

WASTEWATER REUSE PROJECT NABLUS

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Irrigation Management and Operation Plan

Revised 2nd Draft Version

July 2020

Implementation of Wastewater Reuse Project Nablus BMZ-No: 2016 67 823

Irrigation Management and Operation Plan Revised 2nd Draft Version

July 2020



In cooperation with Fichtner Water & Transportation GmbH as JV partner and
Palestinian Hydrology Group (PHG) as sub-consultant

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Implementation of Wastewater Reuse Project Nablus **BMZ-No: 2016 67 823**

Irrigation Management and Operation Plan **Revised 2nd Draft Version**

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ABBREVIATIONS

a.s.l.	Above Sea Level
B/C	Benefit/Cost (ratio)
BOD ₅	Biological Oxygen Demand
CAPEX	Capital Expenditures
COD	Chemical Oxygen Demand
DCF	Discounted Cash Flow
DCI	Ductile Cast Iron
DN	Nominal Diameter
du	dunum (1,000 m ²)
ESIA	Environmental and Social Impact Assessment
FAO	Food and Agriculture Organization of the United Nations
FMC	Farmers Mobilization Campaign
FHW	Farm Head Works
GFA	GFA Consulting Group GmbH
ICA	Israeli Civil Administration
ILS	Israeli New Shekel (1 EUR ≈ 3.82 ILS)
IMOP	Irrigation Management and Operation Plan
IRR	Internal Rate of Return
KfW	Kreditanstalt für Wiederaufbau (German Development Bank)
LSA	Land Suitability Assessment
MCA	Multi-criteria Analysis
MoA	Ministry of Agriculture
N	Nitrogen
NB	Net Benefit
NGO	Non-Government Organisation
NM	Nablus Municipality
O&M	Operation & Maintenance
OPEX	Operational Expenditures
PCBS	Palestinian Central Bureau of Statistics (PCBS),
PHG	Palestinian Hydrology Group
PWA	Palestinian Water Authority
RDI	Regulated Deficit Irrigation
TDS	Total Dissolved Solids
ToR	Terms of Reference
TSS	Total Suspended Solids
WRPN	Wastewater Reuse Project-Nablus
WUA	(Wadi Shaeer) Water User Association
WWTP	Wastewater Treatment Plant

EXECUTIVE SUMMARY

The Irrigation Management and Operation Plan (IMOP) describes the Wadi Shaeer irrigation area, establishes irrigation water needs, assesses farm and area economic aspects, calculates a tariff that will cover the costs of treating wastewater and delivering it to the farmers and the operation of the system by Nablus Municipality (NM) and The Wadi Shaeer Water User Association (WUA). It also briefly discusses the organisational aspects of the Wadi Shaeer operation, pending separate reports of the Consultant on this issue¹. Tariff calculations are not yet final as these depend on the final design and the partition of budget over electrical-mechanical components and civil works (as these have different O&M requirements and different depreciation periods).

Chapter 1 describes the project area. The proposed project area differs somewhat from the original area planned by NM based on consulting reviews. Compared to the originally defined area it extends to the west and northwest based on requests of farmers in that area. It also excludes (on request of Nablus Municipality) the Outside Pilot Scheme², areas located higher than 290 m a.s.l. and the areas that the Israeli Civil Administration (ICA) has marked as archaeological sites as those should not be affected by irrigation activities³. The area of the newly proposed WUA boundary is approximately 3,378 dunum (du)⁴ without agricultural feeder roads, thus larger than the originally proposed area in the Terms of Reference (ToR), which foresee 2,800 du. According to the Land Suitability Assessment (LSA) about 374 of this area is permanently unsuitable for irrigation, bringing the maximum irrigation area to 3,004 du. Due to the extraordinary complex landowner situation it is not realistic to assume that more than 90 percent of this area would ever be irrigated. The proposed revised irrigation area is therefore in line with the ToR.

Climatic and soil conditions are favourable for growing any type of subtropical crops, especially fruit trees. Rainfall variability requires full irrigation almost year around, with peaks in June and July. However, due to the suitability of soil and land, not all soil is suitable for each crop; this is discussed in Chapters 1 and 2.

Socioeconomic data indicate that agriculture is not a major economic activity in the area and that a relatively small part of labour in the area is generated by agriculture. By implementing the Project this will significantly change; Net Benefit from farming is expected to increase by a factor 35 and labour will increase by a factor 3 once the irrigation facilities are fully developed and exploited.

The Nablus West Wastewater Treatment Plant (WWTP) produces a fairly constant daily amount of wastewater (13,000 m³/d in 2019) in the summer half of the year. In the three most precipitation-rich months of the rainy season (December through February), the average inflow into the WWTP is approximately 10 percent higher, due to rainwater infiltration into the

¹ Revised organisational report, training needs assessment, capacity building and training programme.

² The Outside Scheme is not covered by the planned irrigation infrastructure but is under the organisational aspects of the project since the WUA will be responsible to administer it as well.

³ This is the opinion of NM; the WUA believes it is possible to use these areas albeit under prior approval.

⁴ One metric dunum is defined as one decare (1,000 m²).

not completely separated wastewater collection system. As hardly any irrigation takes place in this period, this water is lost for irrigation purposes.

Chapter 2 describes issues related to the cropping pattern. The cropping pattern that was proposed in the feasibility studies could not be confirmed during the analysis carried out by the Consultant. This has several reasons. First, the feasibility studies overestimate the yield of pecan by a factor of 10. Second, the Land Suitability Assessment shows that not more than approximately 336 dunum can be planted with alfalfa and/or pecan/alfalfa intercropping. From an economic point of view, both crops are not attractive; with a low B/C ratio of 1.13 for alfalfa after discount. It is therefore not likely that many farmers will take the risk cultivating alfalfa. These prospects are confirmed by experiences in the Outside Pilot Scheme and in the Jenin Wastewater Reuse Scheme. In both, alfalfa has been uprooted and replaced by fruit trees. Another aspect is that for pecan, farmers must wait 9 years for having a commercial harvest and 17 years before having return on investment; even combining pecan and alfalfa will not change that very much; the moment of return on investment will then still be 16 years.

Without even knowing the low B/C ratio, few farmers interviewed during the farmer survey opted for alfalfa (3 out of 354 interviewees). The economic feasibility of alfalfa is low compared with fruit trees. The ambrosia weed, shown to destroy the alfalfa crop in the Outside Pilot Area, is omnipresent in the irrigation area and soils may not be suitable for growing alfalfa, in particular not with subsurface irrigation. Moreover, farmers seem to be more comfortable with fruit trees and prefer fruit tree crops in general.

It is unclear how many dunum will be cultivated with each of the fruit tree crops selected for the cropping pattern modelling (pickle olives, apricots, almonds, figs and grapes⁵); this will only be known when farmers prepare for planting seedlings. For planning and modelling purposes the Consultant therefore proposes pickle olives for the marginal soils and almond, apricot, fig and grapes for the more suitable land. Such arbitrary decision was needed to establish model calculations on water use and economic outputs in the IMOP.

Strategic reflections on likely future developments of the cropping area lead to the assumption that almost half of the irrigation area will be planted (or remain planted) with olive trees (confirmed solidly by the Ministry of Agriculture), most of the other half with other fruit trees. Possibly a few hundred dunum will be under alfalfa cultivation or be used for intercropping. However, the real cropping pattern depends the choice of the farmers.

Chapter 3 calculates water requirements. The base of these calculations is FAO Manual 56 and the FAO software CROPWAT-8. Despite initial difficulties in obtaining data, Penman reference evapotranspiration values could be calculated for the Nablus meteorological station. The obtained values have been corrected for the fact that the Wadi Shaeer irrigation area is approximately 300 m lower in altitude than the Nablus meteorological station.

The relevant FAO crop factors and leaching requirements have been used to transpose the Penman reference evapotranspiration to a yearly irrigation requirement for each crop, as well as the required peak demand. After deducting effective rainfall, figures for the yearly amount

⁵ As mentioned in the Farmer Mobilisation Campaign Phase 1 final report, grapes are a preferred crop due to producing high income, but at the same time farmers are hesitant to embark on grapes as the needed investments are very high.

range from 505 mm/year for olives under deficit irrigation to 1,333 mm/year for alfalfa and 1,358 for pecan. Peak water demands range from 3.3 mm/d for olives under deficit irrigation, 7.3 mm/d for alfalfa to 9.5 mm/d for pecan.

Regarding the total annual water use, crop development factors have been introduced as well as the percentage of the irrigation area that will be irrigated. It is assumed that for all fruit trees, 80 percent of the area will be irrigated during the first five years and 90 percent after this period. The calculations assume a different percentage for alfalfa and for intercropping; here it is assumed that that 100 percent of the potential area will be used.

Yearly crop water needs depend on the scenario applied. For the most likely scenario 5, full reclamation, olives and fruit trees without alfalfa and intercropping, the calculations show that 1.00 million m³ water will be needed in year 1, 1.74 million m³ in year 5, and 2.25 million m³ in year 30. Other scenarios with alfalfa and intercropping predict yearly water uses that are slightly higher. This assumes using *deficit irrigation* for olives earmarked for oil production, but not for other crops⁶.

Comparing the available wastewater with the irrigation demand during peak periods shows that until 2031, roughly 70 percent of the available wastewater can be used for irrigation during these stages⁷, except during the first 4 to 5 years when trees are still small. After 2030, the surplus of treated wastewater will increase and can be used for extending the irrigation area, for growing more water intensive crops, or for exporting water to other areas, if feasible. Calculations undertaken for the IMOP modelling suggest that – under this scenario - about 30 percent of the yearly available wastewater can be used for irrigation in the years 2027 - 2031. With a full reclamation scenario, this percentage will not exceed 36 percent. This contradicts earlier findings of the feasibility study for the project. The main reason for that is that the feasibility reports have not recognized that the peak demand is the limiting factor for the development of the irrigation area. This was already mentioned in the Inception Report and is again confirmed by the more comprehensive IMOP calculations.

Chapter 4 assesses economic aspects based on collected data (comprehensive data was collected on yields, prices, investment costs of seedlings and irrigation systems as well as operational costs for agrochemicals, machinery, and labour).

Based on revenues and costs, Net Benefits, and benefit/costs (B/C) ratios over 30 years were calculated for mature crops. Discounted B/C ratios against present land use vary between 1.2 for alfalfa, around 1.4 for almonds and pecan, around 1.7 for different types of olives and between 1.7 and 2.4 for apricots, figs, and grapes. This indicates that alfalfa, almond and pecan are high risk crops that may for that reason be avoided by farmers; all other crops have much lower risks.

Labour-based B/C ratios show that values are more or less the same for all fruit trees, including olives (around 2.0). These ratios are high for alfalfa and pecan (5.6 and 3.9 respectively) as

⁶ This approach could be applied to apricots, figs and grapes, though deficit irrigation for these crops is more complicated to apply and accompanied by higher risks.

⁷ Assuming that the WWTP will be equipped with a second production line not later than 2030.

these crops require mechanical harvesting to a large degree. Hence, the availability of labour does not significantly influence the crop choice.

The average undiscounted Net Benefit over 30 years ranges from around 450 Israeli New Shekel (ILS)/du for alfalfa, around 1,000 ILS/du for oil olives, around 1,150 ILS/du for pecan, around 1,450 ILS/du for almonds, around 1,950 ILS/du for pickle olives, around 3,000 ILS/du for apricots and figs, and around 9,000 ILS/du for grapes. Fruit trees score better on income than olive trees, but in particular alfalfa seems not very attractive economically. The numbers indicate that irrigation for all selected crops is profitable.

A SWOT analysis was made that indicates, however, that there are other arguments for the choice of different crops, e.g. the amount of work that must be put in maintenance and harvesting and the control of pests.

Based on the acquired benefit and cost data, cash flow forecasts were made, without discounting and with discounting based on a 6 percent discount rate. These calculations show that the most favourable crop is grapes, followed by other fruit trees such as apricots, figs, pickles olives and almonds. Alfalfa, pecan, and to some extent olives for oil clearly lag.

Total Net Benefits for the entire irrigation area (depending on the selected cropping pattern) amount to approximately 6.7 million ILS/year, averaged over 30 years. The return period of investments is approx. 5 years. For different crops it varies from 1 year for alfalfa, 5 years for most fruit trees (including olives) to 17 years for pecan. The internal rate of return (IRR) for KfW is around 12 percent.

Chapter 4 concludes with tariff calculations. Applying again a 6 percent discount rate and for the most likely scenario mentioned before, the breakeven tariff to be charged by NM to the WUA is around 0.65 ILS/m³, the surcharge that the WUA has to put on top of this tariff to cover operation and maintenance costs and avoid negative cash-flow is 0.25 ILS/m³. Avoiding negative cash-flow cannot be achieved by high tariffs only. A start-up subsidy from the Palestinian Authority (PA) to the WUA will be needed during the first years of operation. This is largely since water use of young trees will be limited in the first 4 to 5 years and the WUA is still confronted with operation and maintenance (O&M), operational overheads and staff costs.

Tariff calculations are still preliminary. The final design has not yet been concluded and cost-saving options are still under discussion. Once the final design is approved, the tariffs need to be recalculated. It also needs to be assessed how the WUA is operating in the period before the system will be completed.

Chapter 5 presents twelve scenarios for different cropping patterns. These consist of three main scenarios depending on the grade of land reclamation (no reclamation, light reclamation, and full reclamation: 2,477 du, 2,641 du and 3,004 du respectively). Under each main scenarios there are three scenarios with Regulated Deficit Irrigation (RDI) one without alfalfa or intercropping, one with alfalfa and one with intercropping, as well as one scenario with Sustained Deficit Irrigation as proposed by the Ministry of Agriculture (MoA)⁸.

⁸ Referred to by MoA 400 mm supplemental irrigation.

These twelve scenarios have been subjected to a Multi Criteria Analysis (MCA), with the criteria total water use in 2051, percentage wastewater reused in 2026, Internal Rate of Return (KfW), farmer income in 2051, employment in 2051, tariff without corrections for negative cash flow, and Net Benefit for the Palestinian economy. Applying a so-called 'song festival score' (soring 1 to 10 for each scenario without applying weights), it turns out that the scenario with full reclamation, with RDI and without alfalfa or intercropping is the most favourable one. However, it is considered that this scenario may go beyond the realistic options to have farmers participating and a similar scenario with light reclamation (scenario 5) seems to be the most likely option and is used in Chapter 4 for more detailed cash-flow, risk and tariff calculations. This scenario should also be the base for the first phase of the design of the distribution system with the option to extend this system in future to cover a more demanding scenario.

To validate the MCA, the decision-makers must give weight to the different criteria. The Consultant may give guidance in this but not decide on the weights.

Chapter 6 briefly recapitulates the present status of the WUA and forms of cooperation between farmers. As these issues are subject to separate studies, they are not extensively discussed.

Chapter 7 on irrigation management describes the preliminary design of the distribution network and sets out general recommendations for its operation and maintenance. The real work on the operation of the system comes shortly before the first year of irrigation when the WUA must set up a rotation schedule. Setting up such a schedule will need support of a custom-built geodatabase (based on GIS software) that can also handle tariffing and invoicing. Such work should be outsourced to the private sector. A budget should be made available by the Client and ToR for such work prepared by the Consultant.

The **annexes** to the report contain maps of the irrigation area and tables depicting the calculations of water requirements, among others.

The most important **conclusions and recommendations** of the IMOP are:

- It is proposed to extend the project area - the irrigable area will grow from 2,874 du in the feasibility studies (including the Outside Pilot Scheme) to about 3,004 du, but without the pilot scheme. As we assume that not more than 90 percent of the area will be irrigated, the area of cultivated dunum is roughly the same as in the ToR.
- The studied cropping patterns differ from the one proposed in the feasibility studies. Thirty-nine (39) percent of the irrigation area is currently covered with more or less dense olive orchards; it is assumed that these will be maintained and upgraded if needed and irrigated, but not uprooted. Part of the less suitable lands are earmarked for pickle olives and the total olive areal will grow to 57 percent. The remaining area (43 percent) will be most likely planted with new fruit trees. It is doubtful whether farmers will cultivate alfalfa as the economic prospects of this crop are weak.
- The total estimated amount of water needed for irrigation after full development of the irrigation area in the year 2036 is 2.25 million m³/year under the most likely scenario 5. This represents around 30 percent of the total wastewater produced by the Nablus West WWTP, as opposed to 50 - 60 percent previously estimated in the feasibility studies. In case the project area will be fully developed - including the use of high areas, archaeological

sites, and areas beyond the present borders that can be irrigated under gravity - it will be possible to use up to 40 percent of the produced wastewater in 2036, provided that an extension of the wastewater treatment plant will be realized before 2030.

- Peak irrigation water demand is projected to be between 3.3 and 9.5 mm/d, depending on the type of crop. As the higher value is for pecan, which may not be cultivated extensively, it is proposed to use a system capacity providing 4.8 mm/d on a 24-hour basis. Occasional higher peaks can be easily handled by such a system. This should be applied for the whole irrigation area as farmers must have the option to alter cropping patterns later.
- With B/C ratios against present cultivation of above 1, irrigation of all selected crops, including olives for oil production is economically feasible. The low B/C ratio for alfalfa may be considered as an unacceptable risk. Fruit trees and olives score much better on B/C, but with the remark that fruit trees give a much better income than olive trees. Other (social, marketing, knowledge, etc.) considerations may prevail when it comes to crop selection.
- In the tariff calculations, the break-even prices for NM and the WUA for delivering water to the farmers are largely below 1.00 ILS/m³, depending on the scenario. It is recommended to provisionally set the tariff for the farmers at 0.90 ILS/m³. To avoid negative cash-flow for the WUA during the start-up period (around there years), it is compulsory to subsidize the WUA, for instance by putting WUA staff on the payroll of MoA. There will be options later to increase water prices and sell more water to avoid negative cash flow. The proposed tariffs should be revised as soon as more details are available on the real cost of construction.
- A proposal for KfW subsidies to farmers has been prepared which amounts to costs for KfW of around 650,000 EUR and for the farmers of around 530,000 EUR. The numbers are not sensitive for the choice of scenario. The subsidy percentage depends on the crop to be grown and varies between 50 and 74 percent. The costs for planting and for installing the on-farm irrigation system (including Farm Head Works) amounts to maximum 1,400 ILS/du, apart from grapes where these costs are much higher. A discussion with farmers needs to be conducted whether this amount is acceptable for them.

1 DESCRIPTION OF THE PROJECT AREA

1.1 CONTEXT

The Wadi Shaeer project area consists of the *Wadi Shaeer* valley north of the *Nablus West Wastewater Treatment Plant (NW-WWTP)*, limited to the south by the Nablus-Tulkarm road including the Outside Pilot Scheme between the WWTP and the road), to the east by the 285 m contour line and the Nablus-Jenin road, to the north by the old Ottoman railway track and roughly by the 255 m contour line further to the west, and to the west by a hill opposing the Bayt Lid junction. It counts 3,782 du without agricultural feeder roads.

The proposed area deviates from the original area as proposed by NM. It includes some areas requested by landowners to be included for irrigation to the north and northwest side of the original area. The latter partly needs reclamation but could be adequate for future irrigation of olives. The inclusion of these areas will also maximise the future use of treated wastewater.

The study area⁹ includes the land of aforementioned project area, excluding the Outside Pilot Scheme (127 du), as well as any land elevated above 290 m a.s.l.¹⁰ (119 du). It also excludes the areas designated by ICA as archaeological sites (211 du). Some of these areas overlap (high areas and archaeological sites, 48 du in cadastral block 4 and 5 du in cadastral block 9).

The area that could be managed by the Wadi Shaeer Water User Association is shown in Figure 1 below; the areas that are excluded from this study in Figures 2 , 3 and 4 (below). The remaining study area is shown in Figure 5 (below) and measures 3,378 du of parcels without agricultural feeder roads. The area contains in total 527 parcels (plots), some of them are split by public corridors but counted as one parcel. Apart from land that is unsuitable for irrigation because of soil conditions, these parcels can potentially be irrigated and are considered as the potential irrigation area.

The average parcel size in the project area is 6.8 du. Parcel size distribution is given in the graph in Figure 6 (below). About 800 du of land has parcels smaller than 5 du. To avoid excessive capital and operational costs, it is advisable¹¹ not to provide Farm Head Works (FHW)¹² to parcels smaller than 5 du. Options for a joint management of FHWs for small parcels are being discussed with farmers in the framework of the second phase of the Farmer Mobilisation Campaign (FMC). It should also be noted here that larger parcels have a complex ownership situation as well; these may be owned by many persons who sometimes do not know which part of the land is theirs. This may present similar problems for the provision of FHWs.

⁹ The area for which the calculations in the IMOP are made.

¹⁰ Considering a minimum pressure for drip irrigation of 17 m water, the lower level of water in the (revised) reservoir of 324 m a.s.l., and accounting for friction losses in the irrigation network.

¹¹ Condition in the ToR of the Project.

¹² Ensemble of pressure regulator, water meter and a flow-limiting device where water is transmitted from the irrigation distribution system to the farm; after the water meter, the farmer eventually adds to that a filtration unit (here not advised because of the good water quality) and a fertilisation unit.

Figure 1 Overview of the Wadi Shaeer project area

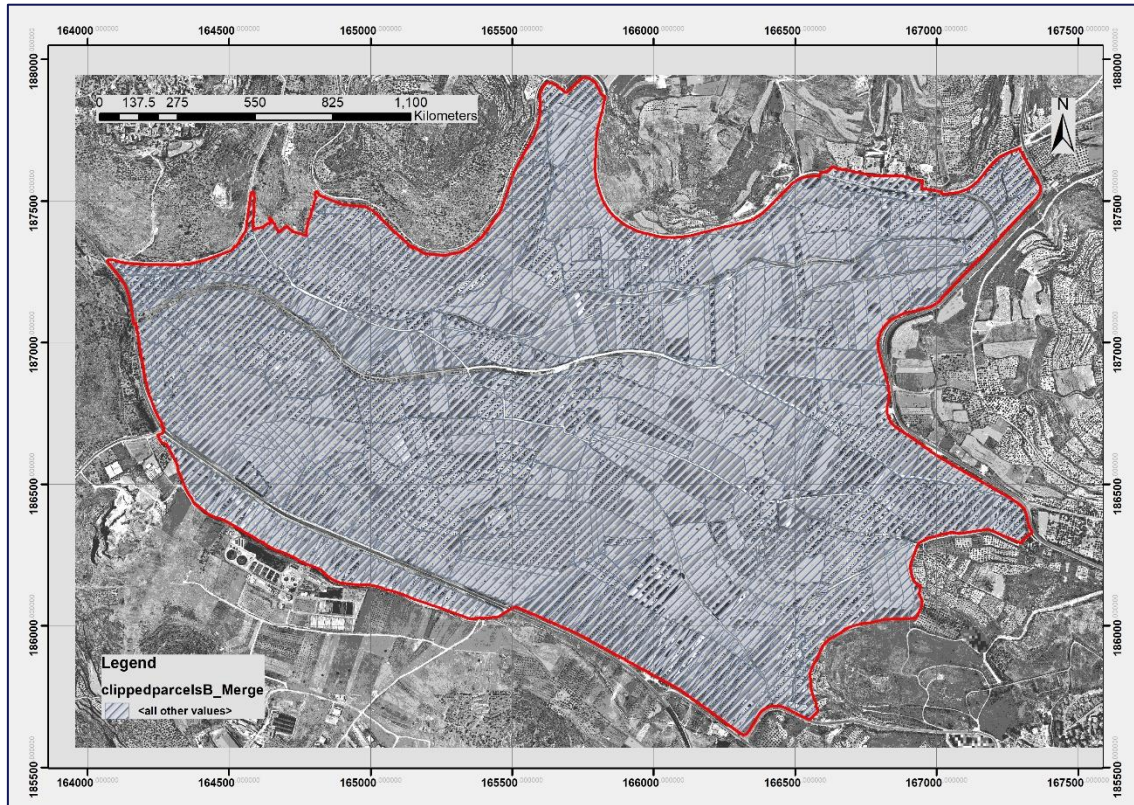


Figure 2 Outside Pilot Scheme

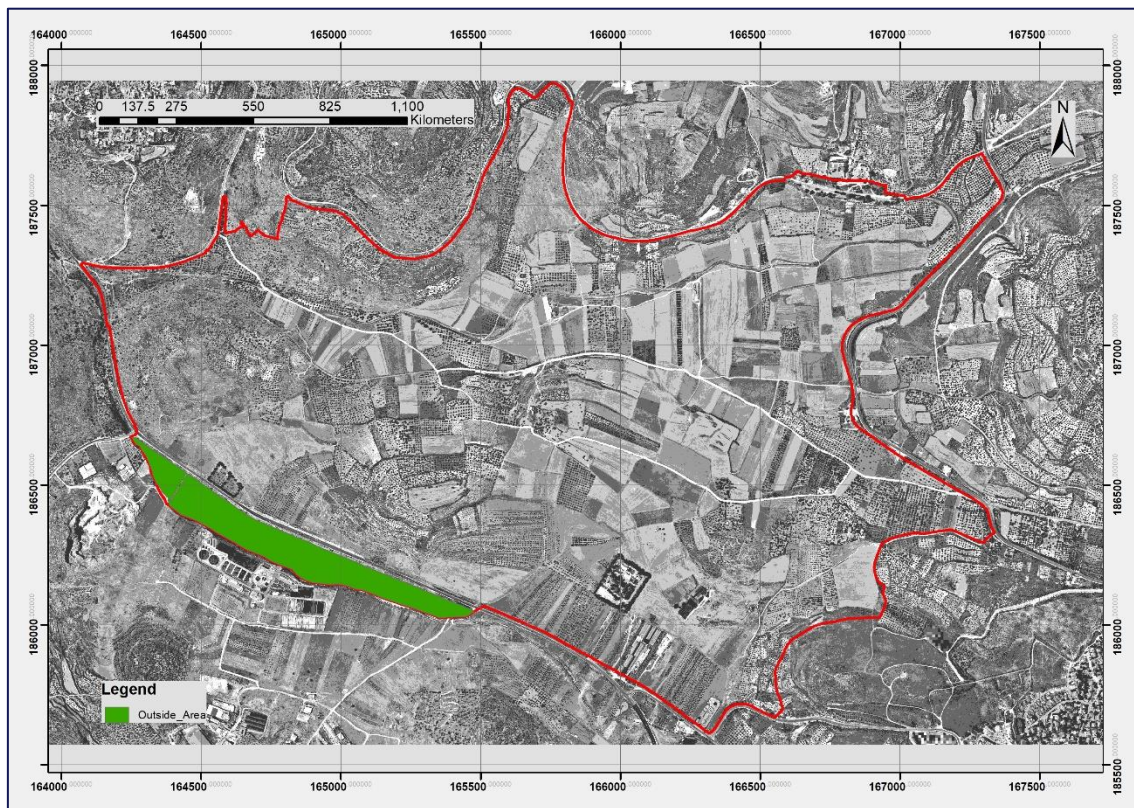


Figure 3 Land above 290 m a.s.l.

