions. The gardens still survive today, where olive, fig, and pomegranate continue to grow untended and are watered by the rains. A combination of rain-fed agriculture and trade sustained their remote but prosperous cities for a thousand years, surrounded by desert.

Step 3: Maximise conservation of soil humidity

- Pit planting is a method of establishing trees in harsh arid conditions with minimum irrigation. This technique is recommended only for dry climates with infrequent rains because the pit fills with water, which in wetter climates would drown the tree. In Palestine, the pit usually drains into the surrounding soil before the next rainfall occurs, and thus the tree is not inundated with water long enough for oxygen depletion or fungal infection to occur. The soil depth may limit the depth of the pit, but ideal dimensions are 1m x 1m x 1m - the planting hole is dug in the base of the pit and the soil enriched with compost, before seedling or sapling trees are planted at the bottom.
    - The pit creates an **ameliorated microclimate** in which the tree can establish. The soil at the base of the pit is shaded as the sun is rising and setting. Only during the noon hours the sun shines directly into the pit when the tree's own leaves will shade the soil around its roots. Because the soil around the roots is not heated by the sun, the **soil humidity** is conserved. Air movement is also reduced inside the pit than, further conserving the **soil humidity**. As soil dries from the surface downwards from winter to summer; planting the tree one metre under the land's surface means that the tree's roots remain in humid soil until later in the season. The pit also has other functions which contribute to more rapid tree establishment:
    - The pit will temporarily collect **runoff**, effectively harvesting rainwater.
    - Both the wind and the rain transport light organic material into the pit, improving the soil fertility and structure to absorb and conserve water.

Photo: Pit planting

- Mulching is essential to conserve **soil humidity** and fertility, and contributes significantly to reducing **water stress**. Less stressed trees are more vigorous and have stronger immune systems, so mulching indirectly prevents disease. Ideally each tree is thickly mulched to a radius of 2 metres. A continuous sheet of mulch is effective, but does pose a fire hazard, and cardboard mulches must be weighted down with rocks or sods to prevent the wind from blowing them away.

- Irrigation assisted establishment: While it is possible to transplant trees successfully into a desert environment without irrigation, the success rate is low and the farmer is restricted to a few desert **pioneer species**. Irrigation can be used to accelerate the **ecological succession** by artificially increasing the **soil humidity** to allow the establishment of a great diversity of tree and shrub species. The plantation should establish in three winters, thus irrigation can be permanently withdrawn at the end of the second summer dry season.

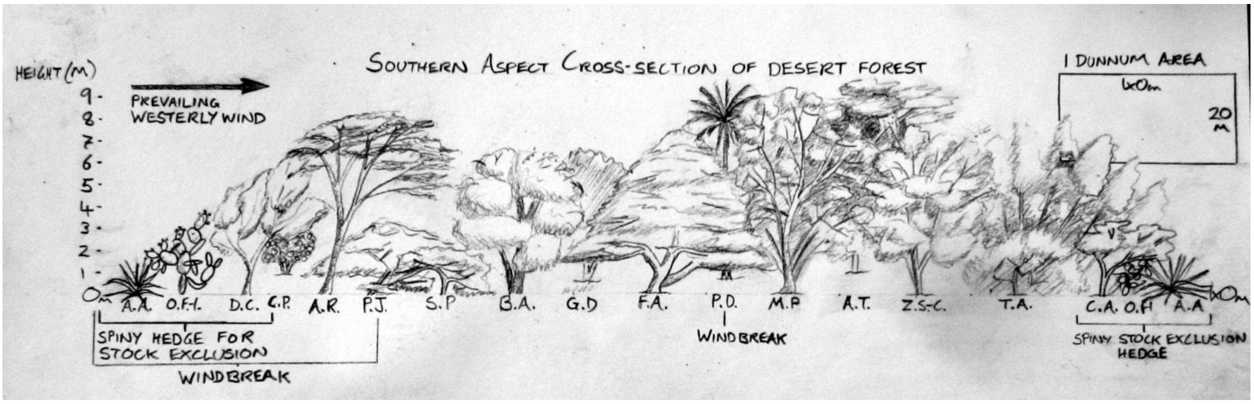
- Drip-point irrigation uses a pressurised network of plastic flexible tubing punctuated with valves which slowly deliver water to each tree.
    - Ideally rainwater is used to avoid soil salination
    - A vertical drain can be used for subterranean irrigation to conserve water and reduce weed competition
    - For greatest efficiency the irrigation rate should be only slightly greater than the evapotranspiration rate: variable valves allow trees on the same line to receive different rates of irrigation corresponding to their species' irrigation requirement

Photo: Village in the Masafer il-yatta, Judean Desert before tree panting

Photo: Village in the Masafer il-yatta, Judean Desert just three years after tree planting.

Photo: Taking tea in the shade of a three year old desert orchard, il-Halawah village, Masafer il-Yatta, Judean Desert.

Sketch of design template for a desertification resistant forest



Key to Sketch of desertification resistant forest cross section. from left to right:

Abbreviation	Tree Species
A.A.	*Agave americana*
O.P.	*Opuntia ficu-indica*
D.C.	*Dovyalis caffra*
C.P.	*Calotropis procera*
A.R.	*Acacia raddiana*
P.J.	*Prosopis juliflora*
S.P.	*Salvadora persica*
B.A.	*Balanites aegyptiaca*
G.D.	*Geofroea decorticans*
F.A.	*Faidheria albida*
P. D.	*Phoenix dactylifera*
M.P.	*Moringa peregrina*
A.T.	*Acacia tortilis*
Z.S-P.	*Ziziphus spina-christi*
T.A.	*Tamarix aphylla*
C.A.	*Crataegus azarolus*
O.F-I.	*Opuntia ficu-indica*
A.A.	*Agave americana*

List of tree species recommended to reverse desertification

Table of tree species:

Latin Binomial	English Species Name	English Variety Name	Palestinian Arabic Species Name	Palestinian Arabic Variety Name
Acacia nilotica				

*Acacia raddiana**	Umbrella tree		سويد	
*Acacia tortilis**	Umbrella tree		سويد	
Albizia lebbeck	Lebbeck			
*Balanites aegyptiaca**	Soapberry		الزقوم	
*Calotropis procera**	Sodom Apple			
Casuarina cunninghamiana	River She-oak			
Casuarina equisetifolia	Coast Sheoak			
Casuarina glauca				
*Ceratonia siliqua**	Carob		خروب	
	Carob	American	خروب	امريكي
	Carob	Baladi	خروب	بلدي
*Crataegus azarolus**	Hawthorne		زعرور	
*Cupressus sempervirens**	Cypress			
Dovyalis caffra	Kei Apple			
*Faidherbia albida**	White Acacia			
*Ficus carica**	Fig		تين	
Geoffroea decorticans	Palo Verde			
Gleditsia triacanthos inermis	Honey Locust			
Leucaena leucocephala	Lead tree			
Moringa	Palestinian		اليسسر	

*peregrina**	Moringa			
Morus alba	White		توت ابيض	
Morus nigra	Black Mulberry		توت اسود	
*Morus rubra**	Red Mulberry		توت احمر	
	Red Mulberry	Baladi	توت احمر	توت بلدب
	Red Mulberry	Iranian (long)	توت احمر	توت ايراني
*Olea europea**	Olive		زيتون	
*Phoenix dactylifera**	Date Palm		فستق حلبي	
*Pinus pinea**	Pine			
*Pistacia atlantica**	Terebrinth			
*Pistacia lentiscus**	Mastic Tree			
*Pistacia palaestina**				
Pistacia vera	Pistachio			
Prosopis alba	White Mesquite			
Prosopis juliflora	Mesquite		السلم	
Prosopis nigra	Black Mesquite			
Prunus dulcis	Almond		لوز	
Punica granatum	Pomegranate		رمان	
Salvadora persica	Toothbrush Tree			
*Tamarix aphylla**	Athel			
Tipuana tipu				
Ziziphus lotus				
*Ziziphus spina-christi**	Christ's Thorn Jujube		السدر	

*indigenous species

4. Phytoremediation for poor quality water sources: sewage, salt, greywater

Trees don't need pure rainwater to grow. Naturally or artificially degraded water sources may be used, and these have one thing in common: dissolved solid load or solute. The dissolved soil load of a water source (salt and/or soda) will affect plant growth.

There are two ways to mitigate the pernicious effects of high salinity or sodicity: dilution and discontinuous supply.

The chemical constitution of the water needs to be tested, either in the field or in the laboratory. The water source is diluted with a higher quality water source until the salinity or sodicity are adequate for plant growth. Otherwise trees can be irrigated occasionally with degraded water so long as it is followed by rain or a purer water source. For example, trees in a domestic orchard can be irrigated in turn with the soap-degraded water from a washing machine in addition to the irrigation supply.

