White Paper on Planting Trees, Using Water-Saving Technology in Oman

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This document has been prepared by the Organisation for Quality and Innovation Strategies (Qualies), as part of the SERC project, in collaboration with the Environmental Authority (EA) of Oman and sponsored by bp Oman.

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Summary: Project in Brief

This report concludes the results of plantations of 3000+ trees in Dhofar 2019-2020 using water-saving solutions in dry regions. The activities referred to have been carried out under the label of the Social and Environmental Reforestation (SERC) project, reflecting our emphasis on a collaborative multi-stakeholder approach. The orderly project period lasted from December 2018 to September 2021. After the main plantations had been completed, monitoring and maintenance work continued. In the period that has passed after project-end, there has been less regular but still certain monitoring and maintenance, as will be returned to. Apart from work related to the plantations themselves, SERC has included a range of other activities in support of public and social engagement.

SERC has been carried out under the responsibility of the Organisation for Quality and Innovation Strategies (Qualies) in close collaboration with bp Oman, the main sponsor, and also Oman's Ministry for Environment and Climate Change (MECA), later the Environmental Authority (EA). MECA provided land, seedlings, and logistical support. Another partner, Threepillars, provided administrative support and in relation to carbon credits.

In order to enable planting of dry regions, the project has made use of - and experimented with - a particular solution devised to address the challenges of tree plantations in dry regions, the so-called Groasis technology, including the Waterboxx®. Groasis technology mimics nature by providing limited water to newly planted saplings, yet enough for them to stay alive and establish deep taproots independent of irrigation by humans. While the viability of Groasis technology has been demonstrated in many other countries, there are instances of weak performances and failures as well, demonstrating the importance of a thorough learning process, proper adaptation to local conditions, as well as professional arrangements for maintenance, including custodial management.

Following several years of carefully evaluated trials, through the SERC project, such practices have been worked out for applying the Waterboxx in Oman. The project set out from the start to test Groasis technology through a comprehensive approach. Three diverse sites were selected for the core plantation, to which others were added later. Throughout, the team behind the project worked closely with the inventor behind the Waterboxx, Pieter Hoff in the Netherlands, who provided valuable advice how to adapt and further develop its functionality and key features in the light of the local context and special challenges.

Almost four years after the initial plantations, as of December 2022, we observe continuously high survival rates for the trees that have been planted. The record is particularly impressive in Mirbat, a very dry area that inhabited hardly any trees for more than a hundred years, yet with a survival rate of some 75%. The other two sites, located at higher elevation and further to the west, where they gain support in the hot season from Dhofar's special weather phenomenon, the *Khareef*, feature survival rates around 85%. While overall growth rates are lower than from surviving trees supported by drip irrigation, our trees have more developed root systems and an increasing share gradually display impressive growth, reaching 3-4 meters as of today. It should then be kept in mind that "our trees" have consumed only about 2 percent of the water that had been used if drip irrigation had been applied.

To date, the project team removed most wbx from the trees that had been planted, except for a few yet small ones and also for a few others that grew too big before the job was done. In some cases, a Waterboxx was left next to the tree for a while after its removal, to provide temporary additional support. Today, the vast majority of the planted trees are independent of human water supplies. In Mirbat, which is exceptionally dry, some wbx were not yet removed as some yet undeveloped trees are judged to still need that support. Madinat Al Haq, on the other hand, is the prime site where some trees grew big so fast that the Waterboxx was not removed in time. Again, we have left a few around those trees for the time being, as demonstration of the success. In due time, when the trees grow so big that the wbx cannot fit them anymore, they will have to simply be dismantled and removed.

Almost all of the removed wbx are safely stored in Salalah however, and can gradually be re-used for new plantations, either in the same sites or in new ones selected for the continuation of the project. The plan is for this journey to allow extensive continued plantations of native trees, bringing life back to very dry regions while using minimal amounts to water, working out a sustainable way of contributing to countering desertification, while achieving both climate mitigation and climate adaptation.

Other related activities that formed part of SERC include spin-off plantations, e.g., with farms, at industrial sites, and at schools. The school activities were particularly important, as plantation activity was mixed with some lectures, training, co-creation of the sites to be planted with the schools, planting by and with the children, and also strong engagement by the schools in the continued maintenance. Reports from the schools roughly a year after the plantations had taken place documented very positive memories, attitudes and continuing impetus of the environmental awareness that had been boosted.

Information on the project can be accessed at the SERC website (www.serc.om). A low profile was kept at the start, for the purpose of not appearing to advertise the activity before trees had actually been planted and results achieved, the project gradually embarked on an effective approach to building awareness, pursuing media campaigns and raising the interest of the local population as well as among decision makers. As the project, as such, has come to an end, a final set of key challenges and tasks ahead centres on securing support for continuous monitoring and maintenance of the trees that have been planted, while also building on the lessons of the project to realize expanded future plantations accompanied by sustainable practices.

1. Introduction

The Middle East is plagued by harsh natural conditions and high vulnerability for climate change. Several decades of reduced precipitation coupled with unsustainable agricultural practices and industrial pollution has led to sinking water tables and acute water scarcity. A continuous retreat of already precious forest ecosystems and natural habitats for multiple species, are accompanied by less biomass, depleted soils, erosion, desertification, and an increasing carbon footprint. These worsening conditions are, in turn, associated with disrupted conditions for agriculture, loss of job opportunities in rural areas, and disrupted food chains.

Turning the tide in support of regenerating nature, as well as rural life and jobs, working out a way of planting and growing trees under the kind of dry, challenging conditions prevalent across much of the Middle East is of high importance. The present project has set out to experiment with, and evaluate plantations of native trees in Dhofar, the southernmost part of Oman. A novel specially adapted water-saving method, the so-called Groasis technology – including the Waterboxx - has been applied. Beyond the plantations themselves, the project recognises that success is not merely about planting trees. A thorough process of engagement is required, by professionals as well as by the public and local communities, building awareness and an appreciation of a holistic approach to achieving sustainable long-term land and water use practices.

The report is structured as follows. After this introduction, the aims, objectives, and organisation are introduced. Chapter 3 presents the main solutions applied in the project. Chapter 4 starts out considering the natural context, including weather conditions, followed by a review of each plantation site. In Chapter 5, performances are examined across the three sites. Taking note of factors influencing performances, Chapter 6 explains variation across the three sites and provides a summary of success factors, challenges, and hazards. Chapter 7 reflects on benefits and costs, including those associated with water savings, commercial returns, carbon credits, social aspects, and biodiversity. Conclusions and recommendations feature in Chapter 8.

2. Aims, Objectives, and Organisation

The present project was devised from the start to achieve the following main goals: to (i) introduce, thoroughly test and calibrate reforestation solutions that are applicable to the specific ecosystem under threat in Dhofar, (ii) raise awareness, create educational and learning opportunities and stimulate behavioural adjustments in support of sustainability, (iii) develop the capacity for 'nature-based', water-saving, carbon-negative reforestation solutions to this environmental problem, (iv) provide engagement and employment opportunities to Omanis, and (v) lay the foundation for innovation and technology that can be scaled to address the wider need of reforestation within the country. At the end of the day, the eventual goal is to lay the basis for large scale plantation schemes, capable of enabling viable greening of vast presently dry areas in Dhofar, and also in other regions in the Middle East and beyond.

To achieve these goals, a pilot-scale, reforestation agenda was devised for testing various native species, try out their performance across selected sites, and experiment with best ways in other respects to support success. In total, the pilot was devised for planting more than 3,000 trees, thoroughly monitored and evaluated. From the start, the plan was for greening 7.5 hectares in 3 plots spanning different climate zones and varying conditions for plantation. Greater areas have been made available by EA, however, and to date an estimated 14 hectares have been planted across 3 main sites (near Mirbat, Madinat al Haq and Teetham). The sites were selected so as to display starkly varying conditions, by way of soil, humidity, existing vegetation, topography and climatic conditions more broadly, so as to provide fruitful conditions for experimentation with different solutions under varying conditions, as a basis for learning what species and practices account for the best results under varying conditions.

A special mentioning should be made of the project's emphasis on *people*. Awareness creation has been tailored to reach diverse groups. Adding to the plantations in Dhofar, spin-offs and follow-up activities have been undertaken, encompassing the plantation of more than 1,000 additional trees, in Dhofar as well as in other parts of Oman. Local community members and organisations, representing farmers, industry, public sector organisations, and schools have engaged in various ways. Mindset change is key for developing a more appreciative attitude to saving water and sustainable resource use, as well as what to settle for when it comes to open grazing by camels, cattle, goats, etc. While following a low-key approach at the start, the project gradually undertook a range of activities to raise the interest of the local population as well as connecting with policymakers and various stakeholder categories. This included radio & TV interviews, social media coverage mainly using Instagram, presentations at various events, lectures and planting sessions at schools and museums, and so forth.

As an important characteristic, the SERC project extends from, and has been based on, many years of engagement by local Omanis in Salalah. A network of professional and locals upset with the deforestation process and determined to do whatever possible to halt it, had evolved several years earlier. Their engagement and guidance were key to shape the agenda, counter scepticism as well as allay expectations among local communities more broadly. Further, through that network, the project team gained access to and could engage those individuals, farmers, service providers, and others who were in the position to offer practical support from a technical, logistic, or resource point of view. Meanwhile, the project team established productive collaboration with various relevant agencies and institutions at regional and national level. Apart from bp Oman and MECA, in 2020 transformed into EA, relations have strengthened with the Ministry of Agriculture, Fisheries and Water Resources (MOAFW), the Climate Affairs Department at the Civil Aviation Authority (CAA), Madayn, the Ministry of Energy, Oman LNG, and so forth.

The main plantations were undertaken on land made available by MECA/EA, which contributed as well with seedlings and logistic support. Other spin-off plantations were undertaken on land offered by farmers, embassies, Madayn, and also Sohar Port. The resulting broad-based experiences and relations importantly lay a basis for future scaling the project to include larger areas in the next phase, potentially increasing the ultimate impact of the efforts that have been made and results achieved to date.

3. Applying Groasis Technology

3.1 The context

Our world is confronted with multiple environmental challenges and issues associated with desertification, sinking water tables, erosion, hunger, and poverty – issues that tend to be interlinked. According to the United Nations, water supplies will fall short for 2.9 billion people in 48 countries in as little as 10 years. In most of those countries, over 80% of water consumption is soaked up for agricultural purposes. So-called drip irrigation, the mainstay of conventional water delivery to agroforestry, particularly in dry regions, meets with several issues:

- Capital-intensive initial installations of equipment that subsequently tends to require costly maintenance and repairs;
- Extensive water usage, commonly in the range 15 to 50 litres per tree per day, and
- Of the given quantity of water provided, some 50 % evaporates regularly, and up to 85 % when conditions are hot and dry.

Responding to these challenges, by contrast, Groasis technology represents a well-researched and carefully tested solution for planting in dry regions using lean technology while consuming minimal water resources. Apart from saving costs and resources, Groasis technology generates substantive benefits from a radically different approach to eco-restoration and the organisation of agroforestry programs.

Even in dry lands, humidity generally resides at a depth of about 3 meters, or somewhat further down. In nature, most seeds that fall to the ground run out of strength, however, and are unable to grow roots deep enough to source water resources. Especially under conditions of severe heat, winds, and lack of supporting mother trees or shade, as well as looming dangers of birds and insects, the odds in favour of survival may sink close to zero.

With conventional irrigation, by contrast, a planted root will find itself awash in water on the surface. A plant that is subjected to extensive irrigation from the start will grow used to the same. As a natural adaptation, the root will stay near the surface and from there on depend on artificial irrigation by humans. Lacking properly developed root systems, trees will be feeble and weakly prepared to cope with severe weather events, storms and the like.

3.2 Key functionality of Groasis

Groasis technology and the Waterboxx® have evolved as an alternative solution that is capable of confronting these varying difficulties. By mimicking the forces of nature, but offering seedlings a helping hand, adopting this approach makes it possible to plant trees while radically reducing water usage and still achieve high survival rates. This is as Groasis technology both spurs and enables the plant to grow roots that search humidity deep in the ground.[1]

Adding some other supportive elements, Groasis in essence represents a biomimicry technology that:

1) improves the soil with eco-friendly soil conditioners – typically coco-peat, compost and mycorrhizae;
2) makes use of the natural capillary system of soil. It should not be applied where the land has been bulldozed and sterilized. Appropriate holes should be dug and watered 1-2 days before plantation;
3) uses plants with appropriate primary roots which should be arranged for healthy vertical growth, and;
4) supplied with a modest trickle of water channelled from the closed Waterboxx through the wick, the tap root is enabled to grow deep and connect with humidity deep in the ground.

A key component is the Groasis Waterboxx®, an ideal alternative and replacement for drip irrigation made from UV resistant polypropylene (plastic), which can be re-used multiple times. The Waterboxx supplies the sapling with minimal water supplies each day, yet an amount that is sufficient to ensure the survival of plants given that the species have been appropriately matched with the local conditions (and given that other risks can be contained as returned to later in this report). Figure 1 illustrates how the Waterboxx works.

When planted in the Waterboxx, a tree sapling typically requires the support of the box between 9 till 24 months. When the tree doesn't need the Waterboxx® anymore, one can carefully remove the box from the tree and re-use the box.

Rather than merely economizing water usage, the Waterboxx provides protection from the sun, excessive heat and other unfavourable external conditions. It allows the sapling, in its early days, to focus on establishing its root system and connecting with water sources in the deep. In effect, Groasis technology represents an **integrated planting solution** for dry, eroded, desert and rocky areas. It is ***not*** a way of irrigation. By copying mother nature, healthy, vertical growth of primary roots is achieved.

[1] http://www.youtube.com/watch?v=EXcw7BCOGaU&list=PL5MDcgMmY2CWXN3s3e1pxfctPiY1e5oga

3.3 An established record

The application of Groasis solutions, and notably the Waterboxx, draws on a long record of trials as well as mature plantations carried out in multiple countries.[2] Its successes have been documented by various agencies, companies, and universities, as evidenced by various rewards:

- The 2014 Accenture Green Tulip Award;
- In 2015, Groasis won the ''Best New Product for Gulf Market – Agriculture'' award of AgraMe;
- Groasis Ecological Water Saving Technology was featured in the Global Opportunity Report 2015 of Sir Richard Branson's 'Virgin Unite', as the best method for water-efficient agriculture;
- Recognized as one of the top inventions of the decade by Popular Science;
- Named National Icon of the Ministry of Economic Affairs for being one of the 3 most innovative companies of the Netherlands;
- In 2019, winner of the "Pioneering and Sophisticated Innovations serving the Agricultural Sector" category, awarded by the Khalifa International Award for Date Palm and Agricultural Innovation;
- In 2020, winner of Boskalis Water Award.

Figure 1: Illustration of Waterboxx functionality

Source: SERC project

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[2] Over 100 videos from 26 countries are available to provide details on the various successful cases of tree planting using Groasis, available in 11 languages, see further www.groasis.com

3.4 Requirements for planting with the Waterboxx

Application of the Waterboxx is relatively simple yet requires avoiding caveats, sharing and drawing on established experience, and fulfilling adequate practice. In hot and dry areas marked by water scarcity and high costs for planting using conventional irrigation, planting with the Waterboxx may in effect represent the only viable option for planting trees at all. At the same time, achieving success under such harsh conditions makes it particularly important to avoid errors. This applies to the planning, pre-examination of site conditions, adaptation to the prevailing soil and weather conditions, and so forth.

At the time of planting, some 40 - 60 litres of water are typically used for each plant. Holes of a size that is adapted to fitting a Waterboxx and allows it to just about reach above the surrounding surface, once placed in it, should be dug beforehand. They should then be filled with the same amount of water that fits in the Waterboxx, two days before, and possibly also one day before the planting takes place. After a seedling has been placed in the hole, the root pointing downward, it will be helped by the water spread a few days ago having strengthened the natural capillary system. The Waterboxx is placed on top, filled by some 16-20 litres. Once the lid is closed on top of it, the water in the box has only one way out, via the wick in the bottom-up of the box, which needs to be placed so to direct it to the root, slowly.

Not only must the preparatory and execution phases be managed accordingly, but proper monitoring and management is important too. Following plantation, each Waterboxx should be checked every 6 to 8 weeks. A box that has run dry, or almost dry, should then be refilled with another 16-20 litres (thus, on average, 10 litres use of water is used per tree per month). We'll come back to the magnitude of water savings this brings, compared with conventional irrigation.

While the plant's minimal access to water allows it to survive, it is spurred to search for more elsewhere. With dry conditions outside the box, offering little, and pointing the root downwards, it will seek for that in the deep. In the event humans act to provide water not just through the box, however, that effect is countered, with the root confused which way to go. Once the young trees secure access to humidity in the ground, they should in principle be capable of sustaining themselves, meaning that the Waterboxx can be removed. In fact, as the trees tend to grow fast at this point, there will be limited time to pursue the removal. This part of the maintenance, pursuing effective removal of the Waterboxx at the appropriate time, we may refer to as custodial management. Following its successful removal, the Waterboxx can be reused for planting new saplings.