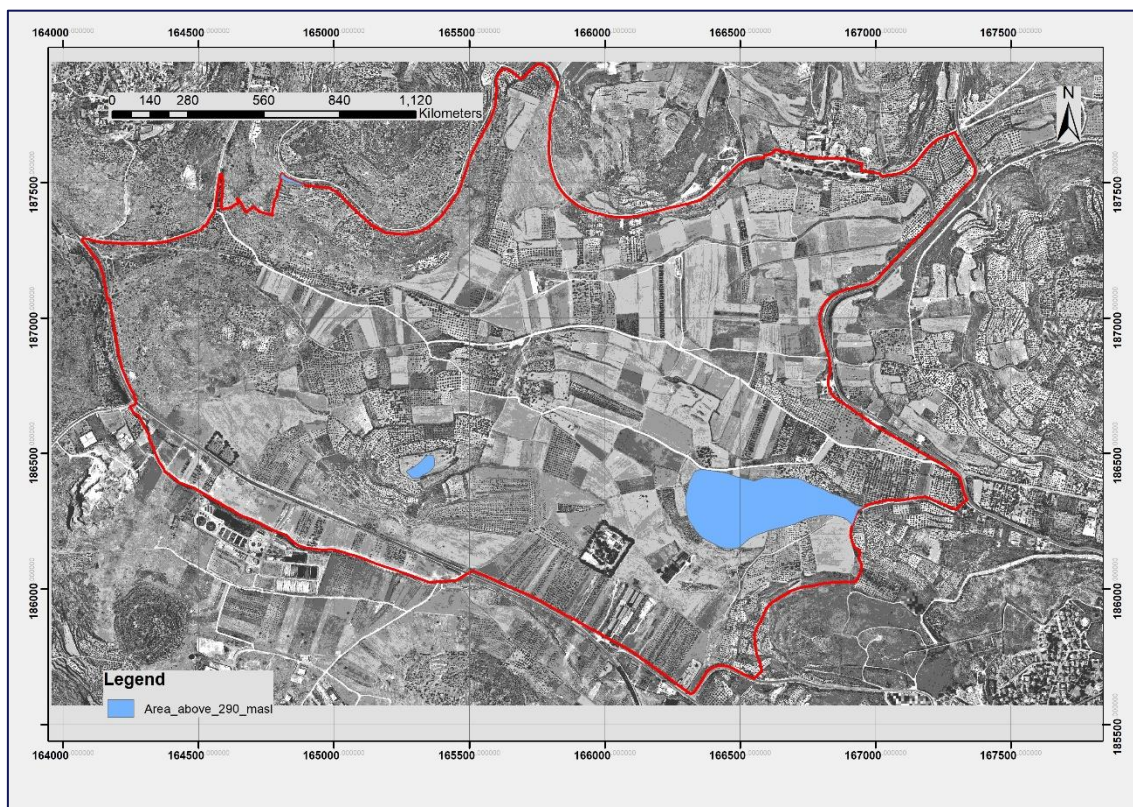


Figure 4 Archaeological sites

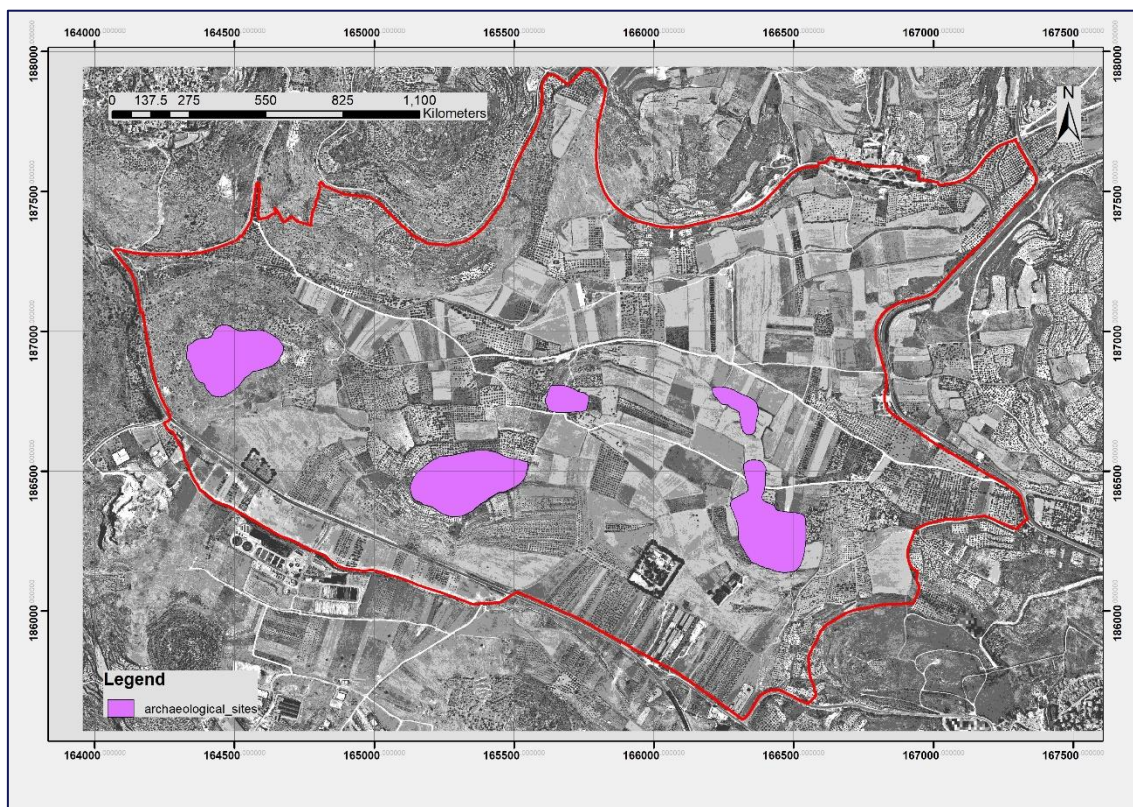


Figure 5 Resulting study area

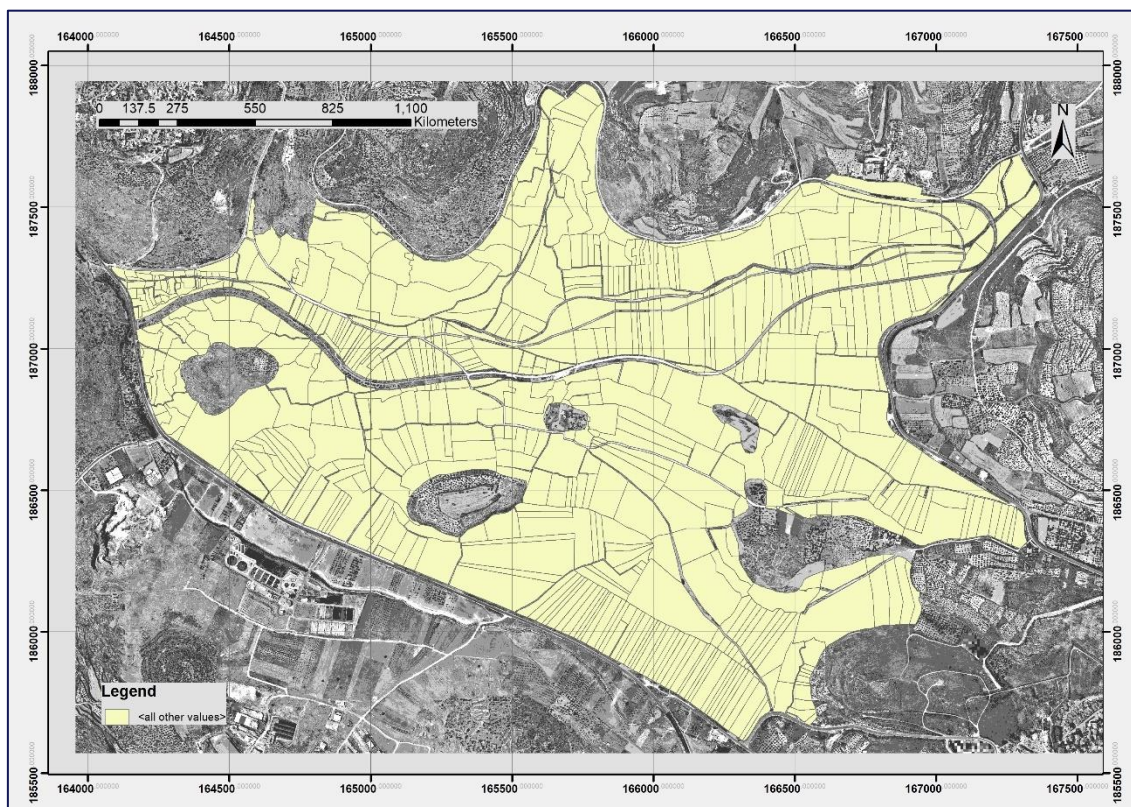
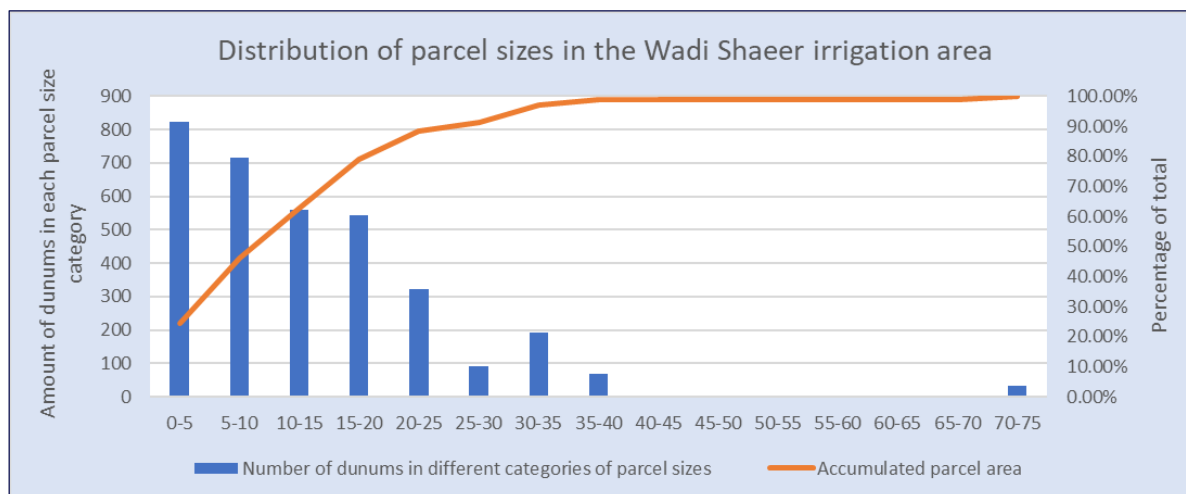


Figure 6 Distribution of parcel sizes in the Wadi Shaeer irrigation area



The land in the irrigation area is located on the territory of four different villages: Burqa, Deir Sharaf, Ramin and Sabastiya. An overview of the parcels and area per involved village is given in Table 1 below:

Table 1 Distribution of parcels and land area per involved village in the project area

Village	Number of parcels	Total area [du]	Average parcel size [du]
Burqa	157	1,344	8.6
Deir Sharaf	130	669	5.1
Ramin	214	1,307	6.1
Sabastiya	58	462	8.0
Project area	559	3,782	6.8

1.2 POSSIBLE FUTURE EXTENSION

The study area serves the calculation of cropping patterns, crop water requirements and economic calculations. It is possible to extent the area in future still using the planned main system. Such extensions could include:

1. The archaeological sites (211 du), provided the relevant authorities give permission to irrigate these.
2. The high areas (119 du), provided the distribution will be provided with a booster pump to put 2 bar more pressure on the water.
3. Areas beyond the present borders that can be irrigated by gravity. These areas can be found north of the ottoman railway track and east of the road from Nablus to Burqa. Together this presents 190 du of land.

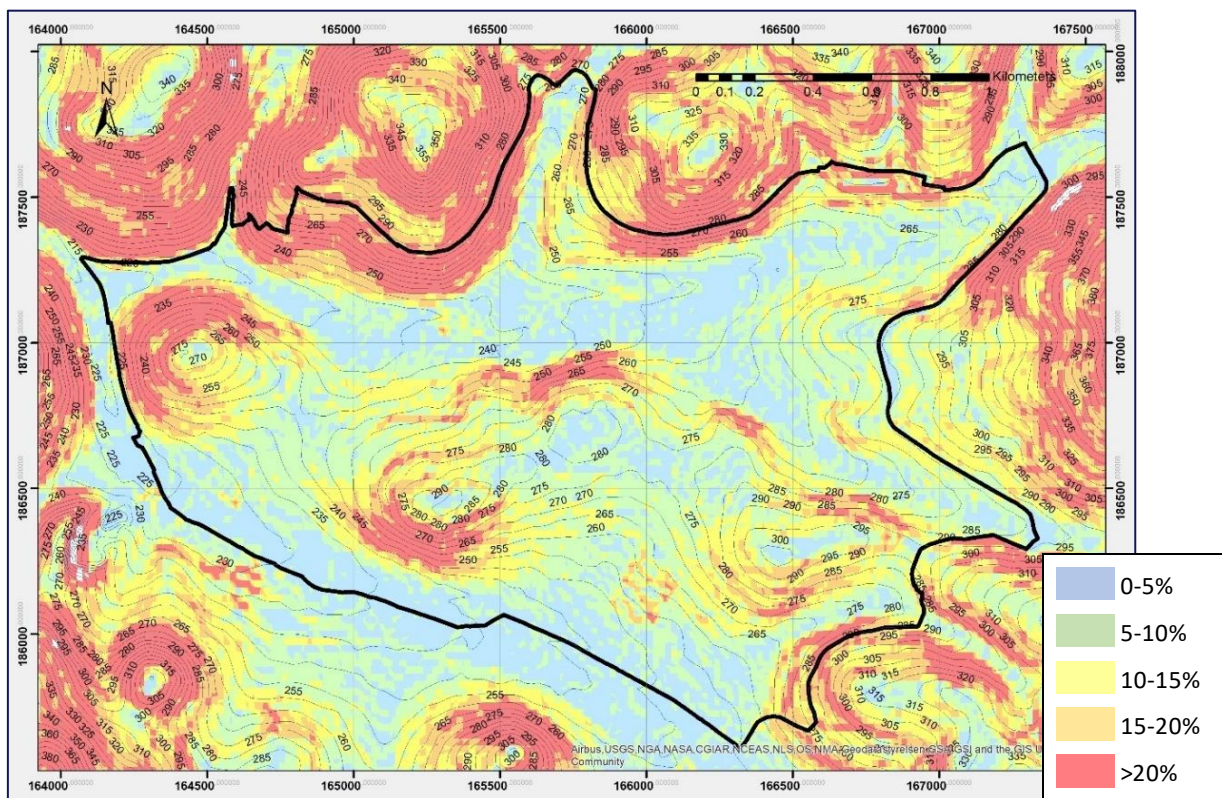
Most of this land is of good quality. This would add around 470 du to the 3,004 du estimated under full reclamation. It would allow using 16 percent more wastewater. Due to shortage of funds, these areas have not been further considered, but provisions should be made in the main system so that these areas can be reached without excessive costs in future.

There is abundance of land to the north and east of the presently planned irrigation area. All this land can however not be reached by gravity and is therefore excluded from the Project. It would require a pumping station, pressure lines and its own distribution system and the price of the water would become excessive. Water for such an extension would also not be available until after 2036, provided as well that the city of Nablus produces considerably more wastewater.

1.3 TOPOGRAPHY AND SOILS

The project area consists of the relatively flat valley of Wadi Shaeer in the northern part of the area - with elevations ranging between 225 and 270 m a.s.l. and slopes around 2 to 5 percent, as well as a number of smaller mounds in the southern part, with elevations up to 300 m a.s.l. and slopes up to 20 percent or slightly higher. A map with slopes is shown in Figure 7. In general, the soils in the central and eastern part of the valley are deep (up to 2 m) and reasonable well developed. The soils in the western part of the area are usually shallow and rocky, in particular those on the steeper slopes. Between mounds and valley there are transition zones where the soils become shallower and rockier with increasing elevation.

Figure 7 Slopes in the project area



A comprehensive Land Suitability Assessment was carried out. Some of the results, outlining land suitability classes, are shown in the maps in Figure 8 to 11 on the following pages.

Figure 8 Land suitability classes from the Land Suitability Assessment

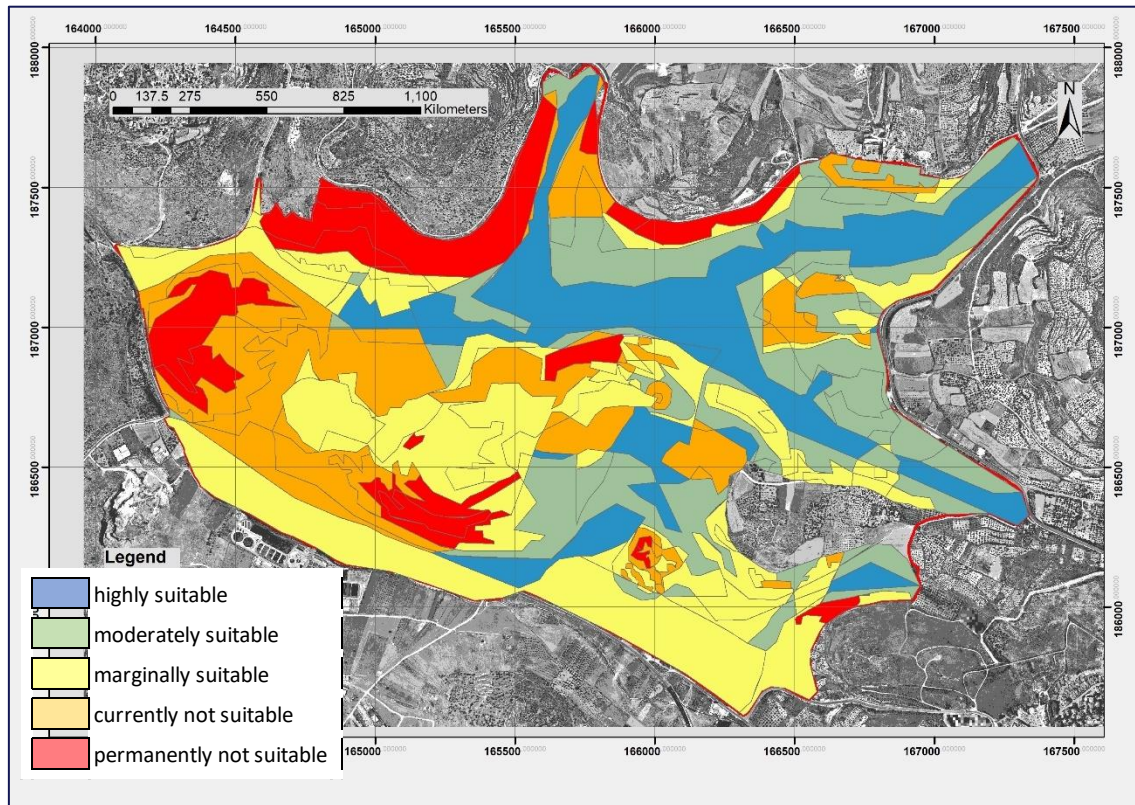


Figure 9 Slope suitability classes from the Land Suitability Assessment

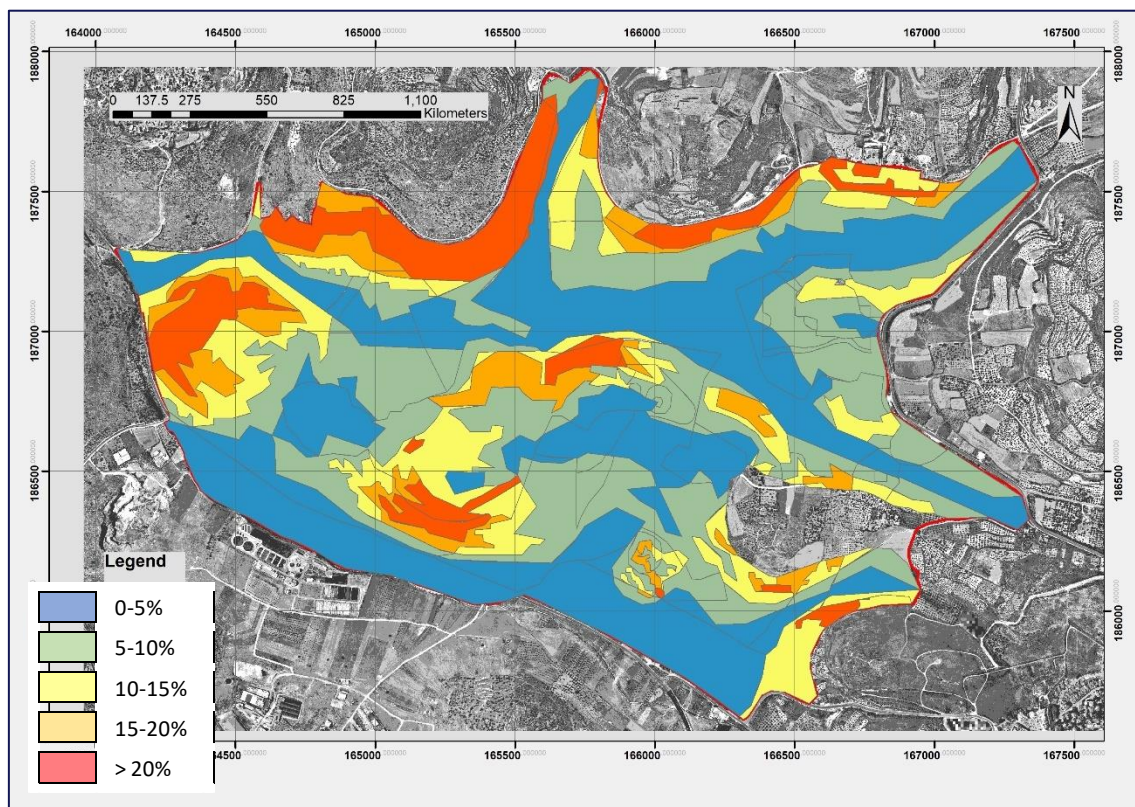


Figure 10 Soil depth suitability classes from the Land Suitability Assessment

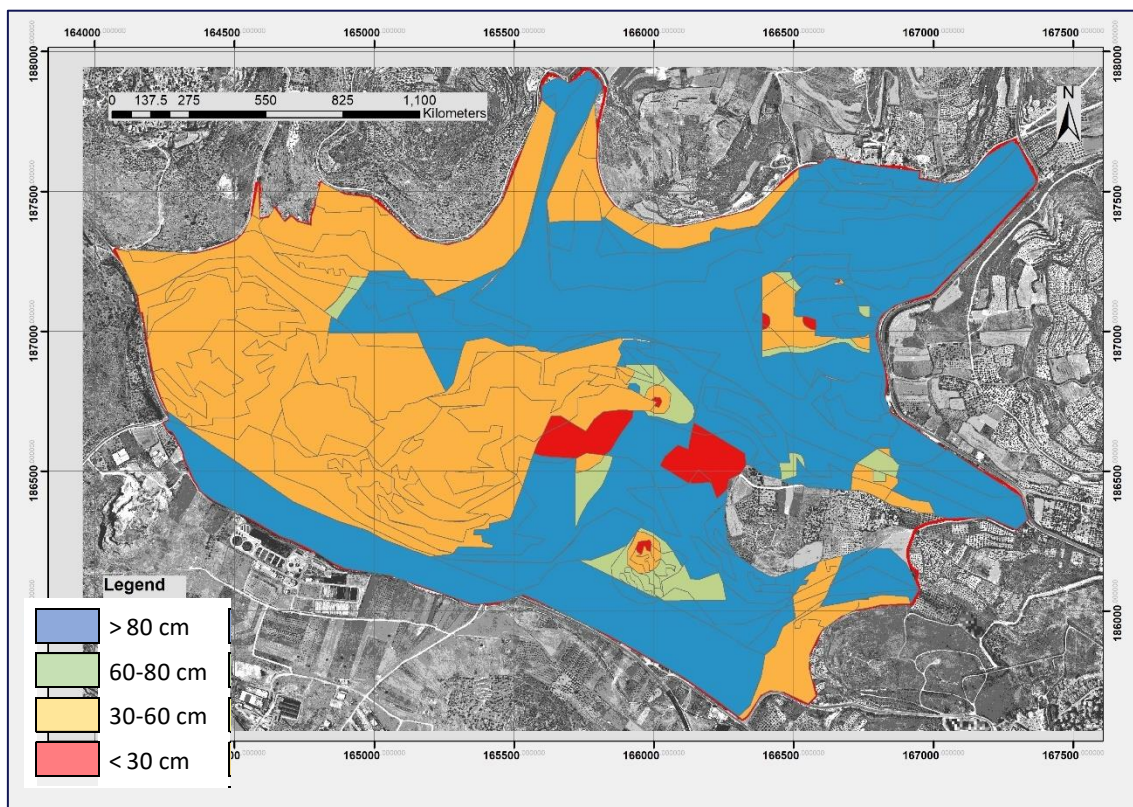
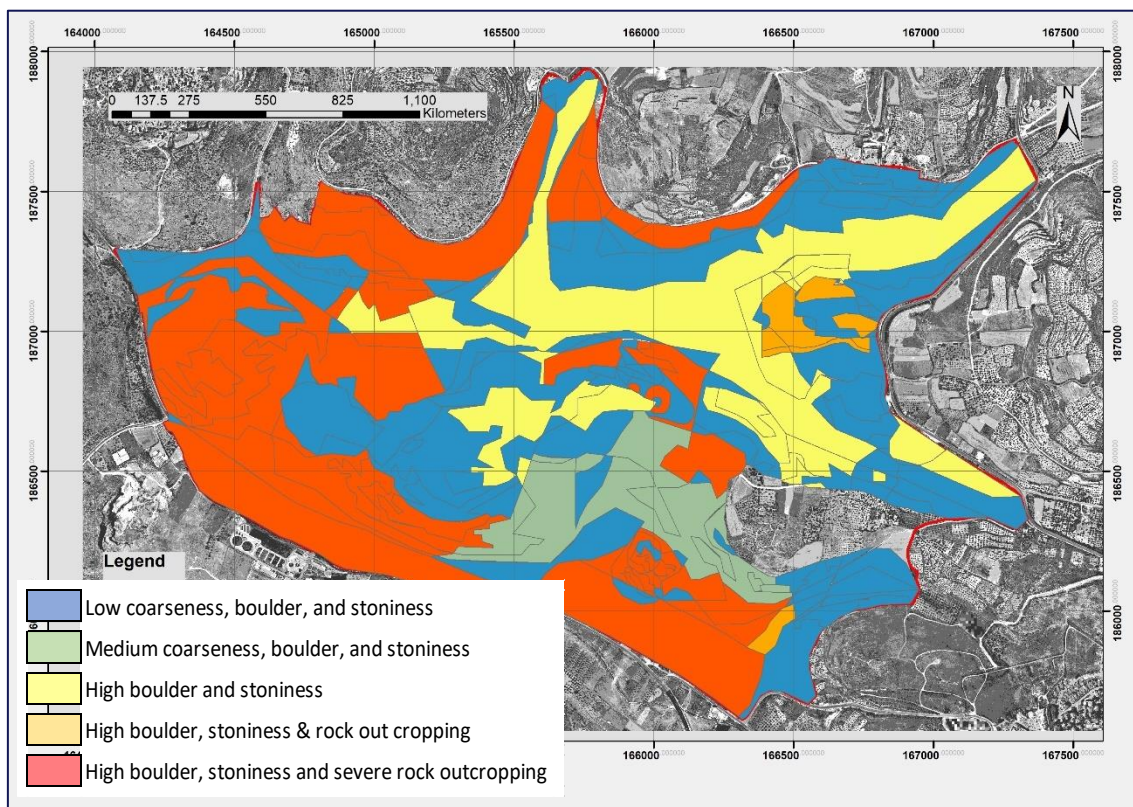


Figure 11 Soil stoniness suitability from the Land Suitability Assessment



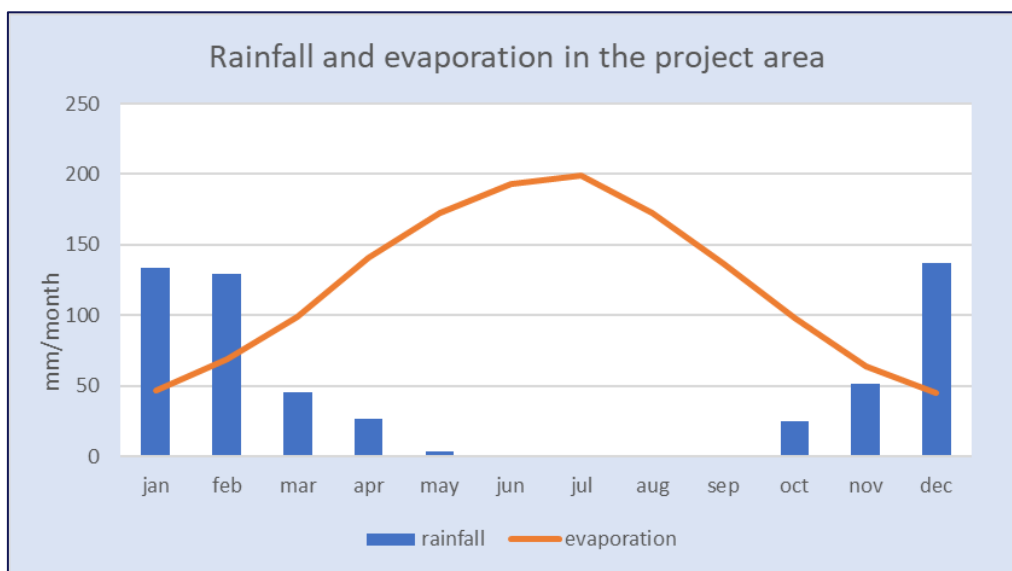
The above maps in Figures 9, 10 and 11 are part of the Land Suitability Assessment report. The soil survey carried out for this report measured slope, soil depth and stoniness in 67 soil profiles in the study area and prepared maps of these three characteristics using GIS interpolation routines. The three maps were in the GIS overlain with each other to produce the land suitability map in Figure 8.