Essentially the water needs to be delivered in a way that does not result in long term accumulation of salts and soda in the soil, which would reduce plant production. Of course some plants are more salt-tolerant than others, but where the salts are concentrating year after year even the most salt-tolerant species will be negatively affected. Species that actively sequester the ionic salts, incorporating them into their leaves, trunks, flowers etc. can be used to remove the solute from the soil. The degraded water then needs to be delivered at a rate not exceeding the trees' ability to remove the additional dissolved salt in the water. Conservation of **soil humidity** is essential as more irrigation means more salt. The forest's total salt sequestration rate increases with maturity, so the irrigation supply can be increased accordingly.

Greywater Irrigation

Greywater irrigation is the reuse of domestic water, with the exception of sewage or any wastewater streams contaminated with faeces. Kitchen sinks, floor drains, washing machines, and hand basins can be separated from the sewage drain to reuse the effluent water for tree irrigation. It is important to manage the quality of the wastewater by preventing its unnecessary contamination: all toxic chemicals (including bleach) should be excluded, and soap and other detergents should be kept to a minimum. Too much soap will result in soil salinisation and **water stress** of the crop. It is not recommended that root vegetables, salads, or creeping crops (where the edible portion of the plant comes into direct contact with the ground water e.g. melon) be irrigated with wastewater for health reasons. That said, a thick mulch layer around a crop like tomato will provide a barrier to contact. Other vegetables like cereals, maize, and sunflowers can safely be irrigated with domestic greywater. Trees, however, are able to make better use of greywater, especially evergreens which utilise the available water whenever the temperatures permit growth (which is almost every day of the year in Palestine). Trees also more able to survive periods of reduced, or no greywater supply, for example when an office or school is unfrequented over the weekend or when a home is uninhabited. Not only are trees more likely to survive, they also retain the growth of the preceding period of resource investment.

Greywater irrigation systems should be kept as simple as possible. Wherever practical, the greywater streams should not be united. For example the kitchen greywater, hand basin greywater, and laundry greywater from one home should exit the house separately to irrigate different crop areas. A single greywater stream can be used to irrigate different plants in turn by either switching the plumbing between static drains leading to each plant, or a single rigid pipe can be pivoted from the house to successively irrigate trees planted along its radius. For example each tree receives water for one day and they are irrigated cyclically. Many more complex and expensive greywater systems exist (branched drains, constructed wetlands and pressurized filtration units) but in the author's opinion these will fail in most circumstances due to the filthy nature of the apparatus and lack of volition to involve oneself in the maintenance of such systems. The more complex the system the more complex the maintenance and repair will be. For simplicity and reliability, a straight pipe of >4% gradient so the water flows with gravity into an infiltration basin or swale, on the periphery of which trees are planted. A fast-growing species is best to make use of the water and fertiliser received.

Sewage and urban runoff irrigation

More contaminated water streams like sewage, road **runoff**, and natural saline springs are commonplace in Palestine. In fact, most of the surface water in the West Bank is sewage or the leakage from mountains of rubbish. These water streams require more careful design to mitigate the health risk posed.

Products of trees grown along the river bank or around infiltration basins must not enter the human food chain. Heavy metal ions taken up by the trees are stored in the plant's tissues and passed on to herbivores (Human and non-human). It is therefore advised to avoid planting popular fruit trees on sewage or urban runoff streams. Sheep and goats should be prevented from grazing the foliage and bark of the trees because the heavy metal ions ingested in this plant material are absorbed and become concentrated in the meat and the milk of the animal and get passed in to the human food chain.

Instead of animal forage and food for humans these situations provide opportunity to mitigate the environmental contamination caused by the sewage but also to produce construction materials like timber, pole and cane and fuelwood. Suitable species are listed in the table of desalinating tree species at the end of this chapter.

Photo: Sewage stream in the Wadi il-Nar, Judean Desert, the consequence of the flush toilet and inadequate wastewater treatment facilities.

Saline springs

The Ghuwar (esp. Wadi il-Melah) and the Dead Sea shore offer surprising opportunities for growing trees. The natural clean spring water is salty or brackish. Testing should be done in order to identify the dissolved solid load, but it is important to remember that many tree species (general list below) can survive with saline water. Check the species profiles for a comparison of salt tolerance. Ultimately the species must be salt-sequestering not just salt-tolerant for a sustainable forest system.

Desalinating species for Palestine

Table of tree species:

Latin Binomial	**English Species Name**	**English Variety Name**	**Palestinian Arabic Species Name**	**Palestinian Arabic Variety Name**
Acacia nilotica				
*Acacia raddiana**	Umbrella tree		سويد	
*Acacia tortilis**	Umbrella tree		سويد	
Albizia lebbeck	Lebbeck			
*Balanites aegyptiaca**	Soapberry		الزقوم	
Casuarina equisetifolia	Coast Sheoak			
Ceratonia siliqua	Carob		خروب	
Chamaecytisus palmensis	Tree Lucerne			
*Cordia sinensis**				
Dalbergia sissoo	Indian Rosewood			
Delonix regia	Royal Poinciana			
*Faidherbia albida**	White Acacia			
Ficus carica	Fig		تين	
Geoffroea decorticans	Palo Verde			
Gleditsia triacanthos inermis	Honey Locust			
Grevillea robusta	Southern Silky-			

	oak			
Leucaena leucocephala	Lead tree			
*Moringa peregrina**	Palestinian Moringa		اليسسر	
Morus alba	White		توت ابيض	
Morus nigra	Black Mulberry		توت اسود	
*Morus rubra**	Red Mulberry		توت احمر	
*Phoenix dactylifera **	Date Palm		فستق حلبي	
*Portulaca oleracea**	Purslane			
Prosopis alba	White Carob			
Prosopis juliflora	Mesquite		السلم	
Prosopis nigra	Black Carob			
*Salvadora persica**	Toothbrush Tree			
Sclerocarya birrea	Marula Tree			
*Tamarix aphylla**	Athel			
Terminalia catappa	Bengal Almond			
*Ziziphus spina-christi**	Christ’s Thorn Jujube		السدر	

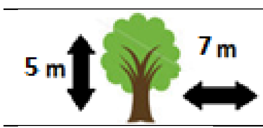
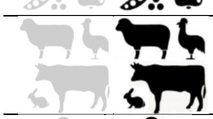
CHAPTER V

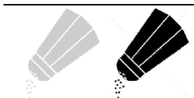
Tree Species Profiles and Illustrative Plates

Featured Tree Species

These species offer a combination of products and services. These featured species are deserving of special consideration for inclusion of agroforestry design in Palestine because they offer a range of high quality products and services thrive in the conditions of our environment. In addition several of these species are endemic to the river Jordan/Dead Sea depression occurring nowhere else on Earth.

Key to featured species profiles

Symbol	Explanation
	Water requirement: the tree needs a minimum annual rainfall of:
	Less than 200 mm
	200-300 mm
	300-500 mm
	500-700 mm
	more than 700 mm
	Estimation of tree size after 20 years
	Indication that the tree produces edible parts such as fruits
	Indication of the tree’s use as animal fodder (including the amount and quality of the fodder)
	Indication of the tree’s suitability for use as timber (taking account of wood quality, growth rate, and growth form)
	Indication of the tree’s suitability for firewood – trees lacking this symbol produce either too little wood, or produce too much (or even poisonous) smoke when burned

	Indication of whether the tree has a positive effect on other plants, such as acting as a wind break, attracting birds or insects, or the propensity for intercropping
	Indication of the tree's ability to improve soil (through nitrogen fixation, mineral mining, bioremediation etc.)
	Indication of the tree's ability to act as a fire break
	Indication of the tree's ability to tolerate or remediate high-salt conditions

Acacia tortilis - Umbrella Thorn

Why?

- Gum Arabic, a food additive, can be derived from this tree
- The Umbrella Thorn, including the species *A. raddiana* and *A. tortilis*, provides excellent animal fodder and is particularly fast-growing
- The dried leaves and grounded fruits can be used for stall-fed animals
- Attractive for many pollinators, and thus is useful for beekeeping
- If kept free from grazers for the first two years of growth it provides an excellent windbreak; through this characteristic, as well as being a nitrogen-fixing species, it is well-suited to intercropping
- The soil become stable wherever grown and therefore is useful for desert and hill slope afforestation
- It is fast-growing and can be coppiced, and thus its dense, hard wood can be used both as fuel wood and for timber for small objects and furniture.

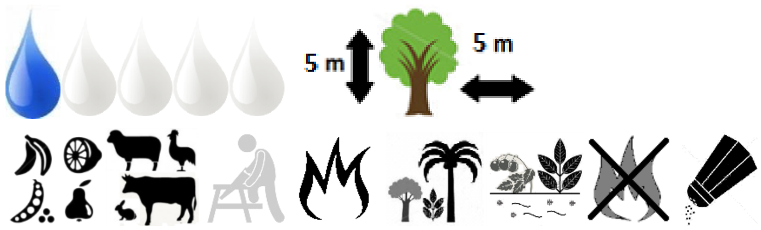
How?