Under the dry and challenging conditions prevalent in Oman, one may anticipate that planted trees require 9 to 24 months before the Waterboxx should be removed. We learned however, that an intermediary stage of partial removal can be beneficial. On this basis, to begin with, we removed some wbx (wbx) from trees that had grown big enough, but then let some of the wbx remain next to their trees, so to offer them prolonged protection and continued limited water supply, notably during the dry and hot season.[3]

4. Geographic Context and Planting Sites

In this chapter we initially reflect on the general conditions for planting at the sites selected for the present project, including the unique weather conditions that prevail in parts of Dhofar. We then turn to examining the specific characteristics of each planting sites.

4.1 Weather conditions

Oman is marked by harsh weather conditions, mostly very high temperatures in the summer, limited precipitation, sinking water tables, increased salination along the coastline, loss of biomass and fertile soils, and so forth (Shamas, 2007). The region of Dhofar represents a partial exception, due to a special weather phenomenon, the seasonal monsoon (or Khareef) which brings thick humid clouds, while also lowering temperatures, during the summer months. The resulting impact in terms of temperatures is indicated by Figure 2, and in terms of precipitation Figure 3. The red circles in the lower left of the Omani map, flag the low average summer temperature along with higher summer precipitation in Dhofar, compared to the rest of Oman, as well as higher average annual rainfall for the year as a whole.

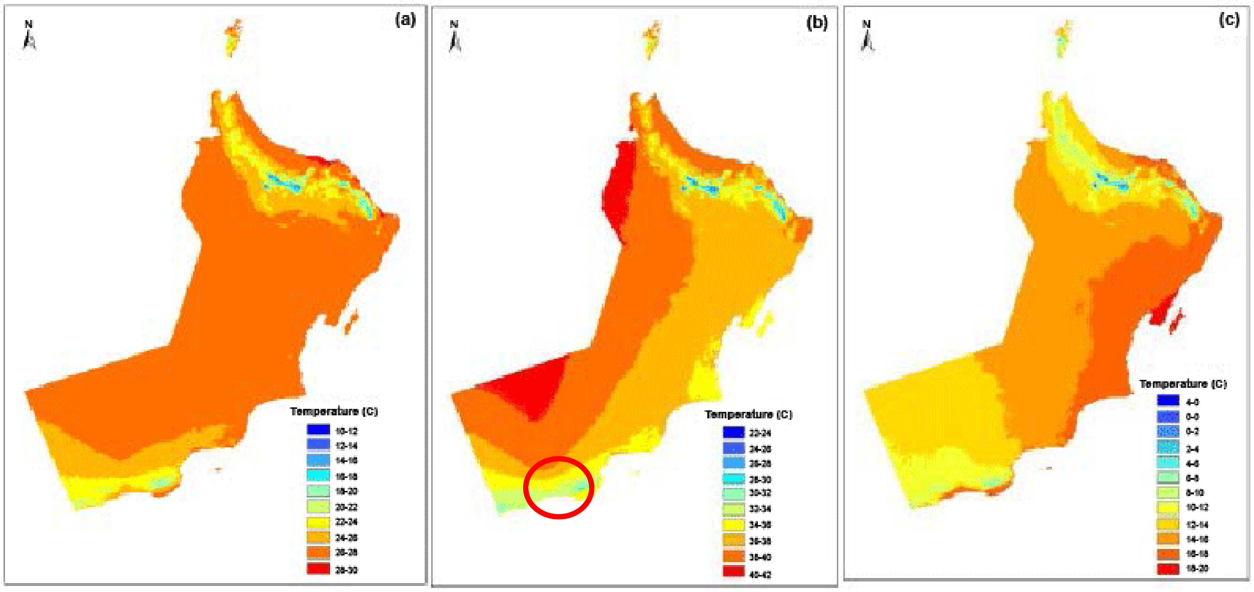
As for ongoing changes and predictions for the future under the influence of climate change, the available evidence points much of Oman losing humidity, compared to today, while the south may go the other way given that the Khareef is maintained (Charabi, 2021).

For some key features of the climate in Dhofar, the following can be noted:

- The climate is dry during most of the year, except summer months (June – September) when the Khareef arrives with thick clouds and humidity. During those months temperatures generally do not exceed 35 degrees;
- The coldest months are January, July and August, with an average maximum temperature of 27°C (80°F); The warmest month is May with an average maximum temperature of 32°C (89°F);
- July is the month with the highest level of humidity, brought by the Khareef;
- January is the driest month, and;
- May is the sunniest month.

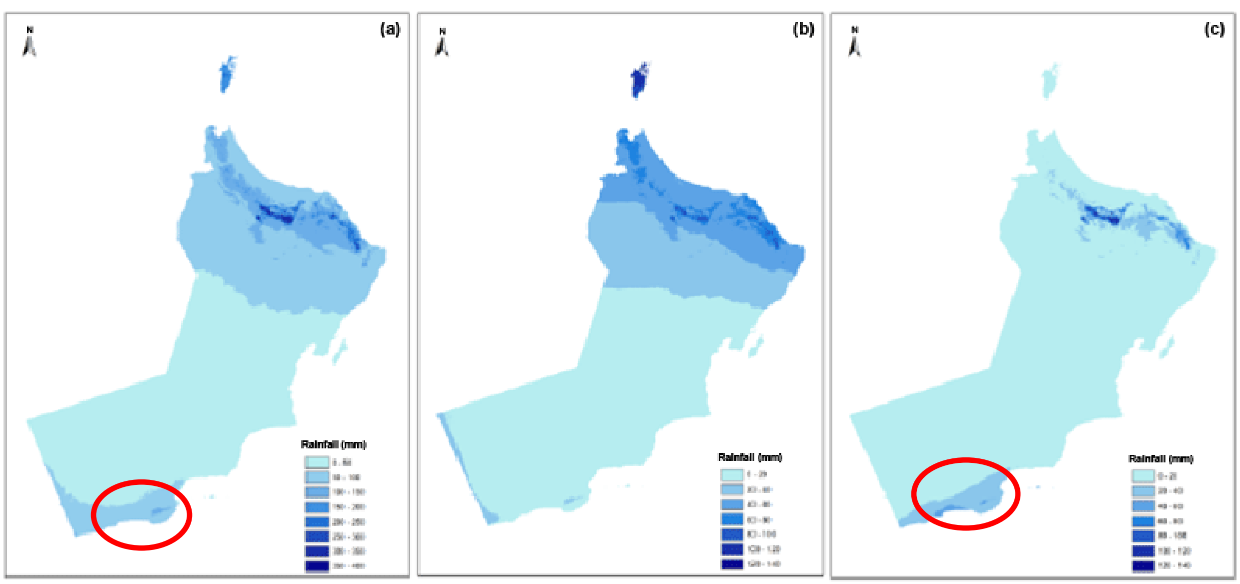
[3] We are using the terms “replacement of the Waterboxx to outside of tree” and removal (completely) of the Waterboxx from the tree”.

Figure 2: Map of Oman, average temperatures*



* Temperature patterns of Oman, (a) Average annual, (b) Average maximum for June and (c) Average minimum for January

Figure 3: Map of Oman, average precipitation*



*Rainfall patterns in Oman, (a) Annual average (b) Winter average and (c) Summer average

Much of the period May – September, otherwise referred to as the "hot" season in Oman, is thus less hot than other parts of the region for those locations reached by the cooling influence of the Khareef.

As a result, Dhofar is home to a unique ecosystem, featuring the bulk of endemic tree and other vegetarian species in Oman (Winbow, 2008). Central to this is a sizeable, seasonal so-called fog forest. While dry during most of the year, this forest temporarily springs to life for 4-5 months each year, with thick, green leaves collecting moist from the fog brought by the Khareef. In a sense, the Khareef and the vegetation are mutually intertwined (Hildebrandt and Eltahir, 2007). Through the forest canopy redistribution, precipitation is spatially distributed in throughfall and stemflow, with especially the latter propelling infiltration and recharge, as effectively as anywhere else in the word (Barros and Whitcombe, 1989; Levia and Frost, 2003).

According to recent estimates, the amount of humidity brought by the fog water is about four times higher than the total of traditional precipitation, i.e., the moisture brought by the fog amounts to some 80% of the total water supply propelling the trees in the areas covered by the Khareef (Shamas, 2017).

The coverage of the Khareef is partial, however, determined by a complex interplay with the local environment. Appendix 1 illustrates the main climatic zones that relate to the Khareef, while Appendix 2 reviews some key features. The total grasslands and woodlands vegetation area on Dhofar's mighty mountain plateau plays a major role in capturing the humidity of the Khareef season and to refill the aquifer catchment area, leading to greatly enhanced soil moisture.

Over the past five decades, some 75% of Dhofar's previous forest cover, or about 6,000 km^2, has been lost. This process of retreat is associated with a vicious circle of fewer trees to absorb moist from the fog, worsening water scarcity with sinking water tables, and an overall 'desertification' of this southern region of Oman (Shamas, 2022).

Despite the losses incurred to date, the soils and local conditions in parts of Dhofar remain relatively favourable to the growth of trees. Dhofar in fact keeps benefitting in multiple ways from what is left of the forest, which is viewed by many locals as inherent to their identity as a people and society.

It is nevertheless increasingly challenging for trees and other vegetation to take root naturally in Dhofar. The difficulties are compounded by the presence of open grazing by large numbers of domesticated animals, such as camels, cattle and goats. With water tables lower in the ground and sea water penetrating deeper into the land, there is not enough time for most young trees to connect with adequate water resources and establish themselves, before they succumb to draught and/or other hardships.

The weather conditions strongly influence the suitable timing to plant, the best arrangements for maintenance, etc.

4.2 The plantation sites in brief

In the present project, we have set out to systematically plant and evaluate the performance of the Waterboxx across diverse parts of Dhofar. Differences apply to soil properties and quality, the thickness of the topsoil, the presence of rock, whether animals such as camels and goats are roaming around, the local prevalence of birds, insects, and other animal life, as well as temperatures, humidity and other weather conditions.

Of the three main sites planted with, two are reached by the Khareef, i.e., Madinat Al Haq and Teetam. The Mirbat site, however, is located beyond the reach of the Khareef, and thus suffers from continued dry conditions as well as elevated temperatures during the hot season that are similar to what applies further north along Oman’s coastline.

The differences between the sites have implications for what species can be grown, what preparations are required, of which requires adaptation in several ways to the local context. If conditions are very dry, mostly sand and rocks, useful methods allow for improved adaptation of the young plant when transferred / planted there. Examples include altering the water holding capacity and breathability of the soil, such as adding CocoPeat, Bio Char, or other suitable agents to the soil. If the soil is poor in nutrients, some bio compost should be added. Use of so-called mycorrhiza, which generally can be collected from naturally recurring trees in the neighbourhood, are highly recommendable. Natural fertilisers are always preferable to industrial chemicals, and pesticides is a no-go.

It should be underlined that all three sites are thoroughly fenced, preventing larger animals from entering. Open grazing is practiced for camels and goats in Dhofar, and the number of animals has grown to an extent that subjects all young saplings to high risk of being eaten, unless they are somehow protected. The Waterboxx by itself cannot withstand such animals, which additionally will sense the presence of water within the box, thereby meeting with double motivations to remove the Waterboxx from the plant and possibly break it, thereby getting to both eat and drink. In the following, we briefly sum up conditions in our three main planting sites:

i) The Mirbat site is located in the coastal plain area (zone 1 as marked in Appendix 2) east of Salalah, 16 km north of Mirbat town. The area is flat and markedly dry, 90 meters above sea level. Falling outside the reach of the Khareef, the Mirbat site is dry all year around, with high temperatures in the summer. Here, when planting started in early 2019, the site showed no signs of pre-existing forest cover, with very scarce presence of any green vegetation (an estimated some 2-4 % groundcover of small desert shrubs and herbs at the time of plantation). The site is highly exposed to extreme heat and wind, adding to the challenges for any reforestation project.

ii) Madinat al Haq site is about 10 km from the city of Salalah itself, located at the outer edge of the northern mountain slopes (zone 4 as marked in Appendix 2), 920 meters above sea level. Conditions for vegetation are generally hospitable, as evidenced by certain pre-existing vegetation, including bushes and trees that account for shadow and healthy soil conditions. Benefitting from the seasonal Monsoon (Khareef), temperatures decline markedly between end-June to mid-September, although trees are required to actually "harvest" the water droplets of the mist. Yet, due to desertification and global warming the monsoon season appears to shrink. Today, the site is close to the border of the previously forested zone of the Dhofar plateau, while also adjacent to the desert plateau.

iii) The Teetam site is similar to Madinat al Haq in terms of height, at about 900 meters above Sea level. Yet, this site is considerably hillier. The surrounding area presents more native Olive trees (Olea Europea), which are hard to find near Madinat al Haq. Due to heavy pressure by grazing animals, almost no generations of trees below 50 years of age can be found in the vicinity, outside the protected parameters, often with only grass appearing during the monsoon season.

While a favourable performance for the planted trees can be expected in Teetam and Madinat al Haq, it is viewed as of high importance to plant in both these kinds of environments, using similar technology and in part the same species. This way it becomes possible to compare the results and lessons learned from plantation in the two areas. Another important reason is that, while Mirbat offers considerably greater challenges, areas marked by this kind of rough soil and climate conditions are of little value today, while still strongly prevalent in Oman, and also in the Middle East broadly. To the extent that we can succeed in planting and having trees survive and transform such areas, this brings important opportunities for value-creation through both economic and environmental impacts in the years and decades ahead.

4.3 Practices applied for planting

The practices of planting have partially been the same across the three sites, facilitating comparisons and lessons from failures and successes. At the same time, it has been important as well to adapt to the special context of each site, which led us to some differences in approach as well. The selection of tree species was slightly different, for instance, see further below.

Throughout, however, we have planted with Groasis technology, and specifically the Waterboxx method. The key steps can be summed up as follows:

- Selecting the site, which has to be fenced in the case of Dhofar (or otherwise another practice needs to be applied to protect against grazing animals);
- Identifying suitable tree species fitting for the selected topographic area, the climatic conditions, humidity and soil conditions, and other key factors;

- Determining the time of planting, depending on the locality, climate, region and periodic weather patterns, it is advised to choose with care the time for planting, as per the vegetative periods (best season/s for growth and individual needs of the chosen plants);
- Identifying the best pattern of planting, usually mixed species to create biodiversity and steer away from Monoculture;
- Ensuring best access to refill the wbx and maintain the trees;
- Preparing the soil: If conditions are very dry, mostly sand and rocks, methods could be taken to allow for a good adaptation of the young plant when transferred / planted there;
- Such methods could include altering the water holding capacity and breathability of the soil, such as adding CocoPeat, Bio Char or other suitable agents to the soil;
- If the soil is poor in nutrients, some bio compost may be added, or a natural fertilizer may be used. We typically don't advice on the use of chemicals for when attempting to create a natural environment and conditions for healthy long-term growth;
- The soil may need to be watered, mulched or covered in advance to enhance the bioactivity of the soil through the increase of microorganisms, fungi, bacteria and insects;
- Measures such as these can help creating a natural environment for the young plant, conducive to green growth and development;
- Preparing holes to accommodate tree and Waterboxx, adding soil conditioner (coco peat) and fertilizer (dried cow dung) plus adding approximately 40 litres of water for each hole one day in advance;
- The next day to plant the seedling into the prepared holes by hand and with hand tools, taking note to manipulate with cutters the roots if required to avoid horizontal roots;
- Applying the evaporation cover and then assembling the Waterboxx over / around each seedling, with the wick under the evaporation cover next to the seedling;
- Filling each Waterboxx with water, ensuring the Waterboxx is properly sealed, and any gaps around the Waterboxx are filled with soil material;
- Placing identification tags with individual numbers on each Waterboxx, and;
- Noting each number, species, date of planting and other relevant data and transfer it later into our monitoring master data base.

4.4 Preparing for the long haul

It should be underlined that preparations for **Monitoring** post-plantation should be undertaken from the start, based on knowledge what indicators to focus on. Depending on the purpose, should each Waterboxx and tree be checked? Given the research component and pilot nature of the SERC project, for instance, it has been particularly important in this case to keep track of the water usage of plants, the performance of different species, their rate of growth, if complementary support needs to be installed, the amount of carbon absorbed (given that the area has been certified for trading carbon credits), and so forth.

Similarly, arrangements for **Maintenance** should consider what is likely to be particularly challenging and important in each location. Where there is risk of grazing animals entering the area, the fence needs to be robust, and efforts be made to explain to locals about the purpose and long-term benefits of the plantation. Where problem appear, there needs to readiness to amend the fence.

On a routine basis, there is the need of checking the water level of each Waterboxx every second month, and then refilling with water where a Waterboxx has run dry, lasting through 12-24 months after plantation, depending on the local conditions Further, checking for possible damage to waterboxx components and, if needed, replacing parts, cleaning pipes of sand and grass /other plants, moving and reinstalling wbx to outside of the trees, levelling around wbx, purchasing support poles and installing them to support trees, with coated wire, and other functional activities required to assist growth.

Despite the basic commonality in approach, the differences between the sites meant that some practices had to be devised differently. For instance, for Mirbat, a more industrial approach was used due to the rather flat topography, which allows easy access by support vehicles and workers and easy overview from afar. In Madinat al Haq, the hilly terrain makes access more cumbersome, particularly during and after the Khareef. In Teetam, site access is even difficult, requiring refilling of wbx with the help water buckets that may have to be carried over 100 m in distance or more, due to the limited access by vehicles. Also, these two sites had some existing vegetation, so that a linear approach of planting was also not feasible. The plantations were arranged however, where no or little vegetation was previously present.