1.4 CLIMATE

The climate of the Wadi Shaeer area is Mediterranean with relatively hot and dry summers and cool rainy winters. Rainfall in the area is around 550 mm/year; most of it falls in the period December through February. Rainfall distribution over the period 2006 to 2019 (Sabastiya rainfall station, the closest-by rainfall station with complete data for a longer period) is shown in Figure 12 below.

E_0 -Penman reference evaporation data over the same period have been calculated using the CROPWAT-8 software¹³ for the climatological station in Nablus and corrected for the height difference between Nablus and Wadi Shaeer (570 and 260 m a.s.l. respectively) using the adiabatic lapse rate¹⁴ and the Hargraves-Samani evaporation equations. The monthly data are also presented in the same figure.

Figure 12 Distribution of rainfall and E_0 -Penman reference evaporation over the year (Sabastiya rainfall station, 2006 - 2019 and Wadi Shaeer evaporation estimated from data of the Nablus meteorological station for the same period)

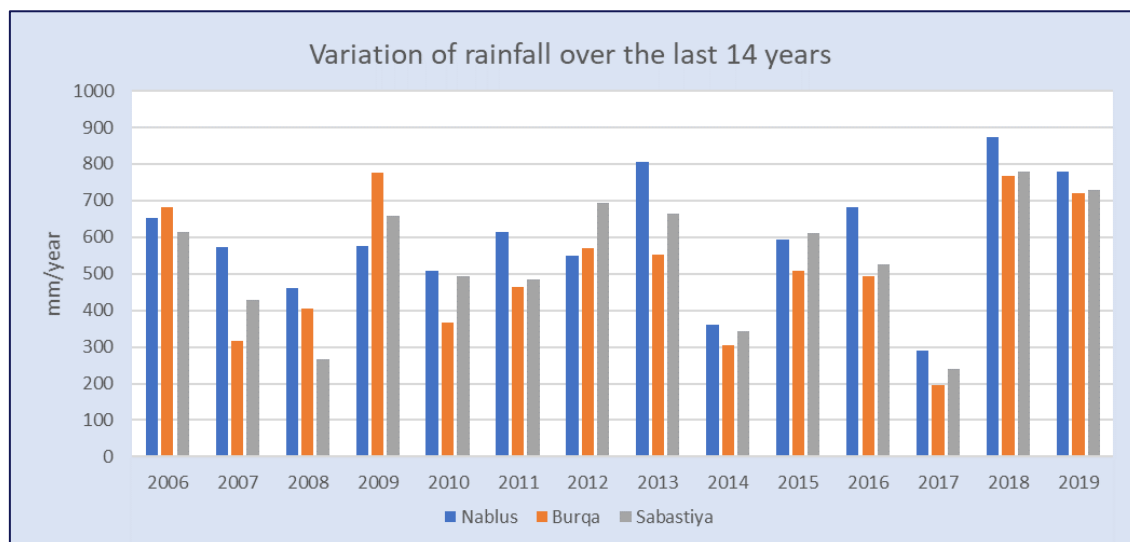


¹³ CROPWAT 8.0 for Windows is a computer program for the calculation of crop water requirements and irrigation requirements based on soil, climate and crop data. <http://www.fao.org/land-water/databases-and-software/cropwat/en/>

¹⁴ Manual of the ICAO Standard Atmosphere (extended to 80 kilometres (262 500 feet)) (Third ed.). International Civil Aviation Organization. 1993. ISBN 978-92-9194-004-2. Doc 7488-CD.

Where evaporation does not differ much from year to year, rainfall shows a large variability. Figure 13 shows the variation of three nearby rainfall stations (Nablus, Burqa and Sabastiya) over the same period 2009 - 2018.

Figure 13 Variation of annual rainfall in the project area from 2009 to 2018¹⁵



1.5 SOCIO-ECONOMIC CONDITIONS

According to the Palestinian Central Bureau of Statistics (PCBS), the population in the four involved villages is estimated for 2019 as follows¹⁶:

Table 2 Estimated 2019 population in the four involved villages

Village	Estimated population in 2019
Burqa	4,277
Deir Sharaf	3,038
Ramin	2,053
Sabastiya	3,301

Other statistical data is not available for the village level.

From data collected during the farmer survey carried out by the project, it can be calculated that the direct cash income from agriculture in the project area is around 1.5 million ILS/year, not counting family labour on olive plantations. This represents about 1 percent of the estimated cash household expenditure in the four villages estimated at 132 million ILS/year¹⁷. Even if other elements of the agricultural value chain would be included, this indicates that agriculture is not a major source of income for the inhabitants of the four villages. To be noted

¹⁵ Contrary to what is usual in standard meteorological analysis in the Middle East, the rainfall of the period January-February is analysed as this analysis needs to coincide with the irrigation season.

¹⁶ Projected Mid-Year Population by Locality 2017 – 2021; http://www.pcbs.gov.ps/site/lang_en/1/default.aspx

¹⁷ This number has a large margin of error. It is calculated from the average per capita cash household expenditure in the Nablus Governorate in 2017 and may not be fully representative for the project area.

in this context that the four villages deploy a significant amount of land in agricultural areas outside the project area, mostly rainfed, but also irrigated based on rainwater harvesting, and using drinking water for irrigation supply.

With respect to labour, the results of the farmer survey show that the total amount of labour in the project area amounts at present to roughly 50 equivalent full-time jobs, which is less than 2 percent of the assumed labour performance of the 4 included villages - estimated to be slightly over 3,000 equivalent full-time jobs¹⁸.

1.6 PLANNED INFRASTRUCTURE

The planned irrigation system is going to use the treated wastewater of the Nablus West Wastewater Treatment Plant (NW-WWTP), which came into operation in 2013. In 2019, the effluent outflow of the WWTP was 5.306 million m³/year of secondary treated wastewater. Summer outflow in 2019 was on average almost 13,000 m³/d. Peak outflow occurs in winter due to mixing with rainwater discharge (refer to Figure 14). As the wastewater collection system is not completely separated, it is estimated that, in 2019, around 12 percent of the yearly collected wastewater represents rainwater infiltrated into the system¹⁹. This phenomenon takes place during the rainy season (December - February) when irrigation demand is almost zero. The surplus water can therefore not be used in irrigation.

Figure 14 Daily effluent outflow of Nablus West WWTP in 2019



The quality of the secondary treated water is characterized by the following parameters (average values 2018):

¹⁸ Calculated by estimating that 50 percent of the population is between 15 and 65 years of age and 50 percent of this eligible population works.

¹⁹ In 2018 this was - with less rainfall - 7 percent. For further calculations we have taken 10 percent.

Table 3 Physical-chemical parameters of the WWTP effluent after secondary treatment (2018)

Parameter	Unit	Yearly average	Minimum monthly average	Maximum monthly average
COD	mg/l	39	30	54
BOD ₅	mg/l	8	6	11
TSS	mg/l	10	3	16
Total N	mg/l	21	7	40
TDS	mg/l	800	655	890
Bacteriological parameters and helminth eggs are not routinely measured.				

The WWTP presently delivers irrigation water to three pilot areas, all with tertiary treatment including filtration (rapid sand filtration / disc filtration) and disinfection (chlorination / UV-disinfection). Laboratory results²⁰ show an excellent quality of the tertiary treated water with E-coli and nematodes absent and TSS (Total Suspended Solids) below 16 mg/l. Such water fully answers class A requirements for irrigation water under the reuse standard 34/2014 and is suitable for irrigation without further filtration (drip-emitters will not get clogged) or specific hygienic caution measures. Nitrogen is borderline for Class A and needs to be followed-up during the irrigation season.

The Project will construct an irrigation system consisting of the following components²¹:

- A slow sand filtration station (six units).
- A balance tank with a capacity of 2,000 m³ as a buffer for the smooth operation of the treatment and conveyance system.
- A pumping station with three variable speed pumps with a maximum capacity of 800 m³/h. It is foreseen that two pumps will be operated; the third one is for emergency standby. The pumping station can be extended with three more pumps in case the Nablus West WWTP will in future increase its wastewater production, up to a maximum of 27,000 m³/d.
- A main bulk conveyance pipeline of DN 600 mm ductile cast iron (DCI) with a length of 2.2 km, overcoming a height difference of approximately 93 m.
- A day reservoir of 10,000 m³ at an elevation of 319 m a.s.l. (the lowest water level in the reservoir).
- An irrigation distribution system with main pipelines of a total length of approximately 12 km and laterals (*total length not known yet*), to be erected with DCI or polyethylene pipes of diameters up to DN 500 mm. The irrigation system will be manually operated for the time being to save on investment costs.
- A fence around the project area to keep wild boar from damaging crops and irrigation systems.

²⁰ Wastewater Treatment Plant Nablus West. Annual Report 2018.

²¹ At the moment of writing this report, the design of the system is still under discussions and above text needs to be adapted when there is a final design and decisions have been taken on cost-savings.

- A KfW subsidy to farmers for planting trees and installing on-field irrigation systems including FHWs.

The layout of the conveyance and distribution system is shown in Annex 3 at the end of the report. More details of the system can be found in the respective design reports.

2 CROPPING PATTERNS

2.1 CURRENT CROPPING PATTERN

From the farmer survey and using aerial photographs, the present cropping pattern could be derived. Due to the phenomena of absentee landowners, the data and the maps have a certain degree of inaccuracy; data could only be collected for approximately 78 percent of the parcels.

This data is also presented in Table 4 and on the map in Annex 4. The map presents four categories: olive orchards, scattered olives, field crops/empty and rocky areas. Crops that are cultivated in smaller quantities (tobacco) or consist of single trees within olive orchards (almonds, etc.) are not indicated on the map.

Table 4 Present cropping pattern in the project area

Sub-Total Sabastiya	Block	# of parcels	Area (du)	Olives		Scattered olives		Field crops/Empty		Rocky	
				# of parcels	Area (du)	# of parcels	Area (du)	# of parcels	Area (du)	# of parcels	Area (du)
Sabastiya	4	58	453	25	174	10	42	23	237	0	0
Sub-Total Sabastiya		58	453	25	174	10	42	23	237	0	0
Burqa	18	6	38	3	17	0	0	1	4	2	17
	19	2	15	0	0	1	3	1	12	0	0
	20	5	37	4	32	1	5	0	0	0	0
	21	61	565	17	104	7	82	37	379	0	0
	22	83	662	21	108	2	29	55	507	5	18
Sub-Total Burqa		157	1,317	45	261	11	119	94	902	7	35
Deir Sharaf	10	11	19	7	12	3	6	1	1	0	0
	12	58	253	24	98	1	3	33	152	0	0
	14	34	258	10	106	1	7	12	50	11	95
	16	27	126	8	44	0	0	18	64	1	18
Sub-Total Deir Sharaf		130	656	49	260	5	16	64	267	12	113
Rameen	8	41	409	9	65	11	159	11	103	10	82
	9	104	603	34	227	11	88	59	288	0	0
	11	69	269	11	28	11	65	25	26	22	150
Sub-Total Rameen		214	1,281	54	320	33	312	95	417	32	232
Grand Total		559	3,707	173	1,015	59	489	276	1,823	51	380

2.2 CROPPING PATTERN PROPOSED BY THE FEASIBILITY STUDIES

The feasibility study elaborated in 2016²² proposed a preliminary cropping pattern based on economic analysis and crop water uses. In this pattern, alfalfa and pecan play a dominant role. It was slightly revised in the later CDM Smith report²³ in 2017. It is recapitulated in Table 5 hereafter.

²² DAHLEM, CDM Smith, ACC, CEWE, 2016. Consulting Services for Implementation of Wastewater Management Nablus East. Final Assessment Report – Potential for Reuse Expansion to 2,000 dunum.

²³ CDM Smith, AHT Group, CEWE, 2017. Consulting Services for Implementation of Wastewater Management Nablus East; Draft Institutional and Social Assessment Report – Potential for Reuse Expansion to 2,000 dunum.

Table 5 Cropping pattern proposed by the respective feasibility studies

Crop	Area [du]
Olive orchards	967
Almonds	12
Pecan (intercropped with alfalfa)	600
Not cultivated	1,100
Total	2,744

2.3 FUTURE CROPPING PATTERN

Regarding the future cropping pattern, farmers indicated in the farmer survey which crops they intent to plant once they receive irrigation water. During the Farmer Mobilisation Campaign (FMC), the Project discussed these indications with the farmers, thereby including the experiences of the Outside Pilot Scheme and a preliminary economic assessment of the individual crops. Based on these discussions, a potential cropping pattern was developed following the following guiding principles:

1. Existing olive orchards (mainly olives for oil production) will be maintained; this was noticeably clear from the feedback received from farmers during the farmer survey and the FMC discussions with farmers.
2. In parcels with scattered olives, gaps will be filled with trees of the same variety (mainly olives for oil production); this is a logical development (same variety in each parcel) and was confirmed in discussions with farmers.
3. To enable machine harvesting, alfalfa will be preferably cultivated in unbroken (at least 100 du) areas, where the soil is deep and without many stones. From the Land Suitability Assessment, this area is estimated at about 320 du in total.
4. Pecan cultivation will be less than anticipated in the feasibility study, as the economic picture (see Chapter 4) is not favourable compared with other fruit trees and the period between planting and full harvest is long, and return on investment takes more than 15 years (breakeven point). It is a good crop under other circumstances where farmers want to invest in an extended future and want to harvest the wood after 100 years. This is not the case in Palestine.
5. Land needing heavy reclamation (substantial visible rock in land suitability class N2), is excluded from irrigation, apart from existing olive orchards. as well as land above 290 m a.s.l.
6. The remaining land will be planted with fruit trees (figs, apricots, prunes, grapes, pickle olives and eventually pecan (although not recommended for economic reasons). Many farmers indicated that they would like to grow avocados, but this is rightfully opposed by the Ministry of Agriculture because of national marketing strategies. The exact area of each crop planted in future is, within the proposed crop selection for this area, the choice of each individual farmer.
7. Intercropping of fruit trees with alfalfa is not seen as a valuable option. It is not suitable for the many shallow soils in the area and alfalfa with its deep root system competes with fruit trees and slows development (observed in literature and confirmed in the

Outside Pilot Scheme (where part of the alfalfa is up-rooted). Moreover, positive experiences cannot be found in literature. An exception can be made for the combination of pecan and alfalfa, as pecan trees are planted widely apart (around 10 m) and could thus leave enough space for mechanical harvesting of alfalfa. Contrary to other fruit trees, there are literature examples of this type of intercropping. However, the area suitable for this type of intercropping is limited (in total about 320 du). To be noted that intercropping requires agricultural skills, more than with fruit trees alone.

8. It is also assumed that with time, farmers may decide to replace olives with other fruit trees - or if future standards would allow, with vegetables and greenhouses. This is however an issue for future consideration.

Based on above considerations, and considering the Land Suitability Assessment, several alternative cropping patterns can be developed. In this context the Project has also studied the relevant crops for such cropping patterns. These include: existing dense olives, existing scattered olives, new pickle olives, alfalfa, apricots, almonds, figs, grapes, pecan, walnut and avocado. For the analysis of these crops, the team has followed diversified methodology including literature review, meeting with farmers of the project area and interviews with experts from MoA, non-governmental organisations (NGOs) and private companies. In addition, the situation of the crops cultivated in the 3 pilot projects of NM were assessed (for more details refer to Annex 9: Data sources).

The results of these studies are presented in Annex 6, *Information on potential crops for irrigation in the Wadi Shaeer project area and SWOT analysis*. To support future decision-making, the annex includes a comprehensive SWOT²⁴ analysis that shows Strengths, Weaknesses, Opportunities and Threats of these crops. The SWOT analysis does not deliver concluding answers on the cropping pattern, but is a guidance tool for decision-makers, such as MoA, the WUA and farmers to make adequate choices for crops to be cultivated, next to other guidance documents such as discounted cash flow (DCF) calculations (vs. Chapter 4) and the Land Suitability Assessment.

Water needs and economic calculations later in the report are based on the developed cropping pattern scenarios. This is further explained in Chapters 3 and 4.

The Land Suitability Assessment puts restrictions on cultivating crops in certain areas of the study area. Such restrictions are mainly related to slope of the terrain, soil depth, and the amount of stones and rocks in the soil. This has resulted in five different land suitability classes (LSC), which are shown in the table below. The table also shows the number of dunums of the respective LSC, the area that can be used in the classes S3, N1 and N2 without any land reclamation, the areas that can be added to cultivation after light and full reclamation and the LSC that results after reclamation.

²⁴ Strengths – Weaknesses – Opportunities – Threats.

Table 6 Land suitability classes

LSC	suitability	total area	irrigated area without reclamation	area for light reclamation	irrigated area after light reclamation	area for full reclamation	irrigated area after full reclamation
		[du]	[du]	[du]	[du]	[du]	
S1	highly suitable	660	660	0	660	0	660
S2	moderately suitable	779	779	0	888	0	921
S3	marginally suitable	905	796	109	851	0	1,181
N1	currently not suitable	623	205	55	205	363	205
N2	permanently not suitable	411	37	0	37	0	37
	totals all land classes	3,378	2,477	164	2,641	363	3,004

light reclamation

109 du in S3 will become S2

55 du in N1 will become S3d

full reclamation

330 du in N1 will become S3d

33 du in N1 will become S2

There are two types of reclamation. Light reclamation meaning that only stones are removed from the top 30 cm and put aside: either as strips along the contour lines or forming low walls without further terracing. Full reclamation meaning that also stones as well as rock outcrops are removed, stone walls are erected, and terraces created. It is estimated that light reclamation will cost around 100 EUR per dunum and full reclamation around 400 EUR per dunum. Light reclamation will make all land in S3 suitable for irrigation, as well as 40% of the land in N1. Full reclamation will make all land in N1 suitable for irrigation. Most land in N2 cannot be reclaimed at a reasonable cost.

The suitability of different LSCs is indicated in Table 54 of the Land Suitability Assessment report. The table is repeated here.

Table 7 Suitability of the land in the study area for different crops

Crop	Land Suitability Class												N1	N2
	S1	S2				S3								
		S2d	S2s	S2r	S2ds	S3d	S3s	S3r	S3ds	S3dr	S3sr			
Olives	++++	+++	+++	+++	++	++	++	++	+	+	+	+	0	
Alfalfa	++++	++	+	+	+	0	0	0	0	0	0	0	0	
Figs	++++	++	+++	+++	++	+	++	++	0	0	0	0	0	
Almonds	++++	++	+++	+++	++	+	++	++	+	+	++	0	0	
Apricots	++++	+	+++	+++	+	0	++	++	+	+	+	0	0	
Grapes	++++	+	+++	+++	+	0	++	++	+	+	+	0	0	
Pecan	++++	+	++	+++	+	0	+	+	0	0	+	0	0	
Walnut	++++	+	++	+++	+	0	+	++	0	0	0	0	0	
Avocado	++++	++	+++	+++	++	0	+	++	0	0	0	0	0	
SSI irrigation	++++	+	+	+	0	0	0	0	0	0	0	0	0	

The indices *d*, *s* and *r* indicate the limitations at the respective LSC for depth, slope and stoniness respectively. A combination of different limitations is also possible.

The number of plusses indicates the scale of restrictions: four plusses mean no restriction, one plus means severe restrictions and a zero means unsuitable.

Based on the GIS attribute tables of the soil maps presented in Figures 8 to 11 below and the information presented in the Tables 6 and 7 above, three main cropping patterns have been generated in the Project GIS one for each reclamation scenario, no reclamation, light reclamation and full reclamation. The results of this exercise are presented in Table 8 and in the maps in Figures 15 to 17 in the pages hereafter.

Table 8 Cropping patterns depending on land suitability classes and step of reclamation

crop/LSC	S1	S2	S3			N1			N2	all classes		
	no recl.	no recl.	No recl.	light recl.	full recl.	No recl.	light recl.	full recl.	no recl.	No recl.	light recl.	full recl.
olives existing	179	229	325	325	325	119	119	119	37	889	889	889
olives improved	25	90	87	87	87	86	86	86	-	288	288	288
olives pickles	-	-	376	263	174	-	55	373	-	376	318	547
almonds	60	44	8	40	52	-	-	45	-	112	144	201
apricots	125	75	0	40	52	-	-	-	-	200	240	252
figs	125	75	0	40	52	-	-	-	-	200	240	252
grapes	36	50	0	110	163	-	-	-	-	86	196	249
alfalfa	110	-	-	-	-	-	-	-	-	110	110	110
intercropping	-	216	-	-	-	-	-	-	-	216	216	216
N1	-	-	-	-	-	418	363	-	-	418	363	0
N2	-	-	-	-	-	-	-	-	374	374	374	374
S3	-	-	109	-	-	-	-	-	-	109	0	0
Total	660	779	905	905	905	623	623	623	411	3378	3378	3378
irrigated	660	779	796	905	905	205	260	623	37	2477	2641	3004
not irrigated	0	0	109	0	0	418	363	0	374	901	737	374