- Propagate from fresh seeds
- Pre-treatment: boil for 5 minutes, allow to cool, and leave to soak for 24 hours before sowing; alternatively, submerse the seeds in 50% concentrated sulphuric acid for 40-50 minutes, rinse thoroughly, and leave to soak for 24 hours before sowing
- Cut and drop branches for sheep and goats who eat the leaves and strip the important mineral- and oil-rich bark from the branches

Acacia tortilis

Photography by T. Fernley-Pearson

Balanites aegyptiaca - Desert Soapfruit



Why?

- The pulped fruit can be eaten fresh or dried, ripe or even unripe; the tender shoots and the young leaves are also edible
- Oil can be extracted from its kernels
- Soap, which pollutes grey water only marginally, can be derived from its fruit
- Dried and fresh leaves, can be used as good fodder during dry seasons
- Its hard and durable wood produces little smoke when burned, and can be used for the production of excellent charcoal; however, due to its slow growth rate and small logs, use for timber is not recommended
- Its evergreen foliage provides shade and shelter
- Flowers are attractive to numerous insect species, making it useful for beekeeping
- It is nitrogen-fixing, and helps to improve the quality of soil upon which it is grown
- It grows well in the hottest and driest areas

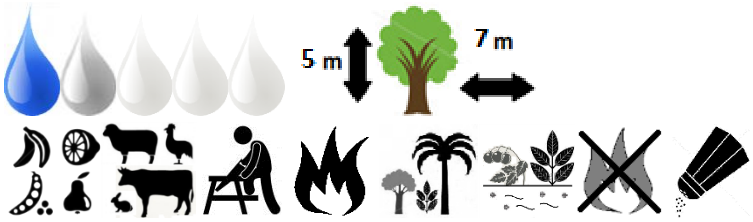
How?

- Sow seeds when fresh as possible
- Soaking the fruits in water for some hours helps separate the pulp from the stones
- Germination can be sped up by submerging the seeds in boiling water for 7-10 minutes, and then cooling them slow
- *B. aegyptiaca* trees can be planted along the banks of irrigation canals for stabilization

Balanites aegyptiaca

Photography by T. Fernley-Pearson

Ceratonia siliqua - Carob tree



Why?

- The fruits of C. siliqua can be used to make syrup or juice, and can also be eaten fresh or dried
- The seeds of this tree, known as *locust beans,* can be used as a food thickening agent
- The fruit provides fodder for all animals, and the carob seed flour is a nutritious additive for animal foods
- Carob trees have closed-grained wood that provides a fine, pink-coloured timber that is extremely versatile, proving acceptable firewood and yielding good, slow-burning charcoal
- This is a weak nitrogen-fixing tree
- Its extensive root system penetrates rock and soil, and is mineral-mining to the benefit of intercropped plants
- It is fire retardant and evergreen, and thus provides an ideal perimeter windbreak
- The carob grows well with all common fruit trees

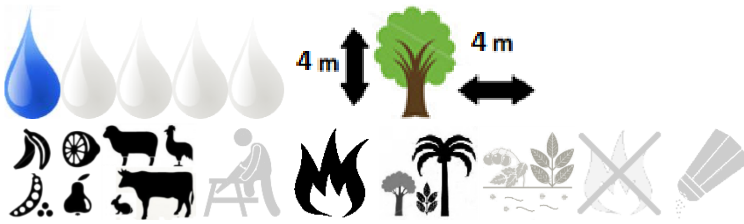
How?

- Sow seeds when fresh as possible
- Before sowing, the seed must be boiled for 1 minute, then left in cold water to cool for 24 hours - this water should be changed after 12 hours
- Sow the seed outdoors at a depth of 1 cm
- Carob trees are either male or female. Only female's produce fruit - grow only females if there is a male in the neighbourhood (as the flowers require pollination to fruit!)
- Carob trees can grow literally right on the rock

Ceratonia siliqua

Photography by T. Fernley-Pearson

Crataegus azarolus – Azarole



Why?

- The fruits are delicious fresh or dried, and can be preserved as syrup
- Both fruits and leaves can be used as animal fodder
- The hard and heavy wood can be used as timber for the production of small wooden items, and also as firewood
- The strong rootstock it develops can be used for the grafting of apple, pear, and quince
- It is good for apiculture, and it attracts birds and insects
- Due to its small size, it is well-suited to being planted in orchards
- This species can be used to provide a protective hedge
- This tree can flourish on every soil type, and is particularly useful for preventing the erosion of thin, rocky soils

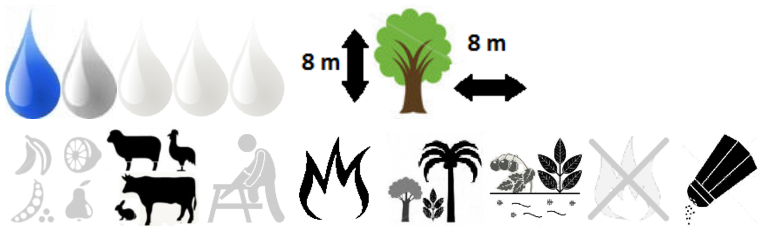
How?

- The seeds are best sown as soon as they are ripe in Autumn
- To speed up the germination process, the seed can be fermented in its own pulp for a few days
- The seed should be sown in containers and then transplanted after one year - it will grow well on thin soil and rocky slopes

Crataegus azarolus

Photography by T. Fernley-Pearson

Faidherbia Albida - Winter Thorn



Why?

- The leaves and pods of *F. albida* make good animal food
- Excellent source of fuelwood but a produces poor quality timber
- Only *Faidherbia* and *Moringa* trees are summer deciduous; these trees are particularly valuable for reafforestation and planting on dry lands, as their lack of summer foliage reduces their water requirement in the driest period of the year - in this way, the food forest can achieve a positive water balance, meaning soil humidity increases year on year
- During the dry season, when the tree is foliated, it shades animals and crops
- The roots grow deep and thick and an excellent mineral-miner and nitrogen-fixer and thus a great choice for intercropping

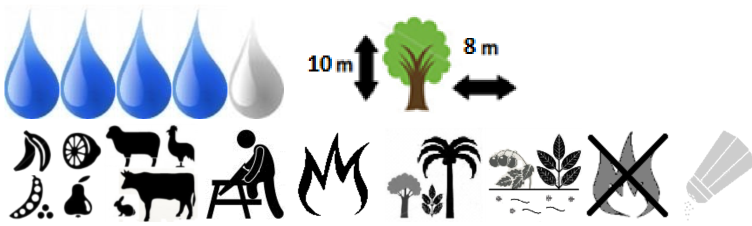
How?

- Use the freshest seeds possible!
- Pre-treat the seeds by boiling for 10 minutes, and then cooling slowly
- Soak for 24 hours before sowing

Faidherbia albida

Photography by T. Fernley-Pearson

Leucaena leucocephala - Leucaena



Why?

- *L. leucocephala* continuously produces tender green pods, green seeds, and leaf tips that are all nutrient-rich and delicious when cooked
- These, in addition to the huge volumes of foliage, flowers, and bark it produces, also provide excellent and highly valuable animal fodder
- Capable of producing copious quantities of pollen and nectar for apiculture
- Excellent source of fuelwood and timber can be used to make straight poles
- A very fast growing species, and, although drought-tolerant, irrigation will greatly increase productivity
- This tree has the highest recorded rate of nitrogen fixation of any tree, and is therefore the best choice for improving soil fertility

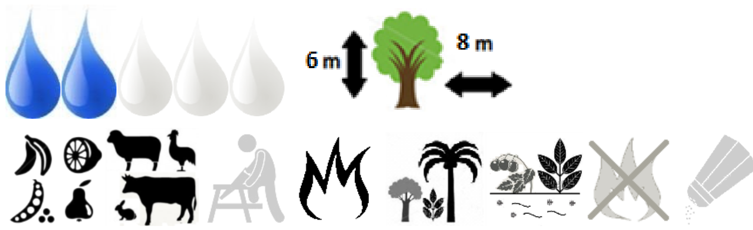
How?

- Propagation from seed is easy: use ripe, fresh seed sown at maximum one centimetre depth
- Boil the seeds for one minute, then soak for 24 hours before sowing for more prompt and synchronous germination

Leucaena leucocephala

Photography by T.Fernley-
Pearson

Moringa peregrina - Palestinian Moringa



Why?

- The leaves, roots, and seeds are exceptionally rich in nutrients, containing a wealth of vitamins and minerals (very high quality food can be produced on the poorest soil)
- A pleasant tasting oil can be produced from its seeds
- Seeds can be used to purify water - placing seed powder into wastewater helps kill bacteria, making it more usable
- Its highly nutritious leaves can be used as fodder for goats, sheep, and poultry
- A further product of this beautiful, thornless tree is fuelwood
- Only Faidherbia and Moringa trees are indigenous summer deciduous; these trees are particularly valuable for reforestation and planting on dry lands, as their lack of summer foliage reduces their water requirement in the driest period of the year - in this way, the food forest can achieve a positive water balance, meaning soil humidity increases year on year
- Nitrogen-fixing and provides a fertile soil for intercropped plants

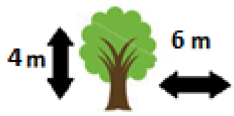
How?

