TESTING THE COCOON TECHNOLOGY IN JORDAN AND LEBANON

Assessment report

December 2021

MENAQUA

Land Restoration

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Executed by:

Menaqua Land Restoration, The Netherlands

In close cooperation with:

Land Life Company, The Netherlands

American University of Beirut

Ministry of Agriculture of Jordan

ACKNOWLEDGMENT

I am proud to share with you this report as the recording of the results of 3 years of literally 'sowing and harvesting' in Jordan and Lebanon by the Menaqua Land Restoration team and its partners. The activities started in November 2018 when we held a workshop with the Menaqua team for the Ministry of Agriculture in Jordan. Until today, exactly three years later, we were busy planting and monitoring almost 5,000 young trees on 7 different locations to contribute to the greening of the MENA region on the one hand and to the evidence-based practice of testing the well-known Cocoon technology in the same region on the other hand.

The present report focuses in particular on the test results and the circumstances under which these results were obtained. Circumstances that, as was known in advance, are difficult and unpredictable in this region due to the influence of an extreme climate. What we also could not predict was the impact of COVID19, which came into effect from March 2020. Due to extremely strict lockdowns, the various test locations could not be visited by our local partners for a number of months.

Nevertheless, it is mainly because of the unwavering enthusiasm in combination with the professional approach of the joined partners that we can present this report to you. Special thanks go to our key partner in Lebanon: Professor Salma Talhouk of the Nature Conservation Centre of the American University of Beirut and her enthusiastic team. She invested a lot of time with us in setting up the project, looking for opportunities to involve the local communities and interpreting the test results as unambiguously as possible.

Our partner in Jordan was the Ministry of Agriculture. Special thanks go to Dr Mahmoud Alferihat and his hardworking team. The Menaqua team spent many hours with them finding the most suitable locations and involving the various officials of the Ministry in carrying out the planting and the monitoring. Due to Dr Mahmoud's excellent network within the Ministry, we also started a follow-up project early spring 2021: the restoration of the Al Hisha Forest in South Jordan.

Our third partner is Land Life Company of The Netherlands: the developer of the Cocoon. In their staff members Arnout Asjes and Harrie Lovenstein we found two very enthusiastic and committed professionals who advised and assisted us from the start about the use of the special Cocoon technology. With this report I hope to give back to them some of additional knowledge on the topic that they have so generously shared with us over the past years.

Finally, and certainly not least, I would like to thank Dr Antonie Dake, CEO, founder and financier of Menaqua Land Restoration. Fueled by his never-ending inspiration, his always sharp view on crucial matters and his abiding confidence that we can create a foothold in the MENA region with Menaqua, we as a team have taken our first steps in this complex but challenging region.

This report is an interesting and highly readable reflection of this process, albeit only a partial one. After 3 years of 'sowing and harvesting', we now see more 'seeds germinating'. The already mentioned Al Hisha Forest restoration project is just one of them.

I would like to finish with wishing you a lot of reading pleasure and exposure to new insights on the application of the Cocoon technology.

On behalf of the entire Menaqua team,

Jeroen Kosterman, Director of Operations.

EXECUTIVE SUMMARY

The current report deals with the testing of the novel Cocoon technology for the planting of forest and fruit tree seedlings in semi-arid areas in Jordan and Lebanon. The technology foresees in the controlled supply of water to the roots of the seedlings in their first growing stages using a bio-degradable container with a capacity of 25 litres (the Cocoon). The test program was set up at various field sites and covered the period from 2019 to 2021. Planting of seedlings with the Cocoon and without this technology were undertaken in order to be able to compare the novel technology 'vis a vis' traditional planting methods.

Test sites in Jordan were identified at Al Faisal Station near Jerash and at Maysara near the city of As Salt. In Lebanon testing was realized in the Beka'a Valley at Aarsal Farm, Ras Baalbak and AREC Research Centre. Area characteristics at the sites including geology and soil types, and the rainfall and evapotranspiration regimes varied significantly. Depending on the test site, the planting design comprised the testing of 1 to 6 plant species for 'With Cocoon' and 'Without Cocoon' scenarios. An average 50 seedlings were used for each scenario. The actual planting seasons were the spring and fall of 2019. The follow-up monitoring of plant performance comprising the assessment of plant survival rates and tree heights, covered a period of 1 to 1.5 year. During the period set-backs including a heat wave, flood waters and the COVID19 pandemics were experienced.

Useful project results could be secured despite the difficulties encountered. Poor plant performances for all scenarios were obtained at the Maysara (spring planting) and Ras Baalbak test sites. These sites were characterized by (too) low rainfall and/or poor soil conditions. The performances at the other sites showing more favourable conditions were acceptable to good with plant survival rates mostly over 60 to 70%. The species *Oleao europea* (olive), *Pinus halapensis* (pinus), and prunes and pyrus varieties including *Prunus amygdalus* (almond) and *Pyrus syriaca* (wild pear) surprised with excellent growth characteristics.

The 'With Cocoon' and 'Without Cocoon' scenarios have been compared with each other for the sites with favorable rainfall and soil conditions. For 50% of the cases the 'With Cocoon' scenarios indicated better growth characteristics in comparison with the 'Without Cocoon' scenarios for the same species. However, for some of these cases the differences in performance were small and lacked significance. For the other cases the 'With Cocoon' and 'Without Cocoon' scenarios showed similar plant performances. The overall better plant growth for the 'With Cocoon' scenarios can be attributed to the more continuous and fine-tuned supply of water to the plant from the Cocoon reservoirs in comparison with the discontinuous irrigation gifts as applied in the 'Without Cocoon' scenarios.

The application of the Cocoon technology can certainly be considered in future scaled-up planting projects in semi-arid areas. Although the technology comes with a price, its *potential* advantages are also clear: better plant growth characteristics, water savings, and less labor needed for the irrigation of seedlings.

EXECUTIVE SUMMARY (Arabic)

يتناول التقرير الحالي اختبار تقنية الشرنقة الجديدة لزراعة شتلات الغابات والأشجار المثمرة في المناطق شبه القاحلة في الأردن ولبنان. تتنبأ التقنية بإمدادات المياه الخاضعة للرقابة لجذور الشتلات في مراحل نموها الأولى باستخدام حاوية قابلة للتحلل الحيوي بسعة 25 لترًا (الشرنقة). تم إعداد برنامج الاختبار في مواقع ميدانية مختلفة وغطى الفترة من 2019 إلى 2021. تم إجراء زراعة الشتلات باستخدام الشرنقة وبدون هذه التكنولوجيا من أجل التمكن من مقارنة التكنولوجيا الجديدة "مقابل" طرق الزراعة التقليدية

تم تحديد مواقع الاختبار في الأردن في محطة الفيصل بالقرب من جرش وفي ميسرة بالقرب من مدينة السلط. تم AREC. إجراء الاختبارات في لبنان في سهل البقاع في مزرعة عرسال ورأس بعلبك ومركز أبحاث
اختلفت بشكل كبير خصائص المنطقة في المواقع بما في ذلك الجيولوجيا وأنواع التربة وأنظمة هطول الأمطار والتبخر. اعتمادًا على موقع الاختبار، تضمن تصميم الزراعة لاختبار 1 إلى 6 أنواع نباتية لسيناريوهات "مع الشرنقة" و "بدون الشرنقة" تم استخدام متوسط 50 شتلة لكل سيناريو. كانت مواسم الزراعة الفعلية هي ربيع وخريف 2019. غطت متابعة أداء النبات التي تشمل تقييم معدلات بقاء النبات وارتفاع الأشجار، فترة من 1 إلى 1.5 سنة. خلال هذه الفترة، شهدت انتكاسات بما في ذلك موجة الحر ومياه الفيضانات وجائحة كوفيد-19.

يمكن تأمين نتائج مفيدة للمشروع على الرغم من الصعوبات التي تم مصادفتها. تم الحصول على أداء ضعيف للمشاتل لجميع السيناريوهات في موقعي الميسرة (الزرع الربيعي) ورأس بعلبك. تميزت هذه المواقع بقلة هطول الأمطار (جداً) و / أو ظروف التربة السيئة. كانت العروض في المواقع الأخرى التي أظهرت ظروفًا أكثر ملاءمة Oleao مقبولة إلى جيدة مع معدلات بقاء النبات في الغالب أكثر من 60 إلى 70 ٪. تفاجأنا بأن الأنواع europea (و الزيتون) Pinus halapensis (و الخوخ) و الصنوبر) pyrus ، بما في ذلك Prunus amygdalus .الكمثرى البرية) تتميز بخصائص نمو ممتازة) Pyrus syriaca اللوز) و)

تمت مقارنة سيناريوهات "مع الشرنقة " و "بدون الشرنقة" مع بعضهما البعض للمواقع ذات الأمطار وظروف التربة الملائمة. بالنسبة لـ 50٪ من الحالات، أشارت سيناريوهات "مع الشرنقة " إلى خصائص نمو أفضل مقارنةً بسيناريوهات "بدون الشرنقة" لنفس النوع. ومع ذلك، بالنسبة لبعض هذه الحالات، كانت الاختلافات في الأداء صغيرة وتفتقر إلى الأهمية. بالنسبة للحالات الأخرى، أظهر سيناريوهات "مع الشرنقة " و "بدون الشرنقة" أداء نباتيًا مشابهًا. يمكن أن يُعزى النمو العام الأفضل للنبات لسيناريوهات"مع الشرنقة " إلى زيادة إمدادات المياه المستمرة والقابلة للتعديل إلى النبات من خزانات الشرنقة مقارنةً بمزايا الري المتقطعة كما هو مطبق في سيناريوهات"بدون الشرنقة" يمكن بالتأكيد التفكير في تطبيق تقنية الشرنقة في مشاريع الزراعة الموسعة في المستقبل في المناطق شبه القاحلة

على الرغم من أن هذه التكنولوجيا لها سعر، إلا أن مزاياها المحتملة واضحة أيضًا مثل: خصائص نمو أفضل للنباتات، وتوفير المياه، وتقليل العمالة اللازمة لري الشتلات.

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1. INTRODUCTION

1.1. Land restoration in the Middle East

Vast areas in the Middle-East are exposed to land degradation. Main drivers are the climate change and socio-economic- and demographic developments, which cause unsustainable land management practices. The adverse impacts of land degradation can be mitigated through afforestation and reforestation, and through more sustainable, climate-resilient agricultural practices including agroforestry. In the Middle-East land restoration initiatives are often very challenging. Water scarcity and -variability, soil properties and complex socio-cultural structures demand an integrated project approach, and the adoption of innovations to improve the success of tree planting.

1.2. The Cocoon project

In 2019, Menaqua was established as a social enterprise, whose mission is to promote land restoration in the MENA region through re-/afforestation and agroforestry. Since its founding Menaqua has worked together with Land Life Company, who apply a wide range of innovative technologies in tree planting and -monitoring world-wide.

Fig 1.1: Reservoir and lid of the bio-degradable Cocoon (left) and Cocoon in the ground with wind shelter (right)

One of the innovations is the so-called Cocoon technology (see also Annex I). The Cocoon is a water-saving device for tree planting. It consists of a reservoir that is filled with water, a lid to reduce water evaporation, and a screen to protect a young plant (seedling) against wind and animals during its initial, critical growing stage (see Fig 1.1). The Cocoon is manufactured with bio-degradable pulp-fiber. This material allows for the slow release of water to the root zone of the seedlings.

To assess the applicability and performance of the Cocoon in land restoration in the Middle East, a pilot project was formulated in two of Menaqua's focal countries in the Middle-East, namely in Jordan and Lebanon. Several test locations (pilot areas) were identified and used for planting and monitoring in the period from 2019 to 2021. The project was carried out by Menaqua and their partner organizations in Jordan and Lebanon, being the Land and Water Department of the Ministry of Agriculture of the Kingdom of Jordan and the Nature Conservation Center of the American University of Beirut in Lebanon. Both organizations have experience in land restoration and their staff is considered to be very knowledgeable in this field of expertise.

The testing of the Cocoon technology in a Middle Eastern environment is required for further introductions and use in the region. The testing forms a first step in this process and based on the results and outcome of the pilot study, the technology will be subject to a scaling up phase and regional applications. The project partners have agreed that a phased approach is mandatory in order to guarantee to companies and donors that investing in the Cocoon technology is a wise move.

1.3. Project objectives

The main objective of the pilot project is to test the applicability and performance of the Cocoon technology 'vis a vis' traditional planting methods practiced in the Middle East. Is the Cocoon a tool that can contribute to better plant growth and water saving in a region that is still dominated by afforestation, agroforestry and fruit tree planting methods dating back many years? The assessment will be done against different climatological, geological and environmental backgrounds.

Secondary objectives of the project concern managerial and social aspects. The project aims to evaluate several ways for local management to implement the Cocoon technology. These ways concern in particular organizational, logistical, land preparation, planting and monitoring aspects. Social acceptance of the Cocoon technology is another issue to be addressed. The project will find out optimum scenarios for the generation of sufficient awareness for the technology with the local population.

1.4. Structure of the report

Chapter 2 presents the set-up and methodology of the project. The physical setting and project development of the pilot areas in Jordan and Lebanon are elaborated in Chapter 3 and 4, respectively. Chapter 5 and 6 present the main results of the monitoring program of the pilots in Jordan and Lebanon. In Chapters 7 and 8, the report rounds off with conclusions and recommendations.

2. METHODOLOGY

The methodology that was adopted to carry out the testing of the Cocoon technology ‘vis a vis’ traditional tree planting consisted of the following key elements.

2.1. Preparatory activities

Test site selection: The Menaqua team and its local partners will make a plan to complete these selections considering the following criteria. For test site selection, the most important climatological factor is yearly rainfall. Sites where the rainfall is above 150-200 mm/year are considered adequate. The rationale behind this criteria is the assumption that trees will survive on local rainfall after an initial watering period and no further irrigation is needed. The variability in geology and soils in the country will also be represented at the test sites. This implies that sites are identified in sedimentary rocks including limestone and sandstone overlain by loamy to clayey and sandy soils (see Fig 2.1). Other criteria include the rockiness of the soils, site access, management capacity and the social coherence in the test area. For a practical execution of activities, the project plan foresees in the identification of 3-4 test sites in each of the two countries.

Fig 2.1: Native oak trees in reddish loamy to clayey soils in the highlands of Jordan

Test site design and species selection: Detailed plans for site design will be made. Criteria for these designs are that, a) spring and fall tree planting are simulated, b) at least 2 species are tested in both spring and autumn plantings, and c) 2 watering schemes are defined for each species using the Cocoon technology and 2 schemes for each species without this technology (see below). This means that for the spring or autumn planting a total of 8 scenarios will be defined. For each scenario about 50 seedlings will have to be planted in order to be able to carry out reliable statistical analyses. The setting up of these scenarios implies that at each test site a design is prepared for the planting of 800 seedlings for the combined spring and fall planting programs. The size of test sites to accommodate these designs will be up to 5 ha considering that planting is mostly done in rows whereby the seedlings are set at relatively short distances from each other.

The species selection focuses on the planting of indigenous trees that survive - in the long run - by their own in the plus 150-200 mm/year rainfall regimes prevailing at the test sites. Forest, agroforestry and even productive fruit trees will be considered for selection (see also Fig 2.2). Knowledge available with the local partners and information compiled from desk studies assists in the selection. An additional criteria is the availability of high-quality seedlings of the species at the local nurseries.

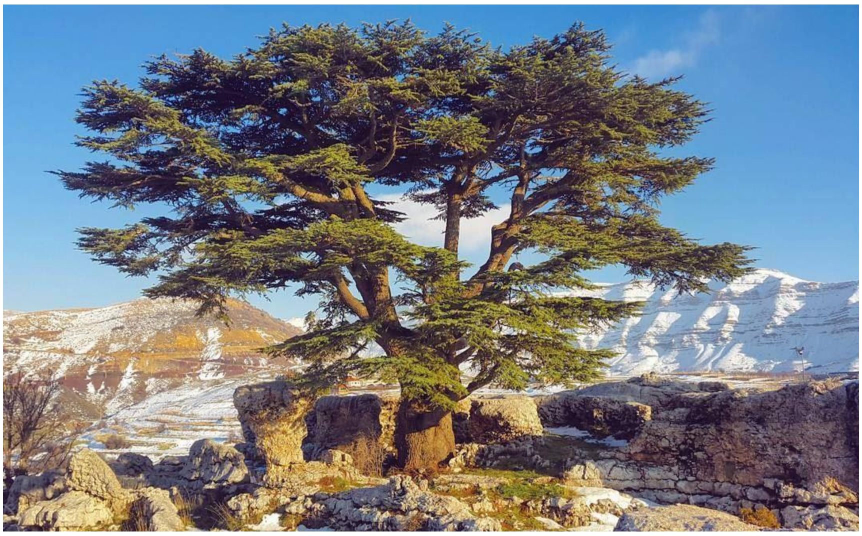


Fig 2.2: The cedar forest tree as the national symbol of Lebanon

2.2. Tree planting and follow up

Tree planting: Following up on the site designs the plantings of seedlings in the spring and fall seasons will be planned. For a smooth execution of the work the local work forces will be offered adequate training. Within a short time, the holes at the test sites to receive the seedlings will be dug with spades or mechanical tools. To place the Cocoons properly, holes with specified diameters and depths are defined. The seedlings can be planted together with mycorrhiza or compost. For the seedlings placed with the Cocoons the degradable containers are filled with water. The seedlings planted without the Cocoons receive an initial round of watering around their stems. Test sites located in areas with sheep or goats are fenced in order to avoid that the animals destroy the vulnerable small seedlings.

Follow up activities: watering, weeding, pruning and monitoring. These activities spanning a period of 1 to 2 years will be planned after tree planting. During the period the scenarios for a species planted with the Cocoon includes watering schemes with summer re-fills or with no re-fills of the containers. The scenarios for a species planted without the Cocoon technology is subject to irrigation schemes following traditional methods and to schemes whereby the seedlings receive no water after the initial watering. Depending on the local rainfall regime the watering intervals vary for the different test sites. Weeding and pruning activities are defined in order to create optimum growing conditions for the plants.

The main aim of the monitoring program is the following up of the growth of the seedlings at the test sites. Parallel with the monitoring of the seedlings, the supplied watering volumes are monitored. Field observations for growth monitoring - including visual inspections and using simple tools - are carried out every two to four months and comprise:

Plant height:	The height of the seedlings to be measured with a ruler;
Vigor:	On a scale of 0 to 3, the vigor of the plant is assessed;
C-status:	On a scale of 0 to 3, the disintegration of the Cocoon is described;
Damage:	On a scale of 0 to 3, the damage to seedlings and Cocoons by animals or rain is determined;
Weeds:	On a scale of 0 to 3, the weed density is reported.

The vigor will be used for the computation of the survival rate or its reciprocal: plant mortality. The field observations are registered in an Excel spreadsheet or with the Land Life Company monitoring ‘app’ installed on a mobile telephone. Observations taken with the ‘app’ can directly be stored in a data base at the Company in Amsterdam. All stored observations and field calculations are used to evaluate the potential for the introduction of afforestation, agroforestry or fruit tree plantings in the region.

3. PROJECT ACTIVITIES IN JORDAN

In Jordan three test locations were selected following well -established criteria. Variability in climate (notably rainfall) and in soil composition were the main criteria playing a role in the selection. This led to the identification of three pilot sites in the northern highlands of Jordan. They included a test site at Al Faisal (Station) located near Jerash, a site at Maysara near As Salt, and a terrain at Faysailiah which lies not far from Madaba. The pilot area at Faysailiah had to be abandoned due to poor local management. At the other two sites tests could be carried out and the project partners secured useful results.

3.1. Physical and social setting

3.1.1. Al Faisal

The test site is located 6 - 7 km south of Jerash inside the valley of a tributary of the Zerqa River (Fig 3.1 and Table 3.1). The Al Faisal nursery run by one of the local government offices lies at a short walking distance south of the site. The main road from Amman to Jerash runs uphill just west of the area beyond the small tributary. At the eastern side of the pilot area the slopes are steep and interrupted by an irrigation canal. The valley floor where the pilot plots were set up is rather narrow at elevations between 270 and 295 m above sea level.

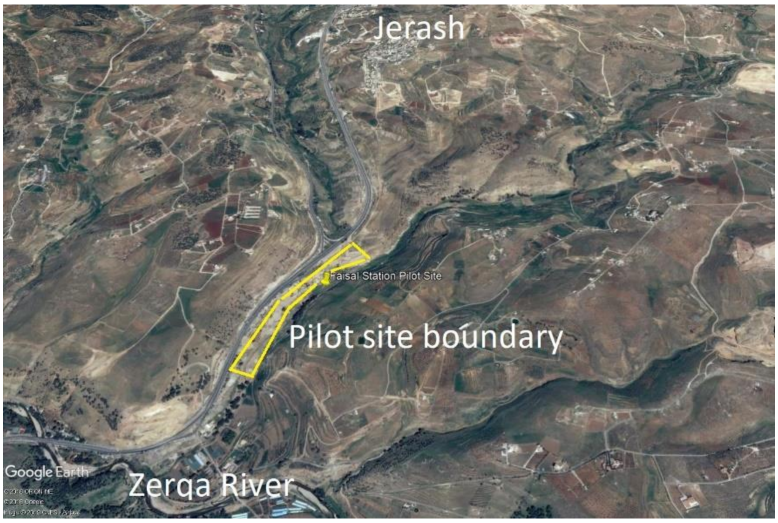


Fig 3.1: Location of the Al Faisal pilot site (boundary in yellow), south of Jerash

The outcropping rocks at the slopes at the western side of the area consist of 'alluvial fans' formed by road building. The eastern side of the plot is bordered with soft sandstones. The valley floor itself is underlain by alluvial (stream) sediments of at least 0.5 to 1 m thick and they are made up of loamy clays with a few pebbles but with quite some organic material in the upper horizons (Fig 3.2).

Fig 3.2: View across the pilot site, downstream the valley

Following the Koppen classification, the climate at the test area can be labelled as Warm Temperate Mediterranean. Characteristic of such a climate are the winter rains and the long dry summers that may run from May until October (see Fig 3.3). Yearly rainfall sums up to about 300 to 400 mm/year. The daily temperatures vary between lows of 10°C in the winter to 25°C in the summer. With these elevated temperatures, the yearly potential evapotranspiration is also high and exceeds the yearly rainfall.

General site data and climate		**Land info and water resources**	
Coordinates	32° 13' 26'' N/ 35° 53' 38'' E/	*Land owner*	Jerash Government
Elevation	270 - 295 m.a.s.l	*Original vegetation*	Possibly woodland
Plot size	1.5 - 2.0 ha	*Current plot vegetation*	Grass: malva silvestrus
Yearly rain	300-400 mm	*Bordering trees*	Grown pinus and eucalyptus
Yearly potential Evapotranspiration	2200-2500 mm	*Fauna*	Few indigenous animals; grazing by sheep
Geology	Sandstone	*Surface water*	Local spring-fed stream
Soil	Loamy clay	*Groundwater*	Exploited deep aquifers

Table 3.1: Key Al Faisal site parameters

The original vegetation at the test site is not known but in view of the climate it seems likely that in the past woodland covered the valley and large parts of the surrounding hills. Today the land - in possession by Jerash Governorate - has degraded and is covered mainly with grass. Locally there have been plantings of pinus and eucalyptus trees (Fig 3.2). The grass is kept short by the local farmers that are keen on having their sheep grazing on the terrain.

The water resources at the pilot site are diverse showing a fair amount of rainfall, local runoff and a running stream alongside the plot area. Groundwater is also available at depth in the underlying rocks. The stream is carrying water for most of the year and is reported to be fed by springs that are located upstream. Waste water or excess irrigation water may also pass through the stream or the irrigation canal. Groundwater from underlying limestone or sandstone aquifers is also exploited by a large government well situated in the middle of the test area.

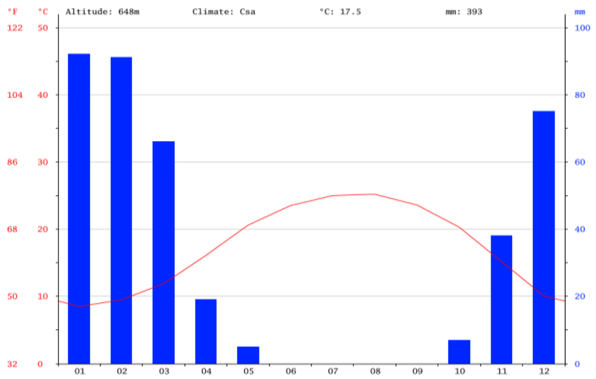


Fig 3.3: Daily temperature and rainfall distribution for Jerash

The social setting at Al Faisal is rural. Located between Jerash in the north and King Talal Lake in the south the area is characterised by the presence of small farming communities. Occasional orchards can be observed at the small farm houses but cattle raising is also a popular activity. The rather hilly and steep terrain is only partly suitable for farming and barren rocky land with scattered afforestation initiatives dominate the local scenery.

3.1.2. Maysara

The pilot site is situated 12 - 13 km northwest of As Salt on the escarpment between the Jordanian Highlands and the Jordan Valley (Fig 3.4 and Table 3.2). The site borders the main road from As Salt to Deir Allah in the valley. The area is north-facing and is part of a vaster area where the local government is developing forestry in an otherwise desolate landscape. The highlands east of Maysara have elevations up to 600 m above sea level and the valley floor is at 250 m below the sea. The site itself has steep slopes and is located at around 330 m above the sea.

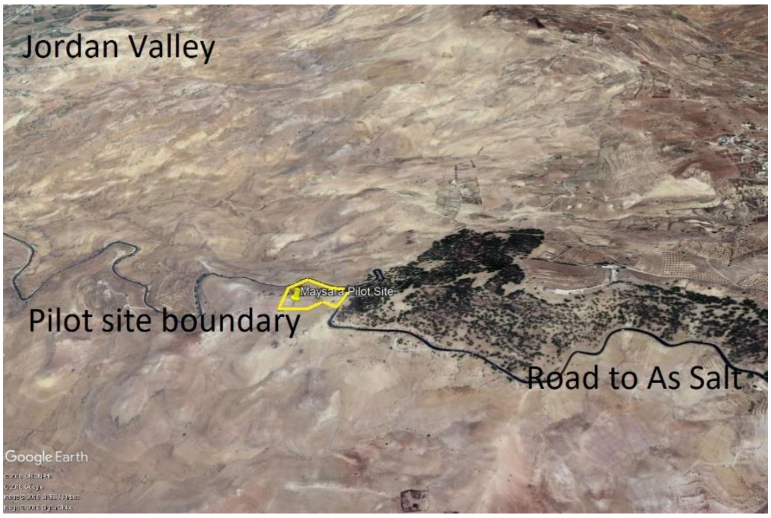


Fig 3.4: Location of the Maysara pilot site (boundary in yellow), northeast of Salt

There are few outcropping rocks at the site. In the places where they are exposed, a light-coloured sandstone can be observed (see bottom left corner in Fig 3.5). The sandstone is brittle and decomposes easily. Over time, decomposition has resulted in the formation of a sandy soil with a predominantly fine texture. Rock fragments are scarce in the soils that otherwise vary in thickness from zero to an estimated 0.5 - 1 m. The soil is also poor and organic matter is at a low level.