Figure 15 Cropping pattern without any reclamation

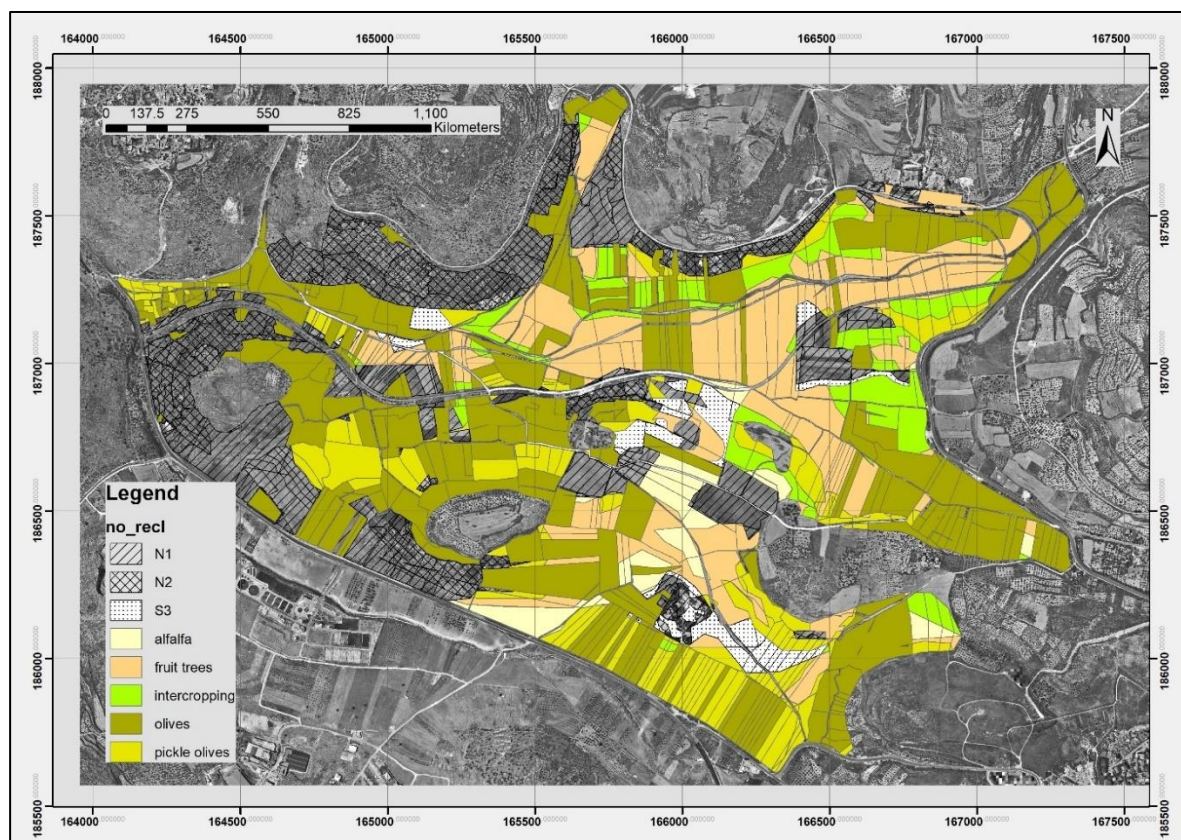


Figure 16 Cropping pattern with light reclamation

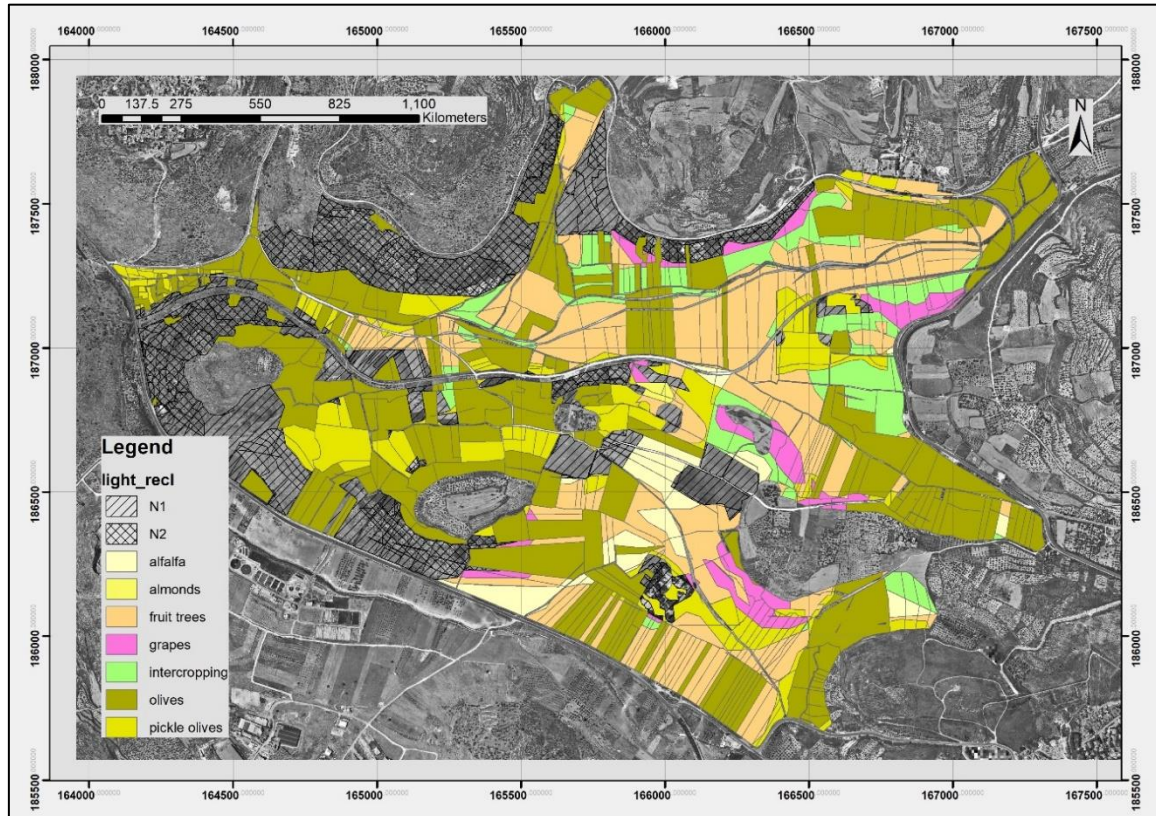
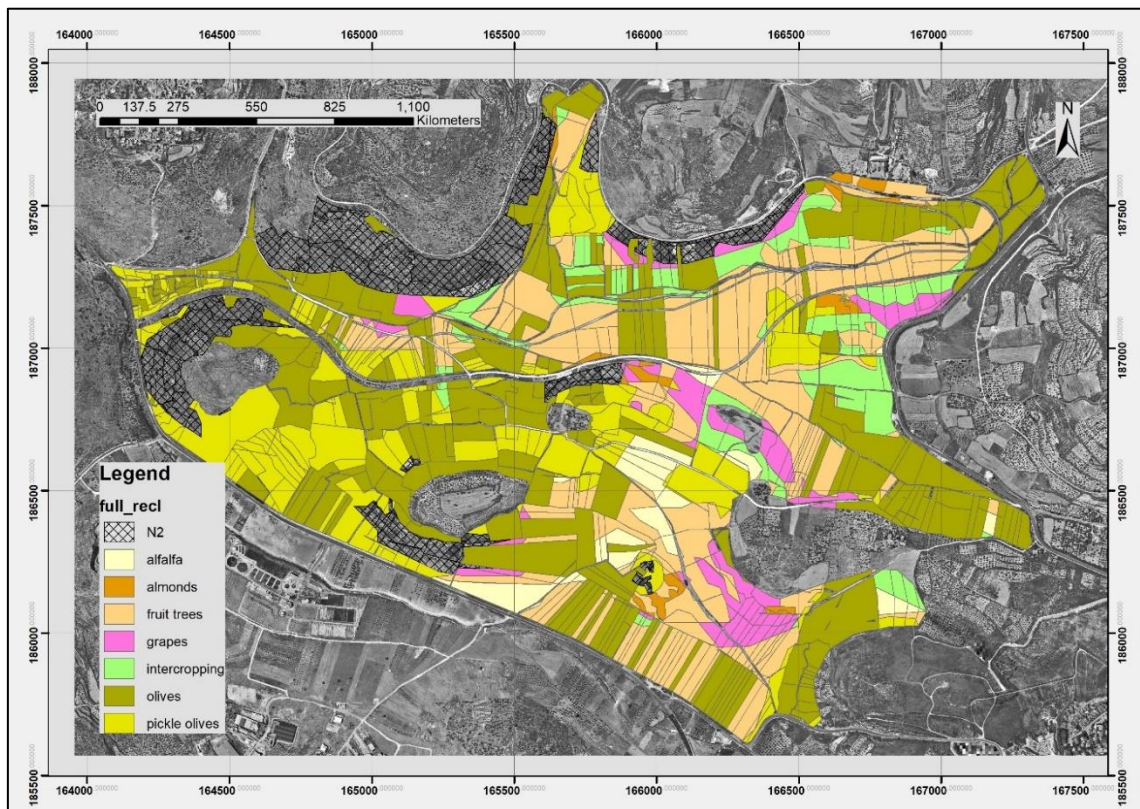


Figure 17 Cropping pattern with full reclamation



Please note that the respective cropping patterns are optimal for the land suitability conditions; they do not consider socio-economic factors such as labour, income, return on investment, risks, etc. and therefore do not present what the farmers decide to cultivate. It is however an important guideline for future cultivation. In Chapter 5 more detailed scenarios, including / excluding alfalfa and intercropping are worked out. To be noted is that land reserved for alfalfa and intercropping can also be cultivated with any fruit tree.

3 CROP WATER REQUIREMENTS

3.1 EVAPOTRANSPIRATION

In consultation with MoA, crop water requirements have been calculated according to the relevant FAO Manual 56²⁵. Calculation routines are like those of the FAO CROPWAT-8 simulation model.

Reference ET_0 evaporation has been calculated for Nablus meteorological station, using FAO CROPWAT-8. As the irrigation area is on average 310 m lower than the relevant Nablus meteorological station, the ET_0 values have been further corrected for the difference in altitude between the Wadi Shaeer irrigation area and the meteorological station in Nablus (260 m a.s.l and 570 m a.s.l respectively). The Manual of the ICAO Standard Atmosphere of the International Civil Aviation Organization (1993) gives for the Mediterranean area an adiabatic tropospheric lapse rate of 6.45 K/km. Considering this adiabatic tropospheric lapse rate, it can be calculated that the temperature in the Wadi Shaeer irrigation area should be roughly 2 K warmer than in the meteo station in Nablus.

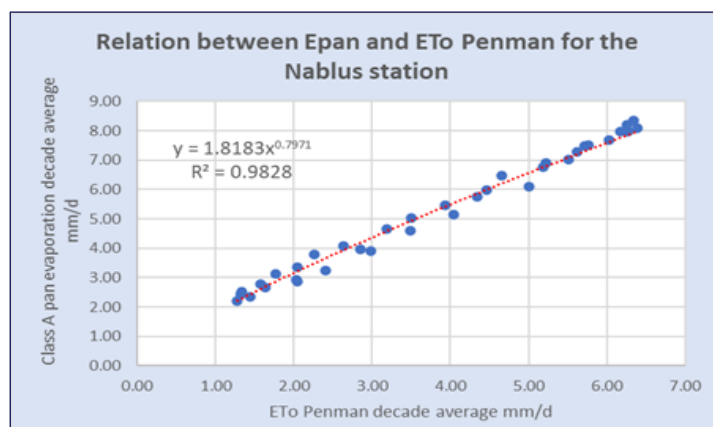
Using the Hargreaves- evapotranspiration equation²⁶, the evaporation rate can be corrected for Wadi Shaeer by multiplying the calculated Nablus ET_0 values by:

$$ET_{0, \text{ Wadi Shaeer}} = ET_{0, \text{ Nablus}} \cdot (T_{\text{air, Nablus}} + 17.8 + \Delta T) / (T_{\text{air, Nablus}} + 17.8),$$

where ET_0 is the reference evaporation [mm/day], T_{air} is the average air temperature for a certain period [°C] and ΔT is the difference in air temperature (°C) between Wadi Shaeer and Nablus.

For verification, we have compared the ET_0 values for Nablus with the Class A pan evaporation in the meteorological station. The correlation between the two variables is exceptionally good, an indication for the reliability of the data. See the graph in Figure 18 below:

Figure 18 Comparison of ET_0 reference evaporation and Class A pan evaporation for the Nablus meteorological station



²⁵ Allan, R., Pereira, L., Smith, M., 1998. Crop evapotranspiration - Guidelines for computing crop water requirements. FAO Irrigation and drainage paper 56.

²⁶ Hargreaves H. and Allen R.G., 2003. History and Evaluation of Hargreaves Evapotranspiration Equation. Journal of Irrigation and Drainage Engineering 129-1.

3.2 YEARLY WATER REQUIREMENTS AND PEAK DEMAND

Yearly crop water requirements have been calculated based on average values of 10-days ET_0 over the period 2006 - 2019. Peak demands have been calculated for each decade. An overview of the most important calculation results is given in Annex 7, which also depicts the values of the effective rainfall following CROPWAT-8 model calculations, applying the FAO dependable rain FAO/AGWL formula in the CROPWAT-8 software.

To obtain crop water requirements, the ET_0 values have been multiplied by the respective crop factors²⁷ (from the same FAO manual), corrected for effective rainfall and for leaching requirements and divided by the irrigation efficiency (90 percent for drip irrigation, 75 percent for sprinkler irrigation):

$$ET_c = (K_c \cdot ET_0 \cdot (1 + LR) - R_{eff}) / E$$

where ET_c is the crop water requirement, K_c is the crop coefficient, ET_0 is the reference evaporation, LR is the leaching requirement, R_{eff} is the effective rainfall and E is the irrigation efficiency.

LR is calculated with the following formula (from the same FAO manual):

$$LR = EC_w / (5 \cdot EC_e - EC_w) / L_e$$

where EC_w is the electric conductivity of the irrigation water (9 dS/m)²⁸, EC_e is the soil salinity at which the harvest is 90 percent of the maximum harvest²⁹, and L_e is the leaching efficiency (here assumed to be 70 percent, for clay soils (as from the FAO manuals).

As agreed with MoA, the K_c coefficients for different crops are calculated using Table 12 from FAO 56, which table is recommended by FAO for planning purposes. Table 12 from FAOP 56 lists typical values for $K_{c\ ini}$, $K_{c\ mid}$, and $K_{c\ end}$ for various agricultural crops. These values represent K_c for the start of the growing season, during full crop development and at the end of the growing season. Moreover, these values have been corrected as indicated in FAO 56, Figure 27. The correction for $K_{c\ ini}$ reflects the wetting of the soil surface; it was agreed with MoA to use $K_{c\ ini} = 0.3$ for olives, $K_{c\ ini} = 0.4$ for all other fruit trees and apply no correction for alfalfa. For $K_{c\ mid}$ and $K_{c\ end}$ formula 62 of FAO 56 was used to calculate relevant reductions.

For olives trees, it is assumed that the farmers will apply deficit irrigation, meaning that the above ET_c values will again be multiplied by the deficit irrigation factor as estimated in the Table 9³⁰ below.

²⁷ From the FAO Irrigation and drainage paper 56 but adapted for the start and length of the growing season in the project area (acquired by interviewing farmers and experts as no publications exist on this).

²⁸ Nablus Municipality: Wastewater Treatment Plant Nablus West. Annual Report for Operations and Reuse 2018.

²⁹ Values have been derived from the original reference "Doorenbos J, and Pruitt W.O. 1977. Guidelines for predicting Crop Water Requirements. FAO Irrigation and drainage paper 24". The 10 percent yield reduction is a theoretical one; in reality the yield reduction will be considerably less as, in this area, good leaching takes place during the rainy season.

³⁰ Estimated from various literature references that do however not give concluding values.

Table 9 Deficit irrigation factors for olive trees

Month / decade	Percentage deficit irrigation
January decade 1 / May decade 1	100%
May decade 2	75%
May decade 3 / June decade 1	50%
June decade 2	40%
June decade 3 / August decade 1	30%
August decade 2	40%
August decade 2 / September decade 1	50%
September decade 2	75%
September decade 3 / December decade 3	100%

Full irrigation without restrictions give the best results in crops - like alfalfa - that are grown for harvesting their biomass. Fruit trees fare well however with deficit irrigation, where the irrigation rate is reduced during certain phenological stages of fruit development. Giving water below the theoretical evaporation demand at specific times during crop development does not reduce yield significantly and improves the quality of the fruit and derived products like olive oil.

In literature³¹ two methods of deficit irrigation can be observed:

1. Regulated Deficit Irrigation (RDI), where the irrigation rate is carefully adapted to the requirements of each phenological³² stage. For olives, this results in the deficit irrigation factors outlined above.
2. Sustained Deficit Irrigation (SDI), where the water rate is reduced but at a fixed percentage of evaporative demand or to a fixed amount per month³³.

The quoted references are both compilations of research over the last 50 years and indicate that RDI is likely to give better results than SDI. The results of the respective calculations and the used Kc factors are depicted in Annex 8. A summary for different crops is given below.

³¹ Fernandez J.E. et al. 2018. Precision Irrigation in Olive (*Olea europaea* L.) Tree Orchards. In Water Scarcity and Sustainable Agriculture in Semiarid Environment. ISBN 978-0-12-813164-0.

³² Recognizable stages of seasonal development such as budding, flowering, fruit setting, fruit development, ripening, harvesting.

³³ This method is propagated by MoA. For dry conditions (we assume that this is mostly the case for the shallow soils in Wadi Sha'er), 400 mm of water is divided over the period May to September (50, 50, 100, 100 and 100 mm respectively).

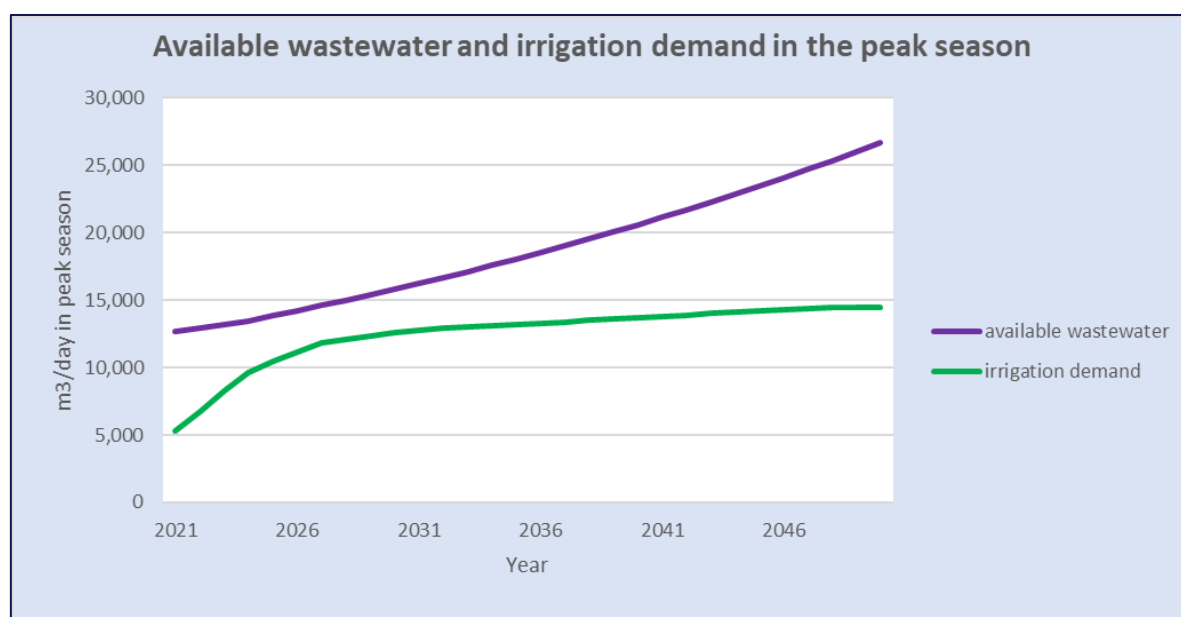
Table 10 Yearly crop water requirements and peak water demand

Crop	Annual water requirement [mm/year]	Peak water demand [mm/d]
Alfalfa subsurface	1,333	7.25
Olives, oil	505	3.32
Olives pickles	843	5.64
Almonds	1,251	8.05
Figs	861	5.64
Avocado	1,379	7.83
Apricots	1,128	7.97
Grapes	1,027	7.23
Intercropping pecan & alfalfa	1,345	8.38

Crop water requirements have furthermore been calculated for a 30-year period starting 2022, considering the development of new trees and the likely percentage of the area that will be planted over time. The relevant percentages are presented in Annex 8.

3.3 DEMAND AND AVAILABLE WATER RESOURCES

In addition, the required peak demand flow has been compared with the flow that can be delivered by the treatment plant. An example of such comparison is presented in Figure 19 below. The graph presented in this figure is for a scenario with full reclamation but without considering alfalfa and intercropping. In Chapter 5, this comparison is made in table form for each individual scenario over the whole planning period of 30 years (refer to Annex 11).

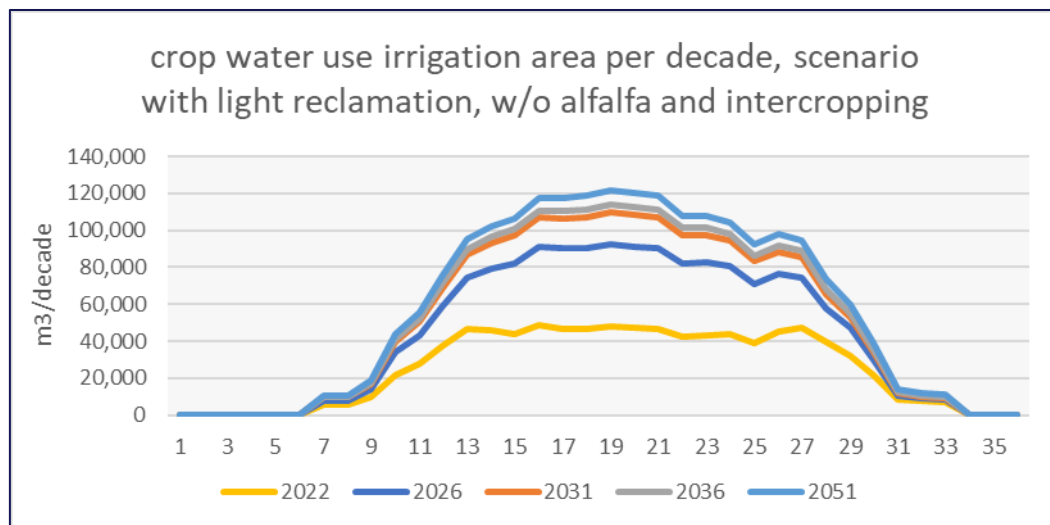
Figure 19 Comparison of the estimated available wastewater and the estimated future irrigation demand

It should be observed that water is abundant under all possible scenarios. It opens the option to also irrigate the land in archaeological sites (209 du), areas beyond the present study area that can be irrigated under gravity (190 du) and in high areas (180 du, provided booster pumping); this would require roughly 16 percent more water, still within the available quantities. After 2031, more water will be available and could be used to extend the irrigated area, to reclaim marginal land, to replace olive trees by more water demanding other fruit trees, or to use water for other irrigation areas, whatever is opportune at that time – which would also increase cash flow for NM and the WUA.

Contrary to expectations raised in the feasibility studies of the Project, 30 to 35 percent of the produced wastewater (depending on the selected scenario) can be used in the study area when accounted over the entire year. This is largely due to reduced irrigation needs outside the three summer months and additional wastewater produced in winter³⁴ due to mixed sanitation systems, which also absorbs rainwater during a time not suitable for irrigation. When the above extension options (archaeological sites, high areas, etc.) will be included, the percentage might increase to 35 to 41 percent.

The water use over the irrigation season during peak demand and its development over the years is presented in the figure below for the scenario with light reclamation without alfalfa or intercropping (Scenario 5):

Figure 20 Water use over the irrigation season



There is a need to discuss the utilization of the surplus treated wastewater as the absorption capacity in the irrigation scheme is limited. There are basically four options:

1. The surplus water will be carried to the border with Israel and sold to Israel. This option may have political complications that are beyond the grasp of the Project. From the financial point of view, it is however a very attractive option.

³⁴ Approximately 7.2 percent in 2018.

2. The surplus water is stored in a large open-air reservoir. This option was mentioned in the feasibility studies in 2016 and rejected for cost and topographic reasons.
3. The surplus water would be injected in the groundwater. Apart from that this is at present not allowed, it should also be noted that the salinity of the treated wastewater is higher than the salinity of the groundwater and the surplus wastewater would hence pollute the groundwater.
4. The surplus water is transported to the Jordan Valley and used for irrigation there.
To be noted that until about 2035, this will be largely winter surplus and can only be used for crops that have no water needs in summer, such as cash crops like tomatoes, cucumber, etc. This is at present not allowed under Palestinian standards for wastewater reuse. In this context, there is a need to study the best use of treated wastewater in the Jordan Valley in combination with other available water resources (springs, groundwater). After 2035 there will also be a summer surplus, which can be used for crops like date palms, grapes, citrus, etc.

4 ECONOMIC ASPECTS

4.1 BASE DATA

As part of the analysis of the selected crops mentioned in Section 2.3, extensive information was collected on yields, costs, farm gate prices and investment costs for these crops, including present crops - mainly rainfed olives and field crops - as well as future crops, including olives (oil and pickle), fruit trees (pecan, apricots, figs and grapes), and fodder crops (alfalfa). Vegetable crops were excluded from the study because Palestinian standards do not allow to irrigate vegetables with treated wastewater.

The information is compiled in the base data sheet, presented in Annex 10. The sheet gives information on yields, farm gate prices, and depreciated costs on planting and irrigation systems, as well as water, agrochemicals, soil preparation, harvesting, labour, oil pressing and other costs. The sheet calculates – for mature trees - costs and benefits, Net Benefit (NB), the benefit/cost (B/C) ratio accounted against uncultivated, the B/C coefficient accounted against traditional olives for full dense olive orchards, and the B/C coefficient accounted against wheat/barley for all other crops. The B/C coefficient against existing crops varies between 1.34 and 2.11, indicating that irrigation is economically feasible³⁵ for all investigated crops in the Wadi Shaeer irrigation area. A brief capitulation of these coefficients is given in Table 11 below.

The B/C ratio has also been calculated for labour costs as is suggested in the final report of the Farmer Mobilisation Campaign, 1st phase. Values are largely the same for all fruit trees (including olives), meaning that the availability of labour does not play a major role in crop selection. However, values are high for pecan and in particular for alfalfa as most of the work in alfalfa is mechanical. This could be a reason to go for alfalfa in case labour is very scarce or expected to be not available.

Table 11 Recapitulation of economic factors for mature fruit trees and alfalfa

	Olive dense, existing	Olive new pickles	Olive scattered, gaps filled	Apricots	Almonds	Figs	Grapes	Pecan	Alfalfa SSI	Inter-cropping
Total cost [ILS/du]*	2,557	3,579	2,583	4,341	3,595	4,243	11,329	2,940	2,948	2,940
Total benefit [ILS/du]	3,731	5,850	3,731	8,000	5,625	8,400	22,500	5,000	3,840	5,000
Net Benefit [ILS/du]	1,174	2,271	1,148	3,659	2,030	4,157	11,171	2,060	892	2,060
benefit/cost ratio against uncultivated	1.46	1.63	1.44	1.84	1.56	1.98	1.99	1.70	1.30	1.70
labour-based benefit/cost ratio	0.91	1.30	0.89	1.74	1.66	1.82	1.64	2.75	2.97	3.92
benefit/cost ratio against wheat/barley		1.72		1.95	1.64	2.11	2.03	1.83	1.34	1.83
benefit/cost ration against olive traditional	1.70		1.67							

The Net Benefit values for all considered crops at their mature stage range from around 890 ILS/du for alfalfa, around 1,160 ILS/du for olives irrigated under deficit, around 2,270 ILS/du for pickle-olives, around 2,030 to 4,160 ILS/du for all types of fruit trees, and around 11,170 ILS/du for table-grapes. These data (at least for known crops such as olives, apricots, and figs)

³⁵ Environmental impacts, such as percolation of treated wastewater with a relatively high salinity to the groundwater and impacts to the ecosystem of the Wadi Shaeer area because of irrigation, have not been studied. Social impacts have been evaluated for health impacts (see ESIA: negligible) and impacts on labour (the present study claims that the amount of labour will increase from roughly 6 person-days/du/year to roughly 17 person-days/du/year).

coincide with expectations of farmers expressed during the farmer survey interviews and during meetings in the framework of the Farmer Mobilisation Campaign. To be noted that grapes bring a high income, but their development may be hampered by investment costs that are more than a tenfold higher than for most other crops.

4.2 CASH FLOW FORECASTS

The data from the table was used for cash flow calculations, undiscounted and discounted at a discount rate of 6 percent³⁶. Results for undiscounted calculations are presented in Figure 21 (with grapes) and 22 (without grapes, to have a clearer picture of the other crops).