- Soak the seeds for 48 hours before sowing
- Moringa is tolerant of poor, dry soils, and grows especially well on the rocks of desert wadis

Moringa peregrina

Photography by T. Fernley-Pearson

Pistacia palaestina - Terebinth

Why?

- Extremely drought tolerant
- *Pistacia vera* can be grafted on the rootstock
- The resin is known as “mastic” and can be used as a preservative
- Traditionally, seeds are milled and added to bread flour to spice it
- Oil can be produced from the seeds
- This tree is fast growing thus its wood is an excellent source of fuelwood and timber

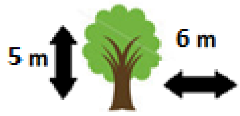
How?

- Soak cleaned seeds in warm water for 3-4 days prior to sowing (although still germination is slow and patchy!)
- Higher germination rates can be achieved by submerging in 50% concentrated sulphuric acid for 90 minutes, followed by soaking in cold water for 24 hours prior to sowing
- Terebinth trees are either male or female. Only females produce seeds.

Pistacia palaestina

Photography by T. Fernley-Pearson

Quercus calliprinos - Kermes Oak



Why?

- Excellent fodder for sheep and goats (acorns are an alternative to barley and maize)
- A slow growing species, providing dense and heavy firewood and timber of the highest quality
- Fire resistant, but regrows in the form of a dense and branched shrub
- Exceptional windbreak and attracts a wide variety of different birds and insects which can benefit intercropped plants
- In the long term, it is the most important species for soil improvement

How?

- The seed is best sown as soon as possible, especially before it dries as it loses its viability
- The young tree should be transplanted soon after growth has started

Quercus calliprinos

Photography by T. Fernley-Pearson

Tree Species' Profiles

Acacia nilotica

- Tender pods, shoots, and seeds are edible
- 'Gomme arabique' for inks, paints, and confectionery
- Pods and shoots are a valuable forage for camels, goats, and sheep
- Popular bee forage
- Excellent fuel wood and charcoal
- Yellowish-white, durable, and hard timber
- Evergreen and therefore leaf interception during a good rainy season
- Nitrogen-fixing
- Good windbreak
- Very drought tolerant
- Gets damaged by severe frosts

Acacia raddiana

- Highly nutritious forage (bark contains oils and minerals)
- Excellent fuel wood
- Durable wood for working/turning
- Excellent apiary species
- Extremely drought tolerant (no irrigation required)
- Nitrogen fixing
- Tolerates light frosts

Acacia tortilis

- Highly nutritious forage (bark contains oils and minerals)
- Excellent fuel wood
- Durable wood for working/turning
- Excellent apiary species
- Extremely drought tolerant (no irrigation required)
- Nitrogen fixing
- Tolerates light frosts

Albizia lebbeck - Lebbeck

- Leaves are a valuable forage
- High quality honey is provided by its nectar
- Excellent fuel wood
- Strong and durable timber
- Gum is extracted from the trunk

- Soap is gained from the bark
- Erosion control due to its extensive root system
- Good nitrogen-fixing species
- Drought tolerant; Mean annual rainfall: 500-2500 mm
- Can tolerate some frost

Arbutus andrachne

- Starwberry tree
- Small, slow growing tree attaining 18m
- Good fruit ripening in autumn
- Attractive bark
- Non-deciduous
- Requires irrigation in all but the highest attitudes in Palestine
- Frost hardy

Atriplex halimus - Sea orache

- Extremely tolerant of pruning
- Leaves of this evergreen shrub are eaten raw or cooked
- Salt extracting plant, ideal to desalinate
- Low-growing windbreak
- Drought tolerant
- Frost hardy

Balanites aegyptiaca

See Chapter V.

Bauhinia purpurea

- Young leaves and flowers are edible
- Leaves make good fodder
- Ornamental species
- Erosion control due to its extensive root system
- Mean annual rainfall: 1000-1500 mm
- Severe frost kills leaves and seedlings but the tree recovers

Calotropis procera - Dead Sea fruit

- Young pods, senescing leaves and flowers of this shrub are eaten by goats, occasionally also by sheep
- Good fuel wood and charcoal
- Drought resistant
- Salt-tolerant
- Pod contains a small quantity of fine silk

Carya illinoinensis - Pecan

- An oil is extracted from the seeds and they are also an excellent food
- Tasty and nutritious nuts
- Does not fruit for 8-15 years

- Grows up to 45 m high
- Cross-pollination results in a better yield
- 38° C and above are well tolerated
- Annual rainfall needed: approx. 750 mm
- Fully hardy

Cassia fistula - Cassia

- High yield of pollen and nectar for beekeeping
- Good timber
- Ornamental
- Mean annual rainfall: 500-2700 mm
- Not frost hardy

Casuarina cunninghamiana - River She-oak

- Excellent fuel wood (see C. equisetifolia)
- Salt tolerant
- Half hardy

Casuarina equisetifolia

- 'The best firewood in the world'
- Good timber
- Excellent windbreak
- Good nitrogen-fixing species
- Suitable for intercropping and agroforestry systems
- - Grows with 200 mm annual rainfall
- Intolerant of frost

Casuarina glauca

- Excellent fuel wood (see C. equisetifolia)
- Species was grown in Israel under a soil crust of salt (50,000 ppm)
- Not really frost hardy

Ceratonia siliqua

See Chapter V

Chamaecytisus palmensis - Tree Lucerne

- Foliage is valuable forage
- Good bee forage
- Nitrogen fixer
- Firebreak
- Species is used to control salinization and to reclaim wastelands
- Remarkably drought resistant; grows with 350 mm mean annual rainfall
- Frost hardy

Citrus x limon - Lemon

- Acidic-tasting fruits are eaten in different forms
- Fruit juice acts as an antioxidant
- An essential oil is gained from the rind

- Flowers can be eaten in ice creams, jams, etc.
- Not drought tolerant, prefers moist soil
- Half hardy

Citrus maxima - Pomelo

- Nutritious and delicious fruits
- Good species for beekeeping
- Good timber
- Essential oil is gained from both fruits and leaves
- Erosion control
- Ornamental species
- Rainfall needed: 1500-1800 mm
- Half hardy

Commiphora gileadensis

- Produces the highly valuable, resinous gum known as "Balsam of Mecca", "Balsam of Gilead" and "Balm of Gilead".
- Economically important crop of the Dead Sea shore and Jordan Valley in antiquity.
- In Latin the resin is called *opobalsamum*; the dried fruit, *carpobalsamum*: and the wood, *xylobalsamum*.
- Resin is used for valuable perfume since ancient times and is renowned is maintained by Biblical references.
- The resin has healing properties
- Cultivation requires hot, dry, frost free conditions in poor, rocky soil
- Tree is slow growing, small (not exceeding 4 meters in 20 years), and have swollen, tortuous trunks and branches with sparse deciduous foliage.

Commiphora myrrha

- Produces the highly valuable, fragment resinous gum known as Myrrh
- The Bible story of the Nativity of Christ names the incense made from this gum as one of the offering made by three Magi.
- Cultivation requires hot, dry, frost free conditions in poor, rocky soil
- Tree is slow growing, small (not exceeding 4 meters in 20 years), and have swollen, tortuous trunks and branches with sparse deciduous foliage.

Cordia sinensis

- Good forage
- Pulp of the fruit can be eaten fresh or juiced
- Edible gum
- Timber is used for small items
- Occurs at an annual rainfall of 600-1000 mm
- Not frost hardy

Crataegus aronia

- Delicious but small fruits
- Good root stock for Rosacea

- Beautiful spring bloom
- Good hedging species
- Requires no irrigation in the highlands
- Propagated from seed or easily from cuttings
- Attracts pollinators and birds
- 5-6 meters after 20 years
- Fully hardy

Crataegus azarolus – Hawthorn

See Chapter V

Cupressus sempervirens

- Essential oil can be gained from the shoots
- Excellent timber
- Drought tolerant
- Fully hardy

Cydonia oblonga - Quince

- Fruit is used for jellies or preserves
- Prefers moist soil
- Fully hardy

Cytisus proliferus

-

Dalbergia sissoo

- Excellent timber known as Indian rosewood
- Excellent fuelwood and charcoal species
- Fast growing
- Can reach 25m in height and 2m in girth
- Not frost tolerant
- Salt tolerant
- Tolerates very sandy soil

Delonix regia - Flame tree

- Acceptable timber
- Useful tree for beekeeping
- Evergreen and therefore with good rainy season leaf interception
- Ornamental species
- Nitrogen-fixing species
- Mean annual rainfall: 700-1200 mm
- Not frost hardy but will grow in nearly frostless areas