Fig 3.5: View across the pilot site, downstream the escarpment

In line with the Koppen scheme the climate at the pilot site can be classified as Warm Temperate Mediterranean. The climate shows the typical characteristics of winter rains and prolonged dry summers from May to October (see Fig 3.6). The Maysara rainfall distribution is similar to the distribution for As Salt as shown in the diagram. Although distributions are similar the total yearly rainfall at Maysara is considerably less than at As Salt. Without having firm data at the site, the yearly rainfall at Maysara is estimated at about 200 mm. Temperatures at the site are higher than at As Salt meaning that the yearly potential evapotranspiration substantially exceeds the yearly rainfall.

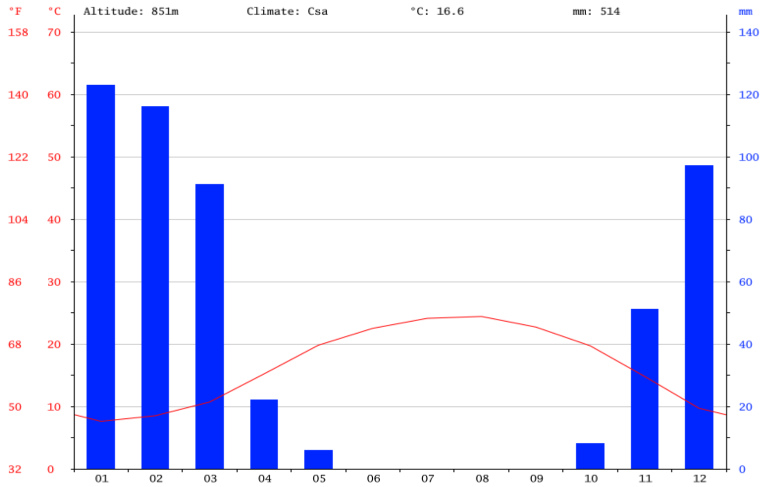


Fig 3.6: Daily temperature and rainfall distribution for As Salt

The original land cover at the pilot site can best be defined as semi-desert scrublands. Thorny bushes and acacia trees where some water collects dominated the scene. This picture can be inspected at other locations down the escarpment. Presently, the land is rather bare but terracing has been undertaken and a substantial amount of half-grown pine and eucalyptus trees provide a nice shady environment (Fig 3.5). Small animals have been noticed and Bedouins have their sheep grazing the small bushes in the area surrounding the test site.

General site data and climate		**Land info and water resources**	
Coordinates	32° 08' 05" N/ 35° 39' 32" E	*Land owner*	Balqa Government
Elevation	320 - 340 m.a.s.l	*Original vegetation*	Semi-desert shrubland
Plot size	Max 5.5 ha	*Current plot vegetation*	Local eucalyptus and pinus
Yearly rain	About 200 mm	*Bordering trees*	Same
Yearly potential Evapotranspiration	2200-2500 mm	*Fauna*	Few indigenous animals; grazing by sheep
Geology	Soft sandstone	*Surface water*	Minor spring
Soil	Fine sand	*Groundwater*	Not known

Table 3.2: Key Maysara site parameters

The occurrence of water at the test site is largely restricted to winter rainfall. Running surface water has not been observed in the area. However, one could note that after heavy rain in the winter flash floods will occur in the normally dry beds of the natural drainage courses. Groundwater emerging from fractures in the sandstone forms a spring at the northern boundary of the site. Spring flow is very low but the water is still used by passers-by to re-fill their water bottles.

The social context at Maysara is typical for the Jordan Valley escarpment. The dry and hot area is not very attractive for people to settle and the population density can be considered as very low. The people that are making a living at Maysara are Bedouins making a living out of raising camels, goats and sheep. Otherwise, there is no human activity with the exception of actions taking place during and after afforestation initiatives to make the area more pleasant.

3.2. Design and species selection for the pilots

3.2.1. Introduction

Following the outline in Chapter 2 on methodology the pilots in Jordan were set up to carry out field tests to investigate the impact of the Cocoon technology 'vis a vis' traditional planting methods. Plant vigor and height, and water use of the young seedlings are amongst the parameters to be evaluated. To perform the test for local circumstances and environmental conditions in Jordan a two-phase planting plan was adopted. Off-season spring plantings were organized that were followed by conventional plantings in the fall.

Forest and fruit tree species were selected for each of these planting seasons. Species selection depended on the availability of seedlings at the local nurseries and the quality of the young trees. Adaptability and resilience to soil and weather conditions were also factors taken into account. The forestry species occur in native woodland patches in the highlands of northern Jordan. The productive fruit tree species matched with the species traditionally selected by the farmers in the country.

With Cocoon and No Cocoon scenarios were defined for each of the species selected. Table 3.3 shows the With Cocoon re-fills and no-re-fill scenarios and the No Cocoon irrigation and no irrigation scenarios. There are in total 8 different scenarios for each planting season including two species at the Jordanian pilot sites.

Code	*Description*	*Remark*
C-NI-S(1)	With Cocoon and no irrigation (no re fills) for species S(1)	Only initial 25 liter fill
C-I-(S1)	With Cocoon and irrigation (re fills) for S(1)	
NC-NI-(S1)	No Cocoon and no irrigation for S(1)	
NC-I-(S1)	No Cocoon, but with normal irrigation for S(1)	
C-NI-S(2)	With Cocoon and no irrigation (no re fills) for species S(2)	Only initial 25 liter fill
C-I-(S2)	With Cocoon and irrigation (re fills) for S(2)	
NC-NI-(S2)	No Cocoon and no irrigation for species S(2)	
NC-I-(S2)	No Cocoon, but with normal irrigation for S(2)	

Table 3.3: The selected planting scenarios

3.2.2. Al Faisal

The test site at Al Faisal was visited to carry out a land suitability assessment and to make a detailed planting design. At the same time species selection, site preparation, tree planting and the installation of fencing were discussed. The underlying valley at Al Faisal station was identified as a site where the loamy to clayey soils were considered to be ideal to raise forest and fruit trees for the testing of the Cocoon technology. In the valley 2-3 ha of land next to the Al Faisal nursery was demarcated for the planting of the 800 trees for pilot testing.

Spring planting

The planting design covered a long strip of land in the low-lying valley at Al Faisal. The area for spring planting was sub-divided into three parts where planting was feasible depending on soil quality, rockiness and vegetation cover (Fig. 3.7: the yellow areas). The design accommodated the 8 scenarios for the two tree species selected for pilot testing. With a sample size of 50 individuals for each planting scenario, a total of 400 seedlings were planted.

Distinct planting blocks were outlined for each planting scenarios (Fig. 3.7: scenario 1-8). Within each block 4-5 planting lines were drawn. A distance of 4-5 m was maintained between the planting lines keeping sufficient distance from dirt roads. At each planting line 10-15 seedlings were taken up in the design with 4 m distance between individual trees. The design was completed with the help of satellite images. The layout also included a fence around the tree planting site to protect the seedlings from being trampled by visitors or by livestock grazing in the valley.

Species	Type	Planting season	Bio-geography
Oleo europaea (olive)	Fruit production (Commercial and native habitat species)	Spring planting - Al Faisal	Land classification: Old remnants of dry deciduous oak forests in Mediterranean region of Jordan. Fruit tree planting at orchards, common. Annual rainfall: 200-350 mm. Biogeography: Mediterranean.
Prunus amygdalus (almond)	Fruit production (Commercial)	Spring planting - Al Faisal	Land classification: Fruit tree planting at orchards. Annual rainfall: 500-800 mm
Ceratonia siliqua (carob)	Forestry /Fruit (Commercial and native habitat species)	Spring planting - Maysara Fall planting - Al Faisal	Land classification: Old remnants of dry deciduous oak forests in Mediterranean region of Jordan. Annual rainfall: 200-350 mm. Biogeography: Mediterranean.
Pinus halapensis (pine)	Forestry	Spring planting - Maysara Fall planting - Maysara, Al Faisal	Land classification: Mountain ranges in northern parts of Jordan. Altitude range: 550-1000 m Common annual rainfall: 400-600 mm, but also 150-900 mm (CABI). Biogeography: Mediterranean.
Acacia tortilis (acacia)	Forestry	Fall planting – Maysara	Land classification: Base of granite mountains, rocky areas, rocky gorges, stony and rocky beds. Altitude range: 200-400 m. Annual rainfall: 100-200 mm. Biogeography: Arabian regional subzone and Nubo-Sindian centre of endemism.

Table 3.4: Details of species used in the Jordanian pilots

The species planted at Al Faisal station in spring were the fruit trees Olea europaea (olive) and Prunus amygdalus (almond). These species are primarily planted by the farming community for commercial fruit production. It is noted that olive trees are also found in the wild at the edges of deciduous oak forests (see also Table 3.4).

Fall planting

The design for fall planting had to cover an enlargement of the spring planting area. The fenced area was extended to include part of the scenarios for fall planting (Fig.3.8: the reddish line). The fall planting scenarios 1, 4 and 5 could be included within the originally fenced area and the scenarios 2, 3, 6, 7 and 8 were accommodated within the extended fenced area. Planting blocks and planting lines were outlined for each scenario similar to the design for spring planting (not shown in Fig 3.8). The design also followed a distance of 4-5 m between planting lines and 4 m between individual trees.

Pinus halapensis (pine) and Ceratonia siliqua (carob) were the species tested during the fall planting cycle. Pinus is a forest tree that is well adapted to the local climate. Carob can be considered both as a forestry and fruit tree (Table 3.4). Naturally occurring in the remnants of deciduous oak forest at lower altitudes the carob requires less water after the initial establishment stage. The tree may grow well at the Al Faisal pilot site.

3.2.3. Maysara

A test site visit was also carried out at Maysara. The test plot lies on a north facing slope that is partially shaded and is protected from too high overhead temperatures in the summer months. At the Maysara site natural conditions are less favorable for afforestation as the soils are poor comprising of hard sands with low organic matter. The rockiness of the soil and sloping terrain with a high risk of run off also provided a challenge for a planting program. However, the area does support the existing vegetation made up of pinus and eucalyptus trees that are well adapted to site conditions. The total test area covered about 5 ha of useful land.

Spring planting

The planting design for spring was laid out along the southern part of the north facing slope covering the pilot area (Fig. 3.9: the area with the red lines within the yellow line). The planting design comprised the 8 scenarios for the two species that were selected for the pilot. With a sample size of 50 individuals for each scenario, altogether 400 seedlings were used in the

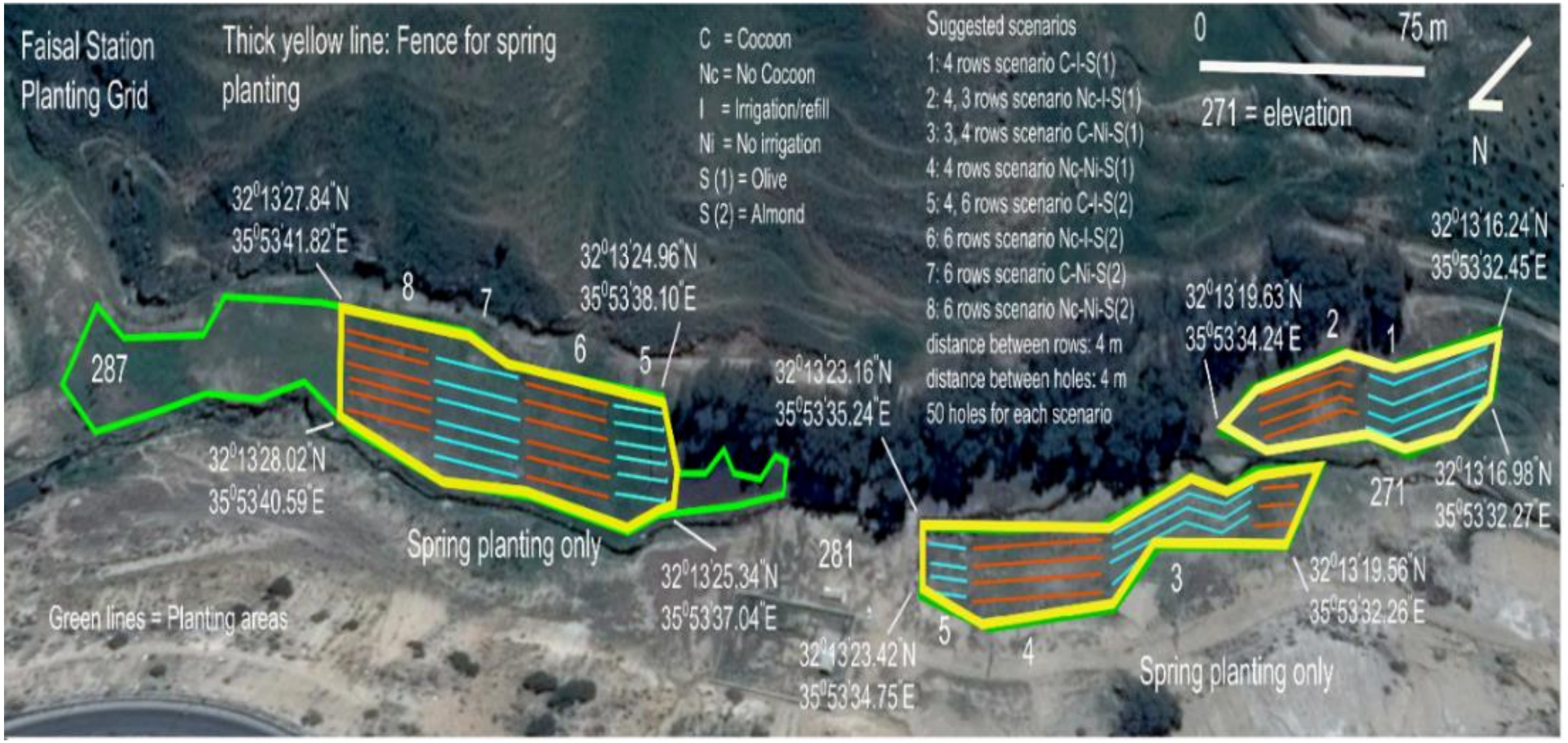


Fig 3.7: Layout of planting lines for spring planting in Al Faisal

Fig 3.8: Layout for planting lines for fall planting in Al Faisal

There was only one planting block consisting of 8 planting lines at Maysara. Each planting line represented one scenario (Fig 3.9: scenario 1-8). The lines drawn with the help of satellite images followed the contours of the landscape. The distance between the planting lines was set at about 5 m and 4-5 m spacing was foreseen between individual plants. The design also did take into account the presence of the existing trees in the area. The design also showed fencing around the planting site to prevent unnecessary disturbances to the seedlings by shepherds and other wild fauna.

The species for planting in spring included Pinus halapensis (pine) and Ceratonia siliqua (carob). The pine was selected since this forest tree is suitable for afforestation in the harsh climate prevailing at Maysara (Table 3.4). The selection of carob for this climate was more experimental. If successful, then the tree could be used for forestry and commercial purposes.

Fall planting

The design for fall planting covered the eastern and northern part of the fenced area (see Fig 3.9 and 3.10). The eastern part became available since the planting lines for the spring seedlings were shorter than foreseen. Planting blocks whereby each block indicated one planting scenario were outlined (Fig 3.10: scenario 1-8). Several planting lines were set up within the blocks. The distances between the planting lines and individual seedlings were similar to the distances used for spring planting.

For fall planting Pinus halapensis (pinus) and Acacia tortilis (acacia) were selected. The planting of forest pinus trees was repeated in view of their proven persistence in the area. Similarly, the forest species acacia was chosen since a few of these trees grow naturally within the site and in its surroundings. Therefore, the tree was expected to be resilient to the harsh growing conditions.

3.3. Tree planting

3.3.1. Introduction

Activities for tree planting include the provision of water, bringing seedlings from nurseries, organizing local labor, and planting the seedlings with or without the Cocoons. The management and supervision of the planting process was carried out by the representatives of the Land and Water Department of the Ministry of Agriculture and Menaqua’s local office in Jordan. Additional supervisors of the local communities were appointed for the Al Faisal and Maysara pilot sites. In view of the similarities in the tree planting process, the description of activities undertaken at Al Faisal and Maysara are combined.

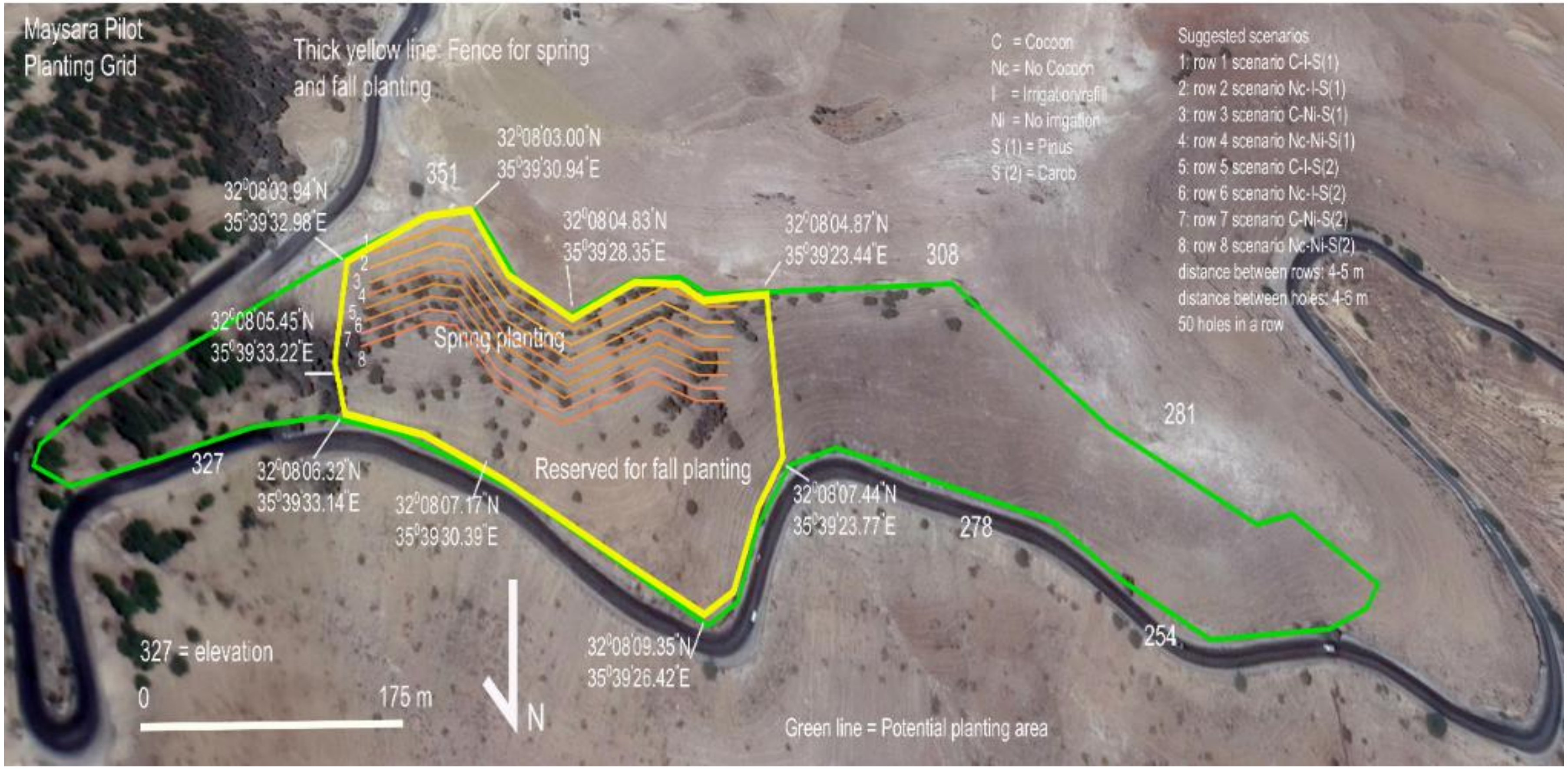


Fig 3.9: Layout for planting lines for spring planting in Maysara

Fig 3.10: Layout for planting lines for fall planting in Maysara

3.3.2. Pre-planting activities

The arrangement of logistics for the supply of Cocoons, seedlings and water to the planting sites was carefully organized. Additional management measures included the coordination with the planters and fence workers. The Cocoons were shipped by Land Life Company from The Netherlands to Aqaba harbor. After custom clearance, the Cocoons were collected from the harbor and stored in a warehouse near Amman. Later, all Cocoons were transported to the sites for the plantings in the spring and fall.

The seedlings of the selected forestry and fruit trees were provided by local nurseries in Jordan. The seedlings of the olive and almond trees and the pinus tree that are planted in Al Faisal were provided by the local nursery which is bordering the pilot area. All carob trees and the pinus and acacia seedlings planted in Maysara were obtained from the government nursery at the Yajouz Forestry Station near Amman. All seedlings to be planted were checked for quality by local experts. Further details on the specifics for species selection are compiled in Chapters 3.2.2 and 3.2.3.

Water had to be transported to the pilot areas from the nearest water supply points. At Al Faisal Station water was taken from the nursery and supplied to the plants by hoses. At the more isolated pilot area Maysara tankers transported the water to the planting location where it was stored in a large tank. Watering at this pilot was also done by hoses.

3.3.3. Time frames for planting

Spring planting

The pilot project for spring planting intended to start on time in March 2019. However, late planting in May was due to delays in the delivery of the Cocoons to the project site and difficulties in logistical arrangements during Ramadan. At Al Faisal the planting was completed from the 20th to the 22nd of May and at Maysara from the 15th to the 18th of May. Starting spring planting at a later point in time was considered to be worrisome due to the onset of high summer temperatures that can hinder the normal growth of the seedlings. Additional soil wetting measures were planned to ensure that the plants would show a healthy 'spring' growing boost.

Fall Planting

The fall planting for both pilot locations was planned in the period October to November 2019. This was considered as an early fall planting. It was anticipated that water in the Cocoon containers would irrigate the seedlings until the wettest months December and January of the rainy season. The late arrival of the Cocoons caused a delay in planting which was only carried out in December. At Al Faisal the planting was done from the 8th to the 12th of December 2019 and at Maysara from the 2nd to the 6th of December 2019. Re-planting activities (also for spring seedlings) were carried out after heavy flooding and destruction of part of the seedlings in January 2020 (see also Chapter 3.4.3).

3.3.4. Site preparation and tree planting

Representatives of the Land and Water department of the Ministry of Agriculture and staff of Menaqua were present during tree planting at Al Faisal Station and Maysara. The planting started with a field workshop to introduce the innovative Cocoon technology (see also Chapter 3.5). Since the Menaqua staff could not be present during the entire planting process it was arranged that the representatives and local coordinators attending the workshop would oversee all planting activities. Additional guidelines and manuals on Cocoon planting methods were given to the guiding staff. At Al Faisal Station and Maysara the planting methods were kept the same as far as terrain conditions allowed. The detailed planting procedure and experiences during planting are listed below.

Step 1: Land clearance and site preparation

To prepare land for tree planting the soil surface was cleared manually by contract workers. At both pilot sites the larger rocks and stones were removed and the superficial weeds were pulled out. It was anticipated that large rocks could hinder Cocoon installation and they were taken away. In Maysara the natural rocky features and sloping terrain proved to be a challenge for site preparation. In addition to clearing the larger rocks and stones the natural terraces were redone to accommodate the 800 seedlings.

Despite land preparation protocols being followed in Maysara it was later observed that the large stones on the upper slopes of the terraces were washed down on underlying Cocoons during rains. This resulted in Cocoon lids and - in some cases - plants being damaged.

Step 2: Excavation of planting holes and pre-watering

Contract workers were hired to excavate the planting holes (pits) and place the seedlings. For spring planting the holes for the With Cocoon scenarios were made 30 cm deep and 60 cm in diameter whereas the holes for the No Cocoon scenarios were excavated in line with traditional practices. The With Cocoon holes proved to be larger than the No Cocoon holes. In addition, it was considered essential that pits should be made not more than 4 days before the planting date. Earlier digging carries the risk that due to drying the moisture patterns in the soil can be disturbed which affects the growth of the seedlings.

In Al Faisal the planting holes were excavated manually in the loamy soil (see Fig 3.11). Simple excavation tools like shovels and pick axes were used but also the engagement of more advanced tools and machinery was reported. In Maysara the excavation was more difficult due to the rockiness and petrification of the sandy soils. Despite these setbacks the holes could be dug manually. At Al Faisal and in particular at Maysara it was noted that small sharp stones at the bottoms of the excavated pits hindered the proper placement of the Cocoons. The stones also made punctures in the container leading in some cases to water leakage from the Cocoon.

Learning from the experiences during spring planting the excavation of the planting holes was done with more care during the fall. The size of the planting holes for the Cocoons was also enlarged. The depth of the holes was adjusted to 40 cm and the diameter to 70 cm. Extending the holes in this way facilitates the (re)-placement of loose soils and/or compost in the pit avoiding the interference of sharp stones. More space for the placement of compost also enhances the water retention capacity of the soils (see also step 3).

Fig 3.11 Excavation of planting hole and overview of Faisal station

After excavation, all planting holes were watered during a period of 24-48 hours prior to tree planting. An estimated 6-10 liters of water per hole was used during the watering activities. The wetting was done to maintain sufficient moisture in the soil in the period between the digging of the hole and planting (maximum 4 days).

Step 3: Bedding with mycorrhizae or compost

The presence of the mycorrhizae fungus facilitates the availability of phosphorous (P) to the plants if this element is available in the soil. The use of mycorrhizae can be considered important when planting in dry conditions where the transport of phosphorous to the roots of the plants is difficult. During spring planting mycorrhizae was not used at Al Faisal Station but it was added at Maysara where the fungus was thought to create an additional phosphorous uptake by the plant roots in the sandy soils. The fungus was placed in the center of the excavated planting hole.

Experiences in the summer of 2019 showed that at Maysara Cocoons emptied quickly. The emptying of part of the examined containers could not be attributed to punctures but was found to have been the result of the poor water retention capacity of the sandy soils in Maysara. In particular the issue became transparent in the summer months (see separate paper in Annex III). This required a different approach during fall planting aiming to prevent exceptional water losses during the following (late) spring and summer seasons. Therefore the planting in fall did not include the use of mycorrhizae. In Maysara as well as at Al Faisal Station compost was mixed with soil and placed at the bottom of all excavated planting holes to increase the soil retention capacity and soil fertility.