Figure 21 Cash flow forecast, undiscounted, for all potential crops

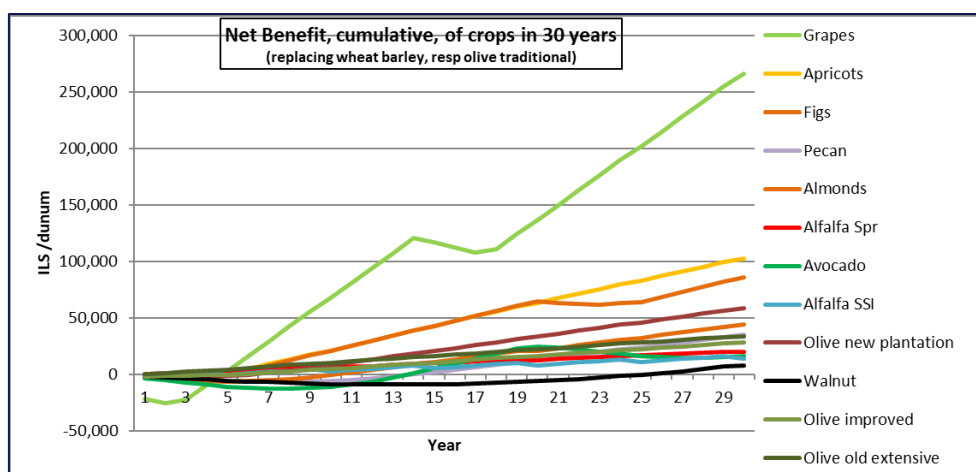
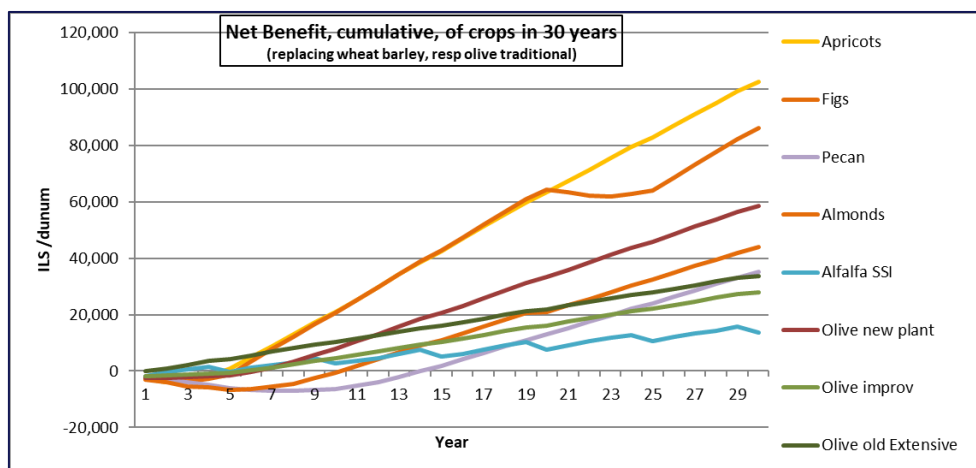


Figure 22 Cash flow forecast, undiscounted for all potential crops except grapes



³⁶ As there is no official discount rate for Palestine, it is usual to use the interest rate of the country's Central Bank, in this case the Palestinian Monetary Authority for the commercial banks minus 1 to 2 percent. This interest rate was 7 percent at the moment of writing this report. To be noted that Palestine does not have its own currency and deals with USD, ILS and JOD. The present interest rates are however much higher than in the USA, Israel or Jordan and their discount rates cannot be copied. The number is in line with international practice which observes discount rates between 7 and 12 percent for developing countries.

It is noteworthy to observe the large differences between the crops.

Grapes stand out having by far the highest Net Benefit after 30 years of cultivation. However, the initial investments are high, and the farmer need to bring up around 25,000 ILS/du for each dunum he/she will plant with grapes. Return on investment is good, the payback period (breakeven point) is just 5 years, despite the high investments. This is the same as for other fruit trees. Average income over 30 years (not discounted) will be almost 9,000 ILS/du.

Fruit trees (stone fruits, figs) require far less capital, less than 4,000 ILS/du and they pay back in around 5 years as well. Apricots and figs (not investigated are other stone fruits like prunes, but they should not differ too much) give good income: Average income over 30 years (not discounted) will be almost 3,200 ILS/du.

Nuts, like pecan, do not present a favourable picture. The payback period of pecan will be almost 17 years and Average income over 30 years (not discounted) will be around 1,150 ILS/du only. Capital needed would be around 6,000 ILS/du. It should be noted that in the USA pecan is rather planted for the value of its wood. After 100 years, one dunum may provide over 500,000 ILS in precious pecan wood, which would bring pecan close to grapes in revenue. This does not apply to Palestine as the country is without wood processing industry and old nut trees are usually cut for firewood.

Alfalfa does not present an overall favourable picture either for two reasons: (i) its undiscounted B/C ratio is low: 1.31, which is below the 1.5 that farmers would normally perceive as acceptable risk, and (ii) its revenues are relatively low: one dunum of alfalfa would not bring more than 400 ILS income per year, averaged over its normal 5-year production cycle. However, capital needed is relatively low, around 2,000 ILS/du (somewhat less than fruit trees) and payback is almost immediately, after a little more than one year.

Olives and almonds have good B/C ratios: around 1.7. Growing olives under irrigation is therefore an acceptable risk. Capital needs vary between 800 and 2,400 ILS/du, depending on whether it concerns existing orchards or newly planted and/or improved olive orchards. Average income over 30 years (not discounted) will be between 900 and 2,000 ILS/du. . Olives stand out in terms of low investment risk and relatively low capital needs, but do not in terms of income, even though they do much better than alfalfa for instance.

Intercropping of pecan and alfalfa have a good B/C ratio of 1.70. Capital needs are around 6,000 ILS/du, around the same as for pecan alone, Average income over 30 years (not discounted) will be around 11,800 ILS/du, slightly better than pecan alone. It should be noted that the management of any intercropping scheme is more complex than one crop alone and farmers should be professionally trained in that.

4.3 TARIFFS

Tariff calculations have been made based on estimated construction costs. An overview of estimated CAPEX (capital expenditure) and OPEX (operational expenditure) is given in Table 12 below. O&M costs are calculated as a fixed yearly percentage of the CAPEX, according to international standards. Depreciation costs based on linear depreciation of 50 years for civil works and 15 years for the electric and mechanical parts are also indicated in the table.

Table 12 CAPEX, OPEX

Fixed cost	CAPEX [EUR]	Percentage	OPEX [EUR/year]	Lifetime [years]	Depreciation [EUR/year]	NM [EUR/year]	WUA [EUR/year]
Other costs (overheads)	200,000	N/A	N/A	N/A	N/A		
TT Civil works	1,000,000	0.5%	5,000	50	20,000	25,000	
TT Pipe works	300,000	0.5%	1,500	50	6,000	7,500	
TT Mechanical *	800,000	3.0%	24,000	15	53,333	77,333	
TT Electrical *	700,000	3.0%	21,000	15	46,667	67,667	
Pressure main	1,700,000	0.5%	8,500	50	34,000	42,500	
Irrigation reservoir	400,000	0.5%	2,000	50	8,000	10,000	
Distribution network	1,900,000	0.5%	9,500	50	38,000		47,500
Farm head works	200,000	8.0%	16,000	50	4,000		20,000
Fence	100,000	8.0%	8,000	50	2,000		10,000

Operational cost	Unit cost [EUR/month]	Units	OPEX [EUR/year]				
Staff NM **	800	2	19,200			19,200	
Staff WUA ***	800	3	28,800				28,800
Operational cost WUA	1,200	1	14,400				14,400

Variable cost	Unit cons [kWh/m ³]	Units [m ³ /year]	kWh/year			Amount [EUR/year]	
Electricity	0.5479	2,500,000	1,369,750			172,118	

Electricity price in ILS 0.48629

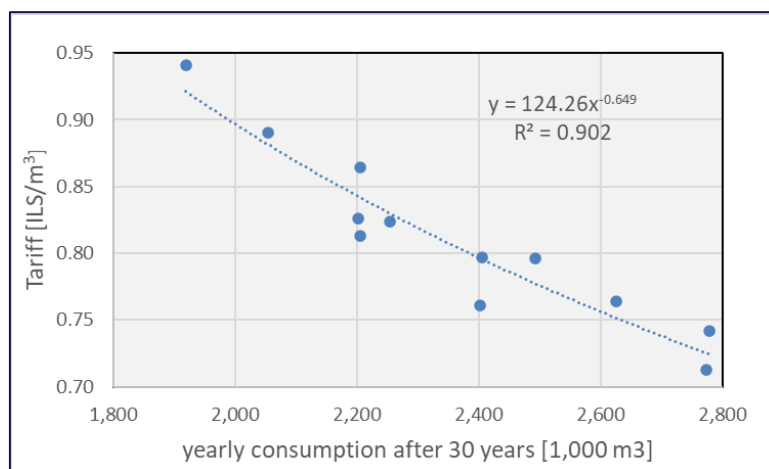
Exchange rate EUR/ILS (InforEuro July 2020) **3.87**

* as spare parts are available, 10% of the amount during the first two years of operation; after that increasing from 60% to 100%

** number of extra staff as indicated by WWTP management

*** it is assumed that one staff will be paid from renting machines

Based on the information in the table, breakeven tariffs have been calculated, using 30-year discounted cash-flow calculations with a discount rate of 6 percent. These calculations include depreciation of electro-mechanical equipment for the tertiary treatment plant and the pumping system. It does not include depreciation of civil works as these have a lifetime of at least 50 years. There is a strong relation between the selected cropping pattern and the tariff; the more water is consumed, the lower the tariff can be. This is illustrated in Figure 23 below.

Figure 23 Relation between yearly wastewater consumption and the water price

To be noted that these tariff calculations are preliminary; they do not foresee potential cash-flow problems and will likely be slightly higher in final calculations. Such final tariff calculations will not be possible before the final design has been approved by the client and bills of quantity provided. The present tariff calculations indicate that a price of 1.00 ILS/m³ is feasible, apart from start-up cash-flow issues and possible financial risks as discussed in the next chapter.

The Pay-Back Period of the project is, without KfW subsidies for on-farm investments, around 5 years; the eventual subsidies will only have a minor impact on pay-back. For most fruit trees, including olives, this is the same. Pecan is an exception here as its payback period is 17 years. Growing alfalfa pays back within one or two years.

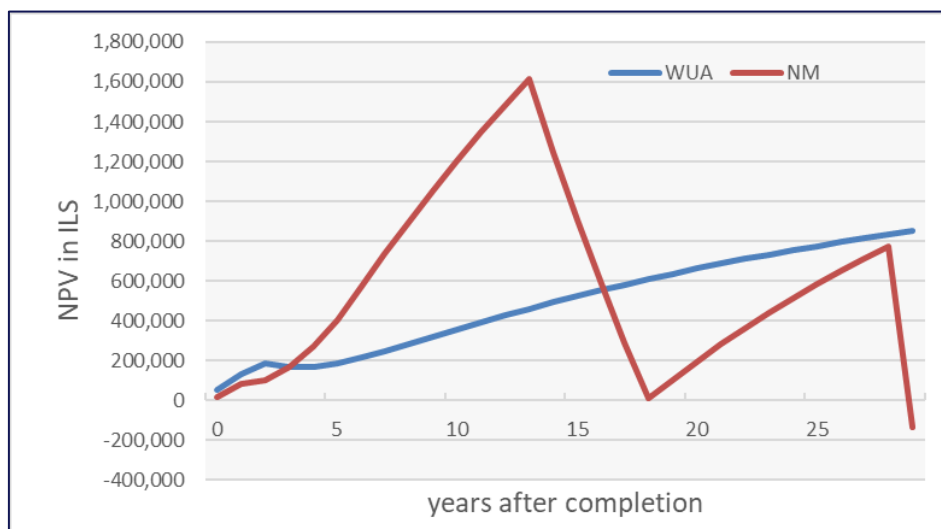
The Internal Rate of Return (IRR) for the KfW investment depends again on the selected scenario. In the scenario with light reclamation without alfalfa or intercropping, it is 12.6 percent³⁷. It is a criterion for the selection of the most appropriate scenario.

4.4 CASH FLOW AND FINANCIAL RISKS

In Chapter 5 different scenarios will be discussed. Anticipating that discussion, the Consultant proposes for the start-up of the project the scenario with light reclamation without alfalfa or intercropping; this scenario seems the most likely to happen.

Based on this scenario, cash-flow calculations were made for NM and the WUA as shown in Figure 24.

Figure 24 Cash-flow forecasts (as NPV) for NM and WUA; scenario with light reclamation without alfalfa and intercropping



Conditions to achieve this cash-flow are:

- It is assumed that the collection rate is Tariffs will be 0.65 ILS/m³ for the WUA and 0.90 ILS/m³ for the farmers.

³⁷ In Chapter 5, the IRR is shown for all scenarios.

- NM will have a positive NPV during all 30 years.
- The WUA cannot have negative cash-flow as it has no access to credit and will then not be able to pay its bill to NM and/or pay salaries of its staff.

To keep cash flow positive for the WUA the tariff would need to be raised to approx. 1.02 ILS/m³. It should be clear that farmers will start losing interest to participate if a tariff above 1.00 ILS/m³ would be applied. It is proposed to maintain the tariff at 0.90 ILS/m³ (also to eliminate risks). This will however only be possible if the WUA receives a start-up subsidy from the PA on operational costs.

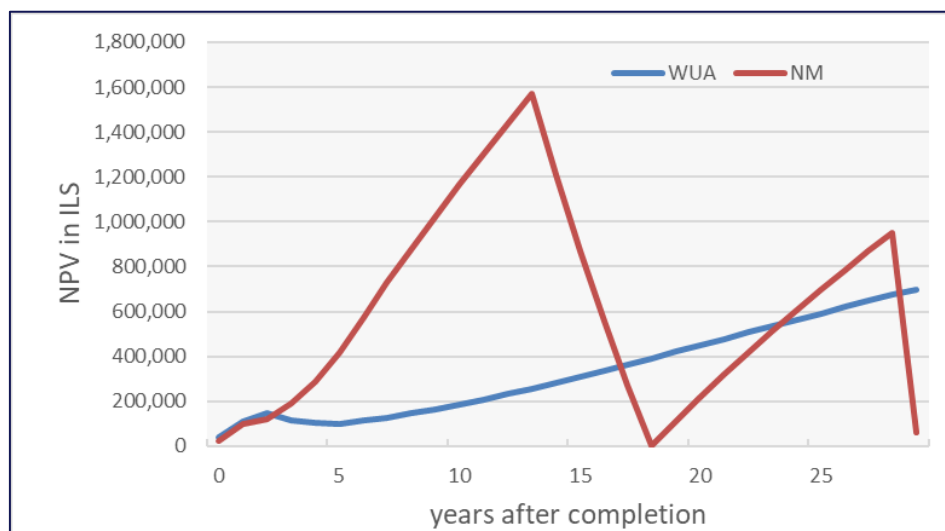
In the above cash-flow projection it is assumed that the PA puts WUA staff on its payroll for three years. This will keep the cash flow positive and build necessary reserves of around that can be either used for improvements and / or extensions of the distribution network, for land amelioration or can be used for subsidizing farmers / members in some way. It also reduces the tariff to 0.88 ILS/m³.

Such subsidy would be fully justified as the Palestinian State is earning considerable amounts of money by releasing less wastewater to Israel. Any other tariff subsidy - for instance, a zero tariff for the first two years as suggested by the WUA to stimulate farmers to join the irrigation schedule – needs transfer of budget to both NM and the WUA under a special arrangement beyond aforementioned subsidy. This would need roughly one million ILS per year.

The tariff calculations in Figure 23 assume that 80% of farmers in the earmarked 2,641 du will join the irrigation schedule in the first year of operation (equalling around 2,100 du). There is a considerable risk that this will not happen. We have therefore repeated tariff and cash-flow calculations for a pessimistic scenario where approx. 1,700 du will join the irrigation schedule in the first year. This number coincides with present membership (representing 1,654 du).

Obviously, this scenario would need a higher tariff. When not enough farmers would join the irrigation schedule at its start, the tariff needs to be increased to 0.98 ILS/m³, close to the 1 ILS threshold. The impact on cash flow is shown in Figure 25:

Figure 25 Cash-flow forecasts (as NPV) for NM and WUA in a pessimistic scenario of less farmers joining the irrigation schedule.



The mentioned start-up subsidy is a crucial issue for the WUA (without they may cease to exist) and the issue needs to be discussed in the Steering Committee meeting between beneficiaries, client, and donor.

To be noted that all NPV calculations include 10% losses in the distribution system and a 60 percent collection rate improving 5 percent every year until a value of 90 percent has been reached.

4.5 KfW SUBSIDIES

For the envisaged KfW subsidies, a model has been agreed with NM in which investments in equipment and seedlings are covered by a financial contribution of KfW and farmers shoulder land preparation, planting and irrigation system installation costs. In the following, the model has been worked out for the situation with light reclamation without alfalfa or intercropping. This corresponds to scenario 5 in Chapter 5, which we consider as the most likely to happen. It is assumed that in the first year of irrigation (as KfW subsidy will only be available during project implementation) the scenario with light reclamation is applicable and that at best 80 percent of the farmers in that scenario will join the irrigation schedule. This leads to a maximum contribution by KfW of around 645,000 EUR and a contribution of Wadi Shaeer farmers of around 530,000 EUR. Part of the farmer contribution shall be in cash (50 percent of the FHWs); part in kind, such as own labour; part is in paid services under the management of the farmer. Construction of the FHWs need to be done by an experienced contractor and will be included in the Lot 2 tender as an option with a unit price and a maximum quantity.

Experiences in the USAID Compete Project and in the KfW subsidised Outside Pilot Scheme show that outsourcing all work on planting and installation of irrigation systems to a contractor leads to adverse results as it hampers the development of the own responsibility of the farmers – the USAID-supported Compete Project is almost abandoned; the Outside Pilot Scheme has not yet managed to involve the landowners and is not sustainable so far.

The subsidy proposal is presented in Table 13³⁸ on the next page.

In this concept, the farmers will contribute on average around 250 ILS/du in cash for a 50 percent contribution to the FHWs plus around (on average, excluding grapes) 590 ILS/du in kind. For grapes, these number are considerably higher, but revenues are also much larger than those for other fruit trees. The percentages of KfW subsidies show equity between the different crops; they are between 47 percent (grapes) and 74 percent (alfalfa); the amounts are largely below the foreseen budget in the Separate Agreement. In the second phase of the FMC, a discussion will take place with the farmers on the affordability of this contribution; The Consultant estimates that a farmer contribution of 840 ILS/du (slightly more than 200 EUR/du) is affordable.

³⁸ The table provides different numbers for each scenario as discussed in the next Chapter. The table serves here just as an example. More detailed information for each scenario will be given in the next chapter.

Table 13 Schedule of KfW subsidies and farmers own contribution for on-farm investments

crop	land prepa- ration	irrigation systems		plants		KfW	farmer	total	area [du]	total investment		KfW contri- bution
		material	instal- lation	seed- lings	planting					KfW	farmer	
Subsidies per dunum for all crops except grapes												
Olives new, pickle	225	513	140	450	300	963	665	1,628	254	244,987	169,176	59%
Olives existing	225	513	140	112	75	625	440	1,065	711	444,500	312,928	59%
Olives scattered	225	513	140	225	150	738	515	1,253	230	170,035	118,656	59%
Apricots	270	513	140	750	200	1,263	610	1,873	258	325,349	157,136	67%
Figs	270	513	140	240	300	753	710	1,463	258	193,973	182,896	51%
Almonds	270	513	140	900	400	1,413	810	2,223	180	254,340	145,800	64%
Alfalfa subsurface	162	2,350	800	350	7	2,700	969	3,669	0	0	0	74%
Intercropping	270	1,275	450	675	104	1,950	824	2,774	0	0	0	70%
							total area		1,891			
							total investments ILS			1,633,184	1,086,592	
							total investment EUR			422,011	280,773	
Subsidies per dunum for grapes												
Grapes	675	1,375	190	2,250	3,200	3,625	4,065	7,690	222	803,300	900,804	47%
							total area		222			
							total investments ILS			803,300	900,804	
							total investment EUR			207,571	232,766	
Farm head units												
Unit costs	1000	Number of units:		300						150,000	150,000	
							total investment EUR			150,000	150,000	
Total investments including grapes										644,582	528,539	

Exchange rate EUR/ILS

3.87

Not all farmers may - for various reasons, personal and financial - be prepared to start irrigation immediately and may not decide to apply for the subsidy in the first year of operation. To stimulate the participation of farmers in the second year of operation, when the Project is already closed, the availability of a subsidy would be very helpful. This issue should be addressed in a Steering Committee meeting to find a solution.

5 SCENARIOS AND MULTICRITERIA ANALYSIS

As was discussed in Chapter 2, three main development scenarios are foreseen, one without any reclamation, one with light reclamation and one with full reclamation. Within each main scenario, four different technical scenarios are foreseen with some variation in cropping pattern and irrigation methods for olive trees. These are:

- a scenario that use Regulated Deficit Irrigation (RDI), without alfalfa or intercropping
- a scenario that uses RDI, with 326 du of alfalfa
- a scenario that uses RDI, with 326 du of intercropping
- a scenario that uses Sustained Deficit Irrigation (SDI), without alfalfa or intercropping

The resulting twelve scenarios are presented in Table 14 below. They form the basis for the Multicriteria Analysis (MCA).

Table 14 Scenarios analysed for the Multi-Criteria Analysis

	crop →	Olive orchards, existing	Olive new pickles	Olive scattered gaps filled	Almonds	Apricots	Figs	Grapes	Alfalfa subsurface irrigation	Intercrop pecan & alfalfa
		[du]	[du]	[du]	[du]	[du]	[du]	[du]	[du]	[du]
Without land reclamation										
Scenario 1	without alfalfa and intercropping, using RDI *	889	376	288	194	281	281	168	-	-
Scenario 2	with alfalfa	889	376	288	112	200	200	86	326	-
Scenario 3	with alfalfa/pecan intercropping	889	376	288	112	200	200	86	-	326
Scenario 4	without alfalfa and intercropping, using SDI **	889	376	288	194	281	281	168	-	-
With light land reclamation and RDI for olives										
Scenario 5	without alfalfa and intercropping, using RDI	889	318	288	225	322	322	277	-	-
Scenario 6	with alfalfa	889	318	288	144	240	240	196	326	-
Scenario 7	with alfalfa/pecan intercropping	889	318	288	144	240	240	196	-	326
Scenario 8	without alfalfa and intercropping, using SDI	889	318	288	225	322	322	277	-	-
With extensive land reclamation and using RDI for olives										
Scenario 9	without alfalfa and intercropping, using RDI	889	547	288	282	334	334	330	-	-
Scenario 10	with alfalfa	889	547	288	201	252	252	249	326	-
Scenario 11	with alfalfa/pecan intercropping	889	547	288	201	252	252	249	-	326
Scenario 12	without alfalfa and intercropping, using SDI	889	547	288	282	334	334	330	-	-

* Regulated Deficit Irrigation

** Sustained Deficit Irrigation

The results of the MCA are presented in Table 15 below:

Table 15 Preliminary results of the MCA

SCENARIOS		INFORMATION			CRITERIA					
Type of reclamation with or without alfalfa and intercropping Irrigation modality of olives		Alfalfa subsurface irrigation	Intercropping pecan & alfalfa	Water needs in 2051 ¹⁾	Percentage of wastewater reused 2026 ²⁾	Internal Rate of Return (KfW) ³⁾	Farmer income ⁴⁾	Employment ⁵⁾	Tariff ⁶⁾	Net benefit Palestinian economy
		[du]	[du]	[thousand m3/year]			[million ILS/year]	full-time job equivalence nt	[ILS/m3]	[million ILS/year]
scenario 1	no reclamation, RDI, w/o alfalfa and intercropping	0	0	2,054	28%	11.3	6.23	186	0.890	11.57
scenario 2	no reclamation, RDI with alfalfa	326	0	2,201	31%	9.8	4.80	148	0.826	10.52
scenario 3	no reclamation, RDI with intercropping	0	326	2,205	30%	9.8	5.18	144	0.813	10.91
scenario 4	no reclamation, SDI, w/o alfalfa and intercropping	0	0	1,919	26%	10.7	5.95	178	0.941	10.94
scenario 5	light reclamation, RDI, w/o alfalfa and intercropping	0	0	2,253	31%	12.6	7.98	227	0.824	13.84
scenario 6	light reclamation, RDI with alfalfa	326	0	2,401	35%	11.4	6.56	190	0.761	12.80
scenario 7	light reclamation, RDI with intercropping	0	326	2,405	33%	11.4	6.94	186	0.797	13.19
scenario 8	light reclamation, SDI, w/o alfalfa and intercropping	0	0	2,205	30%	12.1	7.71	220	0.864	13.44
scenario 9	full reclamation, RDI, w/o alfalfa and intercropping	0	0	2,626	35%	12.5	9.47	267	0.764	16.30
scenario 10	full reclamation, RDI with alfalfa	326	0	2,774	35%	11.9	8.05	230	0.713	15.26
scenario 11	full reclamation, RDI with intercropping	0	326	2,779	37%	11.5	8.44	226	0.742	15.67
scenario 12	full reclamation, SDI, w/o alfalfa and intercropping	0	0	2,492	33%	12.0	9.20	260	0.796	15.68

The results are preliminary as no weights are given to the different criteria. After receiving the IMOP and approving its calculations, relevant stakeholders will be asked which criteria are important for them and weight them on a scale 1 to 5. These weights will be included in the MCA and final results will be provided. Using so called song-festival scoring (where each scenario is given 1 - 10 points for each criterion, scenarios 9 - 12 score best. Of these, Scenario 9, full reclamation, RDI, without alfalfa or intercropping seems the preferred scenario.

However, this scenario requires full reclamation, which comes at a cost of around 150,000 EUR. It can also be doubted if it is wise to reclaim land for farmers without making sure that these farmers are really interested and will start irrigating their land. Sharing costs between the Project and farmers would give a good indication if this interest is there. It should be noted that in the land that is earmarked for full reclamation, only few farmers are member of the WUA, contrary to land which is earmarked for light reclamation. In this sense, the Consultant prefers at this moment to go for Scenario 5, leaving the option open to carry out full reclamation in a later stage.

6 ORGANISATIONAL ASPECTS

6.1 THE WADI SHAEER WATER USER ASSOCIATION

The Wadi Shaeer Water User Association (WUA) will in future manage the irrigation system of the Wadi Shaeer area. Its mission and objectives are set down in its internal regulations as:

Article 4: The Association's Mission

The Association aims at managing the service of supplying irrigation water produced by the West Nablus WWTP, to the farmers of irrigated crops in the area that is covered by this service. This ensures a fair distribution of water, sustainability of the resources, and an optimal exploitation of the produced treated water.

Article 5: The Objectives

To accomplish its mission and practically implementing it, the WUA seeks to achieve the following objectives:

- Ensuring that the prices for supplying the irrigation water are consistent with the regulations and the directives issued by the concerned authorities.
- Implementing a fair water distribution of the water produced at the West Nablus WWTP, between the Association members and non-members, in accordance with the provisions in this regulation.
- Raising the efficiency of utilisation of the irrigation water produced by the West Nablus WWTP.
- Improving the WUA members' technical skills that are relevant to the management of irrigation water in a sustainable manner.
- Keeping pace with irrigation water management techniques aimed at increasing the utilisation efficiency.
- Contributing to the implementation of irrigation water regulations and working in accordance with the regulations and directives issued by the concerned jurisdictions.
- Managing agricultural equipment and machinery efficiently.