Diospyros kaki - Persimmon

- Delicious fruits
- Good timber
- Ornamental species
- Male and female trees occur; both must be planted to grow fruits
- Prefers moist soil
- Frost hardy

Eriobotrya japonica - Loquat

- Delicious fruits
- Good species for beekeeping
- Excellent timber
- Good windbreak
- Evergreen and therefore leaf interception during a good rainy season
- Ornamental species
- Quite drought resistant
- Tolerates light frosts

Faidherbia albida

See Chapter V

Feijoa sellowiana aka Acca sellowiana

- Delicious fruit known as pineapple-guava
- Delicious succulent flower petals
- Woody shrub reaching 3m after five years
- Drought resistant but requires soil humidity while the fruit is maturing in the spring
- Frost hardy and requires two consecutive cold winter days to stimulate flowering
- Tolerates some salt
- Free of pests and disease
- Non-deciduous

Ficus carica - Fig

- Sweet and succulent fruits eaten fresh or dried
- Prefers moist soil
- Fully hardy

Geoffroea decorticans

- Seeds and fruits are valued as human and animal feed
- Good fuel wood
- Acceptable timber
- Not really drought tolerant
- Frost hardy

Grevillea robusta aka Southern Silky Oak

- Fast growing reaching height of 18-35m in twenty years

- Excellent rot-resistant timber
- Good firewood
- Frost hardy
- Requires occasional summer irrigation in Palestine
- Flowers and fruits are toxic

Gleditsia triacanthos inermis aka Thornless Honey Locust

- Fast growing spreading crown quickly provides good shade
- Good livestock animal forage and fodder
- Good apiary tree
- Good fuelwood
- Excellent rot-resistant timber
- Attractive spring flowers
- Nitrogen fixing
- Drought tolerant
- Salt tolerant

Jacaranda mimosifolia

- Suitable bee forage
- Good fuel wood
- Hard and fine textured timber used for carpentry ("rosewood")
- Windbreak
- Very beautiful ornamental tree even when not in bloom
- Needs more than 900 mm mean annual rainfall
- Frost tender when young

Jasminum officinale **- Jasmine**

- Flowers are used to flavour tea or to gain an essential oil
- Pleasant smell

Juglans regia **- Walnut**

- Nuts with a delicious flavour eaten raw or in confections, cakes, etc.
- Delicate oil
- Hard, durable, close grained, and therefore very valuable timber
- Prefers moist soil
- Fully hardy

Leucaena leucocephala **- Leucaena**

See Chapter V

Macadamia tetraphylla **- Macadamia**

- Tolerates fair frosts
- Good for beekeeping due to long flowering period
- Ornamental species
- Self-fertile, cross-pollination generates better fruits
- Not wind tolerant

- **Water stress** and temperatures over 30° C diminish the proceeds
- Half hardy

Malus domestica - Apple

- Delicious fruits are eaten raw, cooked or dried
- Excellent fuel wood
- Hard, compact, and fine-grained wood used as timber
- Prefers moist soil
- Fully hardy

Mangifera indica - Mango

- Vitamin-rich, delicious fruits
- Seed kernels are used as feed for cattle and poultry
- Excellent fuel wood and charcoal
- Timber used for furniture, carpentry, flooring, etc.
- Often interplanted with other fruits and vegetables
- Evergreen and therefore leaf interception during a good rainy season
- Trees start producing fruits after 2-4 years and can continue to produce fruit for more than 100 years
- Very drought tolerant; Grows with 300 mm annual rainfall
- Not frost resistant

Moringa oleifera

- Leaves, young plants, seeds and taproots are a valuable food
- Pleasantly flavoured oil
- Excellent forage; however plant parts are mainly used for human food
- Excellent for beekeeping due to long flowering period
- Windbreak
- Ornamental species
- Excellent for intercropping due to winter **deciduousness**
- Seed powder helps filtering bacteria and viruses out of wastewater
- Very drought tolerant; mean annual rainfall: at least 500 mm
- Frost tolerant

Moringa peregrina

See Chapter V

Morus alba; M. nigra; M. rubra - Mulberry

- Fruits can be eaten fresh or dried
- Hard, durable and close-grained timber
- Wind-resistant; can be planted as a windbreak
- Drought tolerant; prefers moist soil
- Fully hardy

Musa acuminate - Banana

- Delicious and nutritious fruits
- Requires moist soil
- Very frost tender

Nicotiana glauca

- All plant parts are poisonous
- Wastewater tolerant
- Drought resistant

Olea europaea - Olive

- Delicious fruits
- Very precious oil with a pleasant taste
- Good forage
- Excellent fuel wood due to oil content in leaves and wood
- Beautiful wood is a very valuable timber
- Very drought resistant
- Frost tolerant

Persea Americana - Avocado

- Nutritious and very vitamin-rich fruit
- Surplus fruit is valuable forage
- Good for beekeeping
- Essential oil extracted from the leaves
- Mean annual rainfall: 300-2500 mm
- Tolerates light frosts

Phoenix dactylifera - Date

- Sugar-rich fruits are a valuable cash crop
- Ground seeds softened by soaking in water can be used as forage for camels, goats, horses, and poultry
- Strong trunks are used as construction timber
- Leaves are applied in sand dune stabilization and for thatching
- Trees are grown to reclaim salt-affected lands
- Mature trees are suitable for intercropping
- Salt tolerant
- Very drought resistant; grows with 100 mm annual rainfall
- Tender to prolonged frost

Pinus pinea - Pine

- Valuable and delicious nuts
- Good timber
- Soil protection

Pistacia atlantica - Mastic tree

- Nutritious seeds yielding oil
- Essential oils used for perfume
- Resin used in the manufacture of chewing gum, alcohol and lacquer
- Source of tannin for the leather industry
- Sap is dried to be burned as incense
- Strong root stock for grafting pistachio (*Pistacia vera*)
- Drought tolerant
- Frost Hardy
- Slow growth to 7x7m
- Although slow growing provides very good fuel wood and timber

***Pistacia lentiscus* - Mastic tree**

- 'Mastic', a valuable and sweet resin with multiple uses, is obtained from the bark
- Oil from the seeds for lighting or soap making
- Male and female trees; at least one tree has to be male to grow fruits on the female plants
- Can tolerate drought
- Half hardy

Pistacia palaestina

See Chapter V

***Pistacia vera* - Pistachio**

- Delicious, valuable nuts
- Male and female trees; at least one tree has to be male to grow fruits on the female plants
- A resin can be gained from the male trees
- Can tolerate drought
- Half hardy

***Portulaca oleracea* - Purslane**

- Vitamin C rich leaves of this herb can be eaten as a salad

Prosopis juliflora

- Pods are an excellent food
- Forage for sheep, cows, and poultry
- Major honey source in several countries due to its copious nectar flow
- Excellent fuel wood and charcoal
- Acceptable timber for fence posts, furniture, etc.
- Sand-dune stabilization
- Windbreak
- Weak nitrogen-fixing species
- Ornamental species
- Very drought tolerant

- Not frost resistant

Prosopis nigra

- Very fast growing
- Excellent timber
- Excellent fuel wood
- Valuable fodder
- Delicious, protein rich, gluten-free starch flour from fruits
- Good for beekeeping
- Nitrogen fixing

Prosopis alba

- Very fast growing
- Excellent timber
- Excellent fuel wood
- Valuable fodder
- Delicious, protein rich, gluten-free starch flour from fruits
- Good for beekeeping
- Nitrogen fixing

Prosopis juliflora

- Very fast growing
- Excellent timber
- Excellent fragrant fuel wood
- Valuable fodder
- Delicious, protein rich, gluten-free starch flour from fruits
- Good for beekeeping
- Nitrogen fixing

Prosopis tamarugo

- Very fast growing
- Good timber
- Excellent fuel wood
- Abundant valuable fodder
- Delicious, protein rich, gluten-free starch flour from fruits
- Good for beekeeping
- Nitrogen fixing
- Good for bee keeping
- One of the best species to be used for the reforestation of deserts
- Efficient nitrogen-fixer

Prunus armeniaca - Apricot

- Delicious fruit is eaten fresh, dried, or cooked
- Seeds, when sweet, are edible
- Oil used in perfumery and cosmetics

- Hard, durable timber

Prunus avium - Wild cherry

- Sweet fruits with a pleasant taste are eaten fresh or cooked
- Hard and compact wood is used as timber

Prunus domestica - Plum

- Delicious fruit eaten fresh or dried (prune)
- Small tree usually not exceeding 5m in height
- Frost Hardy
- Drought tolerant in highlands but requires occasional irrigation in the lowlands of Palestine

Prunus dulcis - Almond

- Fruits can be eaten dry or fresh
- Frost tolerant (-7°C), not tolerant to frosts in spring
- Self-sterile
- Bears for about 50 years or longer
- Reaches full production at about 8 years
- Drought resistant

Prunus persica - Peach

- Valuable and very delicious fruits
- Not very long-living tree
- Prefers moist soil

Prunus persica nucipersica - Nectarine

- Valuable and very delicious fruits
- Not very long-living tree
- Prefers moist soil

Punica granatum - Pomegranate

- Delicious fruits and juice
- Leaves are browsed by animals
- Hard and durable wood for small wooden items
- Erosion control due to a deep root system
- Windbreak
- Ornamental species
- Used in water purification
- Drought tolerant
- Half hardy

Psidium guajava - Guava

- Delicious and valuable fruit
- Medicinal leaves
- Tolerant of light frosts

- Drought tolerant up to four months but requires irrigation in Palestine
- Small tree attaining 3-4m in height
-

Pyrus communis sativa - Pear

- Juicy, sweet fruits can be eaten raw or cooked
- Heavy, fine grained timber
- Can tolerate atmospheric pollution
- Drought tolerant
- Fully hardy

Pyrus persica

- Can tolerate atmospheric pollution
- Can tolerate droughts
- Fully hardy

Quercus calliprinos

See Chapter V.