Step 4: Tree planting

The With Cocoon scenarios: The seedlings were planted at the centers of the excavated holes whereby the roots extended about 10 cm into the earth at the bottom of the hole. Then, the Cocoon itself was placed in the hole while the planted tree was protruding through the central cone. Simultaneously, additional earth was added to the seedling (next to the root ball) and firmly pressed down to remove air pockets. The spaces at the sides of the Cocoons were filled with earth to prevent damage to the walls of the container. At some particular spots at the pilot in Maysara the placing of -and earth filling at the Cocoons was done improperly during spring planting. Proper care was given to these placement aspects during fall planting at the pilots.

The No Cocoon scenarios: The trees were planted with their roots extending into the earth at the bottom of the holes. Then, the holes were further filled with earth following traditional Jordanian tree planting methods. The earth was pressed tightly to anchor the seedlings into the ground. Care was taken to hold the seedlings upright during planting.

Step 5: Watering

After planting the Cocoons were filled with 25 liters of water which is the carrying capacity of the reservoir. Care was taken that the water level in the reservoir stayed at least 2 cm below the upper rim of the side wall. In addition, one liter of water was added to the seedling using the opening in the cone in the middle of the Cocoon. The seedlings planted without Cocoons received an (initial) irrigation gift of more than 10 liters of water following traditional watering procedures (see Fig 3.12). The precise volumes provided at Al Faisal and Maysara are discussed in the water report (see also Chapter 5).

Fig 3.12: Watering a young seedling (without Cocoon)

Step 6: Placement of lid, soil and shelter

The planting procedure was completed by placing the lids and shelters on top of the Cocoons. The lids were pressed firmly on the water reservoirs. After placing the lids they were partly covered and packed with soil to prevent the lid from being dislodged and to reduce evaporation losses from the reservoir. The center parts of the lids and the holes with the protruding seedlings were left uncovered. The shelters were inserted into the hole with the seedlings and pressed down until the marking line. The shelter is used to protect the plant from direct radiation from the sun especially in conditions with high overhead temperatures. The shelters proved to be useful in protecting the young plants.

After spring planting at Al Faisal Station and Maysara it was found that lids and shelters were generally well placed. At Maysara some lids became loose from the reservoir and at Al Faisal several shelters were blown away due to the strong winds that were blowing during the heat wave in the summer of 2019. Only in a few cases it was found that the shelter was placed too high. During fall planting extra care was taken to secure both lids and shelters properly on top of the Cocoons.

3.4. Follow up activities

3.4.1. Introduction

At Al Faisal and Maysara dedicated follow up activities were undertaken. These included the watering of the seedlings for the appropriate scenarios and the pursuance of plant care and maintenance of the infrastructure on site. Core of the tasks were also the monitoring activities measuring the performance of the plant for the With Cocoon and No Cocoon scenarios. The tasks carried out at Al Faisal and Maysara were rather similar and separate descriptions for the pilot sites are not necessary.

3.4.2. Watering/irrigation:

Without irrigation the survival rates of young seedlings are very low especially in dry and arid landscapes. Several afforestation initiatives consider - without the Cocoon technology - irrigation during the first two to three years after planting as an essential component for nature restoration. For agroforestry and fruit production trees common practice in Jordan suggests that irrigating these trees for a period of around three years is necessary. Normally this is the period until the stage of fruit production. Hereafter, the trees will grow by themselves making use of the winter rains.

In this pilot project part of the forestry and fruit trees were raised with the help of the Cocoons. With the Cocoons the young trees are normally supported with only one initial irrigation of 25 liters of water available in its bio-degradable container. This adheres the purpose of the Cocoon technology which implies to support the young seedling with a minimum amount of water until the plant is established with a well-developed root system. Nevertheless, the planting scenarios with an option to re-fill the container were implemented in the pilots considering the high temperatures and evapotranspiration rates in Jordan during the summer months.

Spring planting

After the start of the spring planting in May 2019, the With Cocoon and No Cocoon scenarios were re-assessed. The (too) late planting in May and the occurrence of a heat wave in the summer months June and July endangered the survival of the planted young seedlings. Therefore - as a fail-safe measure - the plants obtained additional water including re-fills for all Cocoons at the pilot site in Maysara and irrigation for all seedlings planted without Cocoons. The latter exercise was carried out at Al Faisal and Maysara up to some point halfway the summer season (see the Water reports and Chapter 5).

Normal irrigation protocols were followed in the period August to September 2019 for the No Cocoon scenarios. From the fall in October 2019 until the summer of 2020 no irrigation was applied since the winter rains provided sufficient water for the plants. For the summer of 2020 a protocol was made for the watering of the With Cocoon and No Cocoon scenarios for this season.

Fall planting

The fall plantings at Al Faisal Station and Maysara in December 2019 was carried out in a period with sufficient water from rainfall for the seedlings. Similar to the trees planted in the spring no irrigation was applied until the summer of 2020. For the summer of 2020 the same protocol was prepared as for spring planting (see above).

3.4.3. Site maintenance

Maintenance and management of the planting area was assigned to the local supervisors appointed by staff of the Land and Water department of the Ministry of Agriculture and Menaqua. Site maintenance comprised of the maintenance of the young trees and fences and addressing any problems that occur at the planting sites until the end of the monitoring period. Details of the activities are as follows:

Removal of weeds

The control and removal of weeds is important especially in young plantations. Competition with weeds can significantly reduce the water and nutrient access by the seedlings. This results in low plant vigor and a delay for the seedlings in reaching productive stages. Weeds also result in an increase in the risk of attacks by pests and diseases. When dried they can prove to be a fire hazard.

Inspections of images received of the planting sites suggest a high density of weed growth resulting from rains in the wet seasons. At the sites a combination of mowing and manual methods was considered for weed control.

Weeding was done at the planting sites at Al Faisal Station and Maysara in the wet winter season of 2019 to 2020. In Al Faisal the sections and stretches between the planting lines were mowed with the help of a mowing machine or a tractor. Around the plants with the Cocoons weed removal was done manually using hand tools and rakes. At Maysara weed control was much more difficult because of the sloping terrain, thorny bushes and the presence of dangerous snakes. Here the weeding was done manually over a period of two weeks due to the difficult conditions.

Fencing

The fences around the planting areas were installed by local contractors. At Al Faisal the fences for the protection of spring plantings had a length of roughly 700 meters and they were about 2 m high (see Fig 3.7). The extension of the fence to accommodate the fall seedlings had a length of approximately 500 meters (see Fig 3.8). At Maysara the fences set up during the spring plantings also included the area earmarked for the fall seedlings. The length of the 2 meter high fence at Maysara was about 900 m running partly along the road from As Salt to the Jordan Valley (see Fig 3.9).

It was advised that the fences should be inspected and maintained regularly to effectively serve its function of protecting the pilot sites. In the spring of 2020 the fence at Al Faisal was broken through and it was observed that goats or sheep entered the planting area and browsed on the olive plants. Several olive plants were damaged before the fencing was repaired. The fence at Maysara was left intact although it should not be excluded that persons temporarily lifted the wiring of the fence to gain access to the planting area to inspect the seedlings out of curiosity.

Irrigation canal

The irrigation canal at Al Faisal Station runs at the foot of a steep mountain slope just east of the planting area. During field inspection early in 2019 it was observed that the low height of the canal wall and cracks in the brickwork could result in overflows during heavy rains. The overflowing flood water could affect the planting area and cause damage to the young seedlings. The risk was pointed out to the local supervisor with the advice to carry out the necessary canal restoration.

Measurement Parameters	***Units***	***Description***	***Method***
Height	Cm	Measurement of plant height from soil surface	Ruler/measuring tape (manual)
Vigor	0-3	0: Dead 1: Main branch alive with shriveled leaves or no leaves 2: Main branch with medium vigor and no shriveled or dead leaves. Leaves still attached to the main stem. Also assign 2, in cases of disease or pest infestation. 3: Main branch with good vigor and healthy green leaves attached to the stem. No disease or pest infestation.	Visual assessment
Weed density	0-3	0: No weeds 1: One or two weed plants within 1m radius of the seedlings 2-3: Apply the range 2 or 3 depending on the number of weed plants in the proximity of 1m radius around the With and No Cocoon plantings.	Visual assessment
Cocoon damage	0-3	Observation of Cocoon damage rated on a scale of 0-3 0: Cocoon is fully intact 3: Cocoon absent or completely damaged.	Visual assessment
Plant damage	0-3	Observation of plant damage due to external factors such as wind, animals and trampling rated on a scale of 0-3 0: No damage 3- Plant removed or completely destroyed.	Visual assessment
Water volume	Liter	Amount of water provided for young seedlings for the With Cocoon and No Cocoon scenarios. Recorded in separate water reports	With Cocoon: (25liter) x number of fills No Cocoon: Measured using containers or estimated total water use (liters)

Table 3.5: Overview of measured parameters at the Al Faisal and Maysara pilot sites

In November 2019 the canal overflowed after a rain storm disintegrating part of the Cocoons used in the spring planting scenarios with the olive seedlings. Although the olive plants were still performing well after the flood the additional moisture in the soil may affect the test results.

A more serious problem occurred in the middle of the rainy season in January 2020. Heavy rains and flood water caused the canal to overflow again and flood the planting site. At the time of flooding both spring and fall plantings were damaged. The reports from Jordan were that nearly all of the carob seedlings and 70 % of the pine trees were destroyed (see also Chapter 3.3.3).

3.4.4. Performance monitoring

Measurement parameters and equipment

Monitoring of the young seedlings at the pilot locations Al Faisal Station and Maysara was conducted to assess plant growth and water use efficiency for the Cocoon planting technology ‘vis a vis’ traditional planting. In line with the guidelines set out in Chapter 2 on Methodology the main parameters to measure were plant growth characteristics including plant vigor and height. The volumes of water used for the With Cocoon and No Cocoon scenarios were also determined. Additional parameters that could influence plant growth such as weed density and Cocoon and plant damage were also considered during data collection.

Guidance and instructions for data collection is shown in a comprehensive overview (Table 3.5). The recording of data was done on monitoring sheets set up in Excel. Staff of the Land and Water department of the Ministry of Agriculture and technical staff of Menaqua recorded the data first manually on paper-printed versions of the monitoring sheets. At a later stage manual recording was replaced by the tree monitoring application of Land Life Company. The application was downloaded on a smartphone and paired with a Trimble to increase the accuracy of the geo-locations of individual trees up to a few centimeters. For the latest monitoring cycles a Garmin GPS device was used to record and share monitoring data. The recorded data were uploaded into an established database at the offices of Land Life Company for further processing.

Monitoring period and frequency

Monitoring schedules were made for the spring and fall plantings. For spring planting the monitoring of the seedlings was planned to be carried out during a 1.5 year time frame from April 2019 until December 2020. For fall planting the monitoring of the plants comprised a 1 year period from November 2019 until December 2020. The envisaged monitoring frequency was once per 3-5 months with shorter intervals covering the summer season and longer intervals for the winter. Table 3.6 shows the planned months for monitoring.

Pilot site	Monitoring	Spring planting					Fall planting		
		July 2019	Nov 2019	April 2020	July 2020	Nov 2020	April 2020	July 2020	Nov 2020
Al Faisal	Planting observations	•	•	•	•	•	x	x	x
	Remarks						x	x	
Maysara	Planting observations	•	•	•	•	•	x	x	x
	Remarks								

Table 3.6: Original timeline for plant monitoring at Al Faisal and Maysara

After the plantings were done the monitoring schedules had to be adjusted as a result of unforeseen circumstances. These included the late spring planting and the heat wave affecting the seedlings in the summer of 2019. The flooding at Al Faisal Station also influenced the monitoring at this test site. Most of all the monitoring suffered from the outbreak of Corona preventing staff to go out into the field since they had to stay at home. The new schedules meant that monitoring for spring planting at Al Faisal Station (with reliable results) was undertaken during a period of 1 year from May 2019 to May 2020 and at Maysara for a time frame of 1.5 year from May 2020 to January 2021. For fall planting at Al Faisal Station the monitoring covered a period of only 6 months from December 2019 up to May 2020 and for Maysara 1 year from December 2019 up to January 2021. The unforeseen incidents also implied that the lengths of monitoring intervals no longer followed the original scheduling (see also Chapter 5 for details).

3.5. Community involvement

Introductory workshops

Staff of the Department of Land and Water of the Ministry of Agriculture and the field coordinators are individuals with a strong local knowledge on the planting and maintenance of seedlings. During introductory workshops they were also well-trained on the use of the Cocoon technology. Staff of Land Life Company and Menaqua were responsible for the training during two workshops respectively held in Faysaliah and at Al Faisal Station. On 7 April 2019 the workshop at Faysaliah was conducted featuring an introduction of the Cocoon technology.

The teaching staff also gave field demonstrations on the proper placing of the Cocoon in the dug holes and provided an outline on the maintenance tasks to be carried out after planting (see Fig 3.13). On 3 November 2019 the workshop at the Station consisted of a diverse program for departmental staff and coordinators but also for other government staff, scientists from universities and representatives from the private industry in Jordan. There were presentations on land restoration and agroforestry, the Cocoon technology, and on the mid-term results of the spring plantings. Panel discussions and a site visit were also part of the program. During both workshops the organizers welcomed an enthusiastic audience.

Community perceptions

Communities have only partly been involved in the pilot testing. At Al Faisal Station the local farming community has been informed about the experiment and staff and workers at the Al Faisal nursery were heavily involved in the testing of the novel Cocoon technology. Other citizens living in the area were not informed on the technology but might have heard about it from the farmers. At Maysara an established local community hardly exists although there is the scattered presence of Bedouins. They were informed about the tests that were conducted but had no active participation in project activities.

Fig 3.13: Participants of the workshop in Faysaliah

4. PROJECT ACTIVITIES IN LEBANON

Four test locations were identified in Lebanon in line with the set out criteria. Variability in rainfall, rockiness and the social structure at the test site were the main criteria for selection. The four sites lie in the mountains and internal valleys of Lebanon. They comprise farm plots near Aarsal Farm Village, an area bordering Ras Baalbek, a site at Jabal Moussa northeast of Beirut, and a plot at AREC Research Station which was set up near the town of Baalbek. The pilot area at Jabal Moussa had to be given up due to poor site access, damages to the seedlings and des-interest of the local community. At the other sites the tests could be performed and the project partners could collect data fit for analyses.

4.1. Physical and social setting

4.1.1. Aarsal Farm

There are different pilot sites for spring and fall planting in the Aarsal area which is located in the Anti-Lebanon mountains in Baalbek Hermel Province. For spring planting the site is situated at about 5 km south-south-west of Aarsal Farm Village (see Fig 4.1). The site can be reached by dirt roads and lies on a rather flat plateau bordered by small hills. Farmers have planted fruit trees in orchards in parts of the area. With altitudes increasing in a southerly direction, the area itself is at an elevation of about 1840 m above sea level (see Table 4.1).

For fall planting 7 different sites were considered. They are mostly located southwest of the spring planting site. They vary in distance between 9 and 10 km from the village. The sites are on private land owned by farmers eager to participate in the pilot project. The landscape is spectacular and characterised by hilly terrain intersected by small valleys where farmers are also developing orchards. The hills in the terrain reach elevations up to 2100 m above sea level and the valleys are at 10-40 m lower elevations than the hill crests.

The parent rocks at the spring and fall pilot sites consist mostly of light-coloured bedded limestones. Karstic limestones are present as well. At all pilot sites rock outcrops can be found at nearby hill tops. The areas in between consist of loose material either washed down from the hills or formed 'in situ'. Especially at the sites for fall planting, this material is dominant in the flat valleys. Soils have also developed (see Fig 4.2). Tests revealed that the soils are usually over 0.5 m deep and consist of loamy clays with some pebbles. The organic content in the soil is rather low unless farmers have enriched them to enhance the fertility of their orchards.

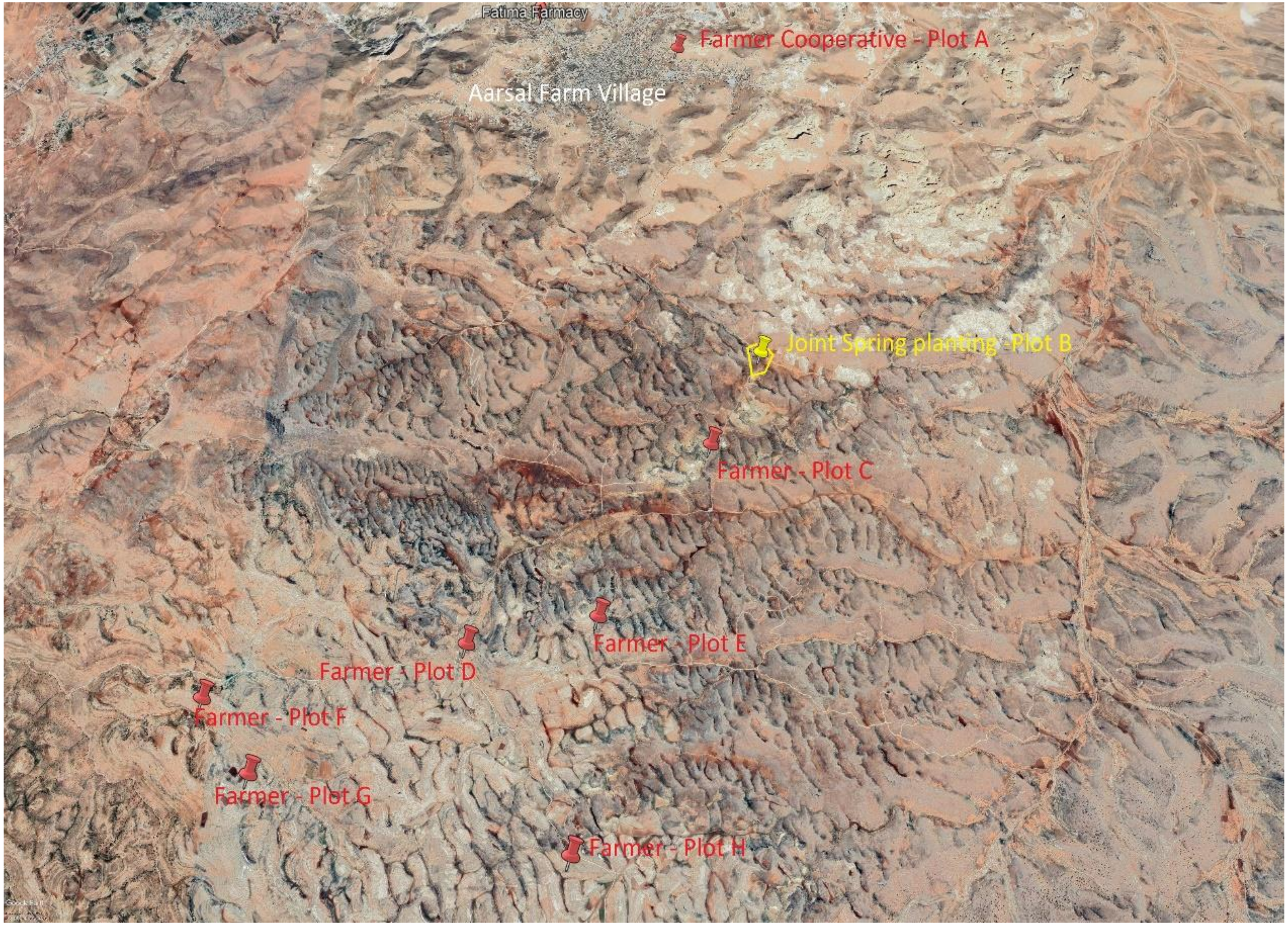


Fig 4.1: Location of the Aarsal Farm pilot for spring planting (in yellow) and fall planting (in red) at the Cooperative and individual farmers

Following Koppen's scheme the climate at the test sites can be categorised as Warm Temperate Mediterranean to Cold Temperate Mediterranean. The climate has winter rains and dry and hot summers from June until the end of September. The summers tend to be a bit shorter than in Jordan. The rain pattern at Aarsal is similar to the distribution of the rainfall measured at the climatological station in Baalbak. This station is located at a distance of 25 km in a south westerly direction (see Fig 4.3). Despite similar distributions the critical yearly rainfall of about 300 mm at the pilot sites is considerably less than in Baalbek. Temperatures at the site can be below zero in winter time. The yearly potential evapotranspiration has been estimated in the range of 800-1000 mm. Thereby it exceeds the yearly rainfall.

Fig 4.2: View across the pilot site for spring planting

The original vegetation at the test sites consisted of scarce plants and trees common for a semi-desert landscape. Scattered conifers (abies) and juniperites together with bushes made up most of the area in former times. Nowadays a lot of this vegetation has disappeared as a result of the introduction of orchards and cattle holding in the area. The farmers focus on the cultivation of commercial fruit trees whereby cherries are favourite. The fruit tree area is relatively small and most of the terrain around the pilot areas is bare and uninhabited.

Water resources in the Aarsal area are limited. Winter rainfall provides most of the water used at the cultivated lands. The farmers plant their trees in relatively large pits that can collect water in winter time. The collected water can be sufficient in average rainfall years for the young seedlings to survive in the hot summers but in drier years they will fall prone to starvation. The well-defined drainage pattern indicates that flash floods in the rainy winter season occur but otherwise the streams in the area are dry. Groundwater resources in underlying limestone or sandstone aquifers may be present but it seems that they are unexploited.

General site data and climate		**Land info and water resources**	
Coordinates	Spring planting: 34° 08' 11'' N / 36° 26' 39'' E /	*Land owner*	Private farmers
Elevation	Mostly 1800 - 2100 m.a.s.l	*Original vegetation*	Shrubs, conifers, juniperites
Plot size	Spring planting 4.5 ha	*Current plot vegetation*	Some agricultural fruit trees
Yearly rain	About 300 mm	*Bordering trees*	Same and bare land
Yearly potential Evapotranspiration	800 - 1000 mm	*Fauna*	Foxes, boars, hyena's, deers and small animals
Geology	Limestone	*Surface water*	Only flash floods
Soil	Loamy clay	*Groundwater*	Not known

Table 4.1: Key Aarsal Farm pilot site parameters

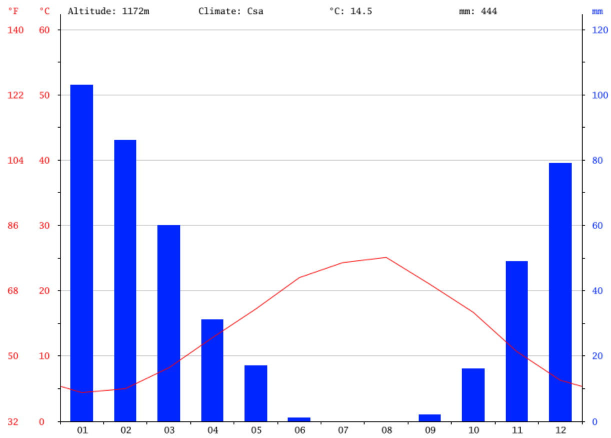


Fig 4.3: Daily temperature and rainfall distribution for Baalbak

The social setting at Aarsal Farm is rural with Aarsal Farm Village being the only populated built up place in the area bordering the Syrian frontier. The farmers and their cooperative own the plots where they grow the orchard trees. Farm houses are relatively scarce and most of the farmers themselves live in the Village. Mining operations have also been initiated in the area. The terrorist movement ISIS was active in the Aarsal Farm area which led to the introduction of strict military control of strategic infrastructure (e.g. roads). The ISIS actions in Syria brought along the inflow of refugees and the establishment of refugee camps in the village.

4.1.2. Ras Baalbak

The pilot site for spring and fall planting in Ras Baalbek is situated in the northern part of the Bekaa Valley in Baalbek Hermel Province. Originally a site was selected just west of Ras Baalbek Village on a flat terrain bordering the local police station. The site was rocky and needed the engagement of a pneumatic hammer for the digging of the planting holes. This kind of digging was considered cumbersome and was one of the reasons to re-locate the site to a more sloping less rocky area just east of the village (see Fig 4.4). The accessibility of the area is good and it is nicely positioned near an access dirt road running along a hill crest (see also Fig 4.5).

Fig 4.4: Location of the pilot site (boundary in yellow) in Ras Baalbak

According to the geological map of Lebanon the parent rocks present at the pilot site are limestones with local patches of conglomerates (see also Table 4.2). There are very few rock outcrops and proper descriptions of the parent rock are hard to be made. Most of the surface profiles consists of loose material presumably being the end product of the weathering of the limestones. The final pilot site was selected in an area with mostly loose rock fragments which facilitates the digging of planting holes. No soil tests were done but it is likely that loamy clays or clayey loams are dominant. Organic and nutrient levels are also thought to be low although no lab tests were carried out.

Following Koppen's overview the climate at the pilot site can be referred to as Warm Temperate Mediterranean to Cold Temperate Mediterranean. The Ras Baalbak area has winter rains and dry and hot summers similar to the Aarsal Farm area. The rain pattern at Ras Baalbak is also comparable with the distribution of rainfall in Baalbak (see also Fig 4.3). Despite the similar pattern the very critical yearly rainfall (for autonomous plant growth) of about 150-200 mm at the pilot area is far less than at Baalbak (and at Aarsal Farm). Temperatures at the pilot can be sub-zero in the winter and are extremely high in the summer. Exceeding the annual rainfall by far an average yearly potential evapotranspiration of 1200 mm (or more) is not uncommon.

The original vegetation at the pilot site is typical for an arid to semi-arid landscape. Scattered trees would have been landmarks in a rather bare area. Bushes (shrubs) and grassland are believed to have been the most dominant vegetation types. Today part of this vegetation has been removed to make place for built up areas and agricultural land. The farmers plant a variety of crops but orchards with fruit trees are also characteristic for the site. In comparison with the pilot area at Aarsal Farm there are far more activities in the immediate vicinity of the pilot at Ras Baalbak.

Fig 4.5: View from the pilot area across orchards and Ras Baalbak town

Water resources in the Ras Baalbak area are relatively scarce. Winter rainfall is the dominant resource and sufficient to sustain the bush and grassland landscape. The rainfall is also believed to be sufficient for orchard trees to survive although the young seedlings need irrigation for 2 to 3 years to survive the hot summer season. The area is hilly and aerial photos show incised valleys indicating that flash floods occur during extreme (rain) events. Groundwater is probably present in the limestones underlying the area but details on this resource are not known.