More specific task of the WUA are:

- Oversee the development of the Wadi Shaeer irrigation area and make strategic plans for its future development in consultation with its members.
- Distribute the available treated wastewater resources in an equitable way to its members and other eligible farmers in the area.
- Make yearly distribution and rotation schedules for managing water allocation and distribution.
- Support their members with advice on crops to be cultivated and irrigation.
- Invoice and collect water tariff fees from the farmers that are using the treated wastewater.
- Operate and maintain the irrigation distribution system.

The WUA was established in December 2018. Membership was opened in summer 2019, (cf. present membership on the map in Annex 5), and its first general elections took place on 21 December 2019. The project has supported the WUA in setting up its organisation and procedures, acquiring a bank account, achieving the threshold membership representing 1,500 du, and recruiting staff. The cooperation with the WUA was hampered by the Corona crisis which severely limited meetings with the WUA board and farmers.

The cooperation with the new Board elected at the end of 2019 has been excellent so far; the new Board is very supportive and committed to serve their farmers and the development of the Project. The WUA needs to be properly prepared for their tasks by setting up their internal organisation, finetuning job descriptions and training of its staff. Setting up management and recruiting staff started in January 2020. By providing the WUA with the crucial staff members, it is expected that the capacity building programme will go smoothly.

As soon as the presently foreseen staff³⁹ is appointed, the Project will carry out a training needs assessment and based on that develop a capacity building and training plan.

To establish a sustainable managerial and operational capacity, operational support to the WUA after the end of the present project implementation period (end of 2022) will need to continue for several years. The WUA should acquire funds for the implementation of this support.

6.2 FARMERS

An important aspect is the contribution of the farmers. After start of operations, NM will charge the WUA for the costs that occur at NM. These costs include the operation and maintenance of the tertiary treatment system, pumping station, conveyance pipeline and reservoir, and the depreciation of the mechanical and electric components of the main system, as well as (additional) staff and electricity costs for pumping.

The WUA in its turn will charge the farmers the amount to be paid to NM plus a compensation for their operational and maintenance costs. In Chapter 5 it was indicated that in viable scenarios, the tariff will stay below 1.00 ILS/m³. The tariffs will be revised as soon as the final design is known. Tariffs may be subject to future variations and need eventually be inflation corrected. As was stated in Chapter 4, the basis for the tariff calculations are that neither NM nor the WUA will make short-term losses nor long-term profits.

The capacity development and guidance of the WUA will be discussed in a separate report (a first draft of the operational set-up was approved by NM in July 2019 but will be enlarged/extended).

Closely linked to issues such as joint management of FHWs, the fast development of the irrigation area needed to collect fees and cover costs, and the improvement of income of the farmers by finding financing and marketing solutions, the Project has embarked on investigating options for farmer organisation beyond their membership of the WUA. This is mainly the

³⁹ Full-time Administrative and Financial Manager, part-time Technician Operation, part-time Agricultural Engineer.

task of the second phase of the FMC, but possible options are identified below and will be discussed later with farmers after approval of the IMOP.

1. **Cooperative organisation** - A cooperative organisation is a formal type of organisation regulated in Palestine by the relatively new law 02-2017 on cooperative societies.

According to the ANERA website⁴⁰: *“A cooperative is defined as a legal entity representing a group of individuals that come together to achieve a common objective. Their purpose is to serve themselves and their community and to work together as a team. The first cooperative in Palestine was founded in 1920. Located in Akka, it was an agricultural cooperative specializing in tobacco.*

However, long before the first official cooperatives appeared, people would come together informally to help each other in the fields. Neighbours would pitch in with their labour and equipment to harvest crops. Sharing the labour made the work move quickly and efficiently. It also built a sense of social cohesion. Olive-picking particularly benefited from this communal approach as the quality of olive oil hinged on moving the picked olives quickly from the tree to the press.”

In its National Agricultural Sector Strategy (2017 - 2022), MoA sees cooperatives largely as an instrument for marketing. Other purposes are not highlighted.

Cooperative ideas coincide with local cultural habits like sharing work during olive harvest, assisting neighbours and family members with a variety of (non-paid) services and so on. However, experiences in Palestine are not always positive. Marketing cooperatives compete with other systems such as share cropping; there is rivalry between families involved in their management; most cooperatives are rather small, limited to the level of families or villages; legal regulations to enhance management were not always clear, etc.⁴¹.

Interviewed farmers seem reluctant to adopt cooperative structures. However, such structures seem to work to some extent for water for irrigation. An example is the irrigation cooperative in Jenin; it was successful for the first 3-4 years but recently ran into problems with collection of fees, payments and cut-off of electricity and abandonment of alfalfa irrigation. The Palestinian Government needs to make sure that the WUA will not run into similar problems and - as was discussed in Chapter 4 – financially support the WUA for its start-up years.

2. **Joint ventures** - A joint venture is business arrangement in which two or more parties agree to pool their resources for the purpose of accomplishing a specific task. This task can be a new project or any other business activity. In a joint venture, each of the participants is responsible for profits, losses, and costs associated with it. However, the venture is its own entity, separate from the participants' other business interests.

There are two types of joint ventures that seem viable for the Wadi Shaeer irrigation area.

⁴⁰ <https://www.anera.org/blog/the-importance-of-cooperatives-in-palestine/>

⁴¹ See among others: Fathi Srouji, 2015. Reforming the Cooperatives Sector in Palestine. Palestine Economic Policy Research Institute (MAS). Jerusalem and Ramallah.

The first one is a **joint venture between two or more farmers**. This can include agreements on sharing FTAs for small parcels⁴² or using machinery together. It can also include the delivery of services from one farmer to another such as seeding, spraying, harvesting, among others. For the project, a joined venture for sharing FTAs is the most relevant one. Project experts will discuss this option with the farmers during the second phase of the FMC and assist the farmers and the WUA in preparing joint venture agreements.

The second one is a **joint venture between farmers and an external non-profit capital provider or investor**. In this concept, the external capital provider brings in capital, the farmers bring in labour and land and both share revenues according to an agreed formula. This would be a workable and politically acceptable solution under condition that farmers remain owner of their land and risks are adequately divided between the joint venture partners. Such joint ventures are valuable business constructions as they ease access to credit without selling out land property (as would in principle be the case with commercial loans).

⁴² The project has started to advise the WUA on clustering of small parcels. A preliminary clustering list has been drawn up, reducing 270 smaller parcels with an average size of 2.6 du to 114 larger parcels with an average size of 8.4 du.

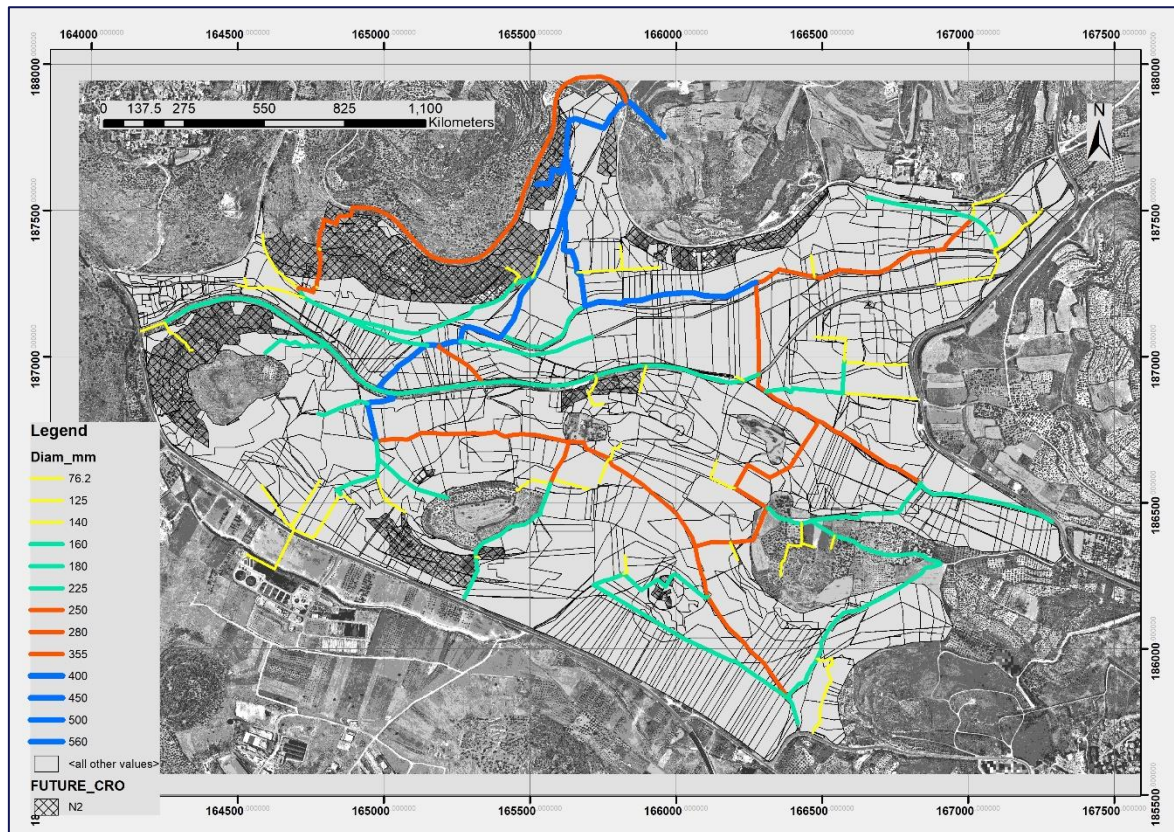
A MoU was prepared by the Project and presented to the WUA. Individual talks with farmers were postponed due to the Corona pandemic, started, and postponed again. The MoU is meant as an agreement between farmers obliging them to jointly use a single FHW with one water meter and manage this farm head works together. Nothing was signed so far.

7 IRRIGATION MANAGEMENT

7.1 THE IRRIGATION NETWORK

The irrigation distribution network is shown in Figure 26 below. The design is preliminary, and some changes may be made after the discussion on cost savings has been completed.

Figure 26 Irrigation distribution system, preliminary design



The design parameters of the network are:

- 5.13 mm/d average water demand (including distribution losses)
- 20/24 hours irrigation, bringing the average irrigation rate to 6.16 mm/d
- pressure throughout the system of at least 2 bar (drip irrigation requires about 1.5 bar minimum after the FHW)
- rotation schedule for fruit trees: once every three days
- rotation schedule olives: once every six days
- design of the main network according to 3,004 du as on the map in Figure 17
- design of the present laterals according to 2,641 du as on the map in Figure 16⁴³

⁴³ In reality, only 80% will be irrigated in the beginning, but more farmers may join soon, and it is not known which parcels will participate. Hence the design needs to be for 2,641 du.

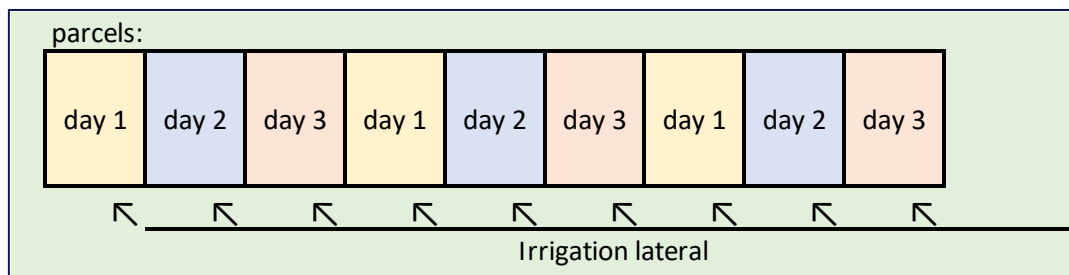
The network is built up of main pipelines approved by ICA and laterals that according to Palestinian authorities (NM, MoA, PWA) and the ICA advisor of the Municipality can be constructed without explicit ICA approval.

The study area contains roughly 500 parcels with an average parcel size of 7 du. As was mentioned before, small [parcels with a size below 5 du will not receive individual FHWs but need to share their FHWs with other parcels. A proposal for such clustering was prepared and is shown in the table in Annex 12.

FHWs will consist of an automatic shut-off metered valve, an air release valve/vacuum breaker, a pressure reducer, and when desired by the farmer (some farmers may go for organic fertilizer) a fertilizer injector and tank. The fertilizer injector should have its own filter to remove undissolved fertilizer particles. Seen the excellent quality of the treated wastewater, a separate 100 µm screen filter would not be needed. The design of the FHWs will depend on the size of the farm. A farm up to 10 du may consume up to 8 l/s and would need a 2" FHW. Larger farms could need larger diameter FHWs. This will be further worked out by the design team in the design report for Lot 2 (Irrigation Distribution Network).

The operation of the Network and the distribution to the parcels is by "shifts" (rotations); adjacent parcels will be alternatively included in consecutive shifts. This is illustrated in the figure below.

Figure 27 Principle of the irrigation rotation schedule



This sounds in principle simple, but with the complex layout of the parcels in the irrigation area, the high variability of parcels sizes and the different crops cultivated, this is an overly complex exercise. The Project will train the WUA in setting up rotation schedules, but this can only be done by on-the-job training during the first irrigation season. As the delays in design and construction may not allow a start of irrigation before 2022, it is not clear at this moment how this training could take place. An extension of project activities or supplementary services beyond the project duration would be required.

The WUA will need GIS-based software and data processing facilities to carry out this task, which will also make a link with the terrain and farmer decisions on crops to be cultivated. It can also serve as a basis for invoicing and subsidizing, but this is not by any means directly linked with the operation of the network (rather a separate interlinked routine). The GIS software should be set-up before the start of the first irrigation season. ToR for the GIS work (to be outsourced to the private sector) will be prepared and discussed and ways to implement the rotation scheduling exercise will be proposed. The GIS software needs to be user-friendly and should be operated by WUA staff.

7.2 OPERATION OF THE IRRIGATION NETWORK

Introduction

Operation of irrigation systems implies a package of organizational & economic and technical arrangements that ensure planned distribution and full use of water resources for good yield of agricultural crops of good quality under irrigation conditions. Therefore, during the operation of irrigation systems their state and the condition and use of irrigated lands as well as proper water use should be taken into consideration.

Operational measures include the implementation of scheduled water use practice to provide the irrigation regime required under specific meteorological conditions on certain land areas under efficient water use; keeping irrigation pipelines, head works and driplines in good working order by guarding, supervision, maintenance and repair of irrigation systems; organization of irrigation water accounting; and control over proper on-farm water use and control over crop management practice on irrigated lands.

Objects of irrigation system operation

The objects of the irrigation system are the tertiary treatment plant, main pressure line and reservoir; the distribution network and the on-farm systems. NM is responsible for operating the tertiary treatment plant, the main pressure line and the balancing reservoir. This operation should aim at keeping the balancing reservoir as full as possible under all conditions, considering the availability of treated wastewater and the irrigation demand. This process can and should be fully automated.

The WUA is responsible for operating the distribution system, the farmers are responsible for operating the on-farm drip irrigation systems and FHWs.

Operation of the distribution system

Being able to deliver water to the farms at any location and any predefined point in time, the WUA needs to prepare a rotation schedule as described above. Farmers must respect this schedule and the WUA has to supervise compliance. Apart from regulating valves (to be introduced in the design), the system functions largely automatic, provided there is compliance with the rotation schedule. Provisions should be made by the designers to make sure that farmers can close the metered valve any time they like without repercussions for the hydraulic operation of the distribution system.

Maintenance of the distribution system

At the irrigation system maintenance stage, the WUA should carry out regular inspection and surveyance of the distribution system. This includes inspection of the proper functioning of control valves (including leaking) and inspection of pipelines on leaking. As the system has a minimal pressure of 2 bars and the earth surface is not plastered, leakage would normally be visible at the soil surface. If not, leak detection equipment can be applied.

To perform the works related to servicing (maintenance) and repair of system components at the maintenance stage, the WUA should be allotted rights of way in accordance with the existing regulations.

Yearly maintenance and repair imply a package of measures for maintenance of the operational capability of the irrigation system and its components. Irrigation should not be interrupted when not necessary. To determine the type and scope of repair works, the WUA carries out an inspection of pipelines and structures in the winter season when no irrigation takes place. Based on the inspection results, a damage statement is drawn up; this statement is used when developing design of routine maintenance or overhaul.

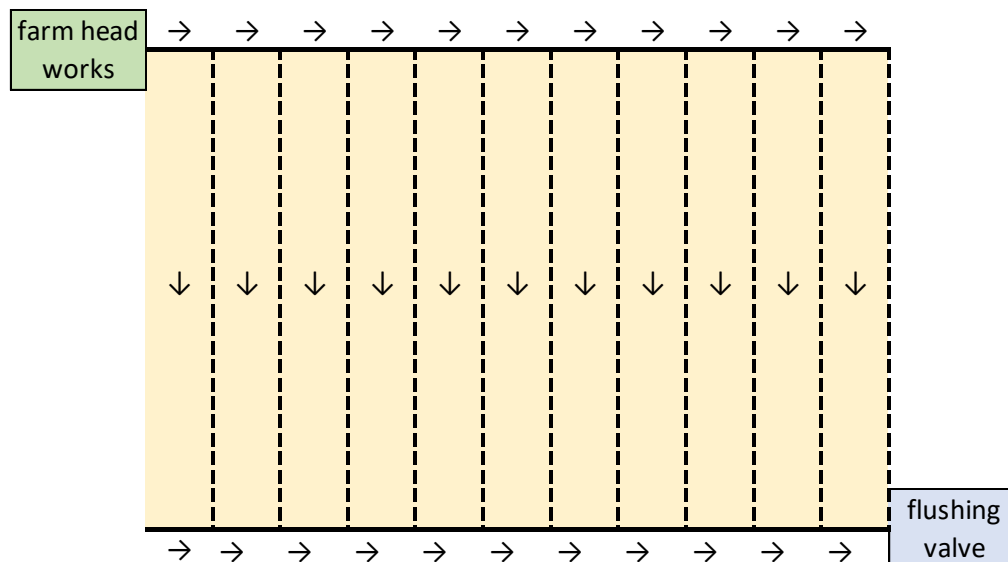
Overhaul is carried out periodically every certain number of years established according to relevant standards. It can be of integrated (across the entire system) or selective (in particular sections) type. Repair type is selected subject to a number of factors; this issue is to be solved individually for each system. Overhaul should be started after vegetative irrigation is over and finished in spring.

Emergency (reconstructive) repair is to be carried out in emergency cases (pipe break, failure of automatic valves) or caused by acts of God (floods, landslides, earthquakes) or vandalism. To speed up liquidation of emergency, this type of repair must be carried out on a round-the-clock basis with maximum mobilization of machinery and equipment, materials, and labour resources.

7.3 ON-FARM IRRIGATION SYSTEMS AND THEIR OPERATION

The design of the on-farm systems will be part of the tender preparation of Lot 2. As farm sizes are rather variable, different designs need to be made for each plot. They follow however all the same principle as pictures in Figure 28 and basically consist of a distribution line, dripper lines and a flushing manifold.

Figure 28 Schedule of a drip irrigation system



Operation of on-farm systems

On-farm operation of irrigation systems is the task of farmers; they should receive advice/support of the WUA. On-farm operating services include among others the control over the water application process; levelling of fields; preparation of irrigation equipment; tree maintenance, fertigation; etc.

When it is their turn according to the rotation schedule, farmers can set the time clock on their automatic shut-off metered valve (respecting the maximum time allowed); the WUA should keep an eye on this process, in order not to create unfair water distribution. When desired, farmers should set their fertigation units at a required time and quantities.

The drip irrigation system may be organised in blocks that can be operated separately, and farmers should take care of opening and closing connecting valves when needed.

7.4 MAINTENANCE OF ON-FARM IRRIGATION SYSTEMS

This maintenance includes⁴⁴:

When operating a new system for the first time

- Flush the piping - main line, sub-mains, and distribution pipes
- Flush the dripper lines
- Check actual flow rate and working pressure for each irrigation shift (when the system is active for at least half an hour)
- Compare the data collected to the design data; tolerance should not be greater than $\pm 5\%$
- Write down the newly acquired data and keep it as benchmark for future reference

Once a week

- Check actual flow rate and working pressure for each irrigation shift under regular operating conditions (i.e., when the system is active for at least half an hour and stabilized)
- Compare the data collected to the benchmark data
- Check that the water reaches the ends of all the dripperlines
- Check the pressure differential across the filters

A well-planned filtration system should lose 0.2 - 0.3 bar (when the filtration system is clean). If the pressure differential exceeds 0.8 bar, check the filter/s and their controller for faults.

Once a month

- Flush the dripper lines.
- If the filtration system is automatic, initiate flushing of the filter/s and check that all the components work as planned
- If pressure-regulating valves are installed, check the pressure at the outlet of each one of them and compare these figures with the benchmark data

⁴⁴ Free after: Netafim website: <https://www.netafim.com.mx/bynder/28DEA0B8-8EF1-4037-9EA133D578881E27-drip-irrigation-system-handbook.pdf>

Once a growing season

In some cases, the following needs to be performed twice or three times in a growing season, depending on the type and quality of the water used

- Check all the valves in the system
- Check the level of dirt in the system (carbonates, algae and salt sedimentation)
- Check for occurrence of dripper clogging
- If necessary, inject hydrogen peroxide and/or acids as required

At the end of the growing season

- Inject chemicals for the maintenance and flushing of the distribution pipes and the dripperlines
- Flush the dripper lines
- Prepare the system for the inactive period between the growing seasons

In the framework of capacity building of WUA and farmers, adequate manuals will be provided for operation and maintenance.

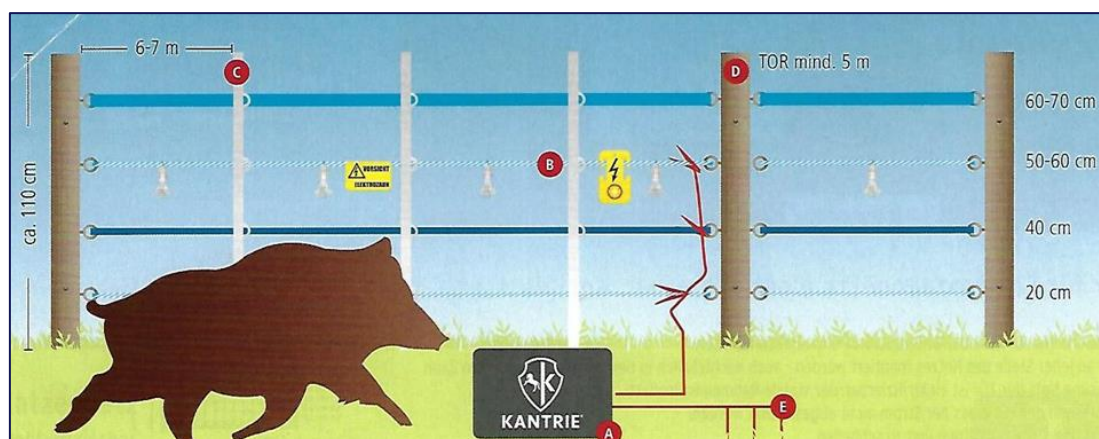
Useful information on design and maintenance of drip irrigation systems can be found i.a. in the NETAFIM Drip Irrigation Handbook⁴⁵.

7.5 PERIMETER FENCE

Cultivated fields in the Wadi Shaeer area are often plagued by wild pigs that destroy both harvest and (when these would be there) drip irrigation pipelines. This situation will worsen when fields are irrigated.

A possible solution will be to fence off the area completely. There are basically two options: a stable metal fence and electric fence. As the most economic and therefore recommended option the components of an electrical fence are described, see also figure below:

Figure 29 Electrical Perimeter Fence - Components



⁴⁵ Netafim website: <https://www.netafim.com.mx/bynder/28DEA0B8-8EF1-4037-9EA133D578881E27-drip-irrigation-system-handbook.pdf>

Legend:

A Energizer, which produces regular current pulses, either with 230V power supplies or 12V battery devices (with or without PV unit)

B Wiring, which transports the current along the fence. For wild boar defence there are specially developed wiring: The blue colour is especially visible for wild animals and due to the copper conductor a 40x higher conductivity is achieved compared to conventional conductor materials. The continuous outer contact of the conductor wires guarantees an optimal contact in case of contact with animals

C Insulators ensure that the current is not led away to the soil

D Posts out of hardwood or plastic

E Earth stakes carry the current back to the energizer

More details can be found in the design report of Lot 2.

Sensitive places in the fencing system are the passages for public roads. Instead of gates that must be opened and closed manually and can sometimes be forgotten to close. Cattle grids are therefore proposed, see figure below:

Figure 30 Cattle grids



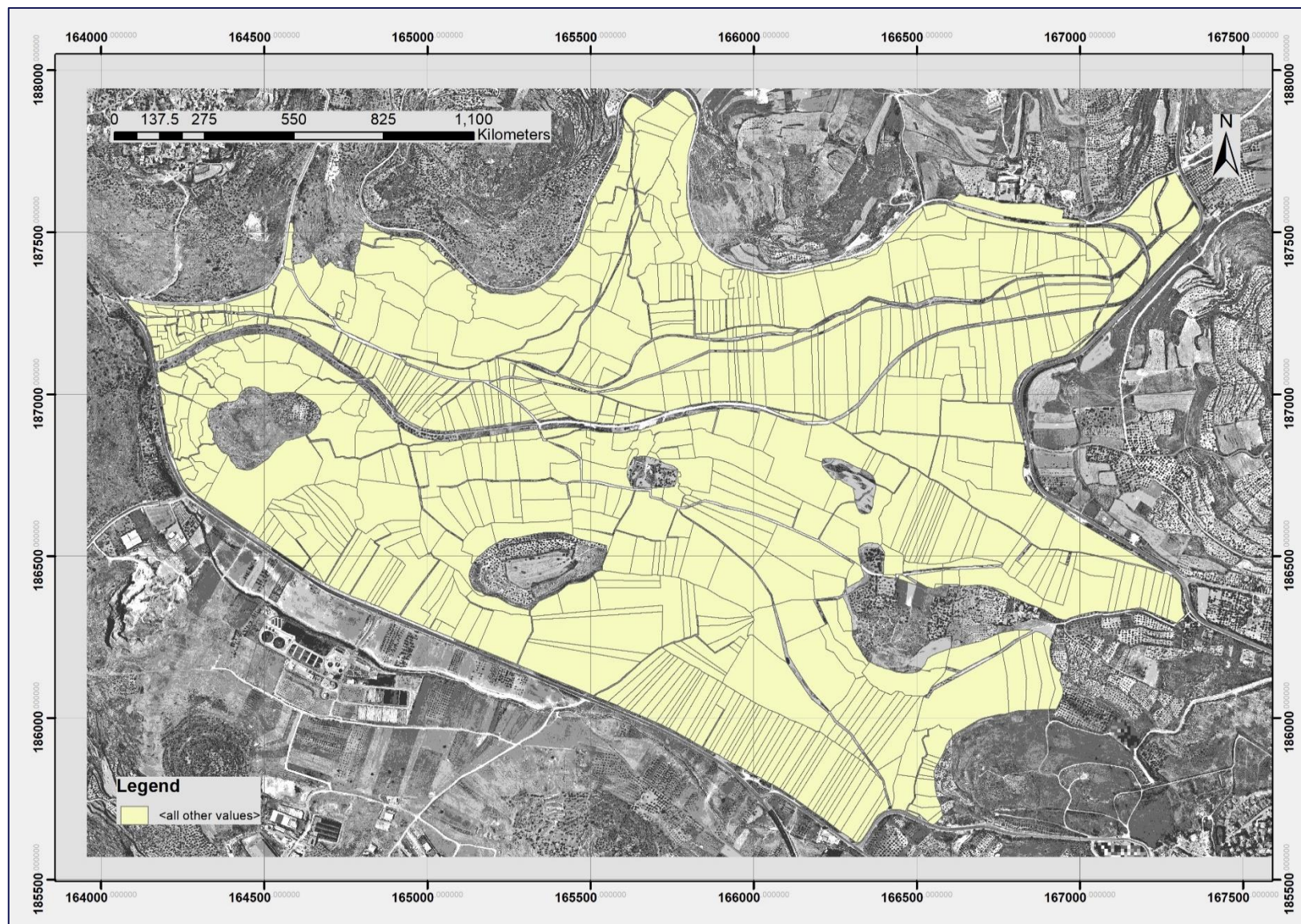
The fencing strategy was discussed with the WUA and MoA who both had preliminary a positive judgement on it.