Rosa x damascena - Damask rose

- Vitamin-rich fruits can be used in pastries and for syrup
- Rose oil
- Ornamental species

Salicornia bigelovii - Dwarf glasswort

- Young leaves and stems of this annual herb are eaten cooked or pickled
- Edible oil similar to safflower oil
- Very salt tolerant, grows on salt marshes by the coast, can be irrigated with seawater

Sclerocarya birrea ssp. caffra - Marula tree

- Very nutritious, valuable fruits for sweetening or eaten as a jelly with a pleasant, sour-sweet taste
- Delicious nuts
- Fruits are eaten by goats and sheep, leaves are slightly poisonous but may also be used in smaller quantities as a fodder in times of drought
- Good timber
- Moderately drought tolerant
- Tolerates light frosts
- Highly salt tolerant

Salvadora persica

- Tender shoots, fruits, seed oil, and leaves are edible
- Valuable fodder with high salt content when irrigated with salt water
- Good source of nectar
- Good timber
- Toothbrushes are made from roots and small branches
- Windbreak

- Reclamation of sand dunes and saline soils
- Drought tolerant
- Highly salt tolerant

Styrax officinalis

- The highly perfumed gum 'storax' can be used as a condiment
- Ornamental species
- Half hardy

Tamarix aphylla

- Manna-like substance
- Fodder with a high salt content (salt-extracting species)
- Good for beekeeping
- Good fuel wood
- Excellent timber
- Erosion control
- Firebreak due to high salt content in leaves
- Frost hardy

Tecoma stans - Tecoma

- Good firewood and charcoal
- Timber is used in construction of buildings
- Ornamental species
- Drought resistant
- Frost intolerant

Terminalia catappa - Bastard almond

- Kernel with an almond like taste
- Foliage is used as forage
- Good-quality timber for the construction of buildings, floors, planks, etc.
- Erosion control due to a vast root system
- Species can be used for reforestation due to its tolerance of droughts and salt
- Ornamental species
- Moderately drought tolerant
- Not frost resistant

Tipuana tipu

- Good species for beekeeping
- Good fuel wood and timber
- Nitrogen-fixing species
- Ornamental species
- Evergreen and therefore with good rainy season leaf interception
- Frost hardy

Vitis vinifera – Grape Vine

- Delicious fruits can be eaten fresh or dried

- Cooked leaves have a pleasant flavour
- Oil is gained from the seeds
- Fully hardy

Ziziphus jujuba

- Small thorny tree attaining 5-8m
- Copious small nutritious fruits tasting like apple
- Good fuel wood
- Drought tolerant but requires occasional irrigation to fruit well
- Frost hardy
- Fruits have medicinal uses
- Flowers enjoyed for their fragrance

Ziziphus lotus

- Tenacious (even recalcitrant) large thorny shrub
- Delicious nutritious fruit
- Root stock for Jujube fruit (*Ziziphus jujuba*)
- Drought tolerant
- Tolerates even goat grazing
- Excellent if fierce lowland desert reaforestation species

Ziziphus spina-christi

- Edible fruits
- Excellent for beekeeping
- Acceptable forage
- Windbreak
- Sand-dune stabilization