The pilot area at Ras Baalbak is located on land reported to be owned by the municipality (see also Fig 4.4). This land is on the western side bordered by the built up area of the municipality of Ras Baalbak. In other directions the scenery is more rural with farmers trying to make a living out of the land. The village of Ras Baalbak is the most north-eastern located village in the Bekaa Valley before crossing the Syrian border. The people living in the area are mostly Muslims but a Christian minority is also part of the population.

General site data and climate		Land info and water resources	
Coordinates	Final pilot area: 34° 15' 41'' N / 36° 25' 20'' E /	*Land owner*	Municipality
Elevation	1030 m.a.s.l	*Original vegetation*	Mainly shrubs and grass, cypress and oak trees
Plot size	Spring and fall planting 2.5 ha	*Current plot vegetation*	Shrubs, grass, and bare land
Yearly rain	150 - 200 mm	*Bordering trees*	Shrubs and orchards
Yearly potential Evapotranspiration	1200 mm	*Fauna*	Foxes, boars, hyena's, deer and small animals
Geology	Mainly limestone	*Surface water*	Flash flows in wadis
Soil	Loamy clay	*Groundwater*	Not known

Table 4.2: Key Ras Baalbak pilot site parameters

4.1.3. AREC Research Centre

The pilot site for the fall planting in AREC is located in the central part of the Bekaa Valley not far from the town of Baalbak in Baalbak Hermel Province (see also Fig 4.6). The site was chosen since the selected area for spring planting in Jabal Moussa had to be abandoned. AREC is the Agricultural Research Centre of the American University of Beirut (AUB). Labs, stores and educational facilities were constructed on the terrain of the Centre which also consists of agricultural lands. The fertile soils are ideal for a wide variety of experiments involving all sorts of species. AREC is close to the main north-south running road through the Bekaa Valley and can easily be reached from Beirut.

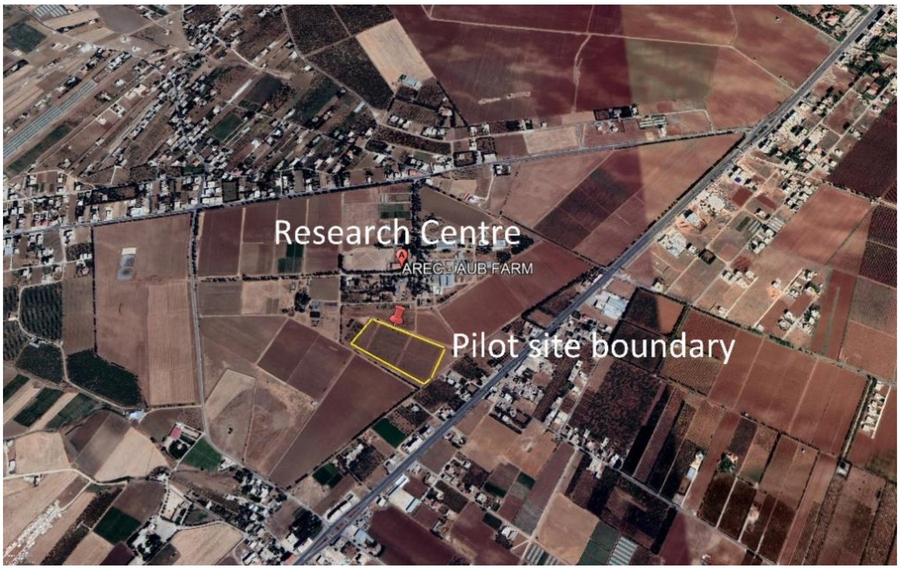


Fig 4.6: Plan view showing AREC Research Centre and the pilot area (boundary in yellow)

Following geological information for Lebanon the pilot site is underlain by shallow lake and river alluvial deposits (see also Table 4.3). The expectation is that limestone rocks form the basis of these shallow deposits. The lake and river deposits have a dark brownish colour and some pebbles may be present in the vertical profile. Soils have developed in the upper parts of the deposits. Most likely these soils tend to be loamy or clayey. Due to the more abundant vegetation in the AREC area the organic content of the soils is higher than at the pilot areas in Aarsal Farm and Ras Baalbak.

Fig 4.7: View of the plot at AREC where boundaries were used for pilot planting

According to Koppen's classification the climate at AREC can be categorised as Warm Temperate Mediterranean to Cold Temperate Mediterranean. Following the pattern typical for the whole Bekaa Valley there are winter rains and dry summers. Long term records show that the bulk of the rain falls from October to May. Some rain falls in June and September whereas no rain is typical for July and August. Since AREC is close to the climatological station in Baalbak the rain pattern and actual amounts of monthly rainfall at the pilot site resemble each other (see also Fig. 4.3). Yearly annual rainfall amounts in the range of 300-500 mm are common for the research centre. Temperatures also vary a lot in the course of the year although less so than at Aarsal Farm and Ras Baalbak. Surpassing the annual rainfall, an average yearly potential evapotranspiration of 1200 mm could be a realistic figure for AREC.

The original vegetation at AREC cannot be observed on aerial photos or in the field as a result of intensified human intervention. Terrain with shrubs and grass land but with more abundant trees than at Aarsal Farm and Ras Baalbak must have dominated the scenery. Due to the higher rainfall the density of trees including cypress and oak would have been higher than in Ras Baalbak.

The human intervention has resulted in a neat pattern of built up areas connected by roads and agricultural lands. On these lands farmers cultivate crops and orchards have also been set up. A large variety of fruit and nut trees grow in the orchards.

The main water resource in the AREC area is the winter rainfall. The amounts are considerably higher than at Aarsal Farm and Ras Baalbak. Rainfall is sufficient to maintain a wide variety of vegetation types including forest and fruit trees. The area is rather flat without any clear indication of water courses. This means that the infiltration capacity for rain water is high and that water is stored in the soil and underlying geological formations. Exploitable groundwater is also present in these formations but to what extent the resource can be developed is not known.

AREC as the Agricultural Research Centre of the AUB is located in a well-known farming area in the Bekaa Valley. The farmers cultivate cereals and plant fruit trees on small plots of land. Agriculture is the dominant sector in the area and there is a healthy pool of workers that can be engaged in all sorts of activities in the fields.

General site data and climate		**Land info and water resources**	
Coordinates	Spring planting: 33° 55' 23'' N / 36° 04' 31'' E /	*Land owner*	American University of Beirut (AUB)
Elevation	995 m.a.s.l	*Original vegetation*	Shrubs, grass, and cypress and oak trees
Plot size	Fall planting 2 ha including central area	*Current plot vegetation*	Agricultural land, crops
Yearly rain	300 - 500 mm	*Bordering land*	Agricultural land, crops and orchards
Yearly potential Evapotranspiration	1200 mm	*Fauna*	Foxes, boars, hyena's, deers and small animals
Geology	Lake and river deposits, limestones	*Surface water*	Little overland flow
Soil	Loam, clay	*Groundwater*	Not known

Table 4.3: Key AREC pilot site parameters

4.2. Design and species selection for the pilots

4.2.1. Introduction

According to Chapter 2 on methodology the pilots in Lebanon were designed to carry out tests to assess the impact of the Cocoon technique 'vis a vis' traditional planting methods. Growth characteristics and water use are amongst the parameters to be determined. To test this impact against the environmental background of Lebanon taking into account local circumstances, a variable planting plan was formulated including conventional and off-season plantings either in the spring or in the fall.

For the planting at Aarsal Farm, Ras Baalbak, or AREC different forest and fruit tree species were identified. The adaptability and resilience of the species to soil and weather conditions played an important role in the selection. The earmarked forest species can still be observed in native woodland areas in the Bekaa Valley and surrounding mountains in Lebanon. The chosen fruit trees match with trees traditionally selected for the orchards in these parts of the country.

With Cocoon and No Cocoon scenarios or treatments were planned for each of the selected species. Table 4.4 shows the different scenarios that were defined for the Lebanon pilot sites. For spring planting the 8 scenarios shown are similar to those specified for Jordan. For fall planting an abbreviated planting scheme was adopted. The With Cocoon re-fill and the No Cocoon no Irrigation scenarios were not tested. Local staff assumed that for fall planting sufficient winter rains would be available making these scenarios superfluous.

Spring planting ***(Aarsal Farm and Ras Baalbek)***	***Fall planting*** ***(Aarsal Farm [1])***	***Fall planting*** ***(Ras Baalbak)***	***Fall planting*** ***(AREC)***
With Cocoon and no irrigation (no re fills) for species 1	X	X	X
With Cocoon and irrigation (re fills) for species 1			
No Cocoon and no irrigation for species 1	X	X	X
No Cocoon, but with normal irrigation for species 1			
With Cocoon and no irrigation (no re fills) for species 2	X		
With Cocoon and irrigation (re fills) for species 2			
No Cocoon and no irrigation for species 2	X		
No Cocoon, but with normal irrigation for species 2			

Table 4.4: The selected planting scenarios [1)] in fact, 6 species were planted in the fall at Aarsal Farm

4.2.2. Aarsal Farm

The pilot at Aarsal Farm was inspected for land suitability assessments and to set up a detailed planting design. Simultaneously seedling selection, adequate site preparation, and the tree planting methodology were discussed. It was confirmed that the hilly area south of Aarsal Farm village was an ideal site with fertile loamy to clayey soils to implement planting scenarios with fruit trees for the assessment of the Cocoon technology. For spring planting about 4.5 ha of land next to the access road to the orchard areas was reserved (see for location Chapter 4.1). The plots for the planting in fall - made available on the properties of individual farmers - had different sizes. A total number of 926 seedlings was envisaged for planting during the spring and fall seasons.

Spring planting

The planting design fitted in the selected terrain that has a triangular shape. Within the triangle sub-areas were demarcated (Fig. 4.8: the red and blue areas) where planting was thought to be feasible in terms of soil depth, rockiness and the absence of other obstacles. The design incorporated the 8 scenarios for the two species selected for pilot testing. For both tree species the sample size was 40 individual seedlings for each planting scenario. This meant that a total of 320 trees was planted.

The two species were planted separately in the two sub-areas. Within these areas 11 blocks were defined that can also be considered as planting lines. Please note that in Jordan the blocks consist of more than one planting line. The blocks consist of clusters of 4 seedlings whereby each plant in a cluster represents one of the 4 scenarios to be tested for a particular species (see also Fig. 4.8). For a species most blocks (9) have 4 clusters and the other 2 blocks consist of 3 and 1 cluster(s). A distance of 4-5 m was foreseen between the blocks (lines) whereas between the individual seedlings 4 m distance was the norm. With farmers and guards being around most of the time the design did not foresee in the construction of a fence around the pilot areas.

The species to be planted at Aarsal Farm in spring were the fruit tree Prunus amygdalus (wild almond) and Prunus ursina (wild plum). The preferable species for planting are cherries which are successfully cultivated by the farming community for commercial fruit production. However, during the time of planting for the pilot tests the cherry seedlings were not available at the nurseries or even on the open market. Wild almond and wild plum are native species and they also fit well in the testing program (see also Table 4.5).

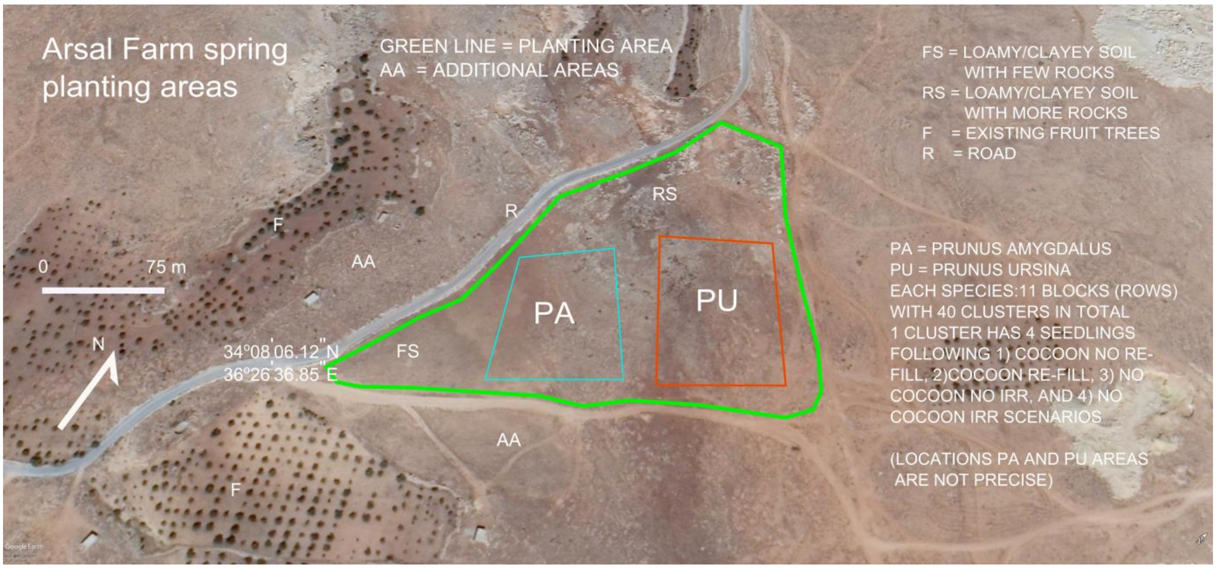


Fig 4.8: Layout of planting in spring at Aarsal Farm (see also Annex II)

Fall planting

The design for fall planting at the farmers properties was left over to the farming communities themselves. Initially the farmers created the idea that the seedlings could be planted at the boundaries of their land but they modified this idea at a later stage. The planting designs included the 2 scenarios for each of the 6 species to be provided to the farmers. This meant a total of 12 scenarios for the 6 species combined. For the species the individual sample size varied but a total number of 606 seedlings were part of the planting plan for the farmers.

The farmers presented the planting designs for the species that they selected in rough hand-written sketches (see also Annex II). They more or less adopted the block like approach that was developed for spring planting. Although this was not fully verified it can safely be assumed that distances between the blocks and individual seedlings are similar to those designed for spring planting.

The 606 trees for fall planting included the (6) species: Pyrus syriaca (wild pears: 165 units), Prunus ursina (wild plum: 33 units), Prunus avium 'Ferrovia' (cherry: 104 units), Pyrus communis 'Carmen' (pear: 136 units), Prunus armeniaca 'Fardao' (apricot: 150 units), and Prunus armeniaca (local apricot: 18 units). The wild pear and wild plum are species native to the Bekaa Valley. The other (4) species are commercial fruit trees that are preferred by the farmers for planting due to their handsome output of fruits.

4.2.3. Ras Baalbak

The initial activities at Ras Baalbak included a site visit to assess land suitability and to set up the field design for planting. Thoughts were also given to the selection of seedlings, site preparation and the tree planting methodology. The sloping area just east of Ras Baalbak village proved to be suitable for the implementation of planting scenarios with forestry and fruit trees to test the Cocoon technology. The loamy to clayey soil would be favorable for planting but the low yearly rainfall of 150-200 mm needed careful selection of drought resistant species (see Table 4.2). At the terrain selected for planting about 2.5 ha of land was available for the spring and fall planting of 550 trees (see also Chapter 4.1).

Spring planting

The planting design fitted nicely in the selected planting area. Within the area three sub-areas were delineated. Two areas at the eastern to southeastern side of the terrain were reserved for spring planting (Fig. 4.9: the red and blue areas). The design for planting included the 8 scenarios for the two species selected for pilot testing. For each of the species the sample size was set at 50 individual seedlings in each planting scenario. This meant that a total of 400 seedlings participated in the tests for spring planting at Ras Baalbak.

For each of the two species a sub-area was reserved. Within these areas blocks were delineated that can also be seen as planting lines. Limited by their size and shape 13 blocks could be accommodated in the northern sub-area whereas 7 blocks were outlined in the southern sub-area. The blocks consisted of clusters of 5 seedlings whereby each cluster represented one of the 4 scenarios to be tested for a particular species (see also Fig. 4.9 and Annex II). Most blocks (7) in the northern sub-area had 4 clusters and the other blocks (6) were designed with 2 clusters. For the southern sub-area there were blocks (4) with 4 clusters and blocks (3) with 8 clusters. A distance of 4-5 m was designed between the blocks whereas between the individual seedlings a spacing of 4 m was adopted.

Species	Type	Planting season	Bio-geography
Prunus amygda-lus (wild almond)	Fruit production. Native habitat/ forestry type.	Spring planting: Aarsal Farm	Fruit tree planting at orchards. Annual rainfall: 300-800 mm. Multiple uses.
Prunus ursina (wild plum)	Fruit production. Native habitat/ forestry type.	Spring and fall planting: Aarsal Farm	Forestry planting/parks/farms for fruit production Annual rainfall: 300-1250 mm. Rain determines fruit size. Elevation 800-2000 m
Pyrus syriaca (wild pear)	Fruit production. Native habitat/ forestry type.	Spring planting : Ras Baalbak. Fall: Aarsal Farm + AREC	Forestry planting/parks/farms for fruit production. Annual rainfall: 300-1250 mm? Elevation 100 – 2000 m. Rocky terrain.
Prunus avium 'Ferrovia' (cherry)	Fruit production.	Fall planting: Aarsal Farm	Fruit tree planting at orchards. Annual rainfall: 300-800 mm. Multiple uses.
Pyrus communis 'Carmen' (pear)	Fruit production.	Fall planting: Aarsal Farm	Fruit tree planting at orchards. Annual rainfall: 300-800 mm. Multiple uses.
Prunus arme-niaca 'Fardao' (apricot)	Fruit production.	Fall planting: Aarsal Farm	Fruit tree planting at orchards. Annual rainfall: 300-800 mm. Multiple uses.
Prunus arme-niaca (local apricot)	Fruit production.	Fall planting: Aarsal Farm	Fruit tree planting at orchards. Annual rainfall: 300-800 mm. Multiple uses.
Rhus choriaria	Woodland and fruit (spice) production. Native habitat/ forestry type.	Spring and fall planting at Ras Baalbek	Bush to small tree. Grows in the wild and is also used as borders of orchards. Annual precipitation: 150 - 800 mm. Used for production of spices

Table 4.5: Details of species used in the Lebanese pilots Common Source: Lebanon Flora

The species planted at Ras Baalbak in spring were the fruit tree Pyrus syriaca (wild pear) and the forestry tree Rhus choriaria. These species are native to the Bekaa Valley. Although native to the valley the origin of the wild pear is Syria. Rhus choriaria is known to be well adapted to the area and the plant produces small fruits that are used for making spices. The size of the Rhus bushes and trees is smaller than the other trees selected for the pilot program (see also Table 4.5). Like all the other trees used in the Lebanese test program the wild pear and Rhus choriaria were planted 'bare root'.

Fall planting

The planting design for the fall was carried out at the third sub-area in Ras Baalbak. The sub-area was located west of the other two sub-areas for spring planting (see also Fig 4.9). Plantings were designed for only 2 scenarios and one species. For the particular species the sample size was 75 seedlings for each of the scenarios. This implied that the design for fall planting showed a total of 150 seedlings.

A block like pattern is believed to have been designed in the sub-area for planting. The blocks apparently had a different meaning than the blocks defined for spring planting. One block did not correspond with an entire line but three blocks next to each other formed a line. In total the layout showed 15 blocks meaning that there were 5 planting lines. Each block was sub-divided into two clusters of 5 seedlings. Each cluster represented one of the 2 scenarios. Similar to the spring planting layout a distance of 4-5 meters was adopted between rows. The individual seedlings in a row had 4 m spacing between each other.

In the fall a considerably lower number of trees was planted than in the spring. The change from 4 to 2 scenarios is one reason for the reduction but the use of only one species is the other explanation. The wild fruit tree species Pyrus syriaca (wild pear) used for spring planting had not been performing well and it was thought not to be realistic to plant the species again during the fall. No replacement for this species was considered. Therefore the forestry tree Rhus choriaria was the only species taken up in the design for fall planting.

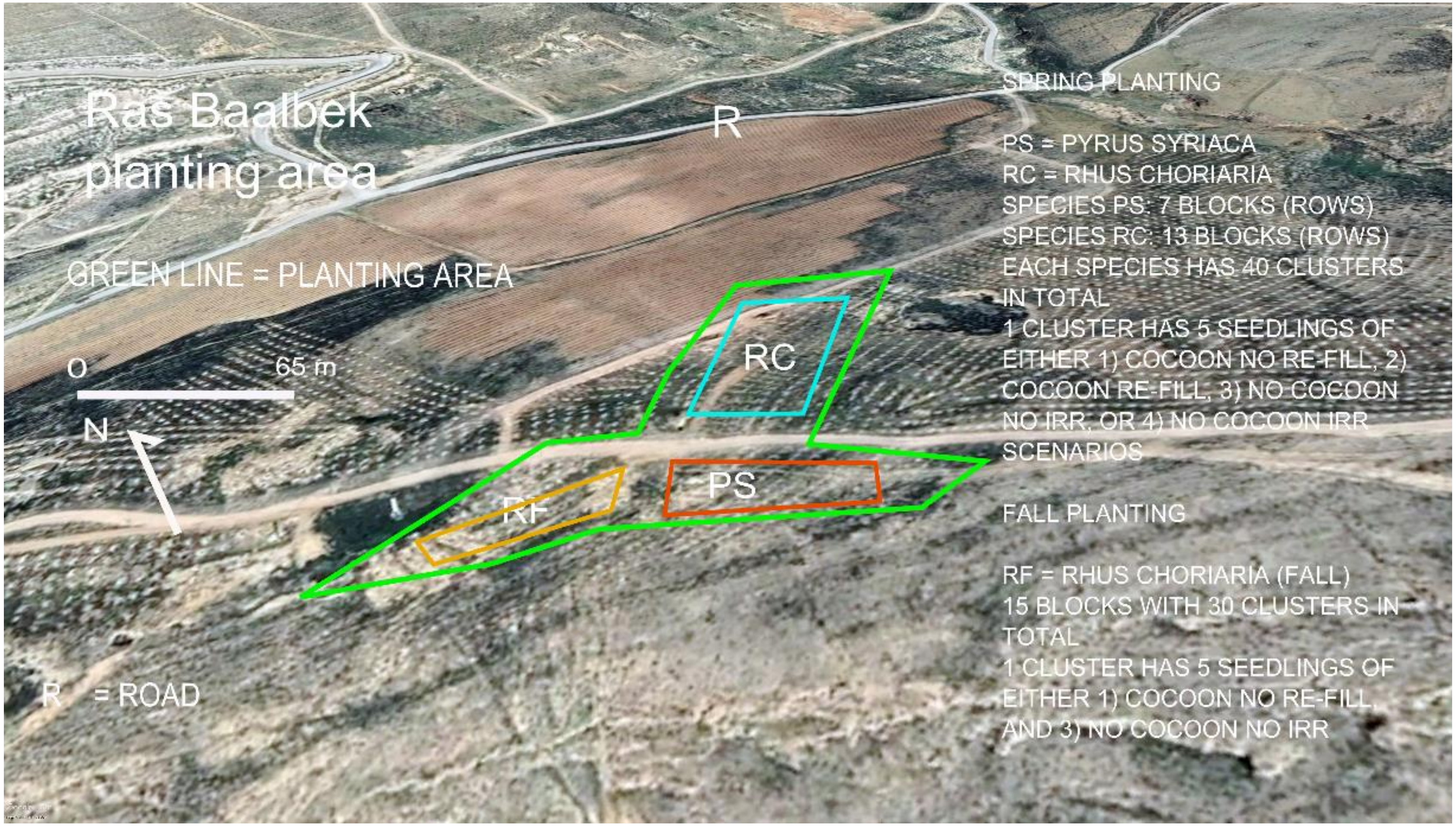


Fig 4.9: Layout of planting in spring and fall at Ras Baalbek (see also Annex II)

4.2.4. AREC

The pilot area at AREC Research Centre station was selected due to the difficulties encountered after spring planting at Jabal Moussa (see Chapter 4 Intro). AREC is a well-known site and land suitability assessments were not necessary. During meetings with the staff of the Centre the planning for the planting design, seedling selection, site preparation, and the tree planting methodology were discussed. The discussions confirmed that the flat area surrounding the Centre is an ideal site for pilot tests involving the Cocoon technology. The loamy and clayey soils and moderate rainfall regime enhance the smooth execution of field testing. The area envisaged for fall planting was located just south of the buildings of the Centre next to an existing orchard. The area comprising about 2 ha in total was partly available for the planting of 101 seedlings.

Fall planting

The idea was to do the planting at the strips of unused land next to the fences surrounding the identified area. The area itself could then still be used for other activities scheduled by the Research Centre. Planting for pilot testing at AREC was only done during the fall for one species. The 2 scenarios taken up in the design included a With Cocoon treatment of 50 seedlings and a No Cocoon treatment of 51 seedlings.

The design showed three blocks consisting of one planting line drawn parallel to the fences (see also Fig 4.10). A total of 93 seedlings could be accommodated at the blocks bordering the fences whereas the other 8 items had to be planted elsewhere. At each of the blocks along the fences clusters of (mostly) 5 seedlings were set up. Each cluster represented one of the 2 scenarios selected for pilot testing. Distances of 4 m between the seedlings were considered to be adequate during planting.

The fruit tree Pyrus syriaca (wild pear) was selected for fall planting in AREC since the species had not been performing well after spring planting in Ras Baalbak. The less rocky soil and higher rainfall at AREC created better conditions for a successful growth of the plant. The plant native to the Bekaa Valley was also planted ‘bare root’ at the Centre. The lines of trees will form a nice natural separation and wind barrier at the fences after they have grown to maturity.

Fig 4.10: Layout of planting in fall at AREC Research Centre

4.3. Tree planting

4.3.1. Introduction

Tasks that were carried out for tree planting comprised the delivery of water, obtaining seedlings from the nurseries, making arrangements for local labor, planting the seedlings and installing the Cocoons. Management and supervision of the planting activities were implemented by the American University of Beirut (AUB) and local staff. At Aarsal Farm the farmers assisted the AUB and they did take the lead in most of the field activities. At Ras Baalbak the Cooperation Without Borders (CWB) and the municipality were involved in the pilot testing whereas at AREC staff of the Research Centre made their contribution. There were quite a few similarities in tree planting at the three selected pilot sites. Therefore, the description of the activities carried out at these locations are combined.

4.3.2. Pre-planting arrangements

Pre-planting activities included the delivery of the Cocoons, seedlings and water to the pilot areas in the Bekaa Valley. The Cocoons were shipped by Land Life Company from The Netherlands to the international airport in Beirut. After clearance at the customs the Cocoons were collected and stored at the AREC Research Centre. Subsequently, all Cocoons were delivered at each pilot site for the plantings in the spring and fall.