ANNEXES

ANNEX 1

MAP OF THE WADI SHAER PROJECT AREA

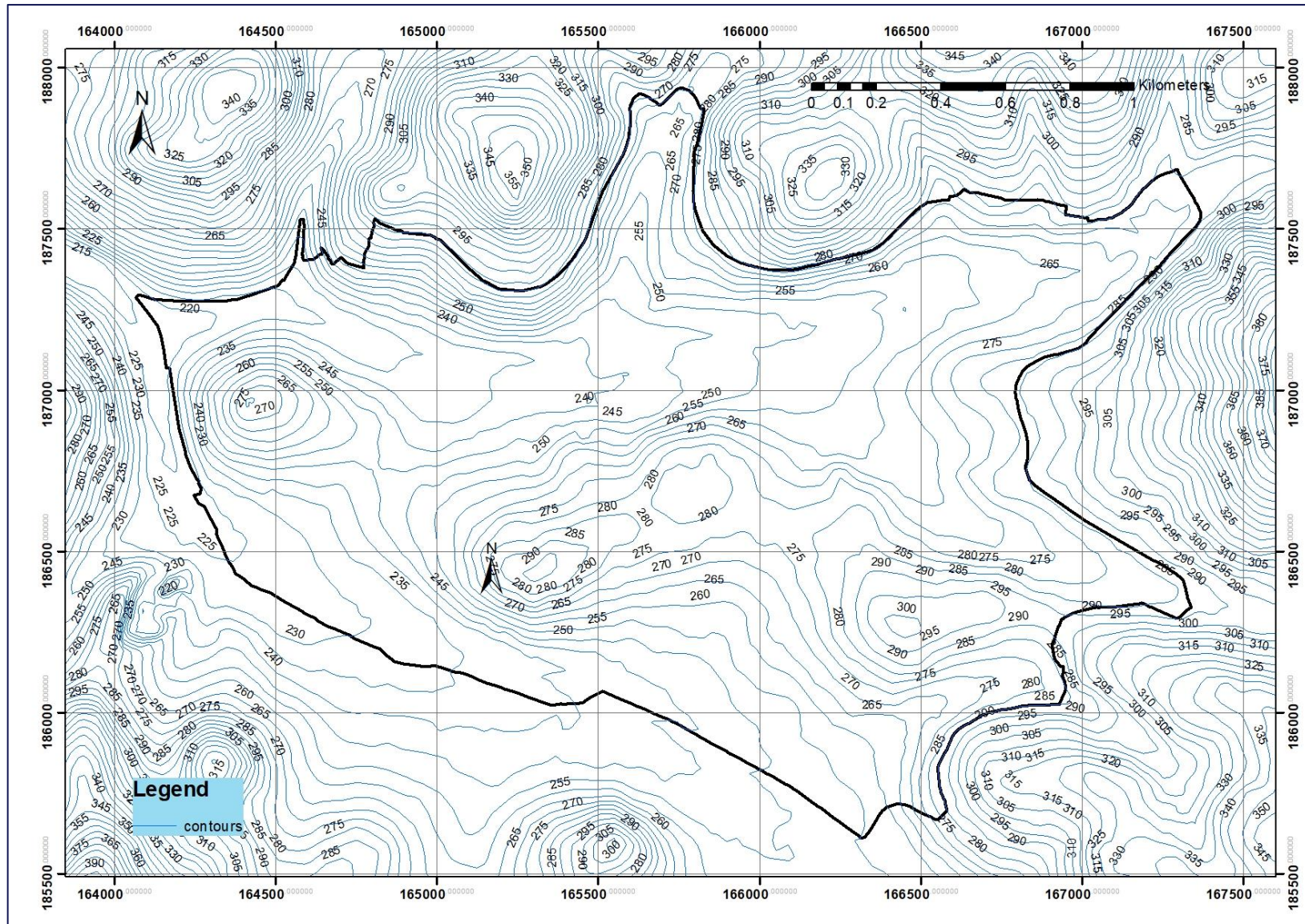
Annex 1 Map of the Wadi Shaer Project Area



ANNEX 2

ELEVATIONS IN WADI SHAEER PROJECT AREA (CONTOUR LINES)

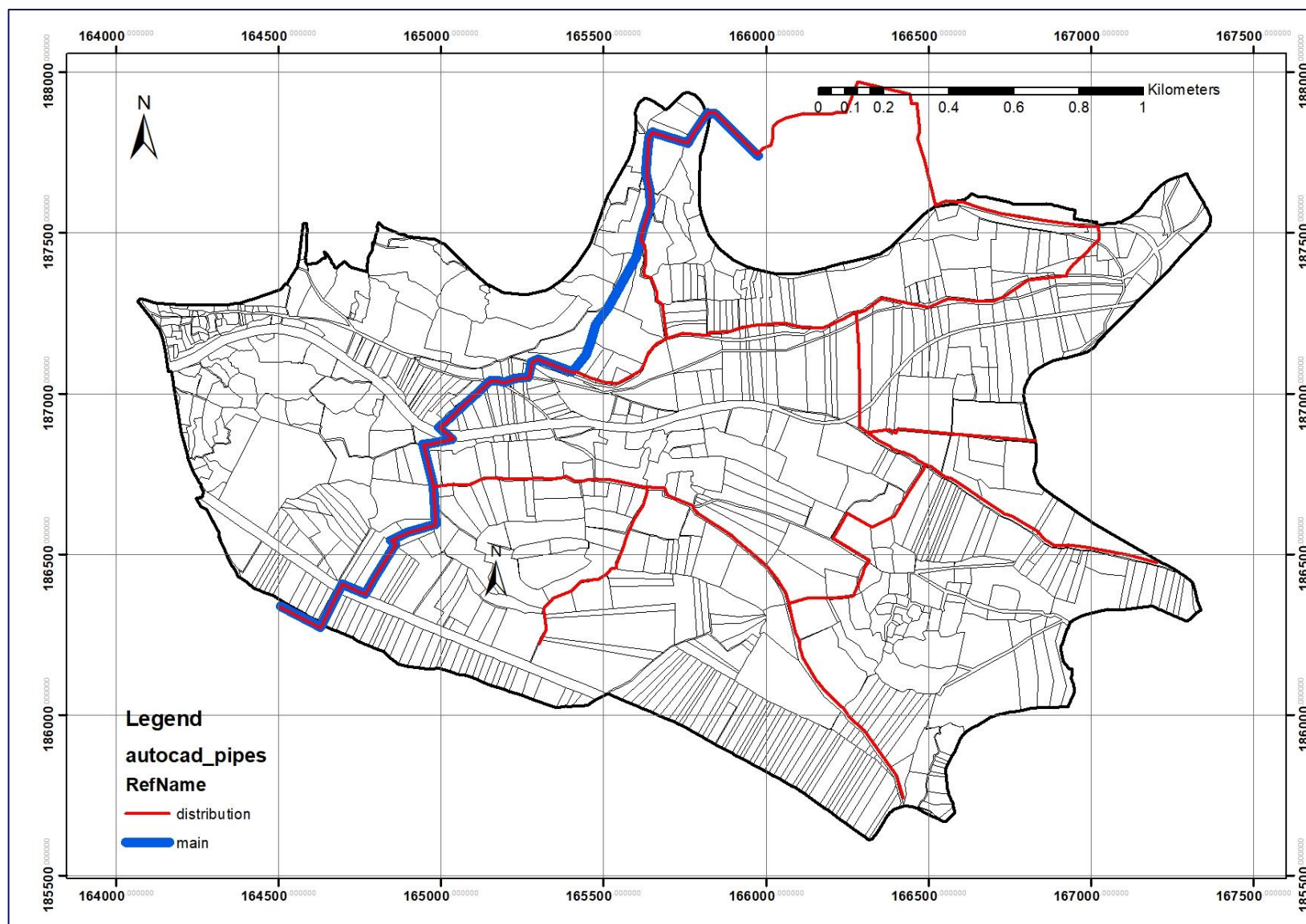
Annex 2 Elevations in Wadi Shaeer Project Area (Contour Lines)



ANNEX 3

OVERVIEW OF THE CONVEYANCE AND IRRIGATION DISTRIBUTION PIPELINES (APPROVED BY ICA)

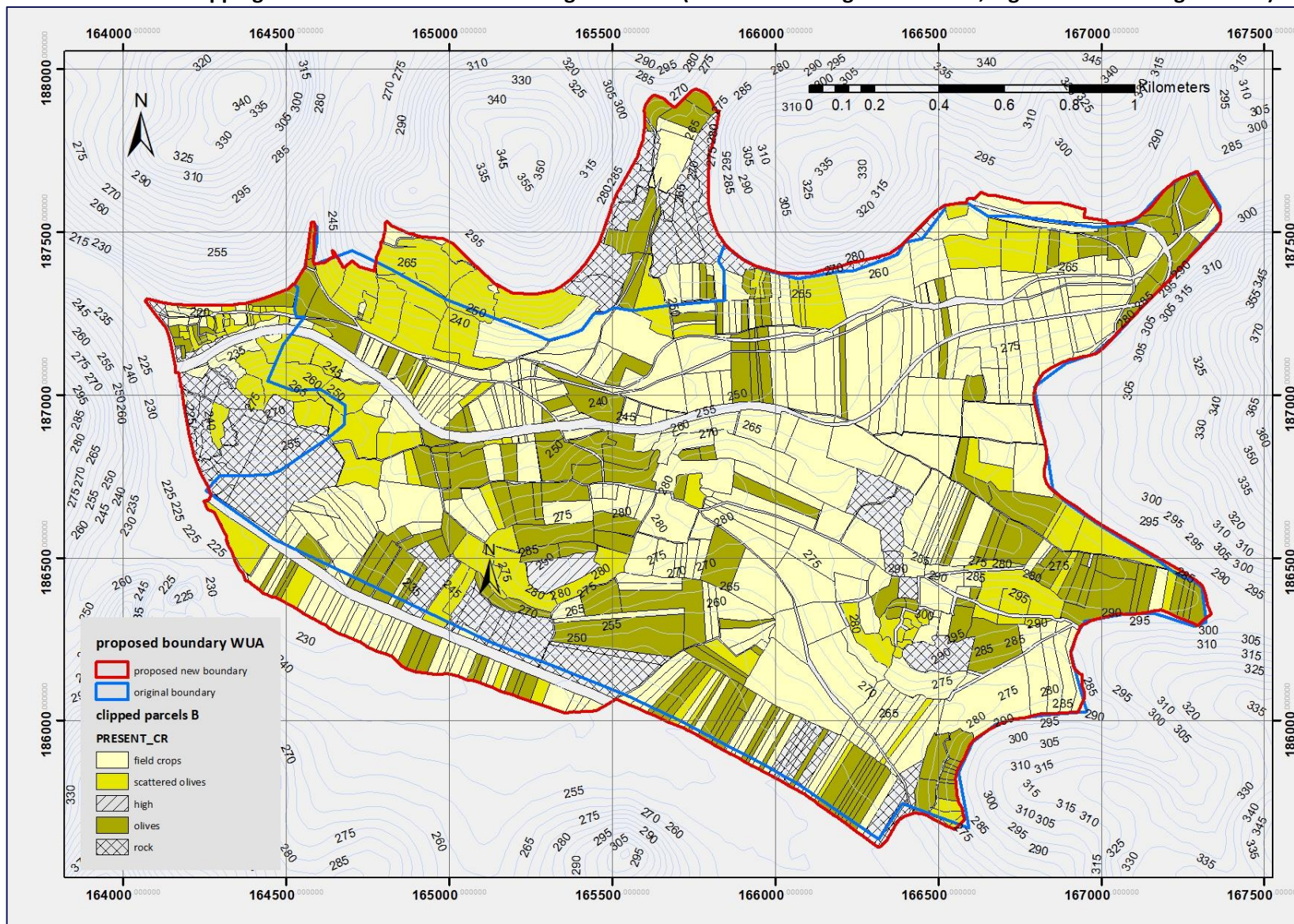
Annex 3 Overview of the Conveyance and Irrigation Distribution Pipelines (approved by ICA)



ANNEX 4

**PRESENT CROPPING PATTERN OF THE WADI SHAEER
IRRIGATION AREA
(BEFORE DEDUCTING OUTSIDE AREA, HIGH AND
ARCHAEOLOGICAL SITES)**

Annex 4 Present Cropping Pattern of the Wadi Shaeer Irrigation Area (before deducting outside area, high and archaeological sites)

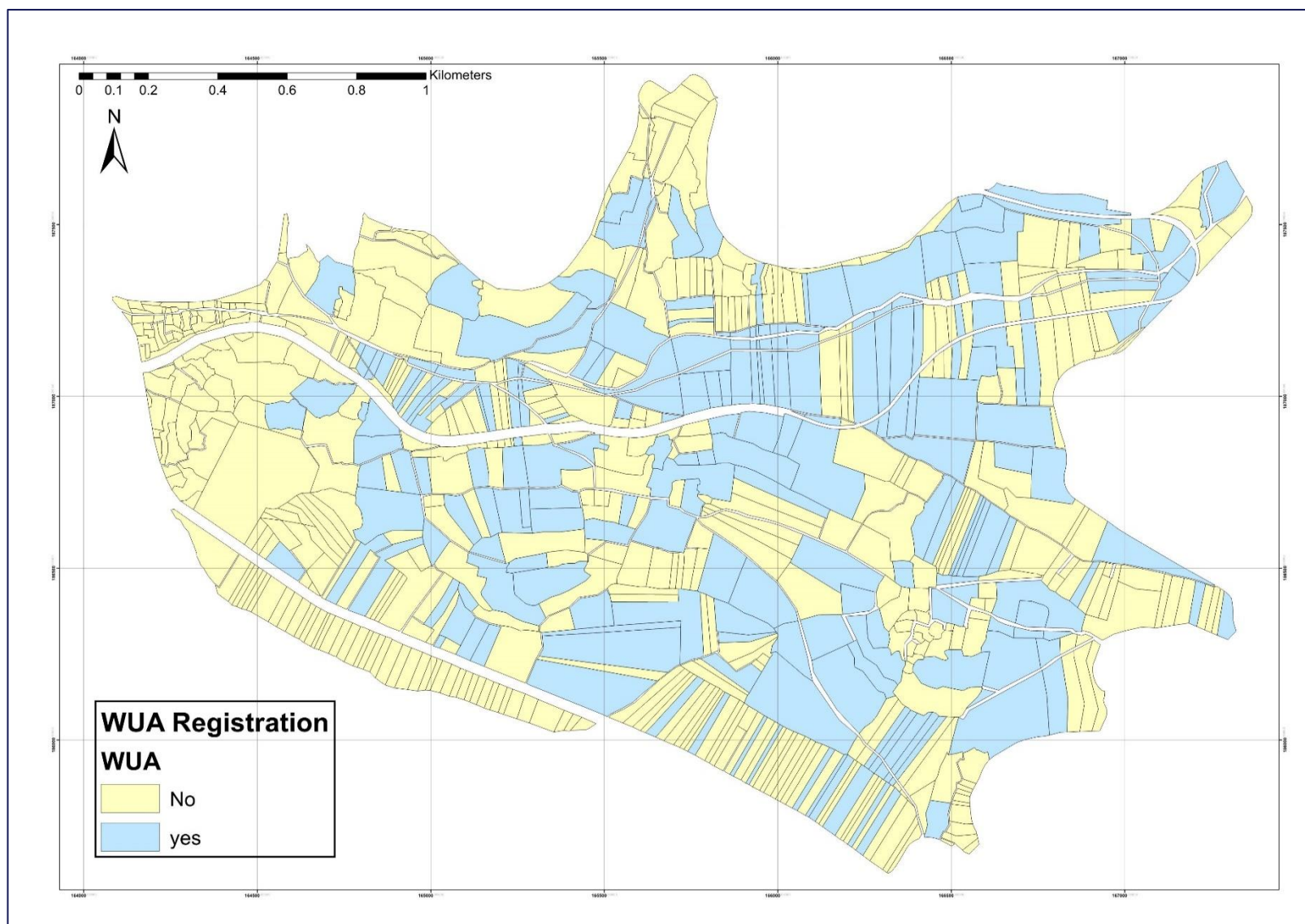


ANNEX 5

MEMBERSHIP OF THE WUA (AS OF 01 DECEMBER 2019)

Annex 5

Membership of the WUA (as per 15 July 2020)



ANNEX 6

INFORMATION ON POTENTIAL CROPS FOR IRRIGATION IN THE WADI SHAEER PROJECT AREA AND SWOT ANALYSIS

Annex 6 Information on potential crops for irrigation in the Wadi Shaeer project area and SWOT analysis

OLIVES

Background

At present, olives occupy a large part of the planned irrigation area. There are approximately 910 du of olive orchards (defined as olives planted in a regular (usually 6 x 6 m) (25-30 trees per dunum) pattern and approximately 453 du of parcels with scattered olive trees (10 trees per dunum or even less). The main variety cultivated in the project area is a local variety called *Nibali Baladi* that is grafted on original root stock, which is known in the area as wild olive known for its solid root stock and slow growth. Therefore, the fruit bearing age for these trees is not less than 6-7 years and the maturity age (maximum yield age) is not before 25 years. This variety and root stock are known for drought resistance and pest resistance more than other varieties introduced in Palestine. For this reason, the traditional rain-fed olive farmers prefer this variety above other high yielding varieties.

Land preparation

When preparing a new orchard of olives, there are several steps to be followed:

- Land cleaning by removing residues of old crops, big stones, and land levelling where and if possible.
- Deep ploughing: the land should be turned over to a depth up to 60 cm by using deep ploughing. This should be between September and November:
- Spreading of fermented manure: Adding fermented manure is necessary for improving the soil physical characteristics and its water holding capacity beside its value as organic fertilizer. The average quantity is about 8 m³/du. The manure should be properly fermented which helps in killing the pathogens, and the weed seeds. Also, fermentation is important for fast decomposition of the manure and absorption by the plants.
- Land fining: This is important for levelling the field and it could be done by either a rotary tiller, tooth harrows or disk harrows. It is preferable to undertake this operation when the soil has a good (but not too wet) moisture content which will help in minimizing the dust and in racking of the big blocks of soil.
- Orchard planning: It is recommended to plant the trees in rows with a distance of 7 meters between the rows and a distance of 5 meters between the trees. To give more light to the trees it is recommended to make the lines from north to south which helps in exposing the trees for more sunlight along the day.
- Holes digging: The holes can be dug either manually or by an excavator. The size should be suitable not less than 50 cm x 50 cm) and the depth should not be less than 60 cm.
- Seedling plantation: The season of plantation of olive seedlings under irrigation can be around the year although it is better to be at the beginning of the spring season. After digging the holes, it is recommended to put the topsoil aside to refill it back around the seedlings. A small amount of fermented manure could be added in a bed below the seedling and covered with a 10 cm layer of **soil**. The topsoil should be refilled around the seedling with gentle compaction.

- For new orchards, it is advisable to add one drip irrigation line with three emitters for each seedling (distance between emitters is 50 cm and discharge capacity of each emitter is 2.2 l/h) Then after two years, another two line can be added
- For existing olives, it is advised to have two lines of drip irrigation with 50 cm distance between emitters and with discharge capacity of 4-8 l/h. These are general recommendations; exact layout need to be studied for each farm separately

Pruning

- The best time for pruning is after harvesting (between November up to February). There are two types of pruning:
 (1) for growth of new trees: The tree should be cut at height of 90-100 cm in the first year. Then in the second season, 3-4 strong branches should be cut at a length of 60 cm. These branches should be fairly distributed along the main stem. Also, smaller shoots on the selected branches should be cut at a length of 40-50 cm
 (2) pruning for production: This should be from the centre of the tree to allow light and ventilation of the tree. In large trees it is advisable to cut the ends of the big branches. In addition, the farmers should keep removing wild shoots emerging from the root stock of the tree.
- After pruning, the farmers should give a good dose of nitrogen fertilizer (might be there is reduced need for this in our case as the treated water is rich with nitrogen).

Fertilization

- Usually the farmers and extension agents can recognize deficiency of macro and micro minerals from the general shape of the tree and from the symptoms on the leaves. This is the easiest way to decide on fertilization programme instead of undertaking soil analysis which sometimes necessary before starting new orchard and leaves analysis for big trees.
- It was noticed in the outside scheme, that vegetative growth of olive trees is going very well without adding nitrogen fertilizer.
- At the same time, symptoms of deficiency of phosphorus was noted on the trees planted within fence of the WWTP. So, they add phosphorus fertilizer which is essential for flowering, fruiting, and construction of good root system.
- Although no need, for nitrogen, they use NPK 20/20/20 fertilizer which supported with micro minerals as a basic fertilizer.
- It was noticed deficiency of boron and ferrous, therefore they added boron as leaf-fertilizer and ferrous in irrigation water.
- For organic fertilizer, as recommended in the land preparation section, it can be spread on all the orchard land (4 m³/du) and it can be added in the whole under the seedling). Usually manure is added every 3-4 years.

Pest and weed control

- Irrigated orchards are more vulnerable to some diseases and pests, especially the fungal disease olive peacock spot (also known as olive leaf spot and bird's eye spot)⁴⁶, as higher

⁴⁶ *Spilocaea oleaginea*, a deuteromycete fungal plant pathogen.

humidity will give proper environment for fungus diseases to grow. Therefore, the farmers should follow the extension programme advised to them from MoA and WUA extension agents.

- For new orchards, it is very important to have seedlings from a trustful licenced nursery and under direct supervision of MoA to assure provision of healthy and disease free seedlings as nurseries are a main source of infection if the seedlings have come from an infected nursery.
- For usage of chemical pesticides before harvesting, it is important to use chemicals with lower toxicity and to take in consideration the safety period of each pesticide could be used as some of the chemical residues will appear in the oil and it will have a harmful impact on the oil and consumers.
- For insect control, it is advisable to use pheromone traps which many kinds of them are available in the market. Their usage as per the instructions of the manufacturers and the extension agents. This methodology is considered as one of integrated methods for pest management as it is safe and efficient.
- For weed control, the farmers should keep maintaining the drip irrigation system to prevent any leakage which results in growth of weeds. Also they should preferably remove weeds between rows mechanically and only use herbicides between the trees If the weed density is not that much, weeding can be done manually by hand.

Harvest and yield

- The alternate bearing phenomenon is known for olives in general. In Palestine, it is well-known, and there is a big difference between good season (*Masi*) and bad season (*Shalaton*). Therefore, the Palestinian average of production as per MoA is around 2.5 litre of oil per tree (i.e. 37.5 l/du of 15 trees)⁴⁷. While harvest of the olive orchards in the project area is reported by farmers as 300 kg/du on average it means their yield is almost double the national average. It is also, above the world average of 210 kg/du. However, irrigated olives are reported to yield up to 2,000 kg/du and a value of 900–1,100 kg/du is reported in many references as adequate for well-kept mature olive trees.
- Harvesting season in the area for pickles usually starts late September/ early October. While harvesting for oil starts after 10 October. MoA advises farmers not to rush for harvesting as early harvesting before complete formulation and separation of oil, reduces the extraction percentage of oil and has a negative impact on the quality of the oil.
- The best time for harvesting is when about 50% of the fruits colour start changed from green to dark colour and when the fruits become softer.
- Harvesting of the fruits in the area is done manually by hand-picking. Some farmers are still using the wrong way of harvesting by stick especially for high fruits which is not recommended, and it will have negative impact on the fruit bearing in the coming season.
- Farmers, usually, wrongly put their fruits in clothes sacs which could damage the fruits before going to the press, especially if they stay for long time before pressing. The farmers forced to use this way in orchard with no access roads and the only way is to carry their

⁴⁷ As per the Palestinian Central Bureau of Statistics (PCBS), the Palestinian extraction ratio of olive oil is 22.3% (olive press survey, 2019). This means the average yield of fruits per dunum of 15 trees is estimated by 168 kg of fruits per dunum.

harvest on donkeys. But in the project situation, most of the parcels are accessible by cars/tractors. So, it is advisable to put their harvest in boxes not more 40-50 cm high.

- For olives irrigated with treated wastewater, is not allowed by law to collect the fruits that fall under the trees and were in touch with the irrigation water. Also, it is not advisable to mix the fallen fruits with the fresh fruits regardless the type of water they use for irrigation.
- Regarding pressing of oil, it was noticed that many farmers store their harvest until they finish their season which could last for few days or even weeks. This is not good practice and will damage the product. It is highly advisable not to store the harvest for long time. It is much better that to press directly after the day harvest and if the daily harvest is not that much, the farmer can press the harvest every two days.
- The leaves should be separated from the fruits.
- The farmers should monitor the press to see if they keep changing the water from time to time and if they use fresh water. Also, the cake should have enough time for mix. In addition, the humidity in the mix should not be less than 50% and the added water should be warm (about 30°C).

Irrigation

It is known that irrigation of olives will dramatically improve the yield and it will minimize the alternate bearing phenomenon. In the economic calculations of the IMOP, the value of 900 kg/du for new varieties of olive trees and 700 kg/du for existing olive orchards has been applied. To be noted that olive trees mature slowly, and maximum yield may only be expected after 25 years, with consequences for cash-flow calculations.

In regard of irrigation, two different scenarios are modelled:

1. Regulated Deficit Irrigation (RDI) approach by applying 505 m³ of irrigation water per dunum, distributed over a period of 9 months from March to November and depending on the phenological stage of the crop and its specific irrigation needs. The philosophy behind this approach is to maintain production and a good quality olive oil as was proved by many researchers that followed deficit irrigation of olives.
2. Sustained Deficit Irrigation (SDI) only by Injecting 400 m³ of water per dunum in three months (July, August and September) as recommended by NM and MoA (based on advice by olive expert Mr. Fares Jabi) on a weekly basis with amounts of 150 m³ in July, another 150 m³ in August and 100 m³ in September for normal rainy years. For dry years it is recommended giving the same amount of water (400 m³/du), but in a longer period starting in May and ending in September (50, 50, 100, 100, 100 m³)⁴⁸.