The variations in weather along with topography, etc., further means that conditions for accessibility vary seasonably. During the Khareef, the two elevated sites are hardly accessible for visits, due to heavy mud and clogged roads. From June to early September, on the other hand, there is no need of refilling the wbx in those sites, due to the presence of ample humidity. Maintenance has to be undertaken when the Khareef is over, to remove some mud, leaves, etc.

For these reasons, maintenance is a rather routine matter in Mirbat, while more flexible and labour-intensive practices are required in the other sites.

The risk of extreme weather events poses a danger for the outcome of any plantation project. When applying the Waterboxx, trees are granted the extra protection offered by the devise in their early stage of development. Additionally, as trees develop stronger root systems, they become better prepared to withstand heavy winds and other demanding weather conditions. Having said that, certain conditions, such as heavy flooding, pose special risks. Since the Waterboxx contains air, a surrounding water flow may lift it from the ground and bring it on the move, possibly hurting young saplings.

Aware of such risks, our team attempted to be proactive, by carefully fitting wbx to the holes prepared for them in the ground, and also in some cases place stones on them. Nevertheless, when a massive storm and rainfall did arrive, as happened in Mirbat in June 2020, about 1000 wbx were affected. Some of them were displaced and ended up tilted but still connected with the tree they had been planted with. In other cases, they were pulled away from the tree and ended up on the ground nearby. When these developments occurred, plenty of mud accumulated in the site as well causing clogging of some wbx, in some cases damaging the saplings.

Subsequent to this occurrence, it was greatly important for the project team, at that time, to have good communication channels with EA, the hosting organisation, and to be able to coordinate a swift response. While inferring some unexpected costs, a team was able to operate on the ground for three weeks, collect and restore all the wbx and, where deemed necessary, repositioning them appropriately to the trees. In the end, only a handful of saplings and wbx were lost. This episode demonstrated the importance of contingency preparations, but also that the damage of even severe storms and cases of flooding can be kept to a minimum. There need to be the ability, however, to manage add-on costs.

Photos 1-2:

Dhofar Tropical Storm, June 2020, damage caused in Mirbat, required swift maintenance

Photos 3-4:

Saplings back on track, Mirbat?? – Aug 2020 Mirbat

A different kind of negative external influence was caused by the pandemic and the associated lockdowns that set in from the spring 2020. As it became more difficult to visit the plantations, and to communicate with partner organisations and EA, the processes for arranging with refilling of wbx became heavier and resulted in delays.

As for species selection, Mirbat offered suitable conditions for species requiring very little water while specialized for its kind of topography. An example is Luban, the source of Frankincense, which has proven one of the best performers among all the tree species planted with in SERC. Luban in fact thrives under conditions that few other species could cope with. An example is a situation with only a thin top-soil layer, in the presence of rock containing chalk. Meanwhile, we mixed with other locally common and well-adapted species such as Ghaf and Tamarind, as well as blended with 3 species of Acacia known to serve as excellent “pioneer” trees, i.e., well suited to conditions requiring initial restoration and regreening of an Ecosystem.

In Madinat al Haq, existing stands of local fig species and some Acacia trees were most successful, and also some Sidr and Tamarind had been tried and introduced. In Teetam we included olive trees and Euclea Schimpera, which, for the most part, turned out to do well. While continuing with those species, we added a few other local varieties in support of biodiversity, notably Anogeissus Dhofarica and Blepharispermum Hirtum, both of which are endemic species currently on the decline due to overgrazing and excessive wood harvesting.

5. Observations and Performances Review across the Three Main Planting Sites

In this chapter, we briefly describe the status of the plantations in each site. The detailed reporting at the level of individual trees and species, is based on the reviews undertaken up to April 2021. That data collection was structured to allow for direct comparisons of performances at the three main plantation sites (Mirbat, Madinat al Haq, Teetam).[4]

The project team put high priority on managing monitoring and maintenance through a series of measures. A key factor was knowledge transfers and training of local expertise and workers which to a varying extent built the capacity to monitor conditions on the ground and undertake regular fixes, such as refilling water boxes, removing mud, supporting a young tree threatening to lose balance. Adding to this, the project team undertook: (i) site-visits, (ii) regularly scheduled meetings with all developers, supporters and stakeholders, (iii) creation of an observatory for processing, structuring and arranging with data to facilitate future replication/usage, (iv) application of a user-friendly digital platform, and (iv) and evaluation/feedback forms.

In conclusion, the approach to the monitoring and evaluation of methodologies/activities practices has to be responsive and participatory. Plant survival rates, health of the planted trees, tree growth, water savings and special events should preferably be tracked and recorded. Comparisons have further been made between species and behaviours across the three main sites.

The monitoring and evaluation work has been orchestrated so as to be well integrated with the implementation and learning process, enabling the project team to identify trends, success factors, threats, and so forth. This work is carefully integrated with the research part and ensure rigorous documentation in all respects. Preparations have further ensured, where appropriate, coordination with EA (MECA) which has prepared for the appointment of a special expert board to lend support and advice. The plan is for this body to have the ability to carry out certain reporting and documentation tasks of high public relevance.

Referring to the detailed review of April 2021, Tables 1-3 present the height distribution of the planted trees across the three main sites. Table 4 sums up key data each of them. Figures 4 – 6 show the distribution of species planted in each site. Tables 5-7 illustrate performance-related factors. Table 6/Figure 7 present survival rates across tree species.

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[4] The detailed data recording of individual tree performances is included in SERC's Data Monitoring Master file, dated April 2021. Subsequent monitoring provided estimates but not precise counting of the number of trees belonging to different categories. Thus far, the general status of the plantations in each site has been observed, recorded, and documented by photos up to November 2022.

5.1 Mirbat Site

The Mirbat site is host to the first batch of trees planted in SERC. It is also the most demanding of the three sites in relation to topography, climate and exposure to harsh weather conditions.

As indicated by photo nr. 5, before our planting under the SERC project, no tree appeared at the Mirbat sight, as far as the eye could see - within and beyond the boundaries of the plantation. There were no indications of any previous established vegetation in the recent history.

The distribution of species is shown in Figure 4. Of the 1270 trees, 754 were planted in March / April 2019, 508 in October 2019, and 8 more in November 2019.

General status of the tree plantation

As of April 2021, the vast majority of trees were healthy, and many well established. 158 trees were confirmed dead (8 had been replanted, half of which died again). 14 were in such a bad state for a period that they were feared dead but then recovered. 9-10 trees were presently sick". Over 50 trees (all Acacia Nilotica) were flowering at the time of monitoring.

For the trees planted in March/April 2019, the plan had been for all wbx to be removed within 24 months. As of April 2021, however, a significant number, 341 trees, were still supported by the Waterboxx. For 763 trees, on the other hand, the Waterboxx had been removed. In some cases, the project team had opted to leave the (removed) Waterboxx next to the tree, for the purpose of lending continued temporary support (then easy to remove later).

Photo 5:

Photo of holes dug and wbx in place - plantation at Mirbat site, March 2019

The particularly harsh conditions of Mirbat, marked by limited access to humidity in the ground, meant that many trees still had not grown too big after 24 months. This, combined with practical and resource issues in establishing effective cooperation with site owners, inducing them to assume responsibility for maintenance, the date for complete removal was shifted to after the Khareef 2021. In reality, some wbx remained in place longer, well into 2022, without causing any problem. As of the fall 2022, basically all wbx used for planting in Mirbat, have been removed, except for a few protecting still struggling saplings that remain small but alive.

Finally, 352 teres were supported by the installation of steel rods, to protect against wind and so as not to lean over. Parts of the Mirbat site clearly present saplings with particularly challenging conditions. Suspected reasons include previous compression of the oil for industrial purposes or underground rock formation.

Related to specific species

Many trees suffered in the past 3 storm flooding. Especially Luban trees were badly affected by mud pooled around them, which then dried and likely suffocated some of the trees.

Most Pioneer trees (Acacia species) were doing extremely well, not only surviving but also growing very strong. Tamarind faced some challenges, yet the tallest one had grown to 2-meter height. Some Sidr tees were struggling in the initial planting and monitoring phase, maybe due to poor seedling quality. Gradually, however, Sidr has come to demonstrate a high survival rate, although the trees continue to develop more slowly than some other species.

Height (size) of the trees

For all the 1270 trees at the Mirbat site, Table 1 shows the overview distribution within size classes. While about half, 50%, surpassed 50 cm height, that number hides a systematic variation depending on the time that had passed from the time of plantation.

Table 1: Size ranges for the trees planted at Mirbat site, as of April 2021

No. of Trees in each category	Size in cm
158	Dead
145	10-30
352	30-50
251	50-70
185	70-90
107	90-110
72	110-200

Among the trees planted early 2019, i.e., 24 months earlier, 464 were more than half a meter in size while 175 were less than half a meter (72/28% distribution). For the trees planted in October 2019, 18 months earlier, 147 were more than half a meter and 321 less (30/70 distribution). For those trees planted in November, however, results were more favourable.

In Mirbat, the trees planted in November 2019 appeared in considerably better health compared to those planted a month earlier. Several factors likely contributed, incl. the precise location, offering better soil and protection by some existing trees, and also the timing as November meant less wind exposure and cooler temperatures at the time of plantation, this shows that not just the time that has passed since plantation, but also the precise slot chosen and other factors surrounding the plantation matter strongly for the results obtained.

The 6 months' period between one and a half and two years after plantation, appeared to constitute a critical juncture of growth taking off for many trees in the Mirbat site. That thus calls attention to that period as an important window for removing the wbx, before the trees grow too big.

5.2 Madinat al Haq:

Madinat al Haq represents the second site, where plantations were undertaken in two rounds. Initially, 248 Trees were planted in November 2019, and 891 in March and April 2020, thus 1139 saplings in total. The distribution of species is shown in Figure 5. The site has vegetation present within its boundaries. Yet, outside its fences, the surface is almost entirely barren, except for one or two old Fig trees per km^2.

Photos 6-7:

Young saplings newly planted with wbx in place, and picture of saplings ready for plantation, Madinat al Haq site, March 2020

As of April 2021, the vast majority of trees were healthy with many well established. 77 trees were confirmed dead while 60 trees were presently sick". No trees were flowering at the time of monitoring. No wbx had been totally removed from trees as of April 2021, yet it was estimated that 37 trees were in a well-established state, and thus ready for that. There was no need of installing steel rods. Some parts of the site appear more challenging, partly due to underground caving caused by badgers and termites. Some trees had clearly struggled in the past dry period.

Of the trees planted in Madinat al Haq, 649 suffered from the very dry season and showed very little sign of foliage. Of those, 354 had no leaves at the time of monitoring, yet were still alive. 316 trees were doing OK, of which 93 were good, and 26 developed very well.

Related to specific species:
Most Fig trees are doing well since this area is their natural environment. Tamarind had some challenges yet young trees are persevering. Of the Sidr tees, about half are in good shape while the other half is barely surviving.

Height (size) of the trees
Table 2 shows the more detailed distribution of the trees falling within different size ranges. At Madinat al Haq, 632 of the trees were less than half a meter while 430 were above half a meter in size. This meant a 60/40 per cent distribution approximately 18 months respective 12 months after the main dates of plantation.

Table 2: Size ranges for the trees planted at Madinat al Haq, as of April 2021

No. of Trees in each category	**Size in cm**
77	*Dead*
295	*5-30*
337	*30-50*
240	*50-70*
106	*70-90*
56	*90-110*
28	*110-200*

5.3 Teetam

The third main site is Teetam, where 595 were planted in October 2020, meaning that the time of measurement, reported here, occurred 6 months later. The distribution of species is shown in Figure 6. Similar to Madinat al Haq, Teetam has vegetation present within its boundaries.

Photos 8-9:

Plantations Teetam site, October 2020

Table 3: Size ranges for the trees planted at Teetam site, as of April 2021

No. of Trees in each category	Size in cm
45	Dead
116	5-30
88	30-50
91	50-70
111	70-90
104	90-110
40	110-150

Outside, the main vegetation consists of small bushes, Olive trees, some fig trees, grass and a few Acacia species. The vast majority of trees look quite healthy, and many are well established. Many suffered in the past dry season, however, with the Khareef shorter than usual. Trees in certain areas were challenged more, apparently due to the underground being rocky substrate, and also due to the influence of some termite hills. Further, the counting showed 45 trees to be dead. Of those alive, none with signs of suffering or disease. No trees were flowering at the time of monitoring. For over 50 trees, the Waterboxx should be removed soon. No steel rods had to be installed for support of individual trees in this location.

Related to specific species
Most Anagaesus Dhofarica, Olive and Fig trees are doing very well since this area is their natural habitat. Sidr tees are also doing ok.

Height (size) of the trees
Of the 595 trees planted in Teetam, with 346 are over half meter in size and 204 less. Thus, the ratio between above/below 50 centimetres amounted to 35/65 only 6 months after the plantation. This represents a significant contrast to the record notably in Mirbat, but also compares favourably with Madinat al Haq. Table 3 shows the detailed distribution of trees falling within different size ranges.

5.4 Selected observations across the three sites

Throughout, most wbx sustain the water level at a similar pace (after regular refills) of about 10 Litres / month, except for Madinat al Haq and Teetam during the Khareef season, when the wbx stayed almost full, requiring no refilling during that period (June-early September).

Height comparisons
As for the width (diameter), for most species, trees with a height of 100 or more tended to have a stem diameter more than 3 cm, with less than that for trees of less height. For Luban, however, trees above 80 cm usually had a stem surpassing 4 cm in diameter. Trees showed little systematic variation across the three sites in this respect, but rather the time that has passed since planting appears as key for the size distribution. A relatively high share of the trees in Teetam has grown bit, given the relatively short period (7 months) passing from plantation to the time of measurement.

Wildlife and flora
For all sites, the plantations had definitely brought enhanced wildlife, compared to the surrounding areas that had not been planted. Animals appearing included many frogs / toads, several snakes, several scorpions, some locusts, many different lizards, many birds, and more insects in general. In Madinat Al Haq and Teetam, additionally, observations were made of more badgers, hares and mice, termites, more locusts. In Madinat al Haq, an Arabian Chameleon appeared. A fox showed up in Teetam. Some Wbx in the Teetam site were negatively affected by termites.

The flora had also increased, reflecting improved opportunistic for plants such as herbs, grasses and small bush growing near or within the wbx, taking advantage of the humidity, possibly competing or complementing the trees. In Madinat al Haq, the indicator plant “Sodom’s apple” appeared.

6. Factors of High Importance for Observed Variation

This chapter further examines the observations made, based on in-depth analysis of the Data monitoring master file and other material. It elaborates lessons that stand out from those observations, along with our experience of having planned and implemented those plantations.

Despite the occurrence of heavy rainfalls in June 2020, the overall survival rate of trees planted in 2019 and first months of 2020 stood above 92 % on average measured in October 2020. The only species seen to been struggling initially in the Mirbat site was Sidr, reflecting the harsh environment. In the 2nd year, however, all planted species performed very well. Naturally, the average survival rate continued to be higher in Madinat Al Haq, where the overage survival rate remained above 92 % late spring 2021. See Table 4 for a summary, and comparison, of our plantations at that time, including the areas and the species planted in the 3 main sites referred to.

Looking at the performance of each species, in each of the sites, most species have done better in Madinat al Haq. Acacia Senegal is an exception, with a markedly stronger performance in Mirbat. Of the other species, for the main species, we note slightly weaker performances in Mirbat for Tamarind, likely due to the hot strong wind the trees are exposed to. Especially Bosvellia Sacra has been performing really well at the Mirbat site, likely due to the fact that this species has evolved to deal with such conditions. The Pioneer trees, the Acacia species, all seemed to be doing fairly well on both sites, with variations in performance likely resulting in the destination location and from differences in the soil from one to another corner, and the different ministry nurseries from where these seedlings originated from.

In the ensuing years, equally detailed calculations of tree growth and survival were not practically possible. The most recent estimates of the overall survival rates, in November 2022, indicate about 75% in Mirbat and between 80 and 90 percent in the other sites, suggesting an average survival rate of about 80 percent across the three sites. It should be noted that the period that has passed since the various plantation were undertaken, now spans between 44 and 25 months. That the survival rate in Mirbat is the lowest primarily reflect its more demanding conditions, but also that more time has passed in that site.

The continued low casualty rates overall indicate that the initial observations regarding the success of individual species remain basically intact. We have not made any observations suggestion otherwise. We have, however, evaluated carefully where we have had casualties. In the following, we elaborate on the causes of failure or shortcomings we have observed, to take these as lessons learned.