The 'bare rooted' seedlings of the selected forestry and fruit trees were bought at local nurseries and markets in the Bekaa Valley. Not all species were available at the time when they were needed for planting and this resulted in planting delays or the selection of species that were not considered priority for testing. This was especially the case for Aarsal Farm where quite a large variety of species was planned for testing (see also Chapter 4.2.2). Nevertheless, a fine selection of seedlings could be secured in the end. All seedlings planted were checked by local experts for quality and size.

Water for irrigation had to be brought to the pilot sites from elsewhere. For the planting in spring at Aarsal Farm the water was delivered to the site by a tanker. For the spring planting at Ras Baalbak a similar solution was adopted. For the planting in fall at these sites the skipping of follow up irrigation after an initial gift required the delivery of only small volumes of water (until the summer season). At AREC Research Centre any water needed was delivered by a tanker or hoses connected to a central irrigation system.

4.3.3. Time frames for planting

Spring planting

Spring planting at Aarsal Farm and Ras Baalbak was programmed for implementation as early as March 2019. However, planting had to be postponed to May due to delays in making available machinery and funds. The farmers at Aarsal Farm managed to initiate and complete the planting activities on the 6th of May and at Ras Baalbak the planting shifted to the end of this month, to be precise, to the 25th of May. Carrying out spring planting in May was considered to be late due to the onset of high summer temperatures and the losses of natural moisture in the soil. The establishment of the seedlings was at risk. However, it was thought that extra soil wetting could be done to make sure that the plants would exhibit the normal 'spring' growing boost.

Fall planting

The fall planting at the three pilot locations was foreseen in November 2019. At Aarsal Farm the planting was completed on time from 23rd up to 28th of November. At the other two pilot areas there was some delay in the planting of the seedlings. At Ras Baalbak and AREC the plantings were completed respectively at the 21nd and 19th of December. At these sites the first signs of plant growth came later in time than at Aarsal Farm but the delays were considered acceptable in view of the occurrence of winter rains.

4.3.4. Site preparation and tree planting

Staff of the AUB was present during all tree planting activities at Aarsal Farm, Ras Baalbak and AREC Research Centre. The planting process began with a field workshop at AREC led by Land Life Company (LLC). During the workshop the novel Cocoon technology was introduced (further details on the workshop are highlighted in Chapter 4.5).

In the field AUB and local staff supervised the actual 'digging and planting' at the three pilot sites which was carried out by contract workers. Menaqua staff was not present during the site preparation and tree planting activities in Lebanon. At the three pilot sites similar planting methods were adopted as far as terrain conditions allowed. The planting procedure and the field observations during planting are summarized below.

Step 1: Land clearance and site preparation

To some extent the soil surface was cleared manually by contract workers to prepare the sites for tree planting. Some of the larger stones were taken away and bushes and weeds that were in the way were removed. At Ras Baalbak the natural rocky features and inclination of the terrain was a challenge to prepare the site properly for planting. At Aarsal Farm and AREC the terrain conditions were more favorable for planting although some work had to be done to make the areas ready for the hole excavation activities.

Step 2: Excavation of planting holes

The contract workers completed the excavation (and planting) activities in a relatively short time. For spring and fall planting the holes for the With Cocoon scenarios were made 30 cm deep and 60 cm in diameter whereas the holes for the No Cocoon scenarios were dug in line with traditional Lebanese procedures. The With Cocoon holes were larger than the No Cocoon holes. To prevent too much drying of the soil it was considered important that the holes were excavated less than 4 days before the planting

date. Field reports indicate that hole digging at Aarsal Farm was done 3 days before planting. At Ras Baalbak the holes were made 'within one week' before the trees were planted. At AREC the period between digging and planting was even two weeks but heavy rainfall prevented the soil from drying out.

At Aarsal Farm the planting holes could have been dug manually in the soft loamy and clayey soils but machinery was engaged to speed up the process. At Ras Baalbak the use of machinery was justified in view of the rocky soils that could also damage the Cocoons. At many locations limestone rocks were removed. Backhoe's were the type of machinery used for hole excavation but the contract workers also assisted with simple hand tools including shovels and pick axes (see also Fig 4.11). The use of augurs proved to be not successful in rocky terrain. At AREC Research Station the holes were excavated manually by the workers with hand tools.

Fig 4.11: Excavating holes with a small backhoe at Ras Baalbek for fall planting

Step 3: Bedding with mycorrhizae or compost

The addition of mycorrhizae in the excavated holes stimulates the uptake of phosphorous (P) by the plants. The use of mycorrhizae is helpful when planting in dry conditions as the fungus increases the mobility of phosphorous to be attracted by the roots of the plants. At Aarsal Farm mycorrhizae was planned to be used during spring planting but the field reports do not confirm the application of the fungus. For this site there are also no reports that compost instead of mycorrhizae was used during spring and fall planting. At Ras Baalbak mycorrhizae was not used. Instead, agricultural soil mixed with compost was placed in the hole to enhance plant growth for the spring and fall plantings. For AREC there are no reports on the use of mycorrhizae or compost during the planting season.

Step 4: Tree planting

The With Cocoon scenarios: Thanks to the training session at AREC Research Centre staff and workers performed well in planting the seedlings at the pilot sites using the Cocoons. The seedlings were placed at the centers of the dug holes whereby the roots extended about 10 cm into the earth at the bottom of the hole. Thereafter, the Cocoon was placed in the hole while the planted seedling was protruding through the cone in the center of the device (see also Fig 4.12). At the same time additional earth was added to the plant (next to the root ball) and firmly pressed down to take out any air pockets. The spaces at the sides of the Cocoons were filled with earth to prevent damage to the walls of the container.

Although care was given to the their proper placement part of the Cocoons were found to be damaged during later inspections. Hardly any damage was noted at Aarsal Farm but at Ras Baalbak a fair amount of the Cocoons had suffered. Improper placement could have been an issue but other external factors may also have played a role in damaging the devices (run off, strong wind, traffic, trespassers, moles, foxes). The damaged Cocoons were replaced with new items that were kept in reserve. During fall planting lessons learnt from experiences of improper placement of the Cocoons were implemented to obtain better performances.

The No Cocoon scenarios: The ‘bare rooted’ planting of the seedlings was done with the roots extending into the earth at the bottom of the holes. Hereafter, the holes were further filled with earth in line with traditional Lebanese tree planting methods. The earth was pressed tightly to anchor the seedlings firmly into the ground. Care was taken to hold the seedlings upright during planting.

Step 5: Watering

The Cocoon reservoirs received 20 liters of water after planting which is almost the capacity of the reservoir. After filling the workers made sure that the water level in the reservoir stabilized at about 2 cm below the upper rim of the side wall. At the Lebanese pilot areas the seedlings planted without Cocoons obtained a similar (initial) irrigation gift following local Lebanese watering procedures. The precise water volumes supplied at Aarsal Farm, Ras Baalbak or AREC are compiled in the water report (see also Chapter 6).

Step 6: Placement of lid, soil and shelter

After having inspected that the Cocoons were placed horizontally the planting process was ended by putting the lids and shelters on top of the Cocoons. Due to the rockiness and sloping terrain the horizontal placement of the Cocoons at Ras Baalbak was quite an issue. The lids were placed neatly on the water reservoirs to avoid evaporation through any open spaces between the two components of the Cocoon. After placing the lids they were partly covered and packed with soil to prevent the lid from being dislodged. The soil also reduces any evaporation losses from the reservoir through the lid. The center parts of the lids and the open space with the protruding branches of the seedlings were left uncovered. The shelters were inserted into the hole with the seedlings and pressed down until the marking line. The shelters proved to be useful in protecting the young plants from direct sun light and the strong winds that can blow in the northern part of the Bekaa Valley.

Fig 4.12: Placing the seedling and Cocoon in Aarsal Farm during fall planting

4.4. Follow up activities

4.4.1. Introduction

At the pilot sites in Aarsal Farm, Ras Baalbak and AREC follow up activities were initiated including watering of the seedlings, pursuance of plant care and maintenance of the site. Monitoring of the seedlings and coordination with local stakeholders of the project was also one of the core activities undertaken by project staff. The tasks carried out at the three sites were similar and separate outlines for the pilot sites are not necessary.

4.4.2. Watering/Irrigation

Without irrigation after planting the survival rates of the seedlings may be low. Irrigation schedules are based on common practices adopted by the local communities in Lebanon. For fruit trees as planted at Aarsal Farm and AREC common practice suggests that irrigating these trees during the summer months is not required in case sufficient winter rain has fallen. Ras Baalbak is drier and here the need for irrigation during the summer months is more urgent. Where needed for fruit trees irrigation is provided until the stage of fruit production. Hereafter, the trees will grow under the influence of rainfall.

During the pilot project about half of the trees were planted with the Cocoon technology in place. With the Cocoons the young trees are helped with an initial watering of 20 liters of water available in its bio-degradable reservoir. The Cocoon technology provides the young seedlings with water until the plant is established with a nicely-developed root system. Nevertheless, the planting scenarios with the option to re-fill the reservoir were implemented in the pilots in view of the high temperatures and evapotranspiration rates in Lebanon during the summer months.

Spring planting

After the spring planting in May 2019 the performance of the With Cocoon and No Cocoon scenarios were evaluated. Planting was done late after the normal planting season and in combination with extremely high temperatures in June and July the survival of the seedlings was at risk. Additional watering had to be provided after the planting of the seedlings. The additional watering included extra watering for all the Cocoons and the No Cocoon scenarios at the Aarsal Farm and Ras Baalbak project sites (see Water reports and Chapter 6).

After the emergency irrigation the standard irrigation procedure was followed in the period August to September 2019 for the No Cocoon treatments. From October 2019 the seedlings were supported by rainfall up to the spring of 2020. No additional water was provided for the seedlings during this period. For the summer of 2020 a schedule was prepared for the watering of the With Cocoon and No Cocoon scenarios. In addition, it was agreed upon by the AUB and the local community in Aarsal that farmers also follow their own protocol for the irrigation of the fruit trees. Further watering and maintenance at Ras Baalbak could not be clarified as management personnel for the site seemed to be less enthusiastic to continue with the tests.

Similar to field observations in Jordan (Maysara) checks carried out in Lebanon showed that the water in the Cocoon only lasted 6 weeks from the date of the fills during planting in May 2019. The re-fills in the mid-summer of 2019 lasted even shorter. This seems to contradict common experience with the Cocoons which are known to retain their water for a period of at least 2 months. The reason for the quick emptying of the reservoir can partly be attributed to the high evapotranspiration rates in the summer of 2019 (see also separate paper in Annex III).

Year	2019								2020						
Month	May	Jun	Ju	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
Cocoon (re) filling	x		x												•
Emergency irrigation	x	x	x												
No Cocoon irrigation				x	x										•
Rain						x	x	•	•	•	•				

Table 4.6: Table showing overview of watering's in Lebanon(x only spring planting • spring and fallplanting)

Fall planting

The fall planting in Lebanon started in November and December 2019 and coincided with the advance of the winter rains. Following the set up for spring planting (2019) no irrigation was applied until the summer of 2020. For the summer of 2020 the same schedule was prepared as for spring planting (see above). The schedule was drafted for Aarsal Farm and Ras Baalbak, and for the site at AREC that had been selected for planting in the fall. Also for fall planting the farmers at Aarsal Farm were given the opportunity to prepare their own watering schedule.

4.4.3. Site maintenance

Maintenance and management of the planting areas was assigned to the local supervisors of the farming community at Aarsal Farm, the people in Ras Baalbak, and the staff of the AREC Research Centre. Site maintenance included the maintenance of the young trees and taking care of plant protection. Any problems that occurred at the planting sites until the end of the monitoring period were also tackled. Further particulars of the activities are as follows:

Removal of weeds

The removal of weeds growing in between the young seedlings is important for plant growth. Competition with weeds can significantly reduce the water and nutrient uptake by the seedlings. This results in low plant vigor and a delay for the seedlings in reaching productive stages. Especially at the Lebanese pilots with their focus on fruit trees these aspects are taken into account. Weeds also result in an increase in the risk of attacks by pests and diseases and when dried they can turn into a fire hazard. Observations at the planting sites at Aarsal Farm and AREC learnt that weed growth resulting from rains in the winter season can be substantial.

Weeding was intensively done during the rainy season of 2019 to 2020. At the pilot sites in Aarsal Farm the sections and stretches between the planting lines were mowed with the help of a mowing machine. Around the plants with the Cocoons weed removal was done manually using hand tools and rakes. Since this method was not followed by all farmers it was found that some of the Cocoons were damaged by the mowing machine. At Ras Baalbak the weed removal was much more difficult because of the terrain conditions. The planting site at AREC is being professionally managed and the weeding was carried out following the normal protocols at the Research Centre.

Fencing

The locations selected for the pilots at Aarsal Farm are owned to the farming community. There was no requirement for large fences around the sites. The farmlands were maintained and managed by the farmers and no trespassers were expected to disrupt the site. At the site only minor damage to seedlings and Cocoons was observed by the supervisors. At (Jabal Moussa) and Ras Baalbak the idea was to place cages around every young seedling. In the end the cages were not placed and human disruption and animals - including foxes and wild boars trying to access the water inside the Cocoons - caused quite bit of damage to the plants and the Cocoons. Also, stones rolling down the hill slopes distorted some of the

Cocoons. AREC is a well-protected site and damage to seedlings and Cocoons has not been reported.

4.4.4. Performance monitoring

Measurement parameters and equipment

Monitoring of the young seedlings at the pilot areas in Aarsal Farm, Ras Baalbak and AREC was done to assess differences in plant growth and water use efficiency between the Cocoon planting technology and traditional planting. Following the plans set out in Chapter 2 on Methodology the main parameters to measure the success of planting were plant growth characteristics comprising plant vigor and height. The volumes of water to re-fill the Cocoon and irrigation volumes provided for the No Cocoon seedlings were also recorded. The additional factors that could influence plant survival in Lebanon such as weed density and Cocoon and tree damage were also assessed during the monitoring sessions.

Guidance and instructions for data collection in Lebanon was similar to the approach adopted in Jordan (see Table 4.7). The data was stored on monitoring sheets designed by the AUB. Supervised by the AUB the recording of plant measurements and field observations was done manually on the sheets for all monitoring cycles by the farmers at Aarsal Farm, members of the CWB at Ras Baalbak, and staff of AREC. Small groups of a few people were formed to carry out the data collection tasks at the pilot sites. After the field activities the monitoring sheets were further processed including the preparation of plant performance graphs using Excel software.

Monitoring period and frequency

A monitoring time frame was designed before the execution of the spring and fall plantings. For spring planting at Aarsal Farm and Ras Baalbak the monitoring of the young plants was supposed to be conducted over a 1.5 year period from April 2019 until September 2020. For fall planting the monitoring of seedlings would be done over a period of less than 1 year from November 2019 until September 2020. The intended monitoring frequency was once per 3-5 months with shorter intervals during the summer and longer intervals in the winter. The original monitoring plan is shown in table format (see Table 4.8).

After the seedlings were planted in Lebanon the monitoring framework had to be adapted as a result of unforeseen circumstances. These were the late spring planting and the heat wave which influenced the growth of the seedlings in the summer of 2019. Most of all the monitoring was affected by the outbreak

of Corona preventing staff to travel to the field since they were obliged to stay at home. The adapted schedules meant that monitoring for spring planting at Aarsal Farm and Ras Baalbak (with reliable results) was carried out over a period of just over 1 year from May 2019 to June and July 2020. For fall planting at Aarsal Farm, Ras Baalbek and AREC the monitoring coincided with a period of only 6-7 months from November and December 2019 up to June and July 2020. The unforeseen problems also meant that the lengths of the monitoring intervals was no longer in line with the original scheduling (see also Chapter 6 for details).

Measurement Parameters	***Units***	***Description***	***Method***
Height	Cm	Measurement of plant height from soil surface.	Ruler/measuring tape (manual)
Vigor	0-3	0: Dead 1: Main branch alive with shriveled leaves or no leaves 2: Main branch with medium vigor and no shriveled or dead leaves. Leaves still attached to the main stem. Also assign 2, in cases of disease or pest infestation. 3: Main branch with good vigor and healthy green leaves attached to the stem. No disease or pest infestation.	Visual assessment
Weed density	0-3	0: No weeds 1: One or two weed plants within 1m radius of the plantings. 2-3: Apply range 2 or 3 depending on the number of weed plants in the proximity of 1m radius around the No Cocoon and With Cocoon plantings.	Visual assessment
Cocoon damage	0-3	Observation of Cocoon damage rated on a scale of 0-3, 0: Cocoon intact 3: Cocoon absent or completely damaged.	Visual assessment
Plant damage	0-3	Observation of plant damage due to external factors such as wind, grazing animals and trampling rated on a scale of 0-3, 0: no damage 3: plant removed or destroyed.	Visual assessment
Water volume	Liter	Amount of water provided for the young seedlings With Cocoon and Without Cocoon.	Cocoon: (20 liter x n no of times) No Cocoon: Measured in container or estimation of total water use (liter)

Table 4.7: Overview of measured parameters at Aarsal Farm, Ras Baalbak, and AREC (similar to Jordan)

4.5. Community involvement

The introductory workshop

The scientific staff of the AUB and the supervisory personnel of the Farmers Association at Aarsal Farm and the CWB at Ras Baalbak have a sound local knowledge on tree planting techniques and community participation methods. During an introductory workshop they were also well-trained in the use of the Cocoon technology. Staff of LLC (Harrie Lovenstein) was leading the workshop which was held at the AREC Research Station on 9 April 2019 (see also Fig 4.13). The workshop included an introduction to the novel Cocoon technology, field demonstrations on the placement of Cocoons in excavated holes and hands on teaching with regards to the monitoring and maintenance tasks to be done after planting. The audience showed a keen interest in the Cocoon technology and lively discussions were also part of the workshop.

Pilot site	**Monitoring**	**Spring planting**					**Fall planting**		
		April 2019	Aug 2019	Nov 2019	July 2020	Sep 2020	Nov 2019	July 2020	Sep 2020
Aarsal Farm	Plant growth measurement	•	•	•	•	•	X	X	X
Ras Baalbak	Plant growth measurement	•	•	•	•	•	X	X	X
AREC	Plant growth measurement						X	X	X

Table 4.8: Original timeline for plant monitoring at Aarsal Farm, Ras Baalbek and AREC.

The 'citizen science' workshops

The pilot projects in Lebanon intended to focus on community acceptance in using the novel Cocoon technology. This included the organization of so-called 'citizen science' workshops involving the training of farmers and interested individuals of the community. The idea is to get the local community involved in research for their own benefit. The workshop training focused on explaining the values of the Cocoon technology, how to measure its performance and how to disseminate the acquired knowledge. Three workshop sessions were conducted in the period from June to July 2019. The sessions were labelled as follows: 1) project introduction and concepts including the Cocoon technology, 2) basic statistics and measurement protocols, and 3) field monitoring. In addition to participation in the workshop sessions the communities were also involved in project activities carried out in the field.

Farmers at Aarsal Farm and Ras Baalbak were the representatives of the local communities mostly involved in the workshop sessions and field activities (see also Chapters 4.1 to 4.4). The farmers at Aarsal Farm showed a keen interest in the Cocoon technology and the AUB received a lot of valuable feedback. The farmers were in general satisfied and found that the Cocoon functioned well in saving irrigation water allowing the seedlings to survive longer than expected. Suggestions were also provided on improving the Cocoon technology and these were considered for implementation during fall planting. The farming community at Aarsal Farm believed that their role was critical to the success of the pilot and still hold that opinion two years after planting.

The CWB staff and farmers at Ras Baalbak were not that keen on the introduction of the Cocoon technology. The CWB staff was expected to develop an inclusive relationship with the farmers at Ras Baalbak. Due to unknown reasons the interest of both CWB staff and farmers in the project to test the Cocoon technology was disappointing although the CWB still provided timely updates on the monitoring cycles and followed up the irrigation procedures. Additional field observations and feedback on the Cocoon was not provided by the local CWB staff. No reason for this lack of commitment to test the Cocoon technology as part of the 'citizen science' program at Ras Baalbak was provided.

Fig 4.13: Participants of the introductory workshop at AREC Research Station

5. RESULTS OF THE JORDANIAN PILOTS

5.1. Introduction

In the following sections the results of the tree planting at the Jordanian pilots at Al Faisal and Maysara are presented. The results primarily focus on the calculation of survival rates and the growth of the tree species. Special circumstances affecting the proper computation of these parameters are addressed. Different statistical procedures were followed for the calculation of the average survival rates and plant height. Details on the procedures are outlined in Annex IV. In addition to the average values of the parameters the results also give an indication of statistically significant differences between the planting scenarios as laid out at the two Jordanian pilot sites.

The results were interpreted taking the typical conditions at the Jordanian pilots into account. The impact of rainfall and irrigation practices was considered. The type and texture of the soil and its rockiness was also a key factor. In addition external factors played a role. These include soil preparation and improvement, the quality of seedlings, general management and monitoring, damage of the Cocoons, and weeding. Cocoon damage and weeds have been monitored systematically while other factors were assessed during ad-hoc field inspections. Within this context the impact of the Cocoon 'vis a vis' traditional planting methods in Jordan was evaluated.

5.2. Al Faisal

5.2.1. Monitoring data

At the pilot site of Al Faisal Oleo europaea (olive) and Prunus amygdalus (almond) were planted in the spring of 2019. Pinus halapensis (pinus) and Ceratonia silique (carob) were used for fall planting in 2019. The monitoring data were inspected which led to the correction of some of the data. Other data had to be removed from the dataset:

- The spring planting scenario No Cocoon no irrigation for olives was not properly monitored. The data were excluded from the assessments;
- For the spring planting of almond and the With Cocoon no re-fill and No Cocoon no irrigation scenarios part of the trees was destroyed by the unexpected flood waters from the irrigation canal in December 2019 and January 2020 (see also section 4.4). Insufficient data was available to carry out the computations;

- For the fall planting of pinus part of the trees was also destroyed by the flood waters of the canal.
- In view of the recent planting of the pinus seedlings it was decided to replace the lost items in January 2020. All Cocoons of the With Cocoon scenarios were re-filled. This led to the decision to exclude the With Cocoon no-refill scenario from further evaluation (but its data was added to the With Cocoon re-fill data set). The same applies to the No Cocoon no irrigation scenario whereby all seedlings also received an extra round of watering;
- The fall planting scenarios for carob failed as all plants were destroyed by the floods from the canal. This species was not re-planted due to emerging doubts about its performance in the pilot.

5.2.2. Assessment of tree species survival

The results of the computations for the tree survival rates at Al Faisal are presented in Table 5.1. The average survival rates related to the seedlings with non-zero vigor are shown (see Table 3.5). Statistically significant differences between the scenarios have been checked by considering the 95% confidence intervals which are also taken up in the table. For the spring planting in Al Faisal 4 monitoring sessions were conducted and the session of May 2020 has been considered for the computations. For fall planting only one monitoring session yielding reliable data was carried out in May 2020.

Planting (date)	Species	Date	Survival rate (95% confidence interval)			
			Cocoon No re-fill	Cocoon Re-fill	No Cocoon No irrigation	No Cocoon Irrigation
Spring (May 2019)	Oleo europaea (olive)	May 2020	72,9 (59,0-83,4)	93,9 (83,5-97,9)		92,0 (81,2-96,8)
	Prunus amygdalus (almond)	May 2020		36,0 (24,1-49,9)		36,0 (24,1-49,9)
Fall (Dec. 2019)	Pinus halapensis* (pinus)	May 2020		100,0 (94,3-100,0)		86,1 (74,4-93,0)
	Ceratonia siliqua (carob)	May 2020				

Table 5.1: Survival rates of species planted at Al Faisal (based on May 2020 monitoring; other monitoring sessions for spring planting: July, August, November 2019, fall planting only May 2020), * Replanted in January 2020.

The spring planting of olives and the fall planting of pinus generally performed well. Most of the scenarios show healthy survival rates over 85%. Rainfall and water gifts were sufficient and the silty and clayey soils must have enhanced the survival rate of the plants. Weeding has also been effective. The spring planting scenarios for the almond trees with a survival rate of only 36% were not successful. After planting this species was apparently more sensitive to the dry summer of 2019 and therefore demands more and well-planned re-filling of the Cocoon reservoirs and an increase in irrigation frequency.

Fig 5.1: Healthy tree growth with the Cocoon at the Faisal pilot site

The With Cocoon re-fill scenario for the spring planting of olives had a similar performance as the No Cocoon irrigation scenario. Apparently the more continuous and fine-tuned supply of water from the Cocoon had the same effect on plant survival than the far higher - but discontinuous - water gifts for the irrigation scenario during the summer of 2019 (see Table 5.2). The With Cocoon no re-fill scenario for olives underperformed with a survival rate of about 73%. The difference with the other scenarios is statistically significant. The poorer performance indicates that the initial amount of water in the Cocoon may not have been sufficient to guarantee plant survival for a substantial part of the seedlings.

The With Cocoon re-fill scenario for fall planting of pinus out-performed the No Cocoon irrigation scenario (see also Fig 5.1). The difference in survival rate is significant. It is noted that during the monitoring in May 2020 the growing period for the pinus covered a time span of only 3 to 4 months. This was partly due to the replacement of the pinus seedlings in January 2020 (flooding). The difference in performance indicates that in their initial growing stage more pinus trees survive as a result of the continuous and fine-tuned (water directly delivered at the plant roots) supply of water from the Cocoons in comparison with the water gifts for the irrigation scenario.

Planting (date)	Species	Period	Water supply in liters			
			Cocoon No re-fill	Cocoon Re-fill	No Cocoon No Irrigation	No Cocoon Irrigation
Spring (May 2020)	Oleo europaea (olive)	May 2019-May 2020		50**		1080***
	Prunus amygdalus (almond)	May 2019-May 2020		50**		1080***
Fall (Dec. 2019)	Pinus halapensis* (pinus)	Dec 2019-May 2020		50		60
	Ceratonia silique (carob)	Dec 2019-May 2020				

Table 5.2: Water supply to seedlings at Al Faisal, * Replanted in January 2020, ** initial and emergency irrigation, *** initial, emergency and summer irrigation (weekly to bi-weekly).   .

5.2.3. Assessment of tree growth

The outcomes of the computations for tree growth at Al Faisal are given in Table 5.3. The average tree heights for the various scenarios as measured in line with the instructions are presented (see also Table 3.5). Statistically significant differences between the treatments were checked by applying the student t-test to the data set. For the computations of tree growth, the monitoring session of May 2020 was selected which is the same as for the assessment of survival rates.

The spring plantings of olives and almonds and the fall planting of Pinus show nice plant heights in the order of 0.5 to 1.0 m. The rainfall, effective watering, favorable soils and weeding stimulated the growth of the seedlings at Al Faisal. The olive trees are generally higher than the almond seedlings. The higher sensitivity to dry periods which also accounted for lower survival rates for almonds (partly) explains their lower plant heights as compared to the olive trees. For the fall planting of Pinus, the trees are much lower than both the olive and almond plants. This can be attributed to the much longer growth period for the olives and almond seedlings at the time of the assessments (May 2020).