It is clear from literature study that RDI gives better results in terms of harvest than SDI⁴⁹.

The Project recommends drip irrigation with pressure-balanced driplines to ensure fair and regular distribution of water over all emitters.

⁴⁸ Mr. Jabi believes that following this irrigation will increase the yield by 250 litres of oil per dunum. (i.e. 1,000 - 1,120 kg of fruits/du depending on the extraction ratio. These numbers come from one single short (one year) experiment with 100-year-old olive trees on deep soil and can therefore not be generalised.

⁴⁹ I.F. Garcia Tejero and Duran Zuazo. 2018. Water Scarcity and Sustainable Agriculture in Semiarid Environment. Pages 87-126. Literature review. Book. Academic Press.

For mature olive orchards, we propose to use two driplines per tree row with emitters having a maximum (standard available on the market) capacity of 4 l/h. With a 20-hour irrigation day and an emitter distance of 50 cm for olives for oil and 30 cm for olives for pickles, this results in a rotation schedule of around 6 days.

Obviously, this needs to be finetuned for each individual farm and young olives when plantation and installation of drip systems start.

Areas to be planted

The Land Suitability Assessment shows that the existing olive orchards and scattered olives occupied around 1,362 du of the revised irrigation land area (refer to Table 6 below), with around 205 du located in currently not suitable land (N1) that needs soft land reclamation to become suitable for irrigation. Another 198 du are in permanently not suitable land (N2). Olives orchards located in land suitability classes N1 and N2 have already gone through some form of land rehabilitation by the landowner/farmer and can be considered as suitable for irrigation. In any case it is recommended not to promote developing fields with scattered olives in area N2 unless heavy reclamation takes place.

For the scattered olives, the plan is to fill the gaps with additional olive trees, which will increase the Net Benefit per dunum. Farming is not yet a full-time job for most of the farmers in the area and the accumulated experience in olive farming allows the farmers to expand cultivation of olives. Referring to the Farmer Survey, many farmers (almost 75%) have shown interest in cultivating and irrigating olives. In addition, the MoA has a strategy to fill the gap between supply and demand on olive production for pickles as most of the olives-for-pickles products in Palestine come from Israel.

For this reason, MoA encourages the cultivation of pickles olive cultivars under full irrigation and recommended to the Project to invest in the following cultivars: *Manzanillo* & *Picholine langdoc* and *Nibali Muhassan* (Improved Nibali)⁵⁰.

Table 16 Areas and land suitability of existing olive orchards and scattered olives

Index Name	Category	Olive Shape Area, dunum
S1	Highly suitable	204
S2	Moderately suitable	319
S3	Marginally suitable	412
N1	Currently not suitable	205
N2	Permanently not suitable	198
	Total	1,362

⁵⁰ These cultivars were suggested by the Head of the Olive Department in MoA, Eng. Ramez Obaid via email to the deputy team leader on 8 December 2019.

Economic calculation, cost estimate and labour

The yield of one dunum of existing olives under deficit irrigation ($505 \text{ m}^3/\text{du}$) is estimated by $700 \text{ kg}/\text{du}$ as agreed with MoA⁵¹. The price of one kg is estimated at 5.33 ILS. So the gross income of one dunum is estimated by 3,731 ILS/year.

The total annual variable cost of existing olives is calculated at 2,562 ILS/du for existing dense olive orchards and at 2,588 ILS/du for scattered olives⁵². This includes the annual running cost and the depreciation on the investment. The net annual benefit for existing dense olive orchards is estimated at 1,169 ILS/du and at 1,143 ILS/du for scattered olives.

For pickle olives the calculations following the same methodology used for all crops show that gross yield is estimated at $900 \text{ kg}/\text{du}$ ⁵³ and the price of 1 kg is estimated at 6.5 ILS/kg. Therefore, the annual gross income will be 5,850 ILS/du, while the annual variable costs are estimated at 3,588 ILS/du. Hence, the annual Net Benefit is expected to be 2,262 ILS/du.

Labour

Labour for olives is in two parts: Machinery work and manual work. Machinery work is for land preparation, holes excavation (which also could be done manually), spreading of manure, spraying, land tilling and weeds cultivation. Manual work is for installation and maintaining of the irrigation network, weeding, pruning, harvesting⁵⁴, and general field management.

For the machinery work the rate is either per working hour or per dunum. Prices of machinery depends on kind of job. For example, for ploughing it is about 90 ILS/h while for spraying it is about 70 ILS/du.

While for the labour work the daily wage estimated by 100 ILS per working day of 8 hours i.e. 12.5 ILS per working hour.

The required working days per dunum is estimated by 13, 13 and 18 working days for dense olives, scattered olives, and pickles olives respectively.

Most of the manual labour is family work either by the owner farmer or by the crop sharing farmer. Because of the small size of the farm, it is rare to hire workers to do the work. It happens sometimes for small families with old parents and young children or with families owning large areas to hire additional workers in the harvesting season to help in harvesting. Usually for hired workers they pay them either in cash or olive oil. Wages for men and women are different. Usually they pay men more than women as the man can climb up the tree and can go on the ladder while women work is only to collect the fruits under the trees or harvest the fruits that do not need climbing the tree.

⁵¹ For existing olive orchards, this yield will be achievable after 3 years of irrigation. This is because yield will grow gradually as shifting from rain-fed to irrigation will take time from the tree to adopt itself and to build a new root system and proper vegetative growth.

⁵² The small difference in cost between dense olive and scattered olives because of the cost of the additional seedlings

⁵³ This yield will be achievable after 10 years of plantation while yielding will start after 3 years of plantation of 18-24 months old seedlings.

⁵⁴ For harvesting, one worker can harvest 100-150 kg/ day. This depends on yield, size and age of trees and type of farming if it is intensive or very intensive.

Marketing and Value chain

Existing olives land area is around 1362 du representing around 44% of the project area. The area which will be included under irrigation if we remove the scattered olives in rocky lands classified as N₂, is around 1,202 dunum. The product of this area is assumed to go for oil production. The estimated yield per dunum is calculated on 700 kg/dunum. Therefore, total harvest will be around 841,000 kg. The oil will be around 188,000 kg (204,000 litres). Usually the farmers do not pay money to the mills. Instead, they pay a share of produced oil in rate of 1:13 up to 1:17 (average 1:15). This means that the farmers will be left with around 190,000 litres. The farmers usually keep part of their product for their own consumption which estimated by 10-12 litres per capita. The estimated population of the 4 villages is around 12,669 individuals as estimated in 2019. They will consume about 139,359 litres representing 66% of their product in the project area. In addition, tangible part of the product goes as gifts to relatives abroad who have shares in the land. This amount estimated by 10% of the product. However, the amount for marketing will not exceed 24% of their product. In addition to this, it is very important to mention here that many land owners give their olive orchard to other people to take care of it and to harvest against share of the product which varies from 40-50% of the product to the farmer.

Marketing of the surplus could be in different forms. It is either from the farmer to the final consumer directly. This kind of marketing is based on trust and reputation of the farmer and the product. This kind of retailing marketing can obtain better prices to the farmer. Also, any merchant and companies now go to the villages to collect the olive oil. It was noticed in the last years that these merchants are undertaking kind of test for the oil before they purchase.

One of the main challenges is the oil packaging and storage. Usually, the farmers, put their oil in 16-litre containers made of tins or plastic which is regular unit for pricing and sale. The oil quality in such containers (especially the plastic ones) deteriorate fast. This need more attention from the farmers. The project training will give special focus to this problem.

For pickles: the proposed area for pickle olive varies between 376 and 547 du. The estimated yield per dunum as estimated in the IMOP will be around 900 kg/du. Therefore, the total production will be between 400 tons.

There are many pickle factories in Palestine depending mainly on the raw products from Israel. The Palestinian Government thinks seriously to find local alternatives. It happened in the last olive season that the Palestinian government suspended import of olive and olive oil from Israel among many other agricultural products. By a lot of pressure by the pickle factories, the government allowed them to resume importing olives for pickles from Israel. This has been faced with wide protest by the public. As the project area is very suitable for production of different varieties of pickles olives and as the farmers have excellent experience in olive farming, in coordination with MoA and upon a request by the Olive Department in MoA, three pickle varieties are proposed to be cultivated. We expect the product will not face any marketing problem as the prices will be competitive and the demand is still much higher than the supply.

ALMONDS

Background

Almonds are native to Palestine. Therefore, Palestinian farm households are traditionally familiar with almond cultivation. It is almost uniquely a rain-fed crop in many districts in the country.

Almond trees grow in semi-arid areas; it can survive hard conditions where many other trees cannot survive. Also, in the Palestinian tradition, the farmers say: “where you find a shrub of Natsheh/ Billan⁵⁵, you can uproot it and replace it with almond tree”. This is indication that almonds can survive hard conditions as Billan which is widely spread in Palestine.

Almonds in Palestine are mostly grown as solitary trees within olive orchards. In the last few decades, Palestinian farmers have restarted to pay more attention to almond farming and expanded the cultivated areas and introduced new improved high-yielding varieties. Aqabba village south of Jenin city is the first producer of almonds in Palestine on a larger scale with a total cultivation area of approx. 2,300 du.

The suitable climate for commercial production of almonds is characterized by rainy winters and dry hot summer. The almond tree needs 200-400⁵⁶ chilly hours in the winter season to break the dormancy stage. Almonds is sensitive for high humidity as pollination of almonds flowers requires low humidity. So, it is advisable not to cultivate almonds in the coastal areas. Although, almond trees can survive hard conditions, for commercial farming, the farmers should select a suitable site for their orchard as almond tree needs soil with good drainage and optimal active depth could reach 90 cm. In addition, as in all stone-fruit trees, the almond tree is sensitive for salinity⁵⁷. Therefore, more attention should be paid for this problem in the design of the irrigation system and irrigation schedule especially when irrigate with treated water.

Land preparation

As in all fruit trees orchards, for preparing a new orchard of almonds, there are several steps to be followed:

- Land cleaning by removing residues of old crops, big stones, and land levelling where and if possible.
- Deep ploughing: the land should be turned over to a depth not less than 50 cm by using special mouldboard ploughs.
- Spreading of fermented manure: Adding fermented manure is necessary for improving the soil physical characteristics and its water holding capacity beside its value as organic fertilizer. The average quantity is about 4 m³/du.
- Land smoothing: This is important for levelling the field and it could be done by either a rotary tiller, tooth harrows or disk harrows. It is preferable to undertake this operation

⁵⁵ Natsheh/ Billan is the Arabic local name in Palestine of prickly burnet. Its Latin name is: *Sarcopoterium spinosum* Spach

⁵⁶ The project area in Wadi Al Shaeer has around 250 chilly hours which the temperature could be less than 7.2°C. This in the period from November to February.

⁵⁷ If salinity it reaches 2.7 dc/m in irrigation water and 4.1 dc/m in the soil, the production will decrease by 50%. The readings of the treated water from the WWTP is about 1.5 dc/m and the project soil is with good drainage. Therefore, this problem will be minor problem. However, the farmers of stone fruits should keep monitor this. drainage is very important.

when the soil has a good (but not too wet) content of moisture which will help in minimizing the dust and in crushing the big blocks of soil.

- Orchard planning: The project plan is to plant 30 trees per dunum. The distance between rows will be 7 m and between trees within the row will be 5 m.
- In sloping areas, it is highly recommended to make terraces with very gentle slope.
- Holes digging: The holes can be dug either manually or by an excavator. The size should be suitable not less than 50 x 50 cm and the depth should not be less than 60 cm.
- Seedling plantation: The season of plantation of almond seedlings grafted on seeds root-stock is between January and March. The height of the seedling should be between 40-80 cm. The direction of the grafted stem should be opposite the wind direction. The distance between the grafting point and the land surface should be around 10-15 cm. Plantation can be around the year although it is better to be at the beginning of the spring season. The topsoil should be refilled around the seedling with gentle compaction.
- Each seedling should be supported with a woody stick 130 cm long and 7-15 mm thick. The stick should be on 10 cm distance from the seedling. The seedling should be tight to stick with a special tie.

Pruning

- For shaping the almond tree, the recommended and the most common among the farmers is the cub shape. For this, the farmers start pruning from the first year in permanent field by keeping three stems on the main trunk and one secondary stem on each main stem. This kind of shaping pruning will continue for 4-5 years until the tree reaches the commercial bearing age. Vegetative pruning could be undertaken once or twice a year (in winter and summer) when the green stems length reach 30-50 cm.
- For regular pruning in almonds, it is advisable to be very soft (only dry stems and interlocking stems that growing toward inside the tree)

Fertilization

- usually the farmers and extension agents can recognize deficiency or toxicity of excess macro and micro minerals from the general shape of the tree and from the symptoms on the leaves. This is the easiest way to decide on fertilization programme instead of undertaking soil analysis which sometimes necessary before starting new orchard and leaves analysis for big trees. Therefore, the extension agent and the farmers should keep monitoring the performance of the trees and put in place a fertilization programme accordingly.
- The growth of the 3 years old almond trees in the WWTP is very good without adding any nitrogen fertilizer and fruit bearing also is excellent as per the judgment of the field supervisor.
- For organic fertilizer, as recommended in the land preparation section, it can be spread on all the orchard land (4 m³/du) and it can be added under the seedling as well. Usually manure is added every 3-4 years).
- For fertilization with macro mineral chemical fertilizers, it is advisable to use soluble fertilizers to inject into the irrigation water in the last 30 minutes of irrigation to minimize leaching of the fertilizer outside the roots zone.

Pest and weed control

- Almond trees are subject to infection by a long list of fungus, bacterial diseases and insects.
- The most common fungus diseases in almond orchards are brown rot blossom blight, anthracnose, red leaf blotch, almond rust, Alternaria leaf spot, root crown rot and almond scab.
- The most common bacterial diseases are: phytoplasmas disease and crown gall.
- The most common insect' infections are almond fruit wasp, anarsia, aphids, cicada, thrip insects, carob moth, capnodis, bark beetle and root knot nematode
- It is hard to control the bacterial diseases, therefore, it is very important to have seedlings from a trustful licenced nursery and under direct supervision of MoA to assure provision of healthy and bacterial disease free seedlings as nurseries are a main source of infection for phytoplasmas disease. For controlling crown gall, it is important to avoid roots wounds as the bacteria usually lives in the soil and attacks wounded roots. Therefore, farmers should pay attention when cultivate the weeds by the cultivators.
- It is important to select the suitable root stock and suitable variety that can resist common disease.
- For weed control, the farmers should keep maintaining the drip irrigation system to prevent any leakage which results in growth of weeds. Also, they should either spray their fields with herbicides or cultivate the land to remove the weeds. If the weeds density is not that much, weeding can be done manually by hand.

Harvesting and yield

- Almond trees are subject to moderate alternate bearing phenomenon. However, good practises and proper orchard management help in minimizing the impact of this phenomenon.
- Yield of almonds under full irrigation could varies from 150-280 kg of dry peeled seeds depending on management and varieties.
- In the project, it is recommended to cultivate Um Al Fahim (Hassan Afandi) variety as a major variety (70%) associated with Kukhaf 54 (30%) as pollinator.
- Average weight of peeled seed of Um Al Fahim variety is about 1.4 g and net ratio of the peeled seeds to the gross weight of the dry seed is about 60-70% as this variety has a soft woody endocarp shell.
- In the IMOP economic calculations, we estimated the yield by 225 kg of dry peeled seeds.
- There are three seasons of harvesting of almonds in Palestine:
 - Harvest of green fruits. This season usually in March/ April.
 - Harvest of semi-dried seeds, where the exocarp shell is still there and the woody endocarp is still not fully mature (white to yellowish colour). This usually could be in May.
 - The main harvest season of dry fruits starts in late June/early July.
- Some farmers store the seeds in the woody endocarp shell. However, it is advisable, to remove the woody shell and to store the dry seeds. For storage of the seeds the humidity of content must be less than 6%.

- There are different ways for harvesting. These are: (1) Mechanized harvesting: this can be used on commercial level when you have large orchards and enough area of almonds to invest in such machines. (2) Manual harvest by hand. This is the safest method for the tree. However, it is time consuming and labour intensive. For this method, farmers need ladders, mattresses, and a metallic or plastic fork for harvesting the fruits. (3) Manual harvest by stick. This method is not recommended as it damages the tree and will harmfully affect the harvest of the coming season.

Irrigation

- Full irrigation of almonds will dramatically improve the yield and it will minimize the alternate bearing phenomenon.
- There are two methodologies of irrigation of almonds in the modern commercial orchards: (1) The regular deficit irrigation which gives low amount of water in the period from June until harvesting less amount of water (around 30%) of ETC). This method needs expert farmers and advance monitoring of the irrigation to decide on the proper time for reduced irrigation. However, in the project, we recommend not to follow this method because of the associated risk. (2) Full irrigation method which is recommended in the IMOP.
- The IMOP crop water requirement calculations show that one dunum of almonds need about 1,250 m³ of irrigation water at 100% crop development age with a highest daily peak of 8.0 mm/d.
- Regarding irrigation systems, the Project recommends a drip irrigation with pressure-balanced (regulated) drip lines to ensure fair and regular distribution of water over all drippers. Two lines of drip irrigation lines to be installed for each row of mature trees. Distance between drippers and their discharge capacity should be calculated, depending on soil moisture capacity and irrigation cycle.

Areas to be planted

- The proposed almond area depends on the scenario. It varies between 112 and 282 du.
- It is proposed to cultivate almonds in ameliorated N1, S2 and S3 lands. S1 land should be left for more sensitive trees like apricots, pecan and also alfalfa.

Economic calculation, cost estimate and labour

The economic calculations of almond crop in the IMOP are based on dry peeled seeds with assumption that most of the crop will be marketed as dry peeled seeds. The yield estimated at 225 kg/du. And the farm gate price of one kg of dry almonds is estimated at ILS 25. So the gross income of one dunum is estimated at ILS 5,625.

The total annual variable cost of one dunum is estimated at ILS 3,596/du. This includes the annual running cost and the depreciation on the investment cost. In this regard the Net Benefit of one dunum of existing almonds is estimated at ILS 2,029.

As in all fruit orchards, labour for almonds is in two parts: Machinery work and manual work. Machinery work is for land preparation, holes excavation (which also could be done manually), spreading of manure, spraying, land tilling weeds cultivation and peeling of the seeds. Labour work is for installation and maintaining of the irrigation network, weeding, pruning, harvesting, and general field management.

For the machinery work the rate is either per working hour or per dunum. Prices of machinery depends on the kind of job. For example, for ploughing it is about 90 ILS/h while for spraying it is about 70 ILS/du.

While for the labour work the daily wage is estimated at 100 ILS per working day of 8 hours i.e. ILS 12.5 per working hour.

The required working days per dunum is estimated at 12 working days.

Most of the manual labour is assumed to be family work.

Marketing and Value chain

The United States of America is the first producer of almonds and its share of the international market of almonds exceeds 70%. Spain follows with about 14%. Syria Morocco and Tunisia are three Arab countries on the list of top 10 producers of almonds with a contribution of 5%, 4.9%, and 3% of the international production respectively⁵⁸. Despite the gradual increase of production of almonds, Palestine is still importer of almonds.

One of the challenges of almonds cultivation is the manual harvest of fruit. In advanced almonds orchards, they use mechanical harvesting techniques. This is quite complicated to be introduced by the Project as the land topography of the proposed area for almond cultivation and the land tenure issue will not allow for introducing mechanical harvesting. Therefore, it is proposed to reserve only a small constant land area to be reserved for almonds estimated at 211 du in all crop pattern scenarios.

The Irrigated Almond Cultivation Manual 2018, published with support by the Australian Aid, in cooperation with MoA, MAAN Development Center, Bethlehem University and ASALA MFI, the annual production of almond in Palestine is estimated at 726 ton of green almonds and 2,058 ton of dry almonds. While the annual consumption was around 1,591 ton of green almonds and 11,375 ton of dry almonds. This shows the great gap between production and consumption estimated at 865 ton of green almonds and 9,290 ton of dry almonds. From here we can conclude that the demand on almonds is still very high and the prices of almonds will remain stable regardless the increase in land area that our project is contributing which is still insignificant with regard to the high market demand.

The expected total product of the project if we cultivate 211 dunum it will be 47,475 kg (47 ton). This amount is very small, and it could easily absorbed by the local market of 4 villages and Nablus town.

One of the comparative advantages of almonds production is its capacity for long-term storage. Almond dry seeds can be stored for 1-3 years in good storage conditions. This helps the farmer to decide on the proper time for marketing their product and avoiding any marketing bottlenecks or crises.

Retailer prices of almonds to the final consumer in the supermarket in Palestine is around ILS 50-60. So, if farmers can sell some of their products directly to nearby consumers it will be consider as additional profit.

⁵⁸ Irrigated Almonds Cultivation Manual, 2018, Palestine.

APRICOTS

Background

Apricots cultivation is widely spread around the world. It was introduced to the Mediterranean basin countries in the ancient ages. Turkey is the first international producer of apricots. Algeria and Morocco are the first two Arab countries in apricot production.

The project area is very suitable for apricots cultivation in regard of climate and soil point of views.

Also, Sabastiya is one of a few areas in Palestine that famous for its Mistikawi apricots. Which is a local variety known for its sweetness and softness. However, it is characterised with its short-shelf life. This variety is grown as a rain-fed tree. Some farmers in Sabastiya as reported in the brief focus group meeting below are giving some supplementary irrigation to their trees after the harvesting season to promote growth of new branches. The farmers of Sabastiya graft apricots on bitter almond which is usually used in rain-fed farming. In the WWTP-Nablus West, NM planted in 2016 Mistikawi apricots on GF4677 root stock which is used as a root-stock for stone fruits trees under irrigation. The trees are 4-years old now. It their first year of bearing on commercial level. For apricots, the Israelis use a new grafting technique called sandwich grafting. They use in this grafting GF677 as root stock. Then they graft on it - as a middle agent - early nectarine cultivars, one called in Hebrew Mifradeem or another one called Odeeb. Then they grafted the Ra'nana apricots on the nectarine⁵⁹.

One of the main climatic constrains of apricot cultivation in the area is the limited chill hours in winter which does not exceed 250 hours while minimum chilly requirement of European apricot cultivars is not less than 300 hours. However, this problem has been resolved by developing a chemical growth regulator for delayed foliation in apples, apricots, plums, cherries, wine and table grapes, kiwi fruit, as well as advancement of budding in sultana grapes. It is spread on trees in spring during the floral differentiation season. One of the commercial products is German product known under its commercial name Dormex, which is available in the Palestinian market. The active material of Dormex⁶⁰ is cyanamide⁶¹. The WWTP has used it this season for apricots. The results are excellent.

The Palestinian Israeli experts strongly recommend planting the Ra'nana variety using sandwich grafting as mentioned above. This variety is widely planted in Israel in warm areas in the North that could be warmer than the project area.

Land preparation

As in all fruit trees orchards, for preparing a new orchard of apricots, there are several steps to be followed:

⁵⁹ This information comes from an Israeli Palestinian expert through a phone call with Mr. Sameer Junaidi (The owner and director General of Al Junaidi company).

⁶⁰ Dormex label. https://www.philagro.co.za/wp-content/uploads/2013/08/DORMEX_LABEL.pdf

⁶¹ The active material in the Dormex is hydrogen cyanamide which is a blue odorless liquid. Hydrogen cyanamide is highly **toxic** and may be fatal if swallowed, inhaled, or absorbed through the skin. **Toxic** effects from contact include severe irritation and ulceration of skin, eyes, gastrointestinal and respiratory tracts. Therefore, farmers should handle Dormex with high caution.

- Land cleaning by removing residues of old crops, big stones, and land levelling where and if possible.
- Deep ploughing: the land should be turned over to a depth not less than 50 cm by using special mouldboard ploughs.
- Spreading of fermented manure: Adding fermented manure is necessary for improving the soil physical characteristics and its water holding capacity beside its value as organic fertilizer. The average quantity is about 4 m³ per dunum.
- Land smoothing: This is important for levelling the field. It could be done by either a rotary tiller, tooth harrows or disk harrows. It is preferable to undertake this operation when the soil has a good (but not too wet) content of moisture which will help in minimizing the dust and crushing the big blocks of soil.
- Orchard planning: The project plan is to plant 30 trees/ dunum. The distance between rows will be 7 meters and between trees within the row will be 5 meters. The row orientation is advised to be north/ south for more exposure to sun light.
- In sloping areas, it is highly recommended to make terraces with very gentle slope.
- Holes digging: The holes can be dug either manually or by an excavator. The size should be suitable not less than 50 x 50 cm) and the depth should not be less than 60 cm.
- Seedling plantation: The season of plantation of apricot seedlings under irrigation could be a long the year. However, it is better to be between January and March. The height of the seedling should be between 40-80 cm. The direction of the grafted stem should be opposite the wind direction. The distance between the grafting point and the land surface should be around 10-15 cm. The topsoil should be refilled around the seedling with gentle compaction.
- Each seedling should be supported with a woody stick 130 cm long and 7-15 mm thick. The stick should be at 10 cm distance from the seedling. The seedling should be tight to stick with a special tie designed for this purpose.

Pruning⁶²:

- For shaping the apricot tree, the recommended and the most common among the farmers is the cub shape. For this, the farmers start pruning from the first year in permanent field by keeping three stems on the main trunk and one secondary stem on each main stem. This kind of shaping pruning will continue for 4-5 years until the tree reaches the commercial bearing age. Vegetative pruning could be undertaken once or twice a year (in winter and summer) when the length of the green branches reaches 30-50 cm.
- For regular pruning of apricots, it is advisable to be in late winter to early spring before buds start to open. When pruning apricots, the following should be done:
 - Remove all damaged or broken stems and limbs.
 - Remove all branches with a narrow crotch—those that grow up or inside more than out.
 - Remove all branches that are below 50 cm of the ground.
 - Shorten the main trunk to a height of around 90 cm.
 - Remove additional branches as necessary to make space of at least of 15 cm between branch and another.

⁶² Tree <https://www.gardeningknowhow.com/edible/fruits/apricots/pruning-apricot-trees.htm>

- Cut the secondary branches at a length of 5-10 cm.

Fertilization

- usually the farmers and extension agents can recognize deficiency or toxicity of excess macro and micro minerals from the general shape of the tree and from the symptoms on the leaves. This is the easiest way to decide on fertilization programme instead of undertaking soil analysis which sometimes necessary before starting new orchard and leaves analysis for big trees. Therefore, the extension agent and the farmers should keep monitor the performance of the trees and put in place a fertilization programme accordingly.
- The growth of the 4 years old apricots trees in the WWTP is good without adding any nitrogen fertilizer. Fruiting this year is the first commercial bearing season. It is very good for the trees spread with Dormex.
- In the WWTP, they inject NPK 20,20,20 in irrigation water on weekly bases from March to September at an average of 100 g per tree per week.
- For organic fertilizer, as recommended in the land preparation section, it can be