Table 4: Species planted in three sites, basic data and performances as of April 2021

Area	Mirbat(مرباط) 17°02'07.0"N 54°49'15.6"E https://goo.gl/maps/gcAT9cADbhS3SJyGA	Madinat Al Haq (مدينة الحق) 17°13'48.9"N 54°24'46.8"E https://goo.gl/maps/gnQrs1V1yRKyzu2s6	Teetam (طيطام) 17°06'58.9"N 53°55'10.6"E https://goo.gl/maps/VsUCBZcKw8Bxj86a7
Survival rate %	85	95.5	92.3
Saplings	*Trees planted:* 1270	1139	595
Plant per hectare[2]	*Trees per hectare:* Approx. 250	Approx. 300	Approx. 300
Species	Boswellia Sacra (اللبان) Ziziphus Spina Christi(سدر) Acacia Senegalensis (قتبه) Acacia Gerrardii (الطلح) Acacia Nilotica(القرط) Tamarindus indica(تمر هندي) Commiphora Habessimica (المر) Flueggea Virosa (الذبين) Prosopius Cineraria (الغاف)	Grewia Bicolor (بشم البياض) Olea Europaea(عتم/موطين) Euclea Schimperi (خليث) Ziziphus Spina Christi(سدر) Ficus Vasta (طيق) Ficus Sycamorus (سوقم) Acacia Gerrardii (الطلح) Acacia Senegalensis(قتبه) Tamarindus Indica (تمر هندي) Anogeissus Dhofarica (سغوت) Blepharispermum Hirtum (قفطوت) Flueggea Virosa(الذبين)	Allophylus Rubifolius (شيرز) Anogeissus Dhofarica (سغوت) Euclea Schimperii (خليث) Ficus Vasta(طيق) Olea Europaea (عتم/موطين) Tamarindus Indica (تمر هندي) Ziziphus Spina Christi(سدر)

1) *Plantation in the three sites does not follow sharp delineations in the terrain and therefore the number of trees per hectare shall be seen as approximate, with roughly estimated deviations from the "rule of thumb" how many trees fit in each hectare, based on the distance between each tree planted that is applied. Due to the particularly dry conditions in Mirbat, this site has the lowest density of planted trees per hectares (250), with the others estimated at (300). The precise number of trees planted per hectare in a particular site needs to take account of the climatic conditions and the depth of the water-table.*

Source: SERC Project monitoring

Table 5: Overview trees planted in SERC, species across locations, and survival rates, as of end-April 2021

Scientific Name	Qairoon Hereti 2019	Mirbat April 30 2019	Mirbat Oct 2019	Mirbat Nov 2019	M Haq Nov 2019	M Haq March 2020	M Haq April 2020	Teetam Oct 2020	Qantab Oct 2020	Sur Madayn 2020	Total planted SERC 30.10.2020	Dead	Survival Rate
Acacia Gerrardii		76	17			84					***177***	11	*93.79%*
Acacia Nilotica	1	230	36								***267***	23	*91.39%*
Acacia Senegal		168	101	1	34						***304***	30	*90.13%*
Allophylus Rubifolius								28			***28***		*100.00%*
Anogeissus Dhofarica							48	232			***280***		*100.00%*
Azadirachta indica									6		***6***		*100.00%*
Blepharispermum Hirtum							47				***47***		*100.00%*
Bosvellia Sacra	1	141	48								***190***	27	*85.79%*
Commiphora Habessimica		2	0								***2***	1	*50.00%*
Euclea Schimperii	1				6	7		68			***82***		*100.00%*
Ficus Sycamorus	1				17	6					***24***		*100.00%*
Ficus Vasta	2				78	149	148	122			***499***		*100.00%*
Flueggea Virosa				1	9						***10***	2	*80.00%*
Grewia Bicolor					5						***5***		*100.00%*
Moringa Peregrina										4	***4***		*100.00%*
Olea Europaea	2				8	2		102			***114***		*100.00%*
Prosopius Cineraria		0	53							22	***75***	10	*86.67%*
Tamarindus Indica	1	102	52	3	46	99	49	1			***353***	30	*91.50%*
Ziziphus Spina Christi	1	35	201	3	45	151	101	28		24	***589***	26	*95.59%*
Unidentified			0			0		14			***14***		
Total planted	**10**	**754**	**508**	**8**	**248**	**498**	**393**	**595**	**6**	**50**	***3070***	**167**	***94.56%***
Planted so far for SERC										**3070**			

Figure 4: Pie-chart, species distribution of trees planted, trees planted Mirbat

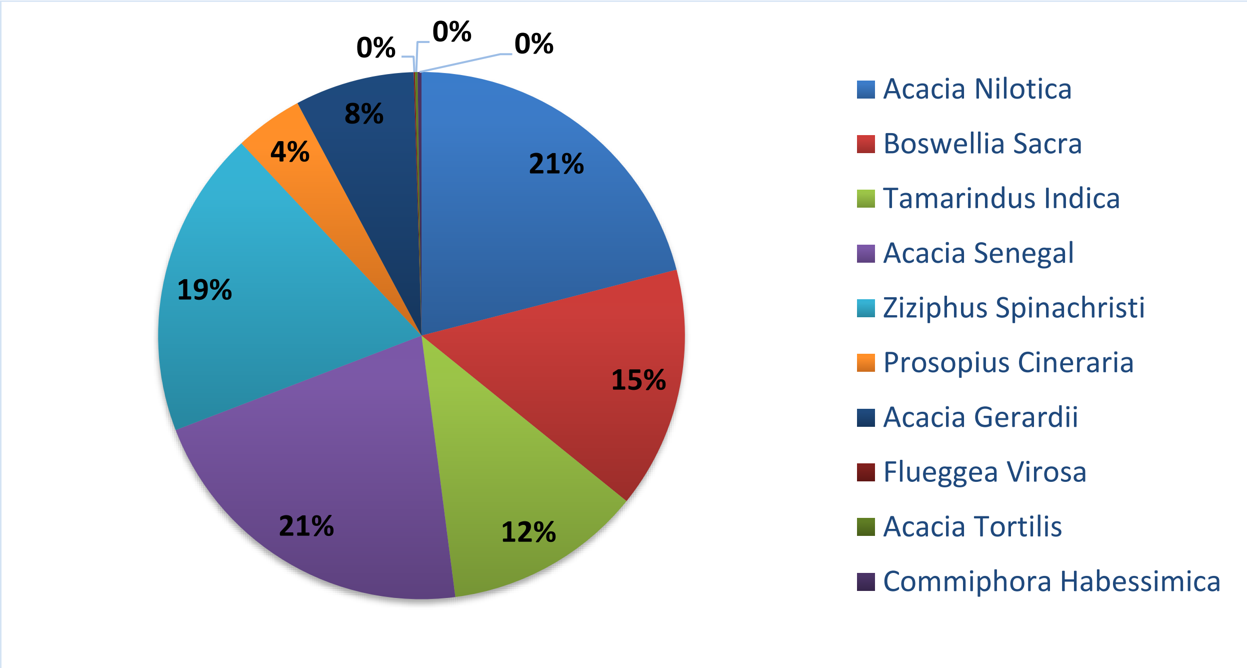

Figure 5: Pie-chart, species distribution of trees planted, trees planted Madinat al Haq

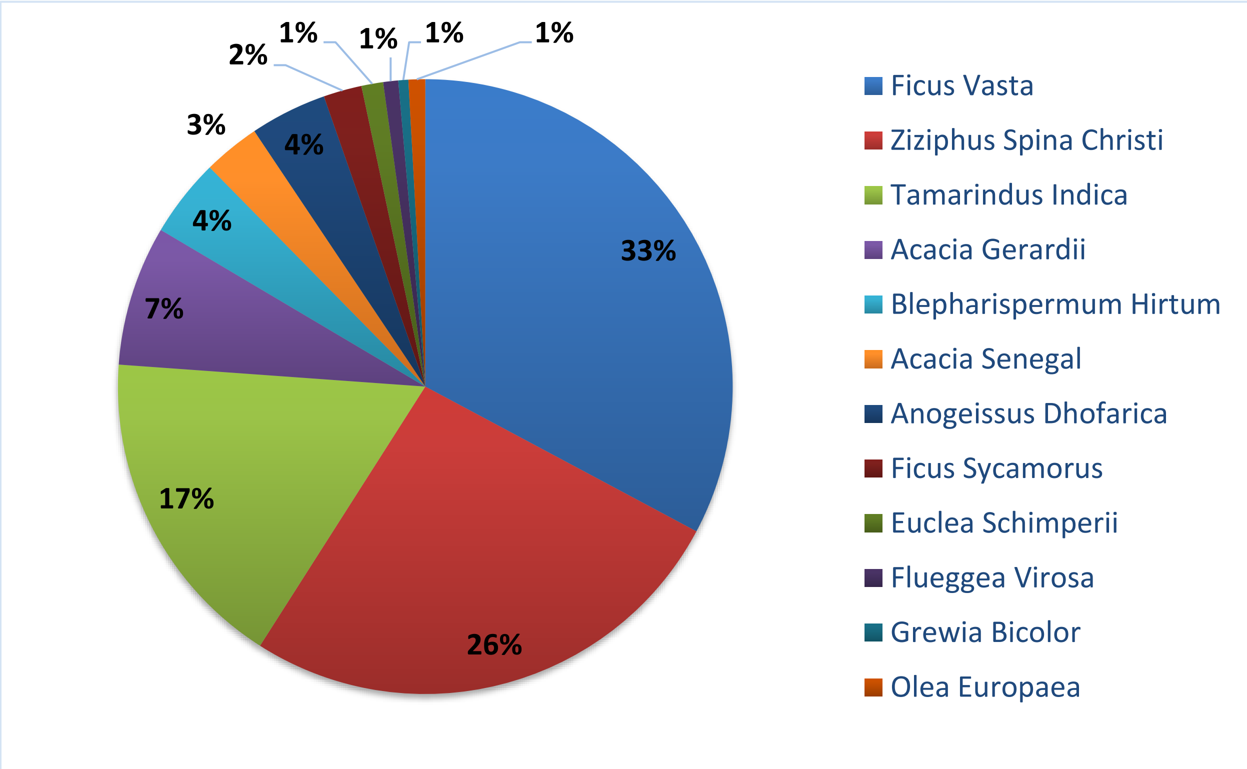

Figure 6: Pie-chart, species distribution of trees planted, Teetam

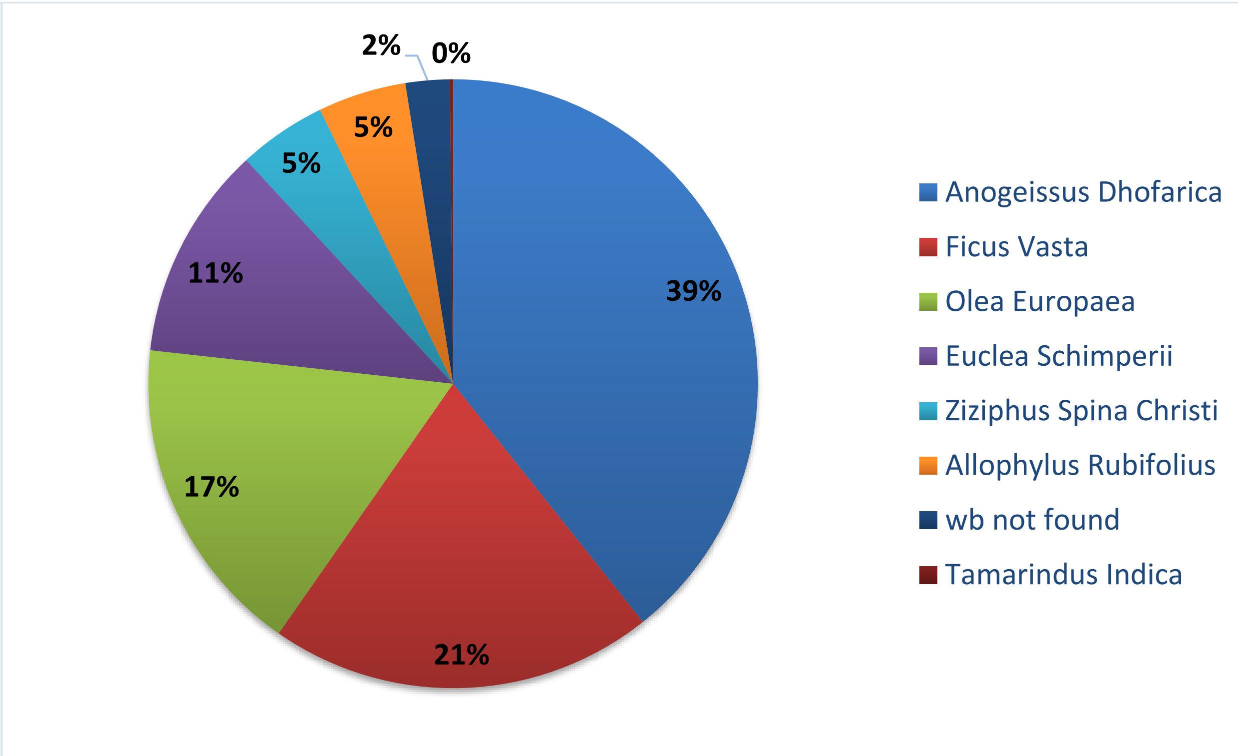

Figure 7: Survival rate across trees species in end-April 2021

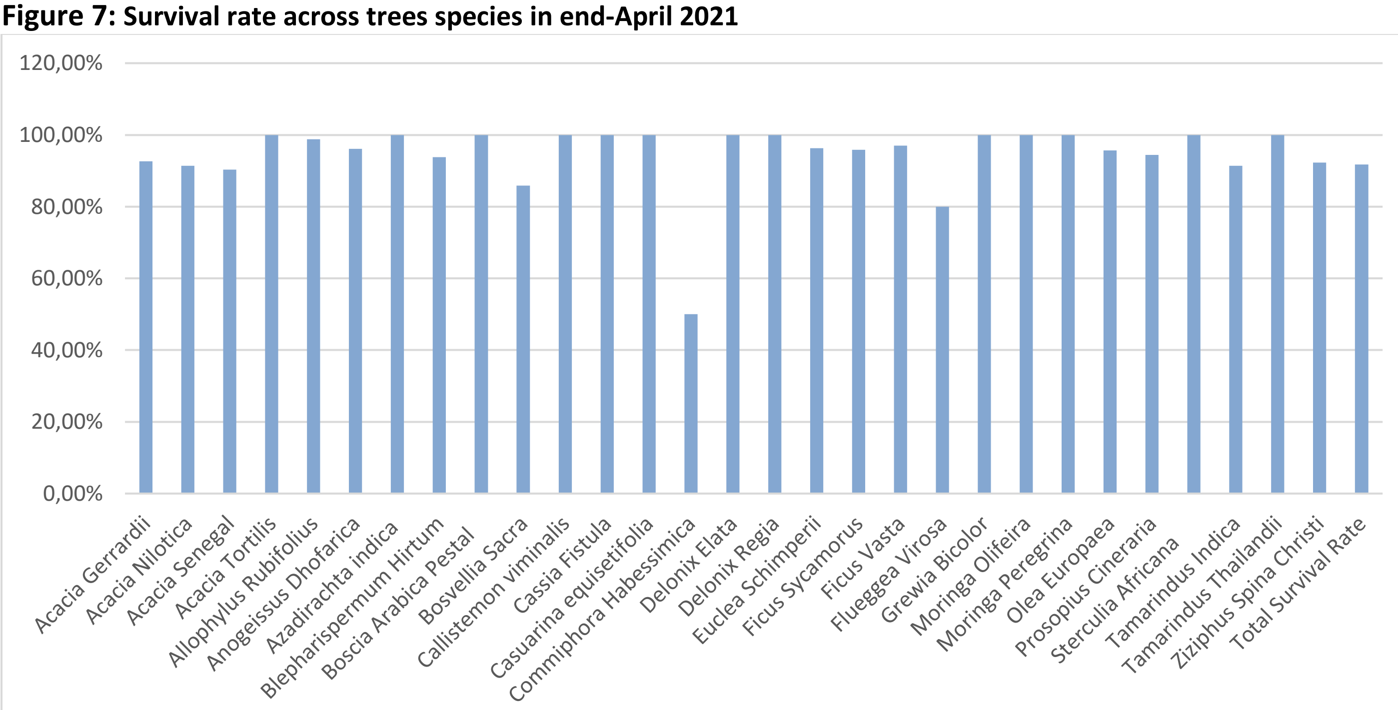

Figure 8: Tree sizes distribution, as of April 2021

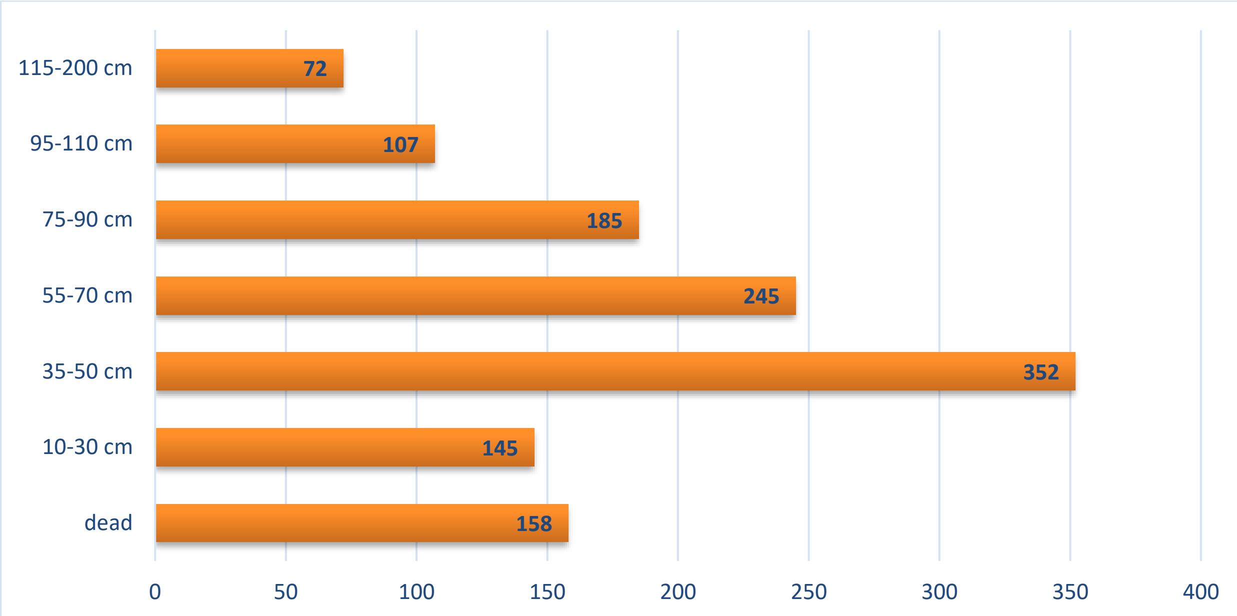

Table 6: Survival rate across trees species, April 2021

Tree Species	Survival Rate
Acacia Gerrardii	*92.66%*
Acacia Nilotica	*91.39%*
Acacia Senegal	*90.37%*
Acacia Tortilis	*100.00%*
Allophylus Rubifolius	*98.81%*
Anogeissus Dhofarica	*96.09%*
Azadirachta indica	*100.00%*
Blepharispermum Hirtum	*93.85%*
Boscia Arabica Pestal	*100.00%*
Bosvellia Sacra	*85.86%*
Callistemon viminalis	*100.00%*
Cassia Fistula	*100.00%*
Casuarina equisetifolia	*100.00%*
Commiphora Habessimica	*50.00%*
Delonix Elata	*100.00%*
Delonix Regia	*100.00%*