The With Cocoon re-fill scenario for olives planted in the spring showed substantially larger tree heights than the seedlings of the With Cocoon no-refill and the No Cocoon irrigation treatments. The differences are significant. Not re-filling the Cocoon in the With Cocoon no re-fill scenario meant that (only) the initial amount of water in the Cocoon was not sufficient to generate optimum plant growth in particular during the summer. And, the far higher - but discontinuous - supply of water of the irrigation scenario during the summer of 2019 had a less beneficial effect on plant growth than the more continuous and fine-tuned supply of water of the With Cocoon re-fill scenario (see Table 5.2)

Planting (date)	Species	Date	Height (cm)			
			Cocoon-No Re-fill	Cocoon-Re-fill	No Cocoon-no irrigation	No Cocoon irrigation
Spring (May 2019)	Oleo europaea (olive)	May 2020	86,3	98,0		85,1
	Prunus amygdalus (almond)	May 2020		71,8		78,9
Fall (Dec. 2019)	Pinus halapensis* (pinus)	May 2020		52,7		55,8
	Ceratonia silique (carob)	May 2020				

Table 5.3: Growth of species planted at Al Faisal, * Replanted in January 2020

The With Cocoon re-fill scenario for the spring planting of almonds resulted in tree heights that are slightly lower than the seedlings of the No Cocoon irrigation scenario. The differences are not significant. The more continuous and fine-tuned delivery of water of the With Cocoon re-fill scenario had a comparable effect on plant growth than the far higher - but discontinuous - water supplies of the irrigation scenario during the summer of 2019 (see Table 5.2).

The With Cocoon re-fill scenario for the pinus planted in the fall had tree heights showing no significant differences with the plants for the No Cocoon irrigation scenario. During the growing period of only 3 to 4 months the effects of the continuous and fine-tuned watering with the Cocoon and the water gifts of the irrigation scenario - in combination with the winter rainfall - were comparable (see Table 5.2). It is not unlikely that the (same) rainfall was the determining factor for plant height in these scenarios.

5.3. Maysara

5.3.1. Monitoring data

At the pilot site in Maysara Pinus halapensis (pinus) and Ceratonia silique (carob) were selected for spring planting. The pinus again and Acacia tortilis (acacia) were planted in the fall (see Fig 5.2). The monitoring data were inspected and found to be difficult to explain in a number of cases. This also led to corrections and removals of items from the Maysara data set:

- The spring plantings of the pinus and carob seedlings obtained additional water gifts. Due to the summer months of 2019 with unexpected high temperatures all Cocoons of the With Cocoon scenarios were re-filled (twice) and also the seedlings of the No Cocoon no irrigation scenario received additional irrigation gifts. This led to the decision to exclude the With Cocoon no-refill and the No Cocoon no irrigation scenarios from further evaluation;
- The fall plantings of the pinus and acacia species received little water since the winter rains provided a lot of water for plant survival and growth. It is most likely that no additional water was supplied after the initial filling of the Cocoons and the water gift for the seedlings planted without this tool. It was decided to remove the With Cocoon re-fill and No Cocoon irrigation scenarios.

Fig 5.2: Hole digging for fall planting at Maysara

5.3.2. Assessment of tree species survival

The outcomes of the computations for the survival rates of the trees at Maysara are shown in Table 5.4. The average rates of survival of the seedlings with non-zero vigor are presented (see also Table 3.5). Statistically significant differences between the scenarios have been checked by looking at the 95% confidence intervals which are also included in the table. For the spring planting in Maysara 5 monitoring sessions were held with the latest one conducted in January 2021. Data for this session are difficult to interpret due to the incompleteness of information on water gifts. Instead, the data of the May 2020 monitoring session has been considered. For fall planting also the monitoring session carried out in May 2020 was taken as the basis for the computations.

The (too) late spring plantings of all seedlings including the pinus and carob species showed poor results. The survival rates were less than 25% with the carobs showing rates even less than 10%. The Cocoons emptied quickly in the hot summer of 2019 and irrigated soils were found to be dry. The lack of water for the seedlings due to the very poor water retention capacity of the sandy soils was considered the main reason for the poor performance (see also Chapter 4.3). The fall plantings for pinus and acacia did well with most of the treatments resulting in survival rates over 90%. The explanation for these fine results can be attributed to the absence of a (dry) summer during the growing period and the measures taken for soil improvement to improve the water retention capacity of the soils (composting).

Planting (date)	Species	Date	Survival rate (95% confidence interval)			
			Cocoon- No re-fill	Cocoon Re-fill	No Cocoon No irrigation	No Cocoon Irrigation
Spring (May 2019)	Pinus halapensis (pinus)	May 2020		12,0 (7,0-19,8)		16,3 (10,3-24,9)
	Ceratonia silique (carob)	May 2020		1,0 (0,2-5,5)		2,0 (0,6-7,1)
Fall (Dec 2019)	Pinus halapensis (pinus)	May 2020	100 (96,2-100)		94,4 (86,4-97,8)	
	Acacia tortilis (acacia)	May 2020	100 (96,1-100)		72,5 (62,9-80,3)	

Table 5.4: Survival rates of species planted at Maysara (based on May 2020 monitoring; other monitoring sessions for spring planting: July, August, November 2019, January 2021, fall planting January 2021).

The With Cocoon re-fill scenarios for the spring plantings for pinus showed survival rates that were not significantly lower than the No Cocoon irrigation scenarios. Although the survival rates are low, the more constant and fine-tuned supply of water from the Cocoon had a comparable effect on plant survival than the far higher - but discontinuous - supply of the irrigation scenario during the summer of 2019 (see Table 5.5). For the carob planted in spring no significant differences in the survival rates between the With Cocoon re-fill and No Cocoon irrigation scenarios were computed. The (small) differences in results for the watering application methods used in Maysara are hardly relevant. It needs to be underpinned that survival rates were mostly determined by natural factors including the mentioned lack of rain in the summer and - in particular - the poor water retention capacity of the soils.

The With Cocoon no re-fill scenarios for the fall plantings of pinus and acacia performed better than the No Cocoon no irrigation scenarios. The better performance of the Cocoons is especially true for the acacia seedlings. The results have to be considered with some caution since the monitoring period since planting in December 2019 covered only 5 months. The difference in survival rate points out that in their initial growing stage more pinus - and especially the acacia - trees survive due to the continuous and fine-tuned (water given right at the plant roots) supply of water by the Cocoons as compared with the initial water gifts in the irrigation scenarios.

Planting (date)	Species	Period	Water supply in liters			
			Cocoon- No Re-fill	Cocoon- Re-fill	No Cocoon- No Irrigation	No Cocoon- Irrigation
Spring (May 2019)	Pinus halapensis (pinus)	May 2019- May 2020		75*		510**
	Ceratonia silique (carob)	May 2019- May 2020		75*		510**
Fall (Dec. 2019)	Pinus halapensis (pinus)	Dec 2019- May 2020	25		30	
	Acacia tortilis (acacia)	Dec 2019- May 2020	25		20	

Table 5.5: Water supply to seedlings at Maysara during planting and summer/fall season, * initial fill and re-fills due to emergency situation, ** initial gifts and follow up gifts due to emergency situation.

5.3.3. Assessment of tree growth

The results of the computations for tree growth at Maysara are shown in Table 5.6. The average tree heights for the various scenarios as measured with a ruler are given (see also Table 3.5). Due to excessive weed growth at this pilot in the winter of 2019 to 2020 the measurements were difficult to perform at a number of locations. Statistically significant differences between the scenarios were checked by carrying out the student t-test for the Maysara data set. For the computations of tree growth, the monitoring session of May 2020 was selected.

The spring seedlings of pinus and carob planted in Maysara show lower growth rates than the olive and almond trees tested in Faisal. Although different species are compared these lower rates can be attributed to the poor water retention capacity of the sandy soils and leaving out compost at the Maysara test site. The effect of the application of mycorrhizae is also less than the placement of compost (see also Annex III). The pinus and acacia trees planted in the fall do not show much difference in height in comparison with the seedlings planted in the spring despite their much shorter growing period. The healthy growth of the pinus and acacia trees can be explained by the application of compost during fall planting. The pinus trees appear to be higher than the acacia trees which is a realistic development: pinus trees are generally higher than acacia trees.

Planting (date)	Species	Date	Height (cm)			
			Cocoon- No Re-fill	Cocoon- Re-fill	No Cocoon no Irrigation	No Cocoon Irrigation
Spring (May 2019)	Pinus halapensis (pinus)	May 2019 May 2020		56,0		55,9
	Ceratonia silique (carob)	May 2019- May 2020		53,0		44,0
Fall (Dec. 2019)	Pinus halapensis (pinus)	Dec. 2019- May 2020	47,6		37,9	
	Acacia tortilis (acacia)	Dec. 2019- May 2020	39,9		35,5	

Table 5.6 Growth rate of species planted at Maysara

The With Cocoon re-fill scenario for pinus planted in the spring showed growth rates comparable with the No Cocoon irrigation scenario. The difference in plant height is not significant. The With Cocoon re-fill treatment for carob trees had substantially better growth rates than the seedlings planted under the No Cocoon irrigation scenario. Once the seedlings have survived the carob tree benefits more from the

Cocoon than the pinus seedling. Apparently, the carob tree is able to generate more growth when exposed to the continuous and fine-tuned supply of water from the Cocoon in comparison with the considerably higher - but discontinuous - provision of water of the irrigation treatment during the summer of 2019 (see Table 5.5). This statement, however, has to be considered with reservation since the assessments were carried out on the basis of (very) few living seedlings.

The With Cocoon no re-fill scenario for the fall planting of pinus resulted in significantly better growth rates than the No Cocoon no irrigation scenario for this seedling. During the short growing period the continuous and fine-tuned watering with the Cocoon resulted in larger tree heights than the initial water gift of the irrigation scenario. Both treatments also benefitted from the (same) winter rainfall.

The With Cocoon no re-fill treatment for acacia planted in the fall showed similar growth rates than the No Cocoon no irrigation scenario. Although the plant height for the Cocoon treatment is slightly higher than for the irrigation scenario the difference is not significant. During the (short) growing period the impact of continuous and fine-tuned watering with the Cocoon and the water gift in the irrigation scenario - both in combination with the winter rainfall - were comparable. Apparently the (same) winter rainfall was the crucial factor for plant growth in these scenarios.

6. RESULTS FOR THE LEBANESE PILOTS

6.1. Introduction

In the parts below the results of the tree planting pilots in Lebanon at Aarsal Farm, Ras Baalbak and AREC are discussed. The results concentrate on the computation of survival rates and the growth of the trees. Special circumstances in Lebanon affecting the proper computation of these parameters are mentioned. Different statistical procedures were adopted for the calculation of the average survival rates and heights of the plants. Details on the procedures are outlined in Annex IV. In addition to the average values of the parameters the outcomes also show an indication of statistically significant differences between the planting scenarios as designed for the three Lebanese pilot sites.

The results were interpreted taking the conditions at the Lebanese pilots into account. These conditions deviate substantially from the situation in Jordan. The impact of rainfall and irrigation practices typical for Lebanon was considered. The type and texture of the soil and its rockiness was also a key factor. In addition, external factors have to be taken into account. These include soil preparation and improvement, the quality of the young trees, general management and monitoring procedures, damage of the Cocoons, and weeding. Cocoon damage and weeds have been monitored regularly in Lebanon while other factors were assessed during ad-hoc field inspections. Within the context of the Lebanese conditions the impact of the Cocoon 'in comparison with' traditional planting methods was evaluated.

6.2. Aarsal Farm

6.2.1. Monitoring data

At the planting site in Aarsal Farm Prunus amygdalus (wild almond) and Prunus ursina (wild plum) were selected for spring planting. The much larger selection of species planted at individual farms during the fall consisted of Pyrus syriaca (wild pear), Pyrus communis 'Carmen' (pear), Prunus avium 'Ferrovia' (cherry), Prunus ursina (wild plum), Prunus armeniaca 'Fardao' (apricot) and Prunus armeniaca (local apricot). The monitoring data for Aarsal Farm were inspected and most data sets were found to be in order for the statistical computations. However, special events that affected the monitoring exercise should be mentioned:

- The spring plantings of the wild almond and wild plum trees were provided with additional water. Due to the very hot summer of 2019 all Cocoons of the With Cocoon scenarios received surplus water in the period May to July whereas the With Cocoon re-fill scenario obtained its refill also in the month of July. All No Cocoon treatments also obtained additional water in the period May to July. The No Cocoon irrigation scenario received irrigation gifts in August and September as well. The data sets for all 4 planting scenarios were used for the statistical computations.

- The fall plantings of all trees covered only the With Cocoon no re-fill and No Cocoon no irrigation scenarios (see also section 4.2.1). This meant that data sets for 2 scenarios were considered for the statistical calculations.
- The fall plantings of the local apricot consisted of only 18 trees. This number is too low to perform trustworthy calculations. This species has not been considered for further statistical analysis.

Fig 6.1: Filling the Cocoon with 20 liters of water at Aarsal Farm

6.2.2. Assessment of tree species survival

The results of the survival rate computations at Aarsal Farm are presented in Table 6.1. The average survival rates for the seedlings with non-zero vigor are shown (see Table 4.5). Statistically significant differences between the scenarios at Aarsal have been checked by considering the 95% confidence intervals which are also taken up in the table. For the spring planting at the site 3 monitoring sessions were completed and the last session of May 2020 has been considered for the computations. For the fall plantings at the individual farmers plots at Aarsal only one monitoring session was carried out in May 2020 and data collected during this activity was used.

The spring planting of the wild almond and wild plum species performed reasonably well. The wild almond with average survival rates in the order of 75% did better than the wild plum. Rainfall and water gifts for most scenarios were adequate and the silty and clayey soils must have stimulated the survival rate of the plants. Weeding was also done and proved to be effective. The fall planting scenarios for (wild) pear, cherry, wild plum and apricot showed variable results with survival rates ranging from 40-90%. The pear, cherry and apricot did well but the wild plum had a disappointing survival rate. Apparently, the selection of the correct species for the Aarsal environment is crucial but also the impact of practices adopted by the individual farmers may have influenced the (variable) results.

Planting (date)	Species	Date	Survival rate (95% confidence interval)			
			Cocoon No re-fill	Cocoon re-fill	No Cocoon No irrigation	No Cocoon Irrigation
Spring (May 2019)	Prunus amygdalus (wild almond)	May 2020	75,0 (59,6-85,9)	90,0 (76,9-96,0)	55,0 (39,8-69,3)	80,0 (65,2-89,5
	Prunus ursina (wild plum)	May 2020	82,1 (67,3-91,0)	68,4 (52,5-80,9)	40,0 (25,6-56,4)	63,2 (47,3-76,6)
Fall (Nov 2019)	Pyrus syriaca (wild pear)	June 2020	67,4 (53,0-79,1)		67,4 (57,1-76,3)	
	Pyrus comunis 'Carmen' (pear)	June 2020	88,3 (77,8-94,2)		89,9 (80,5-95,0)	
	unus avium Ferrovia (cherry)	June 2020	91,7 (80,4-96,7)		90,2 (77,5-96,1)	
	Prunus ursina (wild plum)	June 2020	44,4 (18,9-73,3)		41,7 (24,5-61,2)	
	Prunus armen-iaca 'Fardao' (apricot)	June 2020	65,2 (53,4-75,4)		77,6 (68,7-84,6)	

Table 6.1: Survival rates of species planted at Aarsal Farm (based on May 2020 monitoring; other monitoring sessions for spring planting: August, November 2019, fall planting: only May 2020).

The With Cocoon re-fill scenarios for the spring plantings of wild almond and wild plum performed better than the No Cocoon irrigation scenarios for these species. The difference between the two scenarios is not significant. It is not unlikely that the more continuous and fine-tuned supply of water from the Cocoon reservoir stimulated plant survival more than the discontinuous gifts of the irrigation scenario during the summer of 2019 (see Fig 6.1 and Table 6.2).

The With Cocoon re-fill scenario for the wild almond did slightly better than the no re-fill scenario but for the wild plum the result was the other way around. The With Cocoon no-refill scenario did better. For the wild plum a better soil texture or less rocks at the tree planting site may have played a role in the better performance of the no re-fill scenario.

Planting (date)	Species	Period	Water supply in liters			
			Cocoon No re-fill	Cocoon- re-fill	No Cocoon No irrigation	No Cocoon Irrigation
Spring (May 2019)	Prunus amygdalus (wild almond)	May 2019- May 2020	50*	70*	50**	70**
	Prunus ursina (wild plum)	May 2019- May 2020	50*	70*	50**	70**
Fall (Nov 2019)	Pyrus syriaca (wild pear)	Nov 2019- May 2020	20		20	
	Pyrus comunis 'Carmen' (pear)	Nov 2019- May 2020	20		20	
	unus avium Ferrovia (cherry)	Nov 2019- May 2020	20		20	
	Prunus ursina (wild plum)	Nov 2019- May 2020	20		20	
	Prunus armen-iaca 'Fardao' (apricot)	Nov 2019- May 2020	20		20	

Table 6.2: Water supply to seedlings at Aarsal Farm during planting and summer/fall season * initial fill and refills due to emergency situation, ** initial gifts and follow up gifts due to emergency situation.

The With Cocoon no re-fill scenarios and the No Cocoon no irrigation scenarios for the fall planting of (wild) pear, etcetera, performed equally well with the exception of the apricot species. Overall, the small differences in survival rates are not significant. It is noted that during the monitoring in June 2020 the growing period for the species covered a time span of only 7 months. Apparently, in their initial growing stage the trees benefited equally well from the continuous and fine-tuned supply from the Cocoons as from the initial water gift of the no irrigation scenarios. The winter rainfall also played a role. Possibly, a nice spreading of rainfall events in the winter season of 2019-2020 contributed to the similar behavior of the 2 planting scenarios.

6.2.3. Assessment of tree growth

The results of the computations for tree growth at Aarsal Farm are presented in Table 6.3. The average tree heights for the various scenarios are shown. The heights of the individual trees were measured by the farmer teams in accordance with the instructions (see also Table 4.5). Statistically significant differences between the scenarios were checked through application of the student t-test to the data sets of Aarsal Farm. For the computations of tree growth, the monitoring session of May 2020 was selected.

The spring plantings of wild almond and wild plum show disappointing plant heights in the order of 20 to 50 cm. Most plant heights in May 2020 were even less than the initial heights but the differences are not significant. For the fall planting most plants showed healthy heights in the order of 60 to 70 cm. The plant growths are much better than the performances of the plant species used during spring planting which also had a much longer plant life. The exception was the wild plum which showed a poor performance. Its selection was beneficial for the experiment but the wild plum will be less useful for fruit production.

Planting (date)	Species	Date	Height (cm)			
			Cocoon No re-fill	Cocoon Re-ill	No Cocoon No irrigation	No Cocoon Irrigation
Spring (May 2019)	Prunus amygdalus (wild almond)	May 2020	46,7	43,7	34,5	41,6
	Prunus ursina (wild plum)	May 2020	28,0	31,4	24,5	21,4
Fall (Nov 2019)	Pyrus syriaca (wild pear)	June 2020	66,0		54,3	
	Pyrus comunis ‘Carmen’ (pear)	June 2020	64,9		61,6	
	Prunus avium Ferrovia (cherry)	June 2020	71,7		70,5	
	Prunus ursina (wild plum)	June 2020	25,0		34,0	
	Prunus armen-iaca ‘Fardao’ (apricot)	June 2020	70,2		63,0	

Table 6.3: Growth rate of species planted at Aarsal Farm. Initial tree heights, spring planting: wild almond: 51 cm, wild plum: 27 cm, fall planting: about 50 cm, except the wild plum

The With Cocoon scenarios for wild almond and wild plum planted in the spring season showed larger tree heights than the seedlings for the No Cocoon treatments. The differences are relatively small and for the wild almond in particular they are not significant. The With Cocoon scenarios for the (wild) pear, cherry, and apricot in the fall showed larger tree heights than the no irrigation treatments. Only the With Cocoon scenario for the wild plum displayed smaller plant heights than the no irrigation treatment. The differences are small and not significant. Still, during the initial growing period of only 7 months the effects of the continuous and fine-tuned watering with the Cocoons may have been more beneficial in stimulating plant growth of (most) species than the initial water gift of the irrigation scenarios (see also Table 6.2)

6.3. Ras Baalbak

6.3.1. Monitoring data

At the pilot site near Ras Baalbak resistant species including Rhus choriaria and Pyrus syriaca (wild pear) were planted in the spring. The tree selection for fall planting was limited to only one species which had also been planted during the spring: Rhus choriaria. The monitoring data of the planted species for Ras Baalbak were reviewed. They made a trustworthy impression despite the lack of interaction between the AUB and the CWB teams. The statistical computations could be carried out but special events that affected the monitoring should also be noted:

- The spring plantings of the Rhus choriaria and wild pear were provided with additional water similar to the practices followed in Aarsal Farm. Due to the very hot summer of 2019 all Cocoons of the With Cocoon scenarios received this extra water in the period May to July whereas the With Cocoon re-fill scenario received its re-fill in the month of July. All No Cocoon treatments also obtained more water in the period May to July. The No Cocoon irrigation scenario received irrigation gifts in August and September as well. The data sets for all 4 scenarios of the 2 species planted in Ras Baalbak were used for the statistical computations;
- The fall plantings of Rhus choriaria covered only the With Cocoon no re-fill and No Cocoon no irrigation scenarios (see also section 4.2.1). This meant that data sets for only 2 scenarios were considered for the statistical exercises.

6.3.2. Assessment of tree species survival

The outcomes of the survival rate computations for the test site near Ras Baalbak are compiled in Table 6.4. The average survival rates calculated on the basis of non-zero vigor observations are shown (see Table 4.5). Differences in values between the scenarios at Ras Baalbak have been checked for statistical significance by considering the 95% confidence intervals. These are also shown in the table. For the spring planting at the site 4 monitoring sessions were carried out and the session of June 2020 was considered for the computations. The last session was completed in December 2020. In view of uncertainties in irrigation volumes supplied in the summer of 2020 the results of this session were not suitable for analysis. For the fall planting at Ras Baalbak also the data collected during the monitoring session of June 2020 was considered.

Planting (date)	Species	Date	Survival rate (95% confidence interval)			
			Cocoon No re-fill	Cocoon Re-fill	No Cocoon No irrigation	No Cocoon Irrigation
Spring (May 2019)	Rhus choriaria	June 2020	29,1 (18,8-42,1)	26,0 (15,9-39,6)	34,0 (22,4-47,8)	32,7 (21,8-45,9)
	Pyrus syriaca (wild pear)	June 2020	21,7 (13,1-33,6)	17,8 (9,3-31,3)	10,9 (5,1-21,8)	8,0 (3,2-18,8)
Fall (Dec 2019)	Rhus choriaria	June 2020	18,7 (11,5-28,9)		17,3 (10,4-27,4)	

Table 6.4: Survival rates of species planted at Ras Baalbak (based on May 2020 monitoring; other monitoring sessions for spring planting: August, November 2019, December 2020, fall planting: only May 2020).

The spring planting of the Rhus choriaria and the wild pear under-performed with survival rates below 40%. The Rhus choriara did better than the wild pear showing survival rates even below 20%. Rainfall which is known to be low in Ras Baalbak and the additional water gifts in the summer of 2019 were too little to generate a healthy survival pattern for the plants. Also, the high evaporative demand and the rockiness of the soils did not stimulate plant survival (see an impression at Fig 6.2). The fall planting scenario for Rhus choriaria showed even poorer results than the spring planting for the same species. This is an unexpected result since the spring plantings had to survive the summer of 2019. An explanation for this discrepancy may be found in the lack of winter rain that did not trigger the plants to start growing, worse terrain conditions at the test site for fall planting or simply a below average quality of the fall seedlings provided by the local nursery.

The With Cocoon scenarios for the spring plantings of Rhus choriaria showed slightly lower survival rates than the No Cocoon scenarios. The differences are not significant. The With Cocoon treatment for the wild pear showed an opposite result. The survival rates of the pear trees planted with the Cocoon were significantly higher than for the irrigation scenarios. Somewhat contradictory are the lower survival rates for the With Cocoon re-fill and the No Cocoon irrigation scenarios in comparison with the no re-fill and no irrigation treatments, although the differences are not significant. These variations in results for the watering application methods used in Ras Baalbak underpin again that survival rates are chiefly determined by natural factors including the mentioned low rainfall in the area and the variable rocky terrain conditions (see Table 6.5).

Fig 6.2: An impression of the rocky soils at Ras Baalbak

The With Cocoon no re-fill scenario for the fall planting of Rhus choriaria had a similar survival rate than the No Cocoon no irrigation scenario. The small difference in rate shown in the table (6.4) is not significant. The (fall) information provided does not lead to further insights concerning the watering tools engaged in Ras Baalbak.

Planting (date)	Species	Period	Water supply in liters			
			Cocoon No re-fill	Cocoon Re-fill	No Cocoon No irrigation	No Cocoon Irrigation
Spring (May 2019)	Rhus choriaria	May 2019-June 2020	50*	70*	50**	70**
	Pyrus syriaca (wild pear)	May 2019-June 2020	50*	70*	50**	70**
Fall (Nov 2019)	Rhus choriaria	Nov 2019-June 2020	20		20	

Table 6.5: Water supply to seedlings at Ras Baalbak during planting and summer/fall season * initial fill and re-fills due to emergency situation, ** initial gifts and follow up gifts due to emergency situation.

6.3.3. Assessment of tree growth

The outcomes of the computations of tree heights at Ras Baalbak are presented in Table 6.6. The average tree heights for the various treatments are shown. The heights of the individual trees were measured by the local teams in accordance with the guidelines (see also Table 4.5). Statistically significant differences between the scenarios were determined through application of the student t-test to the data sets at Baalbak. For the computations of the average tree heights the monitoring session of June 2020 was used.

The spring plantings of the Rhus choriaria species showed reasonable plant heights in the order of 25 to 45 cm. On the other hand, the plant heights for the wild pear were rather disappointing and in cases even significantly less than the initial heights for this species. Measurement protocols may not have been correctly followed but it is also true that the poor growth performance of the wild pear ties in well with the very low survival rate of the species in Ras Baalbak. Apparently, the low rainfall and rocky soils at the pilot site hardly enhanced the growth of the wild pear. For the fall planting Rhus choriaria showed acceptable plant heights in the order of 55 to 65 cm. Rhus choriaria is overall performing much better than the wild pear and is the superior choice for planting at Ras Baalbak.