Acacia nilotica

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Albizia lebbeck

Photography by T. Fernley-Pearson

Bauhinia purpurea

Photography by T. Fernley-Pearson

Calotropis procera

Photography by T. Fernley-Pearson

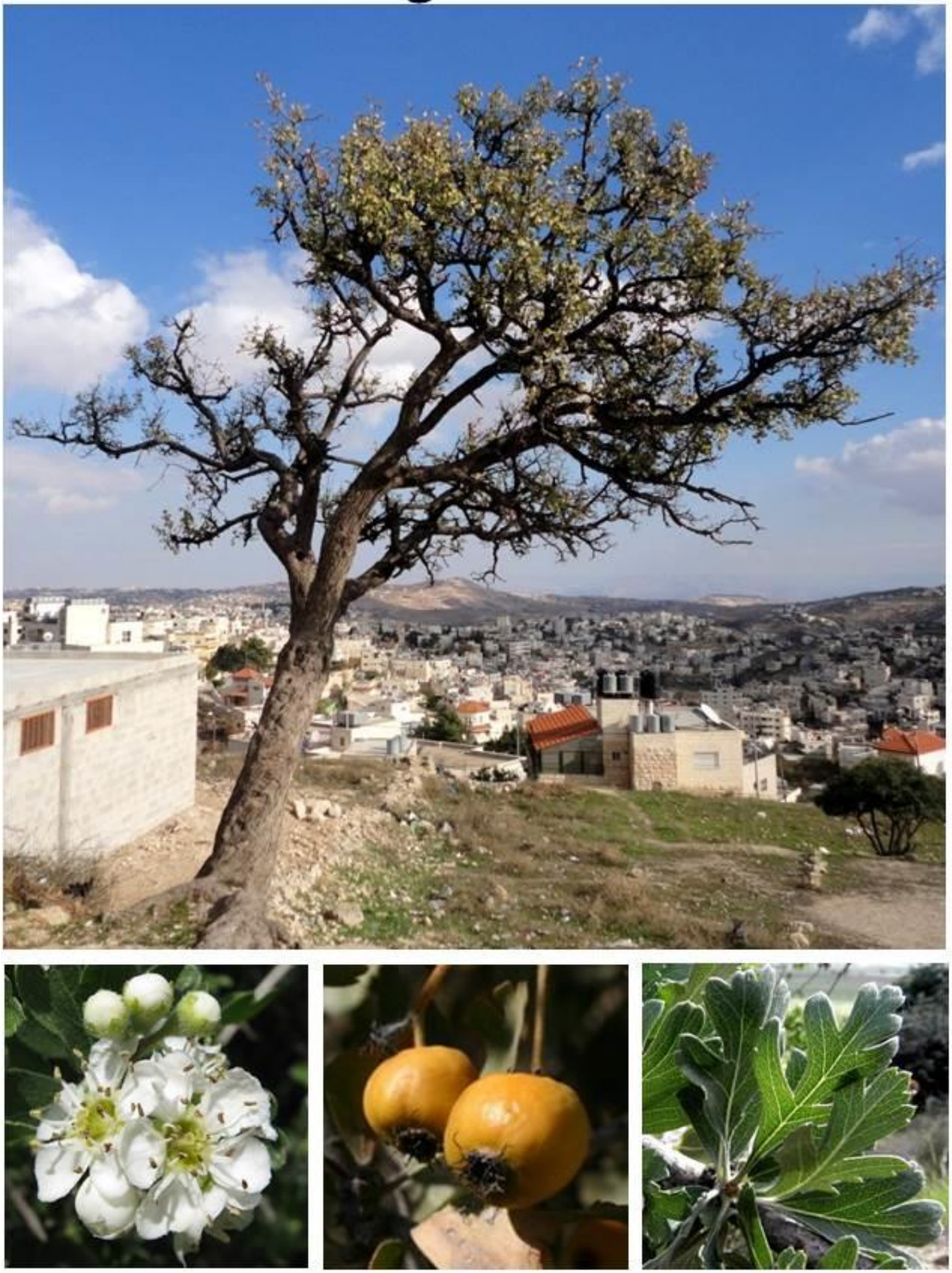
Cassia fistula

Photography by T. Fernley-Pearson

Cordia sinensis

Photography by T. Fernley-Pearson

Crataegus aronia



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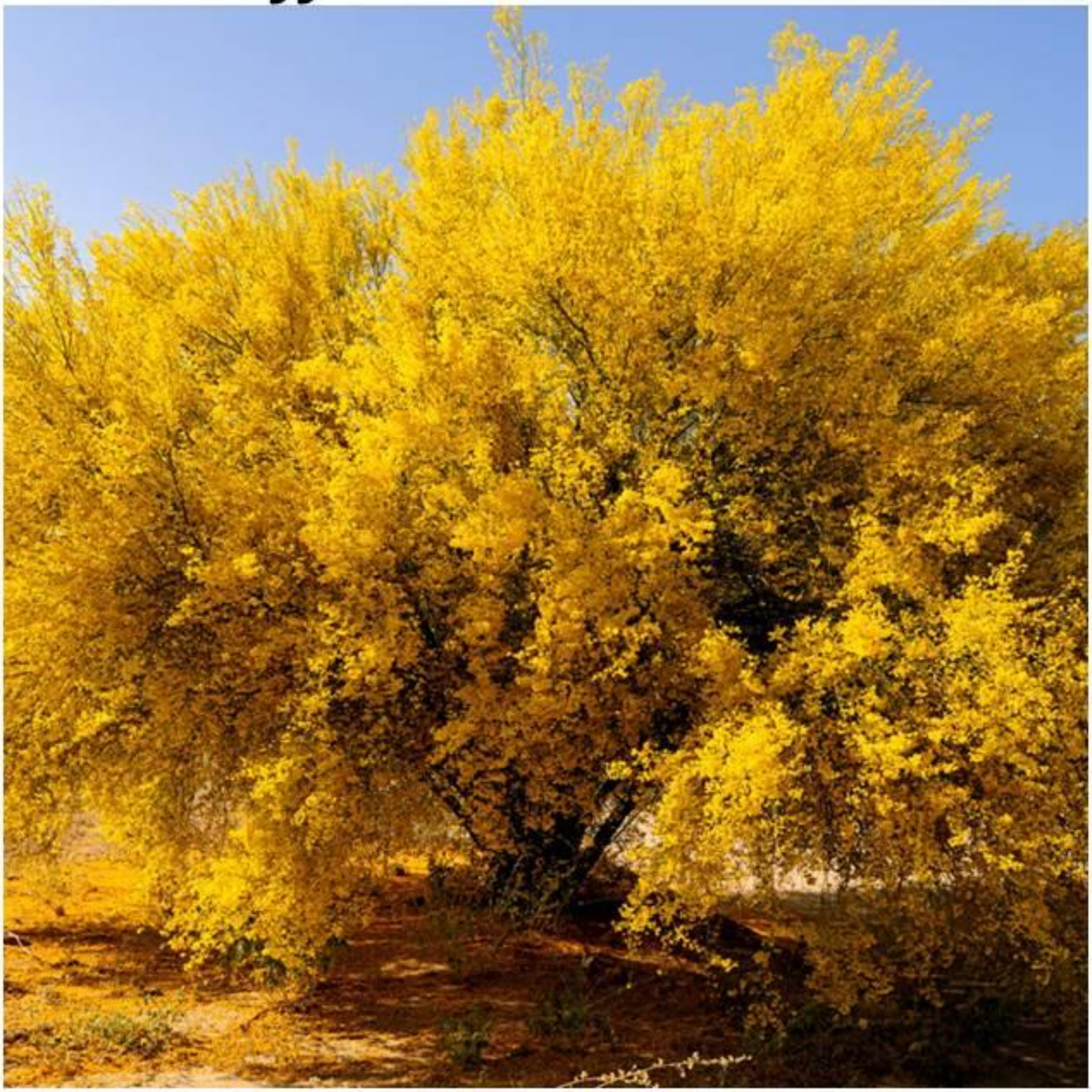
Delonix regia