Euclea Schimperii	*96.34%*
Ficus Sycamorus	*95.83%*
Ficus Vasta	*97.02%*
Flueggea Virosa	*80.00%*
Grewia Bicolor	*100.00%*
Moringa Olifeira	*100.00%*
Moringa Peregrina	*100.00%*
Olea Europaea	*95.69%*
Prosopius Cineraria	*94.41%*
Sterculia Africana	*100.00%*
Tamarindus Indica	*91.42%*
Tamarindus Thailandii	*100.00%*
Ziziphus Spina Christi	*92.29%*
Total Survival Rate	91.73%

6.1 Importance of initial resources

The initial primary cause of death or poor development of the young tree, planted with the aid of the Waterboxx device/Groasis technology, other than those environmental factors which are similar to all other trees on a given site, can be rightly assumed to be the lack of strength of an individual seedling.

After seeing the results, both MECA and Qualies team leaders came to the conclusion that many of the seedlings which had been provided in the past had not been "ready" = strong enough, to be planted in such way as we did, since the Waterboxx system does stress the young trees and they get "starved", there need to be a certain readiness and reserve strength built up before they are transported and planted at site. Weak and underdeveloped seedlings had a clear disadvantage to the stronger developed ones.

Possibly due to some variation in the source of seedlings, it appears that some of the trees belonging to the same species are behaving differently on the same site, e.g., display more horizontal growth, colour variations of branches and leaves (chlorophyll saturation?) and drying out because of lack of strength.

Summarizing these points, we arrive at the following parameters as of primary importance for seedling selection: strength; readiness; age, and; origin of seedling.

6.2 Human Factors

After the "Source factor", initially the second most important cause of poor performance/low survival, had to do with the human factor. Examples of human failure and error are associated with slips, lapses and various kinds of plan mistakes/failure to comply with sound practices.

It had been a bit of a challenge to keep up with quality control while managing the planting of the trees and all other organizational factors. Yet most of the time and effort possible was spent on Quality Control because experience had taught us its importance to gain best results in terms of survival rates.

The first tree fatalities can clearly be contributed to a learning phase when the planters had to first accept and take in the repetitive learning provided by the specialists. As Quality Control and repetitive reminders continued, the favourable impact of increased quality is clearly visible in the rate of survival and progress in development down the rows of the trees planted along the fence line, where the soil conditions are similar.

As such, Human factors include the following errors or failings during the planting:

- Transportation of the seedlings, in part because of logistics challenges, notably mishaps that happened in open pick-up trucks, where the sensitive young plants were exposed to wind, sun and vibration;
- Storage of the seedlings, at site, was often without shade, which accounted for a rough transition from the protection of a nursery to suddenly being out in the open, bright sun
- Lack of knowledge and experience for many of the workers who did the planting, as none of them seem to come from an agricultural background and mostly worked in construction;
- Failure to properly manipulate/treat the root, appropriately cutting off horizontal parts, which is essential for inspiring vertical taproot development;
- Failure to prepare the holes a day before and fill with 40 litres of water. First, we used 20 litres, which we quickly observed appeared insufficient and thus raised it to 40 litres, with good results;
- Failure to place the wick under the evaporation cover! Clearly, all of those (which were still few) wbx where we found this error had occurred, the trees had died, for good reason, as the moisture in the wick evaporates out of reach of the tree's roots;
- We were advised at some point during planting to add soil / sand onto the evaporation cover, to reduce further evaporation of moisture. Once we did that religiously we could see better results in plant development;
- Selection of sites, some individual site areas had been compacted, so capillaries were not as ready to be revived as in less manipulated areas;
- Some wbx had not been closed properly, (this error was relatively easy to spot during planting) resulting in water loss from the wbx;

- Timely refilling of wbx was thwarted by issues of coordination with landowners, and also the inaccessibility of some sites by water tankers, with groups of workers having to manually fill each box with buckets, resulting in extra time and resources required.

The flora had also increased, reflecting improved opportunities for herbs, grasses, and so forth. The large holes we had applied turned out to offer a helping hand when the rains (short and heavy) arrived. Although some wbx had been lifted and displaced, the larger holes enabled more water to be collected under the trees' roots, hence doing them a favour.

6.3 Environmental factors

Obviously, the topography of the provided sites, especially in Mirbat, presents strong environmental challenges, starting with very poor soil conditions, exposure to the elements such as sun and wind, and lack of water or moisture, with little precipitation over the year.

It should be noted that the Monsoon season (khareef) does not extend to Mirbat, meaning that site did not benefit from any relief of moisture appearing in the form of fog during the hot season. Having said that, the khareef still provides the entire region, including Mirbat, with some cooling, i.e., lower temperatures, than is the case in most other parts of Oman. Yet, notably Mirbat suffers from lack of organic matter, insects, and micro biotic life forms such as fungi, bacteria and yeasts, resulting in poor soil conditions and scarcity of readily bio-available nutrients.

Once planted, there had been some signs of life around the wbx, including rodents (likely chewing off plants, leaves, shoots, roots), reptiles (creating burrows in which eggs were laid, under the wbx, changing its effectiveness), Ants (there was an entire anthill encapsulating one Waterboxx) Termites (they eat wood, not such a friend of our trees) and many others. At the Madinat al Haq site, several tracks of badgers could be seen, some even digging around wbx to get to their prey.

There are also competing plants, many of which had tried to gain a foothold in the wbx condensation collection pipes (the blue one), and their seeds were likely brought there either by wind or (more likely) by birds, as we have seen many signs of feathery visitors who must have come to obtain a drop of water from our plastic "oasis " or as we call them "kindergarten for the trees".

Some precipitation occurred only once in 12 months, a short but heavy rain, and any trees planted after October 2019 have only been in the dry period, hence having to withstand harsh conditions and suffering a lot. However, it is good to see that almost all the trees are at least still alive and well as long as water is kept filled up in the wbx.

With SERC taking the shape of a pilot project, we have opted to include a plantation in a very dry area, namely at Mirbat, in order to experiment, learn and draw lessons what can be achieved in terms of plantation and forestation. While there are signs of trees having been present at Mirbat in the past, this may be more than 50, likely more than a century ago. At the time of plantation, not a single tree appeared in that site as far as the eye could see, due to the tough hydrological conditions. Water tables are deep down, at a depth which is not accessible for young tree roots under natural conditions, and the poor surface soil plus lack of shade are not promoting seed germination and seedling development. Having said that, certain humidity finds its way up from the depths, and the question is what it will take for our tree roots to grow strong enough to meet with that and start growing independently from there. When that happens, there is also the question what it will take for the wider soil conditions to evolve, so that the living trees start developing an ecosystem with an ability to gradually retain increasing amounts of water.

At present, we have well over one thousand living trees present in the Mirbat site, with several hundred having grown there for more than two years. An increasing number of them have developed noteworthy strength and resilience, clearly suggesting they have found their own source of water, independently of the Waterboxx. We are therefore at the juncture when systematic removal of the Waterboxx appears imminent for a considerable number of trees.

Due to the challenging environment, however, we have opted to introduce an intermediate step, before proceeding to that stage. This has been to, once the plant displays increased strength and also reaches an actual size at which further growth could cause issues with removing the box, we do lift the wbx off from the plant. However, rather than removing altogether, we leave it next to the young tree, with its basic function still in place (water still in the box, the wick still pointing to the root). Therefore, the tree can still benefit from the Waterboxx, receiving some emergency ratio of moisture, from the wbx.

In this way we ensure that the trees do not suffer too much when removing the wbx (bending / cutting branches, leaves strived off, damage to bark etc.) or risking that the trees grow past the point of "no return" (which would be when the Waterboxx could not be removed anymore because of the way trees stem and branches have developed, such as too thick to remove the wbx overhead). We potentially also give the tree a better chance to grow its taproot deep enough to reach that ground water / moisture, as the Waterboxx provides for a longer time a survival measure of water.

There were many other lessons made from our observations, such as the Luban = Frankincense tree (Bosvelia Sacra) apparently preferring rocky substrate over sandy substrate. Our interpretation is, as the limb is quite soft, this very specialized tree is able to get a better and stronger hold for good stability in a rocky substrate.

6.4 Summary of success factors, risks, and hazards

From the above observations we are able to conclude on the importance of a sturdy training program for the planters, to ensure the highest quality of planting, while ensuring effectivity. These methods were also applied during our outreach and spin off activities, ensuring that the planters see, see again, do under supervision, do again, and then do alone with spot checks, all while cross training more of the staff members so each worker knows what and why the others are doing.

The seedlings need to be of high quality and strength, as well as emanate from a similar topographical area, and mature enough to be used.

Transportation has evolved to higher efficiency, where smaller numbers are transported on a daily base, to reduce exposure time.

We also improved the monitoring scheme to ensure timely refilling of wbx and monitoring of the plant's health status.

We are also able to draw conclusions on challenges, risks and hazards, which may be summed up as follows:

- Timing / Logistics: Serious preparations are required to counter challenges in logistics, such as coordinating shipping materials, organisation of local personnel and planning amongst local stakeholders.
- Ready-to-plant tree seedlings suitable for the specific areas is of high importance: Close collaboration with EA and the Ministry of Agriculture was essential for our ability to overcome this issue, yet at times some seedlings appeared weak / not ready for planting, having been for too long in the small bag, or came from a nursery located in a different topographic region (mountain versus coastal). For the future, long-term propagation of suitable seedlings is required.
- Delays due to government bureaucracy: Government bureaucracy did not impede finalization of the plantations and other activities. A specific challenge is the weak coordination between government institutions in Oman. The project has benefited from excellent relations with EA from the start. Still, lack of resources and slow responses by the public authorities delay and sometimes disrupt activities.
- External events: Pandemic restrained mobility and made planning more difficult from the spring 2020.
- Extreme weather events
    - Heavy rainfalls in June 2020 hit the plantation in Mirbat, requiring two immediate urgency operations. The project lacked contingency funds to cover this. Capacity for such action needs to be put in place.

7 Benefits

The SERC project has demonstrated that planting of native trees is possible in dry regions in the Middle East, without use of conventional irrigation, resulting in high survival rates of the planted trees and healthy long-term development. The trees and surrounding activities bring multiple benefits, as further developed in this section.

7.1 General

Reforestation is associated with multiple benefits. Ecosystem restoration and securing biodiversity are vital for securing sustainable conditions for all life in the long term. As trees establish roots and green the land, they bind water and soil, support microorganism that make the soil more productive, propel natural nutrients, provide living space for fauna such as migratory birds, while hindering erosion and desertification. Trees purify the air and counter pollution, with direct benefits to human health as an increasing number of people suffer and also die from a high presence of damaging so-called particulates in the air. By lessening clouds of dust and sandstorms, trees counter damage to buildings, farms, and also the ocean.

The trees themselves, depending on the species, produce fruits, nuts, and various other products that attain market value, while also providing shadow and beautifying the land. As a consequence, rich evidence show that tree growth raises the price of land. This is very important in dry regions where deteriorating conditions account for an outlook where land in many cases attain very low prices, a develop that can be turned on its end by tree plantations. By dynamizing the local economy, tree plantations generate jobs and help secure the livelihood of local inhabitants. Artisans may benefit directly through access to wood as well as the ability to regenerate and further create value by building on traditional cultural practices.

Another category of benefits emanates from the important stabilising impact of trees in countering climate change. The value of trees in that context has been known for a long time, but it is only recently that such benefits became a factor to reckon with for those that plant, or own the land that trees are planted on.

The following sub-sections elaborate on specific aspects, starting with water savings.

7.2 Water savings

Trees naturally require water to survive and grow. In nature, trees adapt to their natural environment. Species fitted to dry regions may draw on millions of years of evolution, rendering them the capacity to take maximum advantage of, and manage with the help of, miniscule water supplies, especially during the dry season. As an important aspect thereof, many species can collect and store whatever water is bestowed to them once they have access to humidity, and then hold out through extensive periods of severe draught. Such species tend to develop substantive root systems while, at the start, less exposed to the hardship above ground. Their ability to economise and hold on to humidity benefits the surrounding flora and fauna (Hoff, 2009).

As humans plant trees, they compensate for water scarcity by arranging with artificial irrigation systems. In the Middle East, conventional irrigations systems are devised so as to supply each tree with a significant continuous flow of water. Especially in the hot season, high evaporation levels mean that, a lot more water needs to be provided than the tree can absorb. Some 85 percent of the water provided through drip irrigation may evaporate out in thin air. Bestowed with ample of water, the targeted trees grow fast, however, without developing their own capacity to source water. In nature, many tree species have about half their body mass above ground, and half beneath it. With drip irrigation, from the start. the root instead gets used to relying on water supplied by humans, staying relatively small and close to the surface. On this basis, a tree supported by drip irrigation grows primarily above ground, looking good to the surroundings but lacking own capacity.

In the present project, we apply Groasis water-saving technology, including the Waterboxx. The Waterboxx turns water management in tree planting on its head. Instead of splashing huge amounts of water onto the tree, the location/hole where the tree is to be planted, is watered a few days before. The sapling is placed in the location, with the Waterboxx on top. Water is locked up within the Waterboxx, and then fed to the root in a highly disciplined manner, only about 50 millilitres per days. As a consequence, the young tree root is able to survive but needs to put priority on seeking out humidity in the ground. In dry areas, as humidity can be found only deep down, making the connection requires a tree species that is adapted to this kind of environment. A Sidr, for instance, typically consumes only a few litres during several months of the hot season.

The Waterboxx planting device has been tested in numerous dry regions around the world, commonly reported to save more than 90 % of the water required using alternative irrigation methods.

The amounts of water used for our plantations can basically be summed up as:

- About 60 litres per tree when planted;
- Another 10 litres have been provided per month, through refilling taking place every second month.

In SERC, even less water than that has been used, since logistical and resource issues led to disruptions and delays in refilling at times. Also, in Madinat al Haq and Teetam, no refilling was required for 4 months each year, when the trees were supplied with enough humidity by the Khareef. Compared with conventional irrigation programs, where a tree receives between 10 – 120 litres per day, let’s say 20 litres as a low estimate, the average savings stand at more than 98% thus far Further, the savings in water consumption keep increasing over time.

The tentative calculation of our water savings from project start until May 2022, is summed up in Table 7. As can be seen, a separation has been made between each of the three main sites. With the Waterboxx, refilling of water in the Waterboxx has been estimated to have been undertaken up to 30 months for the first round of plantations in Mirbat, and in the other cases up to 24 months after plantation at the most. In the case of Madinat al Haq and Teetam, however, refilling was not undertaken during the Khareef. Overall, each of the trees planted in the driest region (near Mirbat) received a total of approximately 300 litres of water. Compared to the benchmark conventional case, requiring an average of 20 litres a day, the resulting savings are quite astonishing, at 98-99 percent depending on the time of plantation (thus, we have used only 1-2% of the water that would otherwise have been consumed).