The With Cocoon scenarios for Rhus choriaria trees planted in the spring and fall seasons and the wild pear of the spring testing showed larger tree heights than the plants selected for the No Cocoon treatments. The differences are relatively small and not significant. For the growth of the (rather small number of) surviving plants, the more continuous and fine-tuned supply of water from the Cocoons apparently had a more beneficial impact than the supplies used in the irrigation scenarios during the summer of 2019 and the (following) period of winter rains (see also Table 6.5).

Planting (date)	Species	Date	Height (cm)			
			Cocoon No re-fill	Cocoon Re-fill	No Cocoon No irrigation	No Cocoon Irrigation
Spring (May 2019	Rhus choriaria	June 2020	42,9	26,5	26,8	33,4
	Pyrus syriaca (wild pear)	June 2020	29,4	22,3	14,2	14,2
Fall (Dec 2019)	Rhus choriaria	June 2020	63,9		56,6	

Table 6.6: Growth rate of species planted at Ras Baalbak. Initial tree heights, spring planting: Rhus choriaria: 18 cm, wild pear: 26 cm, fall planting: Rhus choriaria: about 50 cm.

6.4. AREC

6.4.1. Monitoring data

At the pilot site at the AREC Research Station planting was only done in the fall of 2019 with one species: Pyrus syriaca (wild pear). The monitoring data taken at the wild pear trees are considered reliable and the computations for the statistical analyses could be carried out. Similar to the set-up adopted at Aarsal Farm and Ras Baalbak there is only a Cocoon no re-fill and a No Cocoon no irrigation scenario for the planting in the fall.

6.4.2. Assessment of tree species survival

The results of the survival rate computations for the pilot at AREC are presented in Table 6.7. The average survival rates determined on the basis of non-zero vigor observations are shown (see Table 4.5). Differences in values for these rates between the scenarios at AREC have been cross-checked for statistical significance by considering the 95% confidence intervals. The intervals in the table are presented between brackets. For the fall planting at AREC only one monitoring session was undertaken in June 2020. The data collected during this session was used for the computation of the statistical parameters.

The fall planting of the wild pear showed rather different results for the items planted with the Cocoon and those following an irrigation treatment. The With Cocoon scenario did reasonably will with an average survival rate above 70%. Rainfall and the water supply from the Cocoon played a positive role.

The silty and clayey soils also stimulated the survival rate of the plants. The impact of the continuous and fine-tuned supply of water from the Cocoon reservoir during the initial growing stage - triggering plant and leave establishment - should certainly be mentioned.

Planting	Species	Date	Survival rate (95% confidence interval)	
			Cocoon no re-fill	No Cocoon no irrigation
Fall (Dec 2019)	Pyrus syriaca (wild pear)	June 2020	71,4 (57,6-82,2)	19,6 (11,0-32,5)

Table 6.7: Survival rates of species planted at AREC (based on June 2020 monitoring; no other monitoring sessions for fall planting).

The No Cocoon scenario for the wild pear performed poorly showing a very disappointing survival rate of only 20%. This result was rather unexpected. The average winter rainfall at AREC is high as compared to Aarsal Farm, and Ras Baalbak in particular, and the soils are fertile. Perhaps the spreading of the rainfall during the winter season was not favorable for plant growth. In addition, a lot of plants were dormant during the monitoring in June 2020 and expected not to survive in the hot summer season. However, some of them would not have died and had given a positive boost to the value of the survival rate.

Planting (date)	Species	Period	Water supply in liters			
			Cocoon No re-fill	Cocoon Re-fill	No Cocoon No irrigation	No Cocoon Irrigation
Fall (Dec 2019)	Pyrus syriaca (wild pear)	Dec 2019 – June 2020	20		20	

Table 6.8: Water supply to seedlings at AREC during fall season

6.4.3. Assessment of tree growth

The results of the statistics for tree height at AREC are presented in Table 6.9. The average tree heights for the two scenarios are shown. The heights of the individual trees were measured by the AREC and AUB teams in line with the protocols (see also Table 4.5). Significant differences between the scenarios were determined through the application of the student t-test to the data collected at the AREC compound. For the computations of the average tree heights the data of the (only) monitoring session of June 2020 was used.

Planting (date)	Species	Date	Height (cm)	
			Cocoon-re-fill	No Cocoon-No irrigation
Fall (Dec 2019)	Pyrus syriaca (wild pear)	June 2020	85,3	67,3

Table 6.9: Growth of species planted at AREC. Initial tree height fall planting wild pear: about 50 cm.

The fall plantings of the wild pear species showed plant heights in the order of 65 to 85 cm. The heights are considered acceptable in view of the short growing period of only 6 months. The With Cocoon treatment performed significantly better than the No Cocoon scenario. This is in line with the better survival rate for the With Cocoon scenario as compared to the No Cocoon set up. The reason for the superior performance of the former scenario is largely similar to the explanation given for the discrepancy in survival rate. The continuous and fine-tuned supply of water from the Cocoon reservoir stimulated plant growth more than the (small) initial water gift for the No Cocoon treatment (see also Table 6.8).

7. CONCLUSIONS AND RECOMMENDATIONS

7.1. Conclusions

The results for the pilot projects in Jordan and Lebanon are combined in order to come up with one set of overall conclusions. Nevertheless, some conclusions apply to one of the countries in particular. This will be clearly indicated. The conclusions focusing on the applicability of the Cocoon technology apply to different parts of the projects and are described in the following paragraphs.

7.1.1 The original set up of the projects

The original formulation of the pilot projects proved to be adequate taking into account the local circumstances in Jordan and Lebanon. Major changes in the set up during project execution were not necessary but minor adjustments were made in the course of activities. Particular aspects can be described as follows:

Partnership. The idea was to liaise with partners having a wide local knowledge in the field of forestry and agro-forestry. They would also have a wide network to facilitate project implementation. The choice of a government institution (Ministry of Agriculture) in Jordan and a university (American University of Beirut, AUB) in Lebanon proved to be adequate.

Field testing. Testing the Cocoons at different field locations was preferred instead of carrying out a desk study or perform testing at a research site. The opportunity to test at field sites under varying climatological regimes and soil conditions was an advantage. In this way the Cocoon could show its qualities in different environments. An added benefit of the spreading of project activities concerned the interaction with diverse local management and communities.

Species selection. The idea was to select for testing various forest and fruit tree species that were suitable for planting at the various test locations. Native plant varieties were preferred. The approach worked out quite well although it should be mentioned that the planting of many species in different seasons led to some loss of focus.

Scenarios and plant numbers. The pilot set up included the design of 4 planting scenarios (or treatments). The basic With Cocoon scenario with only one fill was tested and a re-fill scenario was added to find out about the advantage of an extra water gift in the hot and dry summers (see Fig. 7.1).

The Without Cocoon scenarios included one set up with only an initial water gift and another design with additional irrigation. The 4-scenario set up proved to be fine but for fall planting (see below) the reduction to 2 scenarios including the With Cocoon no-refill and No Cocoon no irrigation scenario was justified (in view of the effect of winter rains). The plant number per scenario was set at 50 pieces. This proved to be a well-chosen number striking a good balance between having sufficient data for the statistical analysis and not using too many plants in the experiment.

Planting period and monitoring length. The project plan foresaw in spring and fall planting sessions. In this manner in-season and off-season planting activities were simulated. The set up generated useful data for initiatives whereby flexible planting times were envisaged. For spring planting the length of the experiment including plant monitoring was set at 18 month and for fall planting at 12 months. These periods are considered satisfactory.

Fig 7.1: Checking the water in the Cocoon reservoir at Al Faisal in Jordan

7.1.2 Project execution

The execution of the pilot projects in Jordan and Lebanon was mostly carried out in accordance with its original formulation described in agreements with the Ministry of Agriculture and the AUB. Nevertheless, the project faced some difficulties. Perhaps the most serious setback concerned the COVID19 pandemic which seriously curtailed travels to the region and field visits. Not all the activities envisaged in the field could be fully completed including the full round of monitoring sessions for the collection of data. Nevertheless, sufficient information could be collected to generate useful project results.

Key observations are:

Selection of pilot areas. The Al Faisal Station, Maysara and Faisaliya pilot areas in Jordan and the Aarsal Farm, Ras Baalbak and Jabal Moussa sites in Lebanon appeared to be a nice mix of locations where the Cocoon technology could be tested under varying climatological regimes and soil conditions. Nevertheless, the Faisaliya area had to be given up soon after spring planting due to insufficient commitment of the local Forestry office in Madaba as the owner of the land. This meant that information from a typical highland area with loamy and clayey soils was not available. The Jabal Moussa site had to be crossed out from the program after the first monitoring round. This was due to its isolated location in the Mediterranean mountains of Lebanon, vandalism by local people opposing the project, and a lack of community involvement. However, a pilot site at the AREC Research Centre proved to be a worthy replacement.

Late planting. In Jordan as well as in Lebanon the spring and part of the fall plantings were late. The delay in the spring plantings (only in May 2019) was due to logistical setbacks in getting the Cocoons from The Netherlands to the project sites. The negative effect on plant growth was partly neutralized by late rains in the spring and thorough wetting of the soil before planting. The delay in fall planting (mostly done in December 2019) was also due to the late delivery of the Cocoons and sub-optimal project coordination. The late planting hardly affected the growth of the trees since winter rains reduced the risk of the dying of the seedlings. Fortunately, the trees in Aarsal Farm were planted on time in November (2019) to prevent any damage of frost to the shallow root system.

Setbacks and disasters. The summer months June and (part of) July 2019 were extremely hot and dry in both countries. There was the risk of an early death of the majority of trees planted in the spring for all scenarios. Except for the pilot site in Al Faisal, it was decided that additional filling of the Cocoons and irrigation were necessary at Maysara, Aarsal Farm and Ras Baalbak. The extra water did not substantially influence the project results. Testing for a normal summer without rain was simulated although its start was delayed from May to July.

The project experienced disasters including flooding, leave eating insects and Cocoon damage. The flooding at Al Faisal in December 2019 and January 2020 destroyed part of the almond, pinus and carob trees. Attacks by insects of other parts of the almond trees caused the reduction of plant vigor and even the loss of plants. In the end the pinus trees lost by the floods were replanted in January. Useful results based on data of the unaffected and restored planting scenarios could still be generated although the outcomes are not fully complete.

Cocoon damage was observed at all pilot areas. There were reports of moles or foxes destroying Cocoons at Aarsal Farm and Ras Baalbak, harsh conditions and runoff affecting the working of the devices at Maysara and Ras Baalbak, punctures in the Cocoon reservoirs caused by sharp stones, and blown away shelters (all sites). Part of the Cocoons was also deformed and even ruptured (uneven pressures on the walls of the reservoir). Although the fences placed at the pilot areas in Jordan were useful, they could not prevent some damage to the seedlings. At Al Faisal sheep managed to break through the fence surrounding the pilot site and damaged part of the Cocoons. At Maysara trespassers cut the fence and 'inspected' the young plants. It is clear that some of the damage could have been prevented. At most pilot sites the percentage of Cocoons that was severely damaged was relatively small. Part of the obsolete items could also be replaced by spare Cocoons available at Al Faisal and Aarsal Farm. Despite the damage still useful statistical computations could be carried out on the basis of slightly smaller numbers of trees than the 50 items originally planted for each Cocoon scenario (40 items at Aarsal Farm).

Fig 7.2: Cocoon planting at AREC Research Station

Damage to the Cocoons was also caused due to shortcomings in design. It was reported that the lid of the device was not solid enough to support the winter snow in the Aarsal Farm area. Another observation was the lack of bio-degradation of the Cocoon even after having been in the ground for over a year (see also Fig 7.2). Apparently, the degradation of the Cocoon did take place at a much slower rate than in other environments. The dry to very dry soil conditions in Jordan and Lebanon for a large part of the year may have delayed the timely degradation of the Cocoons.

Community involvement. The involvement of the local community in the Cocoon technology was best at Al Faisal and Aarsal Farm where local supervisors and farmers enthusiastically enrolled in the workshops and were eager to learn about the Cocoon technology. The 'citizen science' approach as set up by the AUB in Lebanon worked well in Aarsal Farm (see also section 4.5). The participation of the local coordinators and community was much less at Maysara and this was also the case at Ras Baalbak where the 'citizen science' activities were attended by only a few people. In particular the interaction with Cooperation Without Borders (CWB) at Ras Baalbak was far from optimal. The explanation for this discrepancy in involvement can partly be explained by differences in ownership at the various pilot sites. At Aarsal Farm the farmers own the land themselves and they depend on fruit production to make a living. This triggers their interest in trying out a new technology. At Maysara and Ras Baalbak the local people involved do not own the land which is property of the government or the municipality. An essential driving force to be involved in the Cocoon technology is missing.

7.1.3 Project results

Species performance

The project results cover the performances of individual tree species in the pilot areas (see Chapter 5 and 6). The results indicate the close relationship between the success of raising tree species and the climatological regime and soil conditions of the planting environment. The lesson learnt is that certain species will hardly survive in areas where rainfall is marginal and/or the soil conditions are poor. Details on species performance are as follows:

Species planted in harsh environments: The results show that Pinus halapensis (pinus) and Ceratonia silique (carob) planted in the spring at the Maysara pilot and Pyrus syriaca (wild pear) and Rhus choriaria present at the pilot in Ras Baalbak under-performed with low survival rates. The carob and wild pear even had very low survival rates.

The hot summers in combination with low winter rainfall in both areas, the sandy soils at Maysara, and the rocky soils at Ras Baalbak explain the poor performances. The planting of the mentioned species on a large scale in areas similar to the pilot areas will not be a success unless drastic measures are taken. In this respect the addition of compost to the sandy soils in Maysara leading to higher survival rates for the fall planting of pinus trees should be noted (see also Annex III on Water Losses).

Species planted in favorable environments: The outputs indicate marginal to good performances in more favorable areas. Marginal results were noted for Prunus amygdalus (almond) at Al Faisal taking into account the disasters occurring at this site (e.g., insects) and Prunus ursina (wild plum) at the Aarsal Farm pilot site. Good results were obtained for Olea europea (olive) and pinus at Al Faisal, Prunus amygdalus (almond) and other pyrus and prunus varieties at Aarsal Farm, and Pyrus syriaca (wild pear) at the AREC research station. The higher winter rainfall and the fertile clayey to loamy soils at these pilot sites are accountable for the results. There is definitely scope for the scaling up of these species in similar areas.

The seedlings planted in the spring generally show a lower survival rate than the trees planted in the fall. This result does not come as a surprise. At the time of the monitoring session in May 2020 (used for the calculation of the results) the spring seedlings had a much longer growing period and had to survive the dry summer of 2019 in comparison with the fall plantings. The monitoring period should have been longer in order to assess the best season for planting.

The Cocoon technology 'vis a vis' traditional planting

The results indicate positive effects for the Cocoon technology compared with traditional planting methods at a number of pilot areas. The outcomes do not show any site where the traditional planting method with irrigation performs better. Nevertheless, the differences in performance as expressed in survival rates between the trees planted with the Cocoon and the No Cocoon scenarios are relatively small and, in some cases, not significant. Details of the comparative assessment are as follows:

Pilots where the Cocoon has an additional impact. The outputs show the positive impact of the Cocoons for the spring planting of the almonds and wild plums at Aarsal Farm and the fall planting of pinus at Al Faisal, the pinus and Acacia tortilis (acacia) at Maysara and the wild pears at AREC. The assessment is based on survival rates. In some areas plant growth (height) for the With Cocoon scenarios is also better than for the irrigation scenarios.

The main reason for the better performance using the Cocoons is the more continuous and fine-tuned supply of water to the plant from the Cocoon reservoirs in comparison with the discontinuous water gifts as applied in irrigation scenarios.

The advantage is in particular noted for Cocoons that were re-filled. Especially during a hot and dry summer the extension of a continuous supply from the Cocoon is beneficial. In addition, the better plant growth for the Cocoons can be explained by the deeper placed root systems of the seedlings that are less affected by temperature swings.

Pilots where the Cocoon has no additional impact. The results indicate no added advantage of the Cocoon technology for the olives and almonds planted in the spring at Al Faisal and the fall planting of the pyrus and prunus varieties at Aarsal Farm. Apparently, the controlled supply of water from the Cocoon did not have a significant effect on plant survival for these scenarios. Nevertheless, it can be noted that the number of scenarios where the Cocoon has a positive effect is larger than the number of scenarios where this device did not have an impact.

The Cocoon tested in harsh environments. The comparison between the Cocoon technology and traditional planting methods was also envisaged in the pilot areas with a harsh environment including Maysara (spring planting) and Ras Baalbak. The results at these pilots were mostly inconclusive and the impact of the Cocoons could not be assessed. Any positive effect of the Cocoon was over-shadowed by the dominant counter-productive impact of the low winter rainfall and/or the poor soil conditions in these areas.

7.1.4 Water saving

The Cocoon technology was launched with the promise that it could save water. The experiments in Jordan and Lebanon learned indeed that water could be saved in two ways:

- There is the saving whereby - for similar water supplies - the With Cocoon scenarios show better tree survival rates than the No Cocoon irrigation scenarios (see also section 7.1.3). To raise the same amount of trees less water is needed for the Cocoon scenarios.
- The other way of water saving concerns the With Cocoon scenarios whereby much less water is supplied than at the No Cocoon irrigation scenarios. The far lower water supplies by the Cocoons at the pilot areas in Jordan demonstrate this type of savings. It is not unlikely that in Jordan the water supply from the Cocoon was so much lower since (traditional) irrigation practices - as applied at the pilot sites for the No Cocoon treatments - were not efficient. The comparable water supplies for the With Cocoon and No Cocoon scenarios in Lebanon did not lead to water savings for the new technology. At the pilots in this country the use of irrigation water is considered to have been efficient.

7.2 Recommendations

The recommendations as drafted up in the following sections primarily aim at scaled-up projects. The pilot project as conducted in Jordan and Lebanon generated a wealth of information and useful conclusions that will serve as a sound bases for land restoration activities focusing on afforestation, agroforestry and fruit tree planting on a larger scale in the MENA region. This section on recommendations is sub-divided into a part discussing project set up and its execution in general and in a part describing the application of the Cocoon technology.

7.2.1 Project set up and execution

Large projects require the formulation of activities aiming at the creation of environmental and commercial benefits. A minimum of changes in the original project set up during its execution is desirable, but interventions may nonetheless be necessary. Projects are ideally a mix of activities including desk studies, fact finding missions, and field and follow up activities. These last activities form the core business of initiatives in the planting of forest and fruit trees. The sections below are following the line of a standard project set up and discuss a number of suggestions for project execution.

Selection of partners. Key partners in the MENA region know the area well and have proven expertise in large scale forest and fruit tree planting projects. Their extensive networks include local and international organizations. The local partners liaise well with donors and commercial parties willing to put up funds for projects. The type of organizations in a partnership (government, university, NGO's, commercial) is not necessarily the same in the various countries in the region. It is advised that the leading partner undertakes a partner analysis. The assessment leads to an optimum partnership in full control of project activities which will guarantee satisfactory project results.

Selection of planting area: Extensive planting areas need to be selected taking into account climatological factors, terrain conditions, soil properties, flora and fauna, and water availability. The risk of disasters will be considered. Distance to communities and community engagement are also factors to be evaluated. It is advised that a thorough feasibility study and risk assessments including field visits and field testing are carried out before an area is selected for planting.

Suggestions are:

- Sufficient rainfall is available in a selected area for the survival of forest and fruit trees after a start-up watering period. Depending on local weather patterns these periods usually cover a time span of 1 to 3 years. The experiences during the pilot project have shown low plant survival rates in areas with a lack of rainfall (Ras Baalbak). Areas with winter rains only and an annual rainfall below 150-200 mm are not advised for large scale tree planting unless runoff amelioration (water collection), upward seepage of groundwater or permanent irrigation facilities are in place.
- In many places the terrain conditions are related to potential disasters including damages done by flooding ad runoff. Flash floods in wadi's or other water courses, the overtopping of irrigation canals and runoff generation in steep terrain may occur (see Fig 7.3). Depending on the outcome of the risk assessments it may be advised that another area is selected or that preventive measures are taken to minimize the effects of flooding and runoff.

Fig 7.3 Cocoon and saplings affected by overflow from irrigation canal

- Favorable soil properties in combination with few rocks at and below land surface enhance the planting of forest and fruit trees. The lessons learnt from the pilot project is to focus on areas with loamy to clayey (and nutrient-rich) soils with none or only few rocks and to avoid (e.g., sandy) soils with a poor water retention capacity. In case areas with less favorable soils need to be selected project management has to take into account the activities for land improvement at the planting site *(*see *tree planting* below*).*
- The effect of flora and fauna on tree planting has to be evaluated. Extensive weed growth, capture of water by existing bushes and trees, aggressive insects, and the presence of moles, goats and sheep, foxes or other animals may jeopardize the success of a forest or fruit tree project. Project management may discard the selection of an area where extensive harm will be

done by flora and fauna, or define measures to control the negative effects (see also *tree planting* below).

- The effectiveness of the local community in supporting a forest and/or fruit tree project needs to be assessed. It is advised to start projects at a larger scale in areas with a proven commitment by the community. For example, areas where the local community has ownership over the land and directly benefits from the project may be selected.

Species selection: The selection of forestry and fruit tree species to be planted on a larger scale in a region will take into account the scope for the enhancement of land values. These include the re-installment of original landscapes, enrichment of soils, CO_2 sequestration and commercial benefits. It is suggested that during project formulation these (and other) factors area taken into account. It is also advised that the planting of native species is practiced instead of taking up foreign and invasive seedlings in the project plans. Further suggestions are:

- Knowledge on forest and fruit tree species that can best be planted taking into account the criteria outlined above is available at universities and agriculture and forestry departments of (local) governments. It is suggested to tap these sources for species selection. In addition, it is advised to involve local expertise (e.g., farmers) in the selection process and in checking the quality of the seedlings before planting.
- Tree species showed typical performances during the pilot testing and are believed to show similar behavior when planted in scaled up projects. In case of sufficient rainfall and favorable soil conditions it is suggested that species to be considered for planting are - for example - the forest tree Pinus halapensis and the fruit trees Oleo europea (olive), Pyrus syriaca (wild pear), Pyrus comunis Carmen (pear), Prunus avium ferrovia (cherry), and Prunus armeniaca fardao (apricot). The planting of Prunus ursina (wild plum) is not advised and one needs to be cautious with the planting of Prunus amygdalus (wild almond).

Field design. Field design will be based on existing terrain conditions. Mapping features in the terrain itself using prints of satellite images or topographic maps is useful in creating a good background for the design. Some suggestions are:

- Overall plans for an area including blueprints for land restoration, agricultural or urban developments may be prepared or are available at local institutions. The design for the planting of forestry and/or fruit trees should fit into these plans.

- Planting may follow the topographic contour lines and the restoration of existing or creation of new terraces may be considered. These features control land erosion and excessive runoff in particular in sloping terrain (see above). Terraces are common features in the MENA region. South facing slopes are not preferred for planting since the larger radiation (heat flux) from this side may lead to lower plant survival rates.
- The design takes into account the potential impact of flooding from water courses (e.g. wadis) and canals. It is advised to create or adapt earthen or concrete structures in places where floods are expected to form a threat for the trees in the planting area.
- The design maps also show the areas where a particular species will be planted. Distances between planting rows (lines) and individual trees will be indicated. The pilot projects adopted a distance of 4-5 m between rows and trees. Projects at a larger scale may consider similar distances, but other aspects may also have to be taken into account. For example, the larger mature tree heights in such projects may lead to a design with larger distances between rows and trees whereas plans for the re-planting of part of the trees in a row favors smaller plant distances.

Tree planting: Tree planting is quite a logistical and labor-intensive process if done in the traditional way. It is also noted that automatic tree planting machines are developed and engaged in projects. The planting process comprises the acquisition of plants at the nurseries, the digging of holes in line with design, carrying out soil improvement, the planting itself and initial watering. Guidelines with planting methodologies should be made and followed in a diligent manner. A selection of suggestions is as follows:

- Tree plantings in the MENA countries are usually done during early spring or the fall. Depending on the area either the spring or fall planting is referred to as 'in season' or 'off season'. It is suggested to follow local guidelines to determine the optimum planting times.
- In areas with less favorable soils specific measures for improvements will be taken (see also above). In rocky areas stones may be removed from the surface and the dug hole using hand-held tools. In areas with more solid rock planting holes may even be created using a pneumatic hammer. Experience during the pilot project learnt that the placement of compost in holes dug in sandy soils improves the water retention capacity and nutrient levels leading to enhanced plant survival and tree growth.

- The transport of the young seedlings of good quality to the project areas is done shortly before planting. This prevents that the roots of the plants are drying which is especially the case when 'bare root' planting is foreseen. Drying out of the dug holes which reduces the moisture content in the soil by evaporation should also be averted. It is advised to dig the holes not longer than 4 days before planting. Transplant shocks should also be avoided.

Fig 7.4: Area ready for tree planting at Faisal Station

- The planting of the seedlings themselves in sufficiently large holes is immediately followed by the initial watering. It is not uncommon that 20-30 liters of water is supplied to the trees. Water gifts are also defined by following local practices. Depending on local circumstances follow up watering's are given to the plants in line with pre-set schedules. Schedules may be adapted according to local weather forecasts (and soil moisture measurements). Weeds are usually growing after the winter rains in the region has fallen and weeding has to be carried out.
- Measures can be taken in case excessive harm can be done by flora and fauna. Suggestions for measures are additional watering to control water capture, removal of superfluous trees, biological control of aggressive insects, the placement of fences or cages to keep out goats, sheep and foxes, and stepped-up supervision.

Project length and monitoring: Project lengths may be defined running from the initiation of activities to plant maturity or even to the end of the envisaged lifetime of the planted species. Project experience shows that poor results are often a result of short project lengths. Therefore, it is advised to focus on a relatively long project duration of several years so that activities can be supported until local communities can take over the necessary tasks. Monitoring of plant performance all along project execution is suggested in order to be able to take timely action in case of undesired developments.