Photography by T. Fernley-Pearson

Ficus carica

Photography by T. Fernley-Pearson

Geoffroea decorticans



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Jacaranda mimosifolia

Photography by T. Fernley-Pearson

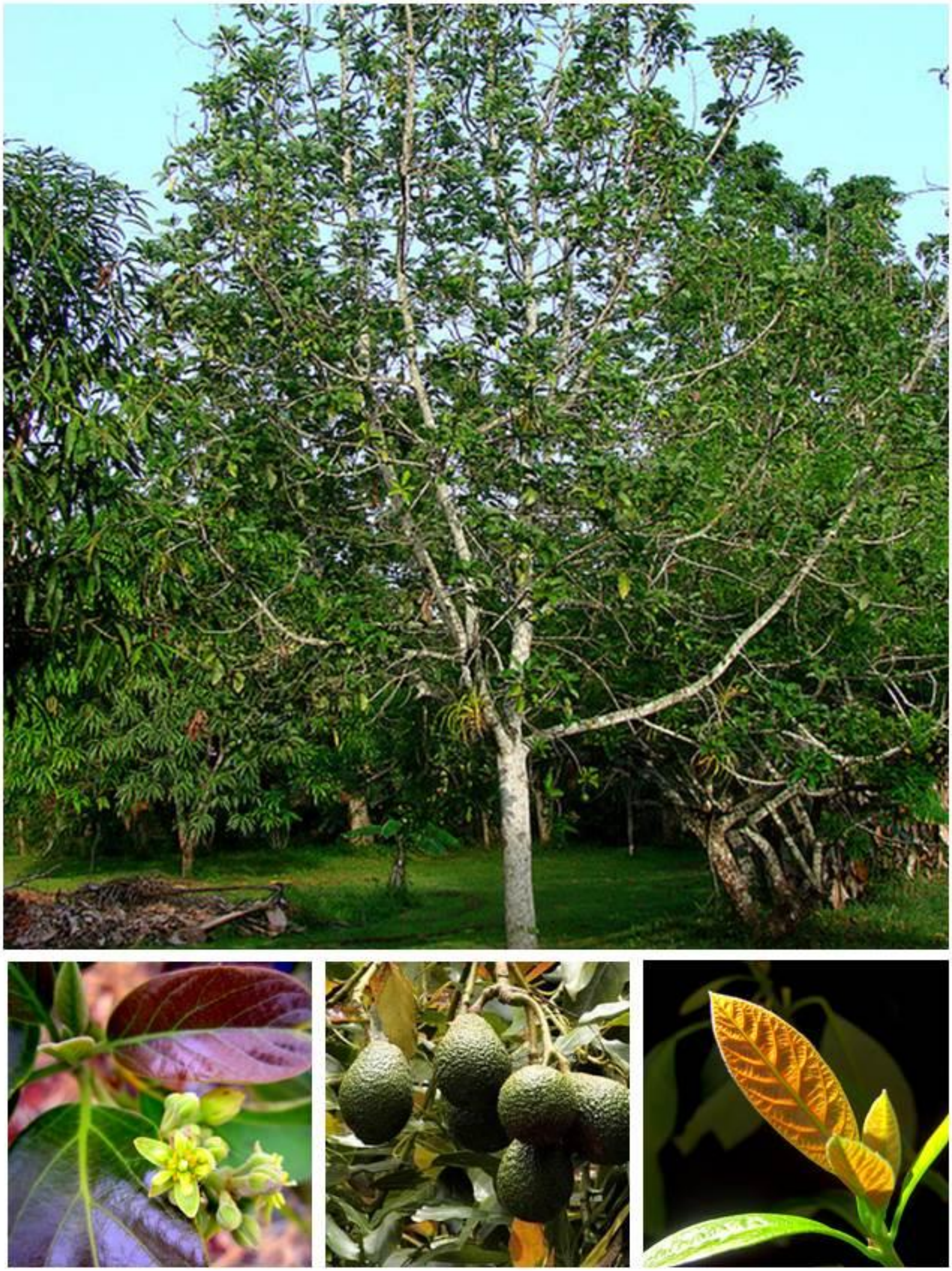
Morus ruba

Photography by T. Fernley-Pearson

Olea europaea

Photography by T. Fernley-Pearson

Persea americana



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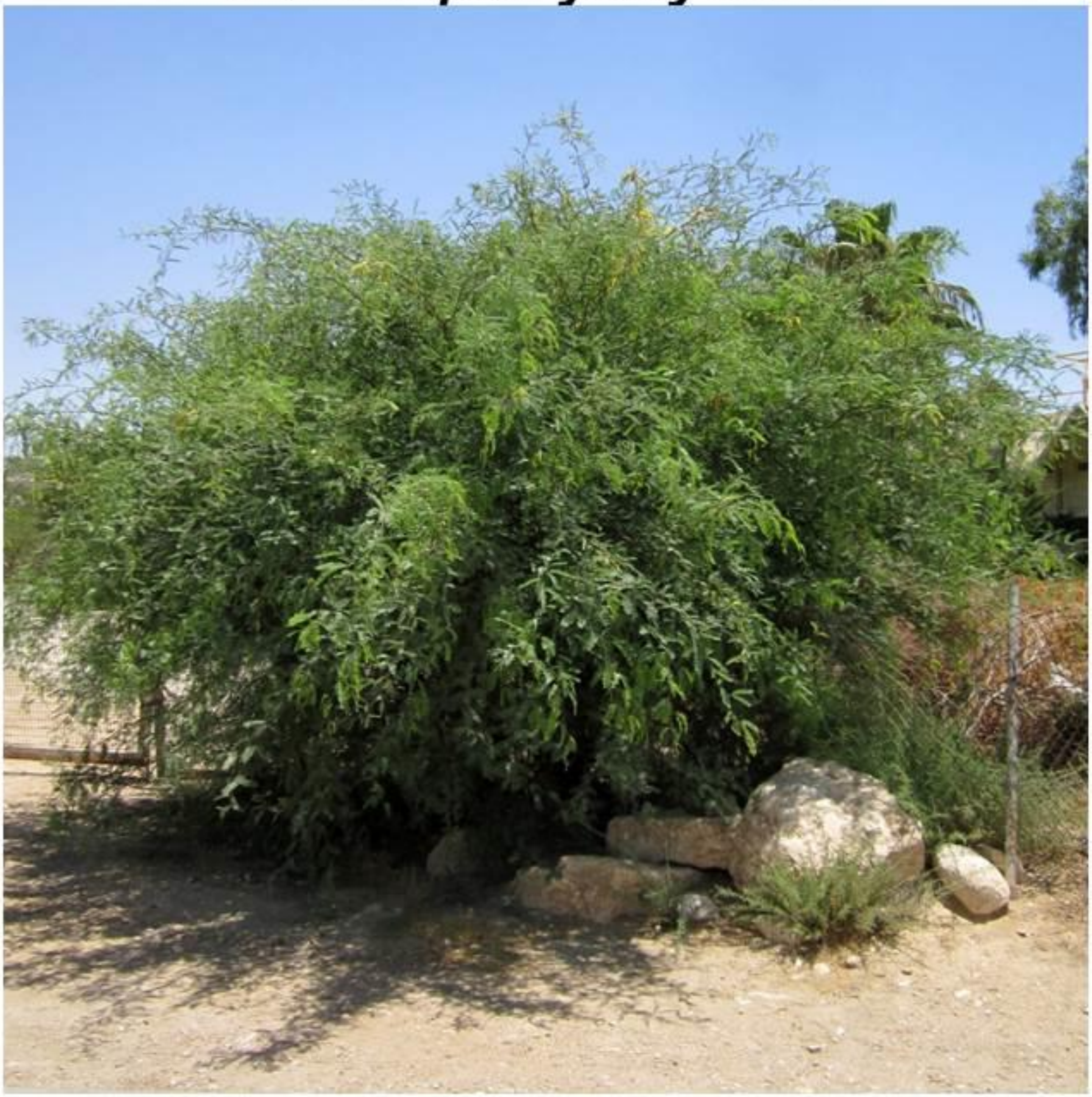
Phoenix dactylifera

Photography by T. Fernley-Pearson

Pistacia vera

Photography by T. Fernley-Pearson

Prosopis juliflora



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Prunus armeniaca

Photography by T. Fernley-Pearson

Prunus amygdalus

Photography by T. Fernley-Pearson

Punica granatum

Photography by T. Fernley-Pearson

Salvadora persica

Photography by T. Fernley-Pearson

Styrax officinalis

Photography by T. Fernley-Pearson

Tamarix aphylla

Photography by T. Fernley-Pearson

Tecoma stans

Photography by T. Fernley-Pearson

Tipuana tipu

Photography by T. Fernley-Pearson

Vitis vinifera

Photography by T. Fernley-Pearson

Ziziphus lotus

Photography by T. Fernley-Pearson

Ziziphus spina-christi

Photography by T. Fernley-Pearson

Glossary of terms

aestivating – *a species which weathers hot, dry periods in a state of dormancy*

afforestation – *the establishment of forest cover in previously-open land*

anthropogenic – *caused or created by human activity*

biodiversity – *the number of different species or types of organism in a particular area*

biomass – *organic material derived from living or recently-living organisms*

cellulose – *a linear polysaccharide of β-1,4 D-glucose – the most abundant organic polymer on Earth, a vital component of primary plant cell walls*

climax – *the natural zenith of ecological succession; a population which is both stable and self-perpetuating*

coppiced – *an ancient and traditional form of woodland management in which trees are periodically cut back to simultaneously promote new growth and provide firewood and timber*

deciduous – *a plant that undergoes seasonal foliage loss and subsequent regeneration*

agroforestry – *an integrative approach of land-use which focuses on the interactions of trees, shrubs, crops, and livestock grown on the same piece of land to their mutual benefit*

deforestation – *the destruction of forest*

disclimax – *a relatively stable alien ecological community, often maintained by human activity, that has displaced the area's normal climax*

ecological niche – *a particular role or position in an ecosystem*

ecosystem – a *synergistic system formed by the interactions of the living and non-living components of a particular environment*

ecozone – *the largest biogeographic divisions of the Earth's land surface, which have developed within geographic boundaries in relative evolutionary isolation*

ephemeral – *a plant which lives one year or less*

evapotranspiration – *the net water returning to the atmosphere (the sum of plant transpiration and the evaporation of soil humidity)*

fertigation – *the application of water-soluble compounds such as fertilisers via irrigation systems*

genetic diversity – *the amount of variation in the genetic characteristics of a species (defined for a population's genomes in three different measures : heterozygosity, number of polymorphic loci, and number of alleles per loci)*

gullying –*the creation of a deep channel or ditch*

herbaceous – *a leafy plant lacking a lignified trunk or stem*

herbivory – *animal consumption of material from a living plant*

heterogeneous – *diverse***,** *of multiple components or members*

landbase – *the area from which a human community derives all their environmental services, physical resources, and material wealth*

lignin – *a complex, racemic, heterogeneous phenylpropaniod formed of of the three variably-methoxylated monolignal monomers p-coumaryl alcohol, coniferyl alcohol, and sinapyl alcohol; a vital component of the stems of woody plants, reinforcing the cellulose, hemicellulose, and pectin in cell walls to provide structural integrity*

metapopulation – *an interacting group of spatially-separated populations of the same species*

microclimate – *a local atmospheric zone where the climate differs from the surrounding area*

nodulated – *roots containing distinctive protrusive structures in which symbiotic nitrogen-fixing bacteria of the group Rhizobium reside*

palaearctic – *the largest of the eight ecozones dividing the Earth's surface, a zoogeographical region consisting of Europe, Africa north of the Sahara, and most of Asia north of the Himalayas*

perennial – a *plant which lives more than one year*

pioneer species – *one of the first species groups of the ecological succession of a disrupted ecosystem*

permaculture – *a practise of ecological design and engineering that maintains sustainable, self-maintained agricultural systems modelled from and around natural ecosystems*

polyculture – *the agricultural practise of planting multiple crops in the same space of land*

promontory – *a prominent landmass which overlooks lower-lying land or water*

psychical – *of, affecting, or affected by, the human mind*

reafforestation – *the regeneration of an area of afforested land*

rhizobia – *a paraphyletic group of nitrogen-fixing soil bacteria which form obligate symbioses with plants of the family Fabaceae (legumes)*

rootstock – *the oft-submerged part of a plant from which new above-ground growth can be produced*

runoff – *water which cannot be absorbed into the ground and so flows across the surface as excess; when the rate of water deposition on the land exceeds the maximum rate of infiltration into the ground*

sclerophyll – *a type of woody plant characterised by hard, waxy, evergreen foliage and short internodes, including both broad-leaved "Mediterranean" plants such as bay* (Laurus nobilis) *and olive* (Olea europaea)*, and thin-leaved evergreens such as Pine* (Pinus)

soil seed bank – *the natural storage of dormant seeds within the soil of an ecological community*

seed dormancy – *when a seed is unable to germinate in a specific timeframe under conditions which would usually be suitable for germination; this would normally help the seed avoid germinating under unsuitable ecological conditions (such as avoiding winter cold, or promoting dispersal to reduce the chance of competition and inbreeding)*

shade plant – *a plant both adapted and acclimated to live in low-light conditions: their leaves have a lower photosynthetic capacity and respiration rate (whilst chlorophyll per unit area remains the same due to reduced stromal volume, the chl A:B ratio is decreased, as are RuBisCO and ETC component concentrations per unit leaf area), making the leaves more susceptible to photodamage but better suited to capturing lower wavelengths of light*

silviculture – *the cultivation and care of forest trees*

soil humidity – *water retained as saturation in the soil*

strata – *a layer of sedimentary rock, of uniform composition*

sub-canopy – *the top layer of the shade-tolerant understory beneath a forest canopy, composed of small mature trees, saplings, and suppressed juvenile canopy-layer trees*

(ecological) succession – *the temporal progression of subsequent colonisation and displacement events which manifest themselves as observable changes in the species structure of an ecological community*

transpiration – *the process of water movement through the soil-plant-air continuum*

vernalisation – *the acquisition of a seed's ability to germinate by exposure to a long period of cold (defined by a reduction in FLC transcript due to heterochromatinisation of the locus in response to epigenetic modification by both polycomb repressive complexes recruited by the lncRNA COLDAIR, the transcription of which is temperature-sensitive)*

(seed) viability – *the ability of a seed's embryo to germinate*

water stress – *when a plant's osmotic potential exceeds the biological optimum, caused either by a limiting water supply of optimum osmolality, or intense transpiration rates exceeding the rate of water uptake through the roots*