Table 7: Estimated Water Savings, plantation using the Waterboxx, 3 sites, Dhofar (draws on detailed monitoring April 2019 – May 2022, L/tree and savings overall in percent)

Water consumption calculation estimate using waterboxxes (wb)								COMPARATIVE CALCULATION				
	per each tree and wb					total ltrs water		per tree / conventional irrigation average				
Dhofar Site / planted	water use	months since planting	refill in Liters average 10 Ltr / month	Total water used per tree	trees planted	used actual	versus	Conventional plantations	Individual tree days, until 20st May.2022	estimated water usage	total if irrigated	Percent water saved
Mirbat	at start	until May.2022	total per group	until today			compare to	tree/ day liters	days since planting	so far / tree		
April 2019	60	37	300	360	754	271440	:	20	1125	22500	16965000	98%
Oct / Nov 2019	60	31	240	300	516	154800	:	20	942	18840	9721440	98%
Total this site					**1270**	**426240**	:		**2067**	**41340**	**26686440**	98%
Madinat al Haq												
November 2019	60	31	180	240	248	59520	:	20	942	18840	4672320	99%
March 2020	60	26	180	240	498	119520	:	20	790	15800	7868400	98%
April 2020	60	25	180	240	393	94320	:	20	760	15200	5973600	98%
Total this site					**1139**	**273360**	:		**2492**	**49840**	**18514320**	99%
Teetam												
October 2020	60	19	160	220	595	130900	:	20	580	11600	6902000	98%
Total this site					**595**	**130900**	:		**580**	**11600**	**6902000**	98%
TOTAL water used above sites					**3004**	**830500**	:		**5139**	**102780**	**52102760**	98%
water saved with waterboxx per tree in liters per month:					590	Liters						
water saved for 3004 trees with waterboxxes since planting					**51272260**	Liters						
Total amount of water estimated saved for 3000 trees planted with the Waterboxx, compared with conventional irrigation methods												
as of May, 20, 2022												

Source: SERC project team calculation

In total, we estimate to have used 830,000 litres supporting the 3000 trees across the 3 sites, as of May 2022. This was between 37 and 19 months after the initial plantations. As basically all Waterboxxes had been removed and refilled by that time, this is also close to the total amount of water deployed for these plantations. In comparison, reliance on conventional irrigation during the same period would have consumed about 52 million litres of water. Of these, some 50-60 percent can be estimated to simply have been lost to the air through evaporation.

Following custodial management and the removal of the Waterboxx, our trees are able to source and store water through their extensive taproot systems, similar to wild trees. Granted with a small canopy of trees at the site, a natural microclimate evolves, marked by improved soil conditions, and further reduced evaporation of water to the atmosphere.

Subtracting our water use from the total amount of water estimated to have been required in the case of drip irrigation, to support the 3000 trees planted with the Waterboxx, we can thus conclude on water savings at roughly 51.3 million litres of water by the SERC project about 3 years after project start. This represents 98 % water savings. The 2 percent consumed in our case were economized effectively by the root systems of the trees we have planted with.

Further, and importantly, the survival of our trees stands at some 80 percent thus far. We do not know what the survival rates would have been with drip irrigation at this point. The trees making it had grown bigger on average, but undeveloped root systems would have represented a poor foundation for their long-term health, making them forever dependent on human-engineered irrigation. The scope of water savings will therefore keep increasing over time.

At the Mirbat site, the keepers looking after the site have been seen to undertake some manual watering of the trees planted with the wbx, after they were removed from the trees. This has been due to their spontaneous sense of care, with no such extended water inherently part of this solution. On the other hand, this kind of add-on irrigation of independent trees is not a problem. As their root systems are in place, the established trees will not be weakened by naturally occurring events nor by humans providing some add-on watering at times.

7.3 Economy: Cost savings and revenues

Water savings represent one of the factors that tend to matter in economic terms. The significance of water savings in this respect varies, however. Where water attains a noticeable market price, the developer/project owner is bound to pay attention. Saving 98% of the anticipated water bill through the first 3 year of the project, and then continuously generating such savings from there on, may represent a game changer. Having said that, where water is provided at only a low cost, or no cost at all, that aspect may simply not be taken into account.
Water usage is associated with other cost factors, however. Of importance are the opportunity costs by way of logistics solutions required for arranging with water, and how those compare - when planting with the Waterboxx - to the case of sustaining alternative planting solutions. For some individual planting sites in Dhofar, significantly smaller than those used in SERC, the fixed cost of recent arrangements with a local irrigation facility amounted to 6000 OMR (approximately 15 500 USD). Adding to foregoing such costs, as there is no need of installing water pumps when using the Waterboxx, there will also be no costs for paying electricity to keep them running, etc.

Table 8: Contrasting cost categories, planting with the Waterboxx vs. drip irrigation

Category	Unit	Waterboxx	Irrigation	Comment on Value
Waaterboxx	Nr.	1 – 1,5 OMR*	-	Diminishes with reuse
Water	Litres (volume)	- 50 000 L**	higher use	financial vs. social
	Logistics	Variable costs	Fixed costs	labour vs. capital intensive
Maintenance	Installed System	n.a	higher	capital intensive
	manual	modest	negligible	labour intensive
Long term costs		negligible	continuous	

- This estimate is based on the assumption of reuse about 6 times
- For the 3000 trees, after about 3 yrs., use of the Waterboxx saved 50 000 L of water in the SERC plantations

On the other hand, the smaller amounts of water required to sustain the Waterboxx do come with some specific logistics cost. In the SERC project, these included hiring a water tanker on the occasion of the plantation itself, and then on each occasion when the wbx had to be refilled. Workers or, alternatively volunteers, have further been engaged to handle the distribution of water on site. In Madinat al Haq and Teetam, where accessibility was the most problematic, workers have had to carry water to each individual tree for refilling. In this case, logistic costs are "variable" and mostly wage related. Again, on the positive side, there will be less costs due to maintenance, as irrigation systems tend to get clogged and require repairs. This has to be weighed against the costs of clearing or repairing wbx, which generally are modest although could jump in the event of flooding, damage by invading animals, or the like.

A key aspect is the differentiation between short- and long-term costs. An initial investment is required or acquiring wbx, which then provide temporary support of the saplings, inducing root growth motivated by the need to source own water access and then grow independent. After 18-24 months, the job is done and each Waterboxx can be removed and reused to support a new round of plantation (in principle, up to 10 times, although 6 times is here viewed as a more probable and realistic target). Irrigation systems require initial fixed costs followed by continued significant maintenance and also costs of water use that basically never end. Table 8 provides a summary overview of key variation in the cost categories for use of the Waterboxx vs. conventional drip irrigation, drawing on the experience of SERC.

A critical cost aspect related to water-savings has to do with the systematic difference between the financial cost of saving water and the socially relevant value. In the dry hot climate of Oman, and much of the Middle East, where naturally occurring water supplies are increasingly scarce, continued water usage is associated with high external costs. Irrigation in support of agricultural activities account for some 85% of current water consumption and represents a direct cause of sinking water tables, reduced productivity in agriculture, land erosion, and so forth. At the same time, the market price of water is fixed an at artificially low level, or not charged at all if taken out of the aquifer. Also, much of the water made available emanates from sea water that has been desalinated, applying energy- and capital-intensive production processes whose costs, again, are not reflected in the pricing. Public subsidies and regulations serve to drive a wedge between the financial costs of using water and the actual value of water to society.

For the above reasons, there is a failure for the true value of the water savings stemming from using the Waterboxx to be reflected in market prices, thereby reducing demand for the solution. On the other hand, besides naturally occurring water supplies, or “quality” water produced using desalination, so-called “grey” water, or “produced” waters are available in significant volumes. These arise not as the intended outcome or investments devoted to their realization, but as a by-product of industrial processes. While not trusted for drinking purposes or for entering the food chain, given the state of overall water scarcity in Oman, such waters are nevertheless recognized as a source of potential value, following purification processes. While several kinds of usage are conceivable and have been tried, support of plantation using native trees in dry regions has been identified to represent viable use, thus playing into hand for applying the Waterboxx. As significant excess supplies of water become available this way, not just free of charge but with their utilisation viewed as beneficial from an industrial as well as societal perspective, this can serve to compensate for the downward bias in the pricing of quality water sources currently discounting the socio-economic value of water.

The economic rationale for applying the Waterboxx naturally depends on a broader range of factors, however. A fundamental consideration has to do with the cost-revenue ratio – what is the actual cost of planting with the Waterboxx and how does it relate to the resulting revenues?

To identify and narrow in on critical determinants in this respect, it is worth reiterating which are the main cost and revenue factors when planting with the Waterboxx:

i) *Main costs of planting with the Waterboxx*: Purchasing the Waterboxx (incl. costs for transport, insurance, storage, logistics); hiring workers, training workers, special preparations of the land, special planting procedures, special maintenance costs, monitoring costs
ii) *Main revenues from planting with the Waterboxx*: Foregoing costs of irrigation, saving water, revenues generated by planted and surviving trees (depending on the species, food, or other marketable items), protecting against extreme weather events, shadow,

beautification, hard economic gains due to increased land prices, benefits from carbon credits.[5]

An obvious initial consideration has to do with the cost of acquiring the Waterboxx. The bigger the scope of the project, the lower the cost of each Waterboxx. Given an effective organisation that takes advantage of each Waterboxx for replanting, not just once but several times, the average cost for each tree planted with this support may over time be reduced to only 1-1,5 OMR for large plantations. Giving scaled usage, it is also fairly straightforward to set up facilities for local production of the Waterboxx in Oman, which may further reduce the cost of each usage to perhaps 600-800 baiza per sapling supported.

On the revenue side, it is naturally critical how the planted trees are faring, and what revenue that generate. As an organic way of growing, the Waterboxx applies cost-efficient complementary solutions. Soil-amendments are natural and no need for procuring costly fertilisers of pesticides as requirements for boosting tree growth and survival. By further creating an incredibly strong and deep penetrating root system, the Waterboxx® plant cocoon makes trees planted more capable of withstanding extreme weather events, such as storms and other kinds of natural impetus.

Having said that, extensive tree plantations in Oman are for commercial, including agricultural, purposes. Such plantations typically take advantage of the most favourable land areas and rely on extensive water usage supporting rapid tree grow and high frequency by way of harvesting.

Beneficial economic returns from applying the Waterboxx may not be expected in such mainstream plantation projects, as long was water remains as heavily under-priced as is the case today. Experience by Groasis from other countries, for instance Ecuador or Spain, demonstrate that the Waterboxx can be successfully used also in support of commercial agriculture.[6] In the case of Oman, our team has experimented with native Oman fruits, such as lime, lemon and mango.[7] The focus here, however, is placed on the requirements for economic pay-off in dry areas, where irrigation is costly or even impossible, due to high socio-economic, market and logistics costs associated with water supplies, and which display high attractiveness of planting with native tree species serving as alternatives to mainstream commercial Agri-forestry products. Examples are Sidr, Luban, and Moringa, which serve as the source of honey, frankincense, and Moringa biproducts (powder, oil, etc.) respectively. Collaboration with the Environmental Authority (EA) as well as with the Ministry of Agriculture, Fisheries and Water Resources, have

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[5] Calculated net of the costs of carbon project preparation, registration, certification, see further next section.

[6] www.groasis.com

[7] Experimentation in such respects, tested by selected Omani farmers and land-owners, is ongoing having benefitted from specific research support by the Dutch Gulf.

enabled detailed calculations of the total relative costs of plantation with the Waterboxx relative the best options available, notably in Dhofar. These have concluded that planting with the Waterboxx is possible resulting in lower overall costs, while resulting in higher survival rates of saplings and comparable commercial outcomes. The results tilt even more strongly to the advantage of the Waterboxx the high the costs of water supplies, the higher the capital costs, the lower the labour costs, the longer the time horizon, and so forth.

Here, our experience in SERC complemented with follow-up consultations and involvement of feasibility-studies by the responsible authorities as well as private sector develops lend very strong support to the presence of a favourable business case. This is partly due to the high survival rates we have been able to demonstrate as consistently achievable also under demanding climatic conditions. The trees grow less rapidly above ground than when irrigated, but the soundness of their root systems account for healthy growth prospects for the long-term. The costs, on the other hand, are concentrated in the early stage, when the Waterboxx has to be procured, the ground prepared, workers hired and trained, and the wbx monitored and maintained. Once the trees are established, the long-term costs, financial as well as socio-economic, are radically reduced.

As already discussed in previous chapters, however, favourable results will require avoiding costly mistakes. Exposure to tough conditions for saplings planted with the Waterboxx carries risks, while also inducing healthier long-term development. In the Middle East, apart from Oman, examples of successful plantations can be found in Jordan, Kuwait, and Bahrain, in the UAE's Ras al Khaimah, Sharjah, and Dubai. Individual projects have failed, however, with less successful experience communicated from some projects in Saudi Arabia. On the other hand, a cheap copy of the Waterboxx, produced illegally in Saudi Arabia, have been used at least in some such cases. Cheap but less functional copies are also known of in Pakistan and China, again though applied with little success. The precise features of the Groasis Waterboxx draws on some 20 years gradual improvement by the founder, the late Pieter Hoff, who went through more than 10 stages of experimentation with different variants of the Waterboxx before ending up with the carefully balanced eventual product. Yet, although planting with the Waterboxx is straightforward and works under a range of conditions, success requires experience and judgement how to adapt the solution to the conditions that apply in the specific case.

In the next stage, important tasks include embarking on the scaling and reproduction of the plantations undertaken in SERC, in larger areas that allow for higher productivity, while also putting greater focus on species that are commercially viable. Again, Luban, Sidr and Moringa are three species of high potential interest in this context. In other cases, the prospect of diverse gains will motivate relying on a blend of complementary tree species, where some will generate outputs of high relevance and value to local communities as well as for market purposes, while others will support biodiversity, beautification, shading, and enhanced land prices.

Such plantations will result in other benefits of high importance for society over the long term, such as countering desertification, erosion, falling water-tables, etc. Those kinds of gains cannot be captured by the investors and project owners. It is for this reason, unless society is able and willing to step in and compensate for gains taking the shape of externalities benefitting wider society, that other schemes are at hand to make up the difference. This is where carbon credits appear as a source of additional monetary returns, envisaged to reward tree plantations particularly with reference to their positive contribution to climate mitigation and adaptation.

The SERC project set out from the start to prepare for registering and trading carbon credits drawing on the trees planted in the project, while also aiming to cover plantations in additional areas inspired by the project, as a basis for achieving an economically viable scale, or critical mass. Next, we review the benefits of carbon credits specifically.

7.4 Carbon credits

A potential important source of benefits from the tree plantations emanates from certifying, registering and trading carbon credits. With carbon credits is understood tradable certificates or permits representing the right to emit a certain unit, e.g., one tonne of carbon dioxide or the equivalent amount of a different greenhouse gas (tCO_2e). Starting with the Kyoto protocol 1997, a market was initiated where some parties could purchase verified carbon emission reductions from others to offset their emissions. A framework for international accounting and verification procedures was devised and keep maturing from there on.

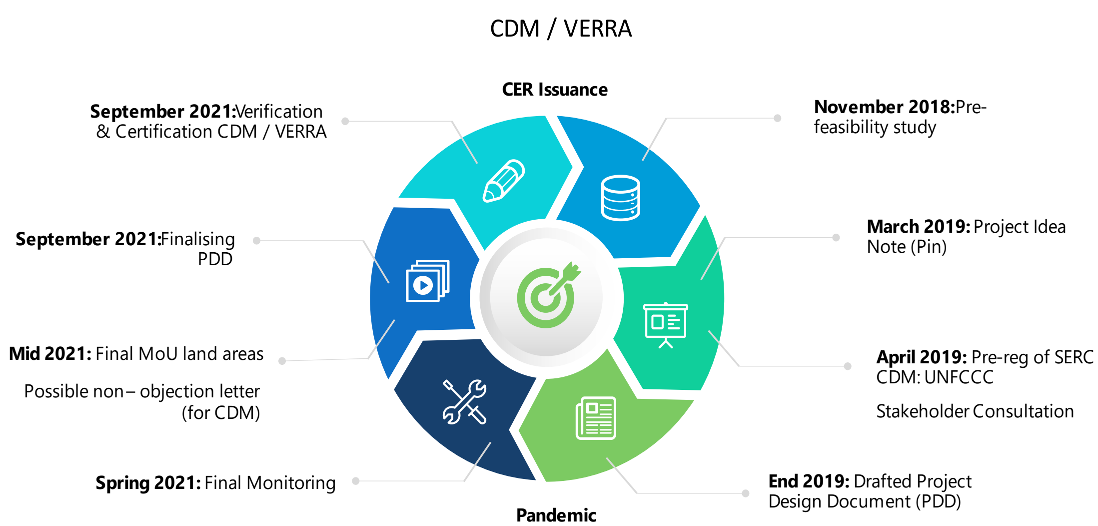
Under the UN Climate Framework Convention on Climate Change (UNFCCC), countries typically commit to achieving targeted reductions in greenhouse gas emissions through national measures. However, the Kyoto Protocol offers additional market-based mechanisms, notably the Clean Development Mechanism (CDM). Thereby, emission-reduction projects in developing countries are allowed to earn certified emission reduction (CER) credits, eligible for trading, purchase, and use by industrialised countries (public and private sector) to meet their emission reduction targets. To offer CER's, emission reductions need to be validated by Designated Operational Entities (third party validators and verifiers) registered by the CDM Executive Board – a rigorous procedure aimed to ensure claimed emission reductions are indeed "real".