7.2.2 Application of the Cocoon technology

The engagement of the Cocoon technology can certainly be considered for the planting of forest and fruit trees in scaled-up projects (see also Annex I). Where the new technology will be engaged the design may nonetheless include a small area without Cocoons serving as a control area to assess the effect of the devices. The lessons learnt from the pilot project showed - in a number of cases - positive effects on plant survival and plant growth 'vis a vis' traditional planting methods (see also section 7.1 on Conclusions). Suggestions for the evaluation and implementation of the technology in the MENA region are as follows:

- A feasibility study will determine the environmental and commercial merits and drawbacks of the Cocoon technology. The exercise covers - amongst others - aspects including (increased) water savings and CO_2 sequestration by the Cocoon. Cost aspects including the net financial benefits from higher plant survival rates and plant growth, and lower labor costs since less 'watering rounds' are needed, will also evaluated. It is suggested that the feasibility study concerning the Cocoon technology is part of the project formulation.
- The study also assesses the various site conditions to be interpreted in terms of 'tree water availability', as defined by rainfall, potential evapotranspiration, (any) runoff water collection and/or upward groundwater seepage, soil texture and soil profile depth (volume, rockiness), with heavier soil texture (or sand mixed with compost) compensating for lower rainfall. There will be a lower limit under which Cocoons will not perform well, also modified by tree species choice (re-water requirement and drought- and heat tolerance), and an upper limit above which Cocoons have limited added value.
- The use of the Cocoon technology is not difficult but requires the necessary precision. It is advised that workshops attended by the local community (e.g., farmers) are organized in order to guarantee the correct installation of the Cocoons. Illustrative manuals should be made available and their guidelines should be strictly followed.
- Especially in rocky areas the planting holes for the Cocoon may be larger than the holes for traditional planting. The larger holes will increase the installation costs. The Cocoon needs to be placed in spacious holes whereby the walls should not squeeze the Cocoon. Small sharp stones should not puncture the device. Experience learnt that holes with a diameter of 40 cm and a depth of 70 cm are adequate to accommodate the Cocoon (including placement of compost).

- The MENA region generally suffers from a long dry summer whereby an additional water supply from the Cocoon is required (in addition to its initial filling). It is suggested to re-fill the Cocoons at the most appropriate time in the summer season. A hole with a removable cover (cork) may be made into the lid of the Cocoon to facilitate re-filling of the reservoir.
- Monitoring of the state of the Cocoon after planting is advised. Damage to the Cocoon and the degree of degeneration are essential parameters to be assessed. For example, damage to the Cocoon lid may be caused by the weight of snow falling in the winter. Leaving out the lid in this season and (re)placing it in spring time prevents this type of damage. Also note that freezing temperature can damage pulp wall integrity, also considering expanding ice formation.
- Research will be carried out in continuation of the findings secured from the pilot testing. The research may be carried out as part of scaled-up projects or as stand-alone activities. LLC and Menaqua are amongst the partners to be involved. Examples of issues identified during current activities and needing further investigation are: 1) *Bio-degradation*. How long does it take before the Cocoon is fully degraded in semi-arid environments? Experience in regions with moderate rainfall shows that the Cocoon falls fully apart 1.5 to 2 years after planting (water gifts from the Cocoon during 2 summer seasons are secured), 2) *Cocoon strengthening*. To withstand harsh conditions including wind, runoff, soil pressure, and frost, it is suggested to strengthen the Cocoon. The material of the lid and container can be made stronger or a degradable frame could be mounted at the inside, 3) *Root development.* It was noted that roots tended to develop horizontally below the Cocoon reservoir instead of protruding vertically downward. Since the roots develop in the direction where water is available, the water column below the Cocoon extended mostly in the horizontal plane. Nevertheless, a vertical extension of the roots is often preferred. Research will shed more light on root development and procedures can be set up to stimulate vertical growth.

The Hague, 11 January 2022

ANNEX I: TECHNICAL INFORMATION OF THE COCOON

by Land Life Company

The Cocoon is an incubator for tree seedlings, enhancing growth conditions towards early tree establishment especially in drier regions. The harsh conditions in these regions are hostile to vulnerable tree seedlings in particular, explaining the low survival rates in conventional plantings.

The Cocoon is designed to provide water and shelter during tree seedling establishment, which is usually its most critical survival stage. Cocoon plantings inherently implies deeper placement of seedlings, with root-balls becoming less exposed to diurnal temperature fluctuations at the soil surface, normally impairing root functioning. The Cocoon stimulates deep rooting thus bridging the dry surface, following evaporation losses and competing weeds normally constraining seedling establishment.

It also shelters shoot growth against excessive transpiration and animal damage. Once tapping into more moisten soil substrata, trees have become established, resulting in stronger and more resilient trees, corresponding with higher survival rates and better performance.

The Cocoon resembles the buried clay pot used in ancient times, in which water slowly seeps into the subsurface to support plant growth and restricts evaporation losses, as would be expected during conventional watering/irrigation of the soil surface.

The Cocoon consists of a donut-shaped water reservoir and lid and a tree shelter. The water reservoir with lid are made of recycled paper pulp/cardboard sealed with a natural wax to enhance water tightness. Both parts are buried in the soil upon a one-off fill with water (~ 25 liters) while a seedling is planted in the central space

The water seeps through the bottom of the reservoir just below the seedling's root ball which stimulates deep rooting. Water discharge varies between 1-3 months pending soil and climate conditions. Also, after the reservoir is empty a moist soil column underneath the Cocoon is protected against evaporation losses. The reservoir may be recharged by rain or surface runoff.

Tree roots may be inoculated with mycorrhiza (natural soil fungus) while raised in the nursery or during planting, enabling roots to more effectively utilize available soil moisture and nutrients.
A paper-based shelter is placed to protect the young tree shoot against high irradiation and desiccating winds as well as attack by small rodents and grazers.

The following aspects should be considered when applying the Cocoon technology.

Environmental conditions

Environmental conditions (i.e., climate and soil, and to some degree pests and diseases) first and foremost define tree choice. This implies that the Cocoon, essentially a planting tool, cannot support tree species, which would otherwise not thrive under local (non-irrigated) growing conditions. Higher rainfall areas, particularly in combination with heavier textured soils, may be less suitable for Cocoons, when common tree planting practices without additional watering warrant sufficiently high survival rates.

To apply Cocoons the following conditions should be met:

- Top soils of at least 30 cm depth, as the Cocoon is buried into the soil.
- If present (small) rocks in the top 25 cm should be cleared to prevent the pulp wall to be pierced through, resulting in premature water release.
- Subsoil is preferably deep and medium textured for adequate water retention to support tree growth after establishment through the Cocoon. This requires subsoil during the year to be recharged by rain, (sub)surface runoff or relatively shallow ground water. (Irrigation would defeat the purpose of the Cocoon).
- Chemical soil composition is less critical for reafforestation, unless productive (fruit) trees are considered, which may require additional fertilizer. Soils should be checked on salinity levels and other aspects which may be detrimental to selected tree species.

Planting material

The success of tree establishment using the Cocoon very much depends on the quality of planting material. Bad planting material cannot be compensated through Cocoon enhanced growing conditions. Additionally, healthy planting material should also be properly planted, without voids between root ball and planting hole.

Towards the Cocoon the following criteria for planting material should be followed:

- Nursery trees are preferably less than 1 year old.
- Plant containers should not be larger than 4 liters, with diameter less than 15 cm, to properly fit within the Cocoon.
- Shoots are healthy, free of insects and diseases. Shoots should preferably not measure more than 40 cm, or may be pruned back (1-3 main stems), also to reduce leaf area against excessive transpiration losses. Leaf thinning may also be applied.
- Root are healthy, free of insects and diseases (no rotting smell!).
- Roots should not be circling at the bottom of the container (or growing upwards: J-rooting), as these root conditions will hamper deep rooting after planting. Some circling roots may be pruned at planting: however, when a substantial part of the root mass is pruned, tree growth may be severely set back. Ideally plant containers allow for air-root pruning, resulting in a multi-branched root system.
- Seedlings are preferably inoculated with mycorrhiza (see above) at the nursery.

Planting

The planting procedure is explained in a separate manual. It should be stressed that the root flare (root collar) should be around 10 cm below soil level, and not be covered by soil.

Monitoring

Periodic monitoring after planting provides information on growth and vigor. Tree growth is assessed by measuring tree height using a measuring tape/stick. Rodents grazing on saplings may cause negative growth. In order to also account for tree volume (multiple branching), additional stem diameter is measured at the tree base. For Cocoon trees this may be cumbersome as long as the tree shelter is still in place. Older trees are recorded using diameter measurement as breast height (DBH).

Tree vigor is a health indicator, also giving insights on survival rates. Survival rates during tree establishment in the first year can mainly be attributed to the Cocoon. Survival rates in subsequent years may clearly also be affected by extreme drought or other factors like grazing and fire, all beyond the scope of the Cocoon.

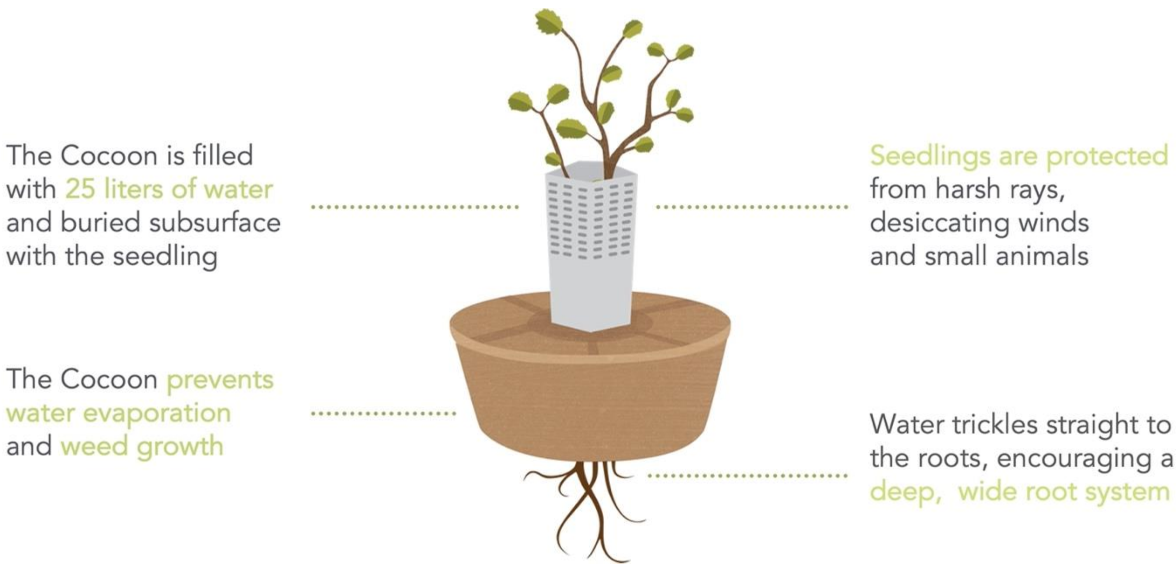
Vigor is assessed by the following semi-quantitative scores during their normal growing period (i.e., no vigor scores of deciduous species during fall and winter):

3: Healthy tree, with more than 75% of green, not wilted leaves. Also, active growing points (apices) may be visible.

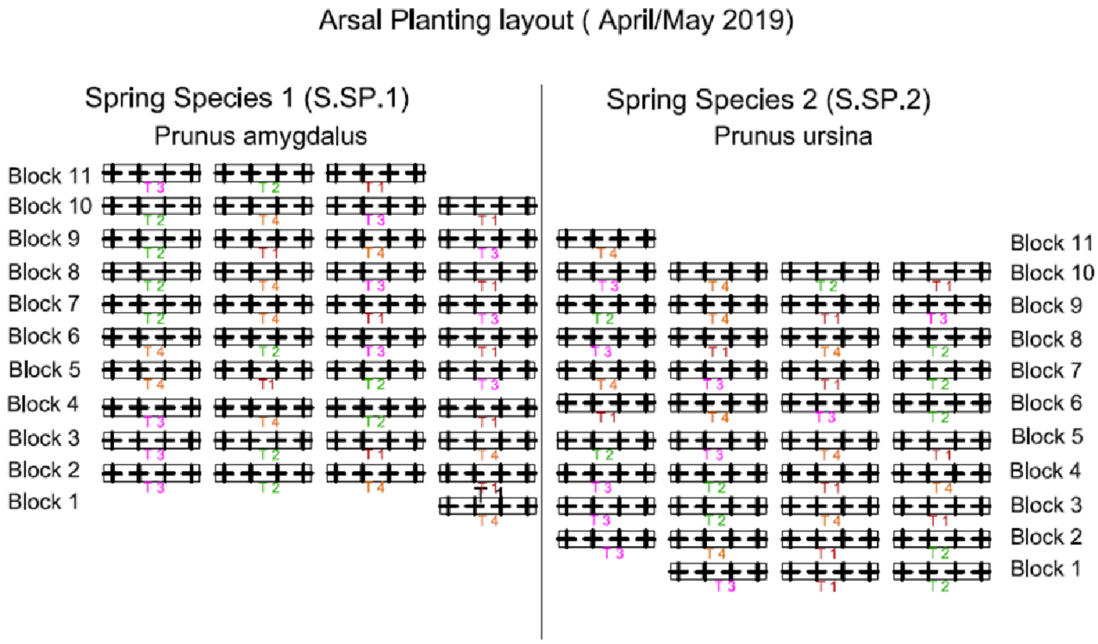
2: Affected tree, with 25-75% of the leaves being wilted, yellow or brown

1: Severely affected tree with less than 25% of the leaves being green (i.e., the majority wilted, yellow of brown)

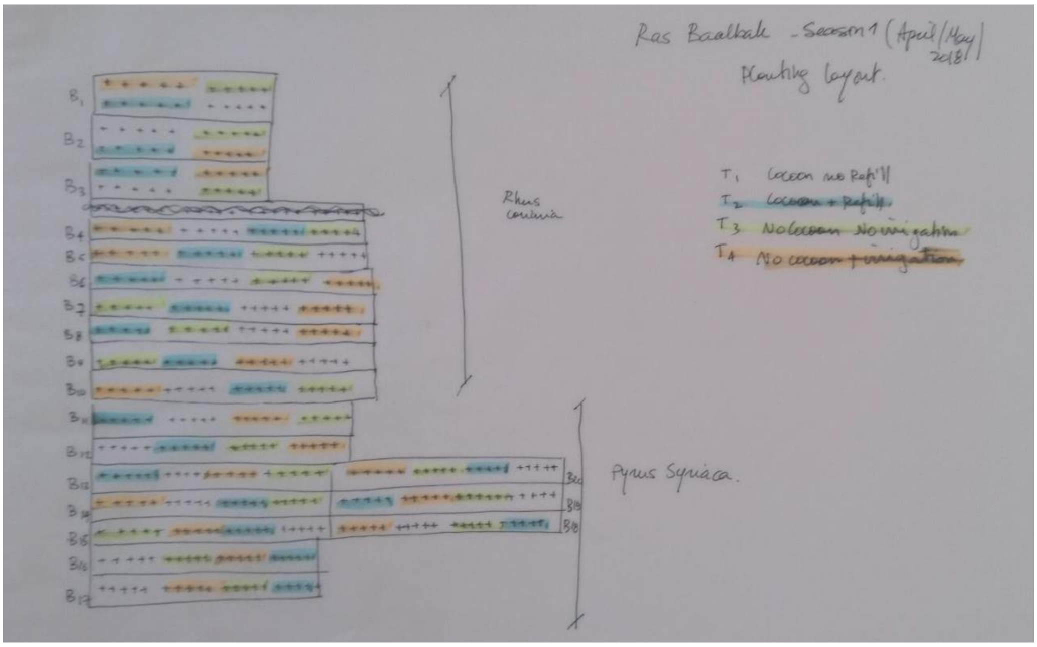
0: Presumably dead tree with no or only wilted leaves. Trees, however, may still recover by re-sprouting after a rain event.



ANNEX II: HAND-DRAWN MAPS OF THE PLANTING LAYOUTS IN LEBANON



Map of spring planting design at Aarsal Farm



Map of spring planting design at Ras Baalbak

ANNEX III: WATER 'LOSSES' FROM THE COCOON

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Pilot areas Jordan and Lebanon

Problem definition

In pilot areas in Jordan and Lebanon higher than anticipated water 'losses' from Cocoons were noticed after spring planting in May 2019. Spring was followed by a hot summer with temperatures rising up to 40^{0}C in places. The 'losses' were observed at plots were forest and fruit trees were planted. Details are compiled in the table below. Please note that water 'losses' resulting from punctures or ruptures in the Cocoon bottoms - whereby the water is lost within a couple of hours - are not taken into account.

Location	**Trees**	**Soil type**	**Initial water lost in**	**Re-fill lost in**	**Soil moisture**
			(weeks)	*(weeks)*	
Lebanon					
Arsal Farm	*Cherry*	*Clayey loam*	*6*	*3-4*	-
Jordan					
Maysara	*Pinus and carob*	*Sand/some loam*	-	*4*[1)]	*Dry*
Faisayliah	*Pinus and carob*	*Clayey loam*	-	*4*[2)]	*Dry*

[1)] 4 Cocoons without damage inspected (one had a bit of water left), [2)] 1 Cocoon without damage inspected

Tests and monitoring in other parts of the world by Land Life Company show that water stays in the Cocoons for longer periods. Two to three months are no exception. In this period, the 'losses' comprise the delivery of water from the Cocoon to the plant. This paper tries to find an explanation for the apparently excessive losses experienced at the pilots in Jordan and Lebanon.

Water balance and influencing factors

The water balance can be considered for a circular soil column with the Cocoon placed in the center. The top of the column consists of land surface and the Cocoon, whereas the bottom of the column is the groundwater table. The water balance simply says that the inflow of water into the soil column minus its outflow equals the change in soil moisture. The balance and its components can be formulated as follows:

$$(P_{eff.} + Q_{cocoon} + Q_{cap}) - (Q_{trans} + Q_{perc} + Q_{lso}) = S_{soil}$$

Inflow

P_{eff} = Part of rainfall entering the soil column in the immediate vicinity of Cocoon

Q_{cocoon} = Water delivered by the Cocoon

Q_{cap} = Capillary flow (upward flow) of water from the groundwater table

Outflow

Q_{trans} = Transpiration by the seedling (and by weeds and from the soil in the vicinity of the Cocoon)

Q_{perc} = Percolation of water to the groundwater table

Q_{lso} = Lateral water losses

Soil moisture storage

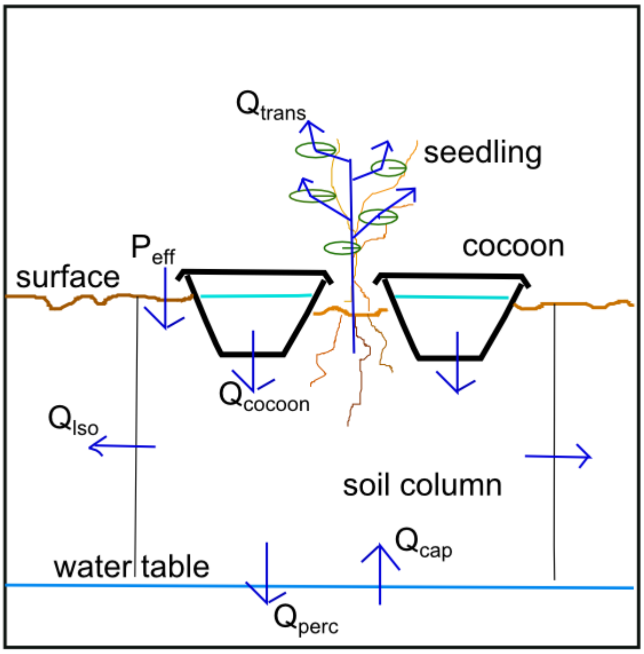
S_{soil} = Change in soil moisture

In case of deep groundwater tables (over 1 to 2 m below land surface), the capillary flow (Q_{cap}) is non-existent and the water balance reduces to:

$$(P_{eff.} + Q_{cocoon}) - (Q_{trans} + Q_{perc} + Q_{lso}) = S_{soil}$$

The components of the water balance are illustrated in the cross-sectional area through the soil column as shown below. The key component is the transpiration by the seedling (Q_{trans}). This is the transfer of water into the atmosphere taken up by the roots of the plant. In addition (rain) water collected on leaves is lost into the air by direct evaporation. The amount of water lost by transpiration and evaporation depends on solar radiation, humidity, wind speed, etc. The combined (potential) transpiration and evaporation (or evapotranspiration) can be computed with formula including the Penman-Monteith equation. A crop factor is then applied. Other formula like the Turc formula are based on air temperatures.

The functioning of the stomata at the leaves is a factor influencing plant transpiration. Especially during hot periods, characteristic for the dry summer periods in Jordan and Lebanon, the stomata tend to partially close and curtail the loss of water through transpiration. In addition, the plant roots may play a role in restricting water uptake in particular in areas where trees are exposed to desiccating strong desert winds.



Water transport from the Cocoon to the plant

In the soil column, the transport of water is governed by the Darcy equation for unsaturated flow. For example, for vertical flow (z direction), the equation can be written as follows (see also SWAP Manual by Feddes and van Dam):

$$q(z) = - K(h) \times [\partial(h + z)/\partial z]$$

q(z) = soil water flow rate

K(h) = permeability or hydraulic conductivity of soil material

h = soil water (moisture) pressure

z = vertical coordinate

The flow of water (moisture) from the Cocoon to the roots of the plant follows the above equation (or rather its equivalent into the direction of flow). Due to the transpiration by the plant, a high negative soil water pressure is created in the root area whereas less negative pressures develop below the bottom of the Cocoon. The difference in water pressure triggers the flow of water. The flow of water does not necessarily have to proceed from the Cocoon to the roots. Depending on the pressure distribution in the soil (and its permeability), the flow of water from the Cocoon may also be in a downward or lateral (sideways) direction.

Interpretation of water 'losses'

The excessive (potential) evapotranspiration in Jordan and Lebanon in the summer of 2019 is one explanation for the high water 'losses' from the Cocoons. The high temperatures experienced in the pilot areas could be inserted in - for example - Turcs formula and high evapotranspiration rates will be calculated. These higher rates have caused an increased transfer of water from the seedlings into the atmosphere. On the other hand, closure of the stomata has set limits to this transfer. In addition, the seedlings were in the earliest stage of plant development and one would expect that leaf areas were still too small to transpire water up to their potential levels (for open water surfaces potential evaporation may reach 8 mm/day for summers in the pilot areas). In view of the closure of stomata and small leaf areas, the high water 'losses' from Cocoons cannot be fully attributed to the high evapotranspiration rates in the pilot areas.

The distribution of water pressures developing in the deeper parts of the sandy soils before and after Cocoons and seedlings were installed offers another explanation for the high water 'losses'. In addition to the water pressure difference between the soil below the Cocoon and the root area - causing the moisture flow to the roots - also differences with deeper layers in the soil were established. The low negative water pressure below the Cocoon and the higher negative pressures at deeper levels where - and when - soils tend to be drier (a dry soil has a high negative water pressure) caused a downward flow of water from the (Cocoon) reservoir. Eventually, part of this moisture may have left the soil column as lateral water losses or deep percolation (Q_{lso} and Q_{perc} - see illustration). Especially when summer proceeded and soils tended to be drier and drier, the downward flow increased which caused substantial 'losses' of water from the Cocoons. This process is illustrated by the quicker emptying of the Cocoons further into the summer season, after they were re-filled with water. In addition, the quicker emptying of the Cocoons after their re-fills in summer may partly be attributed to material deterioration and degradation as well as animal activity (micro-pores).

Finally, a note has to be made on the permeability (K_h) of the soil column where the Cocoon is placed. For coarse grained (sandy) soils, the permeability tends to be high whereby also the 'water - holding' capacity or the water retention capacity of the material decreases. The flow of water to deeper levels is stimulated by a higher permeability - although partly offset by smaller pressure differences -leaving the soil around the Cocoon dry. An example of this process is shown in the pilot area in Maysara, Jordan. The sandy soils - and deep groundwater table - in this area permitted a rapid transport of water from the Cocoon towards deeper levels. This left the soils around the Cocoon dry and resulted in low plant survival rates (35% during July monitoring).

Conclusions

Based on the field observations and theoretical interpretations, the following conclusions can be drawn and measures be taken:

1) The high water 'losses' from Cocoons in the pilot areas in Jordan and Lebanon were only partly caused by excessive transpiration from the leaves of the seedlings. A crucial factor was also the increased 'loss' of water (moisture) from the Cocoon into the soils and to the deeper parts of the soil. Especially in the sandy soils at Maysara with their low water retention capacity the moisture was quickly beyond capture by the roots of seedlings. This resulted in low survival rates. In the loamy and clayey soils at Aarsal Farm with a much higher water retention capacity the moisture remained longer around the (deeper) roots of the seedlings. The survival rates were much better than at Maysara;

2) The late planting in May 2019 and the high temperatures of (early) summer 2019 meant that seedlings were planted in drying out soils which stimulated the flow of water from the Cocoons into the soils and to deeper levels (deep flow especially at Maysara). The Cocoons emptied relatively quickly;

3) The quick drying out of the soils can be reduced by intense wetting of the soils during planting. Water should not only be poured into the Cocoon, but thorough wetting needs to be done also in the soil around the reservoir. The wetting will in particular be useful in somewhat saline soils;

4) Even if the planting in spring is carried out earlier, it is not unlikely that re-fills of the Cocoon are necessary for the seedlings to survive in summer. The advantage of timely - and sufficiently deep - planting in spring is that roots have grown more deeply into the soils and are able to capture moisture at deeper levels, when summer begins;

5) High soil permeability's and low water holding capacities (especially in sandy soils) also stimulate the loss of Cocoon water to deeper levels. Water availability at the plant roots is reduced. Mixing sandy soils with fine grained (loamy/silty) compost will help in reducing permeability's and improving water holding capacities.

6) The use of more water tight Cocoons releasing less water through the semi-permeable wall of the reservoir may also be considered.

Latest update: 06 January 2022

ANNEX IV: STATISTICAL TESTS

Introduction

For each tree species four management scenarios were applied: a) Cocoon with no refills; b) Cocoon with refills; c) No cocoon and no irrigation; and d) No cocoon with irrigation. To be able to detect whether the results of the scenarios show significant differences all monitoring data have been analyzed statistically.

Confidence intervals

For the assessment of survival rates a 2-step approach was applied. At first the 95% confidence intervals were calculated, using the Wilson score intervals. Differences in survival rates are significant if confidence intervals around the average survival rates do not overlap. However, in the case that the confidence intervals do overlap there may still be a significant difference between the average survival rates. To exclude or confirm such significance an additional assessment was made, in which the 95% confidence intervals of the *differences* between the average survival rates were calculated[1].

T-tests

For the assessment of the tree heights the t-test was applied. The one-sided t-test with a 95% confidence level was applied. The t-test enables the comparison of tree heights of 2 scenarios and to assess whether or not the observed differences are significant.

[1] Four scenarios 1, 2, 3, 4 will give 6 pairs of differences (1-2, 1-3, 1-4, 2-3, 2-4, 3-4), which are to be analysed. If the 95% confidence interval of a pair of differences contains the value 0 the differences are (statistically) not significant.