From the start, the inclusion of forest plantations was a subject of controversy in international policy circles. Some have seen tree planting as an excuse for emitters of CO2 to be able to escape cutting their carbon footprint, failing to recognize that tree planting probably represents the most cost-effective way of removing carbon from the atmosphere, especially given the presence of so many other benefits in this case. Other concerns have centred on the highly fragmented nature of the carbon market, resulting in huge discrepancies between prices in different markets. Yet another concern has centred on existing forests being neglected as carbon sinks, while compensation has accepted incorporation only of new plantations.

Strong adherence to globally accepted carbon standards is key for lending recognition to any particular project. Actual compensation levels hinge on credibility while also subject to "quality" mark-ups for projects that demonstrate net-additions of the forest plantations themselves, notably by the fulfilment of various SDGs (Sustainable Development Goals), including preserving biodiversity, water-savings, soil-presentation, etc.

While optional entry points exist for arriving at internationally certified carbon credit projects, CDM has remained the clearly preferably mechanism for market certification linking carbon absorption in emerging and developing economies with offsets in industrialised countries (see Box 1). In the fall 2018, CDM remained readily available. The SERC project team thus set out entry to prepare all necessary steps for fulfilling an effective registration process, fulfilling all requirements of CDM, illustrated in Figure 9. The basic paperwork engaged highly professional international experts from the start, duly certified for auditing and verification by the relevant international governing bodies. The pre-feasibility study was completed early 2019, followed by work on the so-called Project Idea Note (PIN), in turn finalised in March 2019. That document outlined all relevant details of the planned project, including the entities involved, project location, project specifications (e.g., technologies involved, techniques, duration, scope, etc.), and expected outcomes. The UNFCCC approved and pre-registered the project on March 19th that year. See Figure 10 for an excerpt from UNFCCC website, listing the projects in Oman. The stakeholder meeting, mandatory under CDM, was held in April in Salalah, see photos 10 and 11.

Figure 9: Carbon Credit Preparation and Registration Type



Source: SERC project

Figure 10: Omani carbon credit projects pre-registered with CDM

Prior Consideration of the CDM (https://cdm.unfccc.int/Projects/PriorCDM/notifications/index_htm)

Search Criteria

Date Received from: to:
* format DD/MM/YYYY

Project Title

Reset Query | S e a r c h

Project Title	Entity Name	Host Party	Date Received
Associated Gas Recovery and Utilization Project at Khamila	The Government of the Sultanate of Oman, represented by the Ministry of Oil&Gas	Oman	29 Sep 2019
Social and Environmental Reforestation Cooperation in the Middle East	Organization for Quality and Innovation Strategies (Qualies)	Oman	19 Mar 2019
Nimr Produced Water Treatment Plant, Phase 3	BAUER Nimr LLC	Oman	17 Jun 2017

Source: Excerpt from website of the UNFCCC, carbon credit projects in Oman

Photos 10-11:

Public stakeholder meeting hosted by EA in Salalah, April 2019

Box 1: Alternative entry points to Carbon Credit Markets

In order to obtain international recognition for a carbon credit, project developers need to select a globally accepted carbon standard and follow its requirements. In recent years, improved accounting and verification has strengthened the basis for trading based on carbon sequestration through forestry projects.

Optional market entry points are at hand, comprising the following main categories:
i) Government regulated compliance carbon markets, incl. Clean Development Mechanism (CDM), and;
ii) Voluntary carbon markets, incl. Verra - formerly known as VCS – Verified Carbon Standard, Gold Standard, and Plan Vivo

Any of the above provide viable access points to carbon trading (for governments, individuals, companies or individuals) to purchase credits to mitigate or offset emissions, although the terms and opportunities vary in noteworthy respects.

From the start, CDM represented the *officially recognized* bridge between carbon absorption in emerging and developing countries, on the one hand, and offsets in industrialised countries, on the other hand. The Clean Development Mechanism (CDM) is the main compliance standard, referred to as Certified Emission Reductions (CER), with its specific hard-core methodologies to calculate emission reductions (carbon offsets).

The main alternatives, Verra (formerly known as VCS – Verified Carbon Standard), Gold Standard and Plan Vivo, are the most widely used *voluntary carbon standards* which all offer access to the markets for carbon trading, for individuals, companies or governments to purchase greenhouse gas or carbon credits to mitigate or offset emissions. In many respects, these voluntary standards adopt the same stringent criteria as CDM for proving carbon reductions. However, they rely less on government bureaucracy and non-objection procedures thus facilitating for speedier action and effective registration of a broader spectrum of multi-stakeholder initiatives, which is of high importance in countries where obtaining government sanction is hard to come by.

Following the Paris Agreement, however, CDM has gradually been phased out. While initially planned to happen in 2020, the disruptions of the pandemic led to some prolongation. Registration of new projects under CDM has ceased, but a window remains for previously pre-registered projects to complete their certification process. New projects, and those previously pre-registered but not accepted for CDM completion, however, must now register in the voluntary markets.

While VERRA and other voluntary carbon standards are partly compatible with CDM, they lack the means for official offset between the different categories of countries. For this reason, most projects subject to voluntary registration, and traded in voluntary markets, receive much lower compensation levels, in many cases just a few USD per tonnes of carbon absorbed. Having said that, the carbon markets are staged in a phase of intensive evolution. Once serious certification is at hand, for quality projects offering well documented, substantive results, other avenues, including cross-border agreements on a bilateral basis, are opening up new avenues for achieving high compensation levels. Prices in the European ETS market, hovering around 70-80 USD per tonnes of carbon, offer a benchmark upward. Part of the difficulty in bridging this gap centres on challenges in emerging and developing countries to achieve reliable and stable conditions in support of sustainability, as verified by professional auditing and verification.

Source: SERC project

The work to complete SERC's registration under CDM advanced through 2019, with two basic conditions in focus: i) signing of an MoU with MECA, as landowner, specifying the land-areas to be covered, and; ii) obtaining a Non-Objection Letter (NOL) from the Climate Affairs.

Department of MECA, in their capacity as designated authority in Oman. In the 4th quarter, MECA formed an internal committee to execute the remaining points. An updated PIN was prepared and delivered to the Climate Affairs Department on November 25th. In 2020, the arrival of the pandemic and associated lockdowns delayed processing both in Oman and in international committees and auditing activities. In the fall 2020, MECA, was closed down and replaced by the Environmental Authority (EA).

While the CDM framework remained in place, the SERC team left it open whether to complete the registration of carbon credits for the SERC project under CDM or shift to VERRA. The former continued to require an NOL, while an MoU specifying the land areas would suffice for the latter. In parallel, the compete required project plan - the so-called Project Design Document (PDD) – has remained available in draft form. The PDD is similar to the PIN, although containing more technical and detailed information on the carbon credit estimations, baseline, forecasted carbon sequestration, monitoring program and the methodologies used for all of this. The PDD was drafted in 2019 with the carbon calculations refined based on the status of trees planted thus far. Its finalization, however, hinges on the final scope of the plantation areas to be included. See Appendix 6 for further elaboration, including possible prices for carbon trading.

As the pandemic has given way in 2022, a number of new plantation activities have come on-line, partly drawing on the positive experience of SERC's pilot activities. In one case, plantation of 30 000 Luban trees is under consideration in a dry region in western Dhofar, highly suitable to the local conditions and with the Waterboxx offering a natural attractive option for their realization without dependency on scarce water resources, as elaborated above. Several other areas planned for plantation can be added. In several cases, these form part of new schemes developed to engage in scaled plantation activities, which have momentum in Oman as well as in other GCC countries in recent years. Meanwhile, the regulatory set-up for managing carbon credits have again been subject to changes while at the same time, the need of advancing to an enabling and supportive regulatory framework is now widely accepted.

In order to achieve economically viable plantation activities, using water-saving technologies, the successful completion of a carbon credit project offers important additions on the revenue side. Beyond the funding as such, however, its most important contribution may have to do with the fact that the operational model accompanying such a project creates a direct link between effective maintenance and monitoring, and the subsequent rewards by way of payments resulting only from verified and audited absorption of carbon credits. It is an often-neglected positive aspect of such schemes that they are able to focus attention on the need for different stakeholders to get together and collaborate in support of tangible results, and revenues, which can then keep flowing over extended periods of time, or 30-60 years.

7.5 Social benefits: the case of education

The benefits of SERC have not been limited to tree-planting activity and the thereby directly associated pros and cons. From the start, the rationale for the project included the importance of working out new means of diffusing information, create awareness and grow competencies in support of nature-based solutions projects. At the start, however, following the strict advice of experienced local stakeholders and advisors, the project plan did not venture into any tangible communication activity. This was partly due to the backdrop of various previous campaigns having loudly announced various environmental and other initiatives, resulting in high expectations that had then led to nothing. In order not to create another spiral of disappointments, the SERC team was serious about initiating and realizing a substantive part of the plantations, demonstrating that trees could indeed be supported, survive, and grow, before any social media, ratio, or TV attention was called for.

A first exception in this respect was the Stakeholder Meeting publicized in local media and arranged in Salalah in March 2019, as that represented a mandatory building block for pre-registering the carbon credit project with UNFCCC. That meeting met with great success and welcoming by the various actors and competencies that were represented, spanning government, business, journalists, bloggers, environmental experts, academics, and so forth. Gradually, other activities were developed and carefully initiated, in support of awareness creation and involvement by specific stakeholder categories.

Ensuing rounds of networking activities broadened connections with such groupings. Among them, an interest spread among local landowners and farmers, of which a few tested the Waterboxx. Other groupings featured industry bodies and corporation where again, some proceeded with plantations. Another effort for community outreach started with visits to schools. Interested school representatives and teachers were approached about the ideas of arranging guest lectures and subsequent plantations in their school yard, with the school children actively involved.

After a presentation to children at Mirbat school, the administration and school children made a decision, the same week, to follow up by arranging a visit to the site, followed by the planning of their own tree in the school yard.

Contacts with schools were subsequently developed nation-wide, rendering the strongest response from international schools. Over the subsequent year, lectures and plantations were undertaken at ABA, BSM, Sultan School and the Sharooq School in Sur, besides Mirbat school. Collaboration with the national museum of Oman further involved the invitation of school children from around Oman, two from each class, to take active part in a pioneering workshop for school children on "valuing water". That particular model for inspirational awareness creation, was arranged under the guidance of leading academic expertise on traditional Omani water solutions, by way of the UNESCO chair at Nizwa University. Contributions were made as well by leading international academics. [8]

Between 6-12 months after the respective school activities, follow-ups were undertaken with the responsible teachers, collecting information on impacts and lessons learned. All responsible school representatives reported very positive results. Additionally, visits to the various schools demonstrated that the trees that had been planted were doing very well. At the Sultan School the initiative led to the development of a "botanical garden", with walk paths surrounded by information material about trees and nature developed by the schools' personnel and pupils in collaboration. At a special ABA School event, the SERC team distributed an earmarked evaluation assessment of the organisation, substance, and presentation itself. The answers to this evaluation provided high scores for all the areas covered, with many respondents expressing interest in a repeat event.

Another set of evaluation forms explicitly inquire whether participants' awareness had been increased, targeting coordinators/mentors/discussion leaders at the five main events where presentations had been made to large audiences (ABA, BSM, ESO, Sultan School, Mirbat School). Through the answers collected to the special questionnaire, the SERC team could estimate the awareness-enhancing impact of our activities. This included obtaining a ranking in which areas

[8] While that particular learning model was less closely devised to reflect SERC, compared to the other school activities, it presented a holistic approach to "valuing water" which gathered inspiration from SERC. Following the pioneering event at the national museum in Oman, the model has been applied successfully at schools in Germany, Iran, Italy and South Africa.

follow-up work would be most valuable, as an indirect method to inquire about increased receptiveness and thus awareness.

The evaluation of the impact was executed by asking three key questions. The feedback from all five events confirms increased knowledge by participants, particularly in the areas of tree-planting and water saving technologies. The participants expressed interest in taking part in follow-up events where they could plant trees. All respondents were keen to contribute by spreading information about the importance of greening activities. The last question served to select which areas of environmental concern the participants believed to be of particular importance to Oman. Greening, water management and energy savings came out as top priorities.

Various volunteering tree planting groups were established, declaring their support of the project and readiness to engage in planting their own trees using the Waterboxx.

1) The extensive and diverse communication flow, coupled with interface with officials and experts, appear to have contributed to a markedly increased awareness of the need of planting trees in various parts of Oman, including the Muscat area;
2) Staring in the 3rd year of SERC, the Omani government launched related tree-planting initiatives, notably the 10-milliion trees project and the green alliance, which called on the private sector to support and engage in planting of native trees, which clearly took inspiration from SERC. The SERC team collaborated from the start with these initiatives, which recognized SERC's plantations as contributors to their objectives;
3) Several volunteer groups have started up as a result of the project, or been activated to connect with and support its activities, some of which are prepared to take active part in the planting of trees;
4) A social Media buzz was achieved, both on the Omani National channel, and within the Expatriate community, about planting trees;
5) Since project-start, a number of organisations got in touch and expressed an interest in planting with water-saving technology, e.g., the "Environmental Society of Oman" (ESO) is considering a tree planting activity for members. "Outward bound Oman" is similarly considering a tree planting program for their clients;
6) A growing interest has been visible in planting trees in Landscaping areas around Embassies, Hotels, Industrial estates, companies;
7) Three School activities, which had been promised to be achieved within the total project duration, were achieved within 11 months of starting the project, and with many times more students involved than had been foreseen at start;
8) Another 2 school activities are already planned for the coming 3 months. Additional schools have connected with us as well, expressing strong interest.

Starting in the second year, SERC featured a number of social media posts, as well as interviews on radio & TV, and also presentations in national and international conferences. Taken together, the indications of the impetus include the following.

7.6 Environmental and Economic value of planting with native tree species

One of the reasons to plant native trees in Oman with our project is to further strengthen the survival of certain tree species, as some of the native species are in decline here due to environmental pressure, such as mentioned above (over grazing, desertification, lower ground water levels, illegal wood cutting, etc.). Many of the species are valuable to Oman not only because they are unique to its environment and various ecosystems, but many bring medicinal, historical, social and economic benefits.

The value of restoring of unique ecosystems is well documented and, in the case of SERC plantations, several significant improvements were verified. These include the return of particular insects, butterflies and birds; re-appearing in tandem with the growth of the trees.

Several of the species planted with in the project have long been viewed by locals as associated with medicinal virtues One of these, Arak (Salvadora Persica) the toothbrush tree, has been used for making toothpaste from its extract. Another example, Castor (Rizinus communis), is used as purgative; Henna (Lawsonia inermis / L. alba) for cuts, pains and hair loss; Mangrove (Avisennia Marina) used for boils and abscesses; Myrrh (Commiphora Myrrha) for abdominal pain, digestive and respiratory disorders; Neem (Azadirachta Indica) for skin problems, Sidr (Ziziphus Spina Christi) for hair care and against hair loss, and many others such as Acia varieties, gum Arabic.
Historical value includes the trading of Frankincense, of high importance to Omani society and international linkages since several millennia. Separately, in traditional Omani culture, prominent local meeting places were organised under certain old trees (such as the old fig tree “Ariesh” near Qairoon Hereti).

Social value further flowed from the creation of gathering places for families and groups arranged under trees taking advantage of their shading, e.g., enabling the arrangement of picnics, or the collection of certain fruits on a seasonal basis, hiking and sightseeing as in the case of visiting the ancient Baobab trees near Mirbat.

Directly monetised economic value was gained through harvesting such as frankincense resin, fruits such as tamarind, figs, mangoes and other fruits, nuts, and many other raw products.

The SERC project, abstaining from monoculture, has aimed from the start to arrange with healthy combinations of tree species planted adjacent to each other, while also selecting locational conditions suitable to each. Taken together, the project has added value by cherishing and communicating the importance of biodiversity and raising interest in planting a range of native species which have become increasingly scarce, some of them outright in peril of disappearing. As a conspicuous example, the Frankincense tree, Bosvellia Sacra, is known to be in decline. [9]

Another species planted with, nowadays in limited supply, is the Anogeissus Dhofarica. Belonging to the Combretaceae family, this species is found in Oman and Yemen, where it is endemic to the South Arabian fog woodlands, shrublands, and dune ecoregion. According to Patzelt (2014), this species is classified as “under threat from development, agriculture, biological resource use, recreational activities and potential climate change”. The same source classifies as near threatened Blepharispermum Hirtum, a species representing one of the main constituents of the Anogeissus Dhfarica forest, unique in the world. Native to Oman and Yemen, this tree grows in escarpment woodland habitat and is now vulnerable to overexploitation for its wood.

Again, these various species have featured in SERC plantations, with the ambition of raising attention for their cultural and social value, beside the natural heritage their represent. By increasing awareness among different social groupings, the objective of SERC includes the promotion of innovation, i.e., ways of further developing viable strategies of sustainable value creation partly drawing in natural diversity.

8. Conclusions and Recommendations

Through a wide spectrum of activities, undertaken since the start of SERC late fall 2018, the project has proven that plantation of native trees using water saving solutions is possible across dry, degraded land areas. Challenges of sinking water tables, desertification, erosion, and the sheer disappearance of biomass and naturally occurring native tree species can be countered by applying so-called Groasis technology, including the Waterboxx.

By planting across three main testing sites in Dhofar, offering a varying set of conditions, the project has consistently demonstrated that savings of some 98 percent of the water conventionally used in support of drip irrigation, can effectively be saved while enabling about 80 percent survival rates for a spectrum of attractive native tree species.

[9] For example of articles highlighting this development, see: https://www.savefrankincense.org/frankincense-declinehttps://www.abc.net.au/news/2011-12-21/frankincense-industry-in-decline/3741974https://www.usatoday.com/story/news/nation/2019/07/02/frankincense-trouble-iconic-resin-boswellia-tree-decline/1627497001/https://www.bbc.com/news/science-environment-16270759

The key devise deployed in support of such tree planting, the Waterboxx is needed only through the first few years following plantation. Once the early stage of plant life has been passed, through which the saplings have been stimulated and induced to develop deep root systems of their own, the Waterboxx should be removed and then re-planted with, to support plantation of another young tree, and then yet another, and so on.

The planting solution applied in SERC is associated with numerous benefits, besides water savings and high survival rates. Evaluating the benefits of planting this way requires considering the opportunity cost. Planting trees with drip irrigation is expensive and, in dry regions, both ineffective and environmentally damaging. High fixed costs of putting in place equipment for irrigation, e.g., by way of grid structure and pump installations, are accompanied by costs of maintenance, replacement of pumps and tubes after a few years, and so on. Groasis technology, by contrast, uses no pumps, tubes, or energy, and consumes very little water. Mother Nature has always been able to grow without irrigation. With the use of the Groasis Technology the planter can again use that force to grow sound and healthy products, by mimicking nature.

The benefits of the tree planting embarked upon by SERC are better (less) appreciated the more (less) accurate the pricing of water resources, given manageable (inflated) labour costs and appreciation (neglect) of rural employment opportunities, adversity towards (more subsidised) capital costs, and the greater (weaker) the extent to which long-term benefits are appreciated. Yet, far from the full scope of societal benefits will be taken into account by investors and project owners. Partly to compensate in such respects, carbon credits, whose pricing stand to be upgraded by add-on benefits associated with fulfilment of several SDGs, can further add to the business cases.

Tree planting projects bring the potential to sequestering carbon from the atmosphere, helping to combat climate change. The SERC project set out from the start to arrange with the preparation and registration of carbon credits, to generate such complementary long-term benefits. The project is pre-registered by UNFCCC under CDM since April 2019 and staged to be fully certified for carbon trading using best available certification mechanism, once the precise land area to be incorporated has been determined and agreed with responsible landowners, as verified by signed MoUs.

While tree species traditionally grown for commercial purposes have not been the focus on the SERC project, the native species planted with offer numerous important benefits. Some provide living space for fauna such as migratory birds, improve the soil through increased bio activity and hence raising the economic value of the land, combating desertification and raising the water table, lending support to the livelihood of local inhabitants and artisans through its products, facilitating learning and knowledge exchange, and many others.

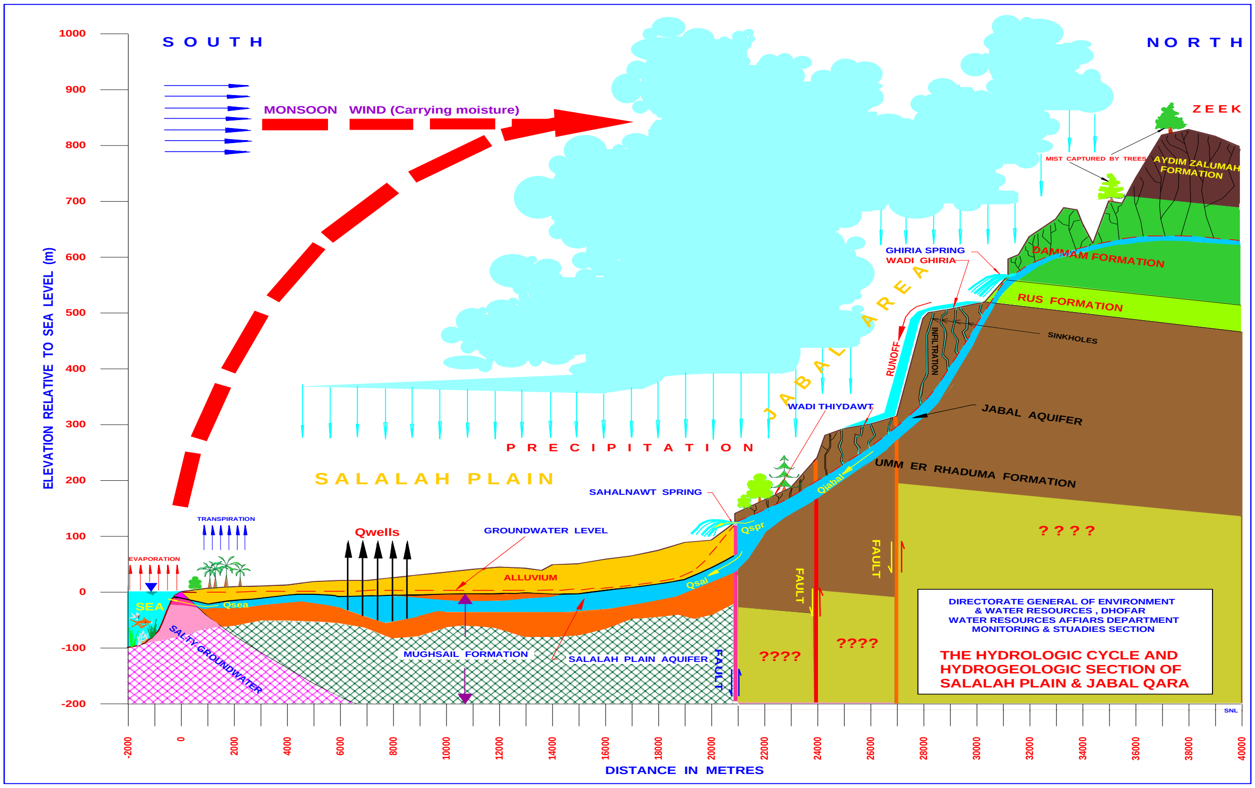
Some gains emanate from biodiversity as well as values associated with heritage, culture, health, food, and experience industry more broadly. Additional opportunities abound, such as plantation with Omani mango and lemons, or figs. Testing in such respects is under way and further expected to take off as the spin-off projects as well as wider diffusion, replication and scaling of the SERC experience is set to go forward in new activities.

Educational and social activities represent another important real of activity where SERC started out with a low profile, but gradually engaged in far-reaching communication and diffusing work, including with farms, industry, volunteer organisations, schools, museums, and with policymakers. The numerous activities and contacts have clearly contributed to the intensified policy effort in Oman to realize large-scale plantation projects and also the realization of other nature-based solutions, e.g., those related to wetlands and mangrove forests in coastland regions. Some of the most important include the government-powdered 10 million trees project, and the Green Alliance in Oman. It remains to be seen how the combination of these various initiatives can realized stronger contributions to sustainable development in Oman, the Middle East and beyond.

Based on the experience of SERC, integrating of a comprehensive set of activities in support sustainability, beyond the planting of trees as such, is of high importance. Sufficient resources need to be allocated to training, monitoring, maintenance, and also social engagement, with awareness creation and outreach. Budgets need to account for unexpected costs such as managing extreme weather events.

Appendix 1:

Figure A1: Hydrological section and cycle of the Salalah basin, Dhofar, Oman

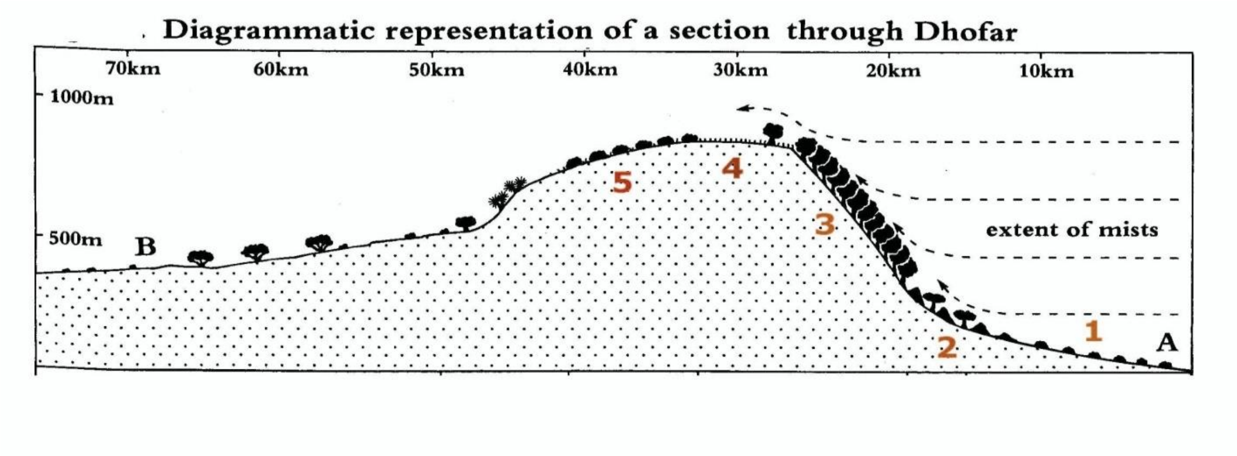


Source: Provided by Prof. Mahad Shamas

Figure A1 illustrates the relationship between the monsoon, mountain vegetation's, the fog water interception, landforms, and the recharge of the Salalah plain aquifer, in a profile from the mountain to the sea.

Appendix 2:

Figure 2A: Phytogeographic zones of Dhofar, Oman



The ecosystem of the Dhofar region supports more than 750 terrestrial plant species, of which about 50 are endemic (Miller et al., 1988).

See above an ideal transect stretching, from the right-hand side, south northwards, i.e., starting with the coastal plain by the Arabian Sea (A) to the southern slopes of the coastal range, and then descending gradually through the dry plateau and the vast desert area down to the Saudi-Arabian border (B). The distance covered by this illustration is about 300 kilometres. Listed from 1 to 5 are the most interesting phytogeographic zones, as follows:
1. The coastal plain – Mostly sandy shores and steep rocky cliffs.

2. The southern slopes of the coastal mountains – The slopes and valleys of the coastal range facing the Arabian Sea, covered with dense woodlands due to the monsoon.

3. The northern mountain slopes towards Thumrayt - In this north-facing area (900-700m), beyond the coastal chain, the effect of the monsoon moisture fades away.

4. The pre-desert area - Further inland, passed the dry plateau, a large area slopes gently from 700 to 400 m of altitude, featuring small, rounded, rocky hills and low depressions excavated by multiple wadis.

5. The desert – Stretching from Thumrayt, 200 km northwards to the Saudi-Arabian border, descending from 400 to 250 m of altitude, a desert-looking land marked by low round-shaped rocky hills and pebbled plains alternated with flat sandy areas.

Appendix 3:

Organisations/stakeholders engaged by SERC

The SERC project has featured contacts and engagement by a significant number of actors and stakeholders in Oman, and also some in other countries, and internationally. Here below we list some of the important connections with Omani.

Selected meeting activities that were part of the SERC project

1) Consultations/contacts with government institutions, notably the Ministry of Environment and Climate Affairs (MECA), which was reorganized as the Environmental Authority (EA) during the 2nd yr. of the project. The contacts concerned both the headquarters Muscat, and the well-developed special establishment Dhofar. All three main sites consisted of land belonging to MECA/EA. The cooperation was particularly close on the preparation and implementation of plantations, obtaining saplings which was consistently handled by MECA/EA with great effectiveness, and increasingly on the arrangement of maintenance. Other ministries with which their contacts included the Ministry of Agriculture, Fisheries and Water Resources, the Ministry of Commerce and Industry, Ministry of Education, and also public authorities such as Ithraa and the Research Council, both of which were submerged by ministries during the project.
2) Other actors in Oman:
    a. Meetings held with stakeholders, companies, university, social media, friends of the environment, local farmers, village elders, landscape architects, horticulturists, video bloggers and Oman TV;
    b. Meetings held with school representatives, pursuing contacts with about 10 different schools, included counselling connected with management of planted trees, as well as educational tips, etc. Actual plantations were undertaken at six international schools, in Dhofar, Muscat and Sur, executed through co-creation with teachers and pupils;
    c. Exchange of research and project experience with experts at several Omani universities, including Dhofar University, SQU, National University, and Nizwa University;
    d. Contacts with several farmers and plantations at various farms, in Dhofar as well as in other parts of Oman;
    e. Collaboration with the Dutch embassy, enabling testing of the Waterboxx for the purposes of growing fruit trees;
    f. Planting at hotels and private construction sites;
    g. Meetings held with volunteer groups, at least in two different configurations;
    h. Contacts with the Environmental Society of Oman (ESO) which included some join activities;
    i. Meetings held with local fisherman in villages;
    j. Meetings held with Oman Botanical Garden, including several visits to their main facility and advice regarding species and conditions for planting;

k. Meetings with Industry estate company, including Madayn which led to their planting of 50 trees using the Waterboxx in Sur and developing plans for reserving 40 hectares for greening, part of this with plantation with the Waterboxx, without irrigation;
l. Plantations with the Waterboxx by Oman LNG in other areas in Sur;
m. Planting with the Waterboxx by PDO testing its functionality in 11 different sites, during 2022;
n. A collaboration with Sohar Port and Sohar University testing the combination of growing seedlings which hydroponics and planting with the Waterboxx, starting in 2019 onwards;
o. A stakeholder seminar was hosted by EA in January 2022, devoted to sharing experience on the Waterboxx with various government organizations and other sectors;
p. Visited Nizwa Technology Center and 7D Cinema site for possible greening engagement, contributing with planting using water-saving Groasis technology within the framework of a planned botanical garden;
q. Contacts pursued with Children's Public Library about planting trees;
r. Contacts pursued with the National Museum, including joint workshops with youth at the National Museum on November 13th, 2019, for a 2nd joint workshop in the spring 2021
s. Meeting held with Outward Bound Oman;
t. Presentations of the project at numerous conferences and events, including at the EA in Dhofar,27,28 July 2022, and the Global Forum in Muscat, October 2022.

Photos A3: 1-2

Presentation by Thomas Andersson on behalf of the SERC team, Seminar at EA on SERC project, January 17, 2022

Photos A3: 3-4

Presentation by Wafa al-Maamari of the SERC ream, at conference on Sustainable Development organised by EA in Dhofar, 27-28 July 2022

Appendix 4: Photos from SERC sites in 2022

Photos A4: 1-5

From Mirbat Plantations upper spring 2020, lower fall 2022

Photos A4: 5-7


From Madinat Al Haq Plantations, fall 2022

Photos A4: 8-9


From Teetam Plantations, fall 2022

Appendix 5: Monitoring and Maintenance Activity

Photos A5: 1-4

From SERC Plantation sites, snapshots from monitoring work

From SERC Plantation sites, snapshots from monitoring and maintenance work

Appendix 6: On the Returns from Carbon Credits

Following agreement on the land areas to be incorporated, the PDD already prepared for the SERC project can be finalised, including the monitoring plan and predictions for the carbon sequestration to follow during project life span. As the Clean Development Market (CDM) mechanism which was instituted through the Kyoto Protocol has come to an end, the existing pre-registration may be complemented with fulfilment of the requirements for the project to be certified for international carbon trading based on VERRA.

The conditions for carbon registration practices by VERRA are similar to those for CDM, e.g.., in regard to landowner engagement, except that no official No-objection letter is required. Before the registration is complete, a 3rd party verifier will have to visit the sites for auditing. A relatively favourable arrangement has been pre-ordered for this purpose. The need of auditing will remain equally important throughput the lifetime of the project.

The associated costs are relatively burdensome in the years before the trees have grown to full scale. Smart arrangements, such as auditing via satellites and smart apps, can be applied to reduce the need of visitors by international auditors, thus keeping the costs down.

The level of compensation attained by trading in the end will depend on two factors: i) the amount of carbon absorbed, and; ii) the price obtained.

Each tree will approximately sequester 0.05 metric tons of CO_2-equivalents per year, which equates to the carbon emissions of driving a car some 200 fewer km in a year. Absorption picks up as the trees grow bigger, however. Using the above rule of thumb, 20 trees absorb 1 ton annually, 200 trees 10 tonnes. We may estimate that as the average annual rate of absorption per hectare in SERC during the life span of the project, given that the plantations continue to do well. The duration of the carbon credit project is set at 60 yrs.

In the most established markets, the price for absorbing a tonne of CO_2 currently hover in the range of 70 USD. Rates well above 100 USD are widely expected in the near future, given the growing pressures on governments and emitters of greenhouse gases to limit their footprints.

Despite the progress made, however, some 80 % of global carbon emissions are still not covered by carbon pricing. The carbon sinks of existing forests are equally neglected. Pricing on the ground in developing markets, under the aegis of carbon credit registration in the voluntary markets, are often limited to a few USD per tonne. These conditions are deeply unsatisfactory and significant adjustments are inevitable. Already now, certified quality projects achieving multiple SDGs, such as SERC, enjoy various channels for achieving compensation levels that approach those in leading markets for carbon trading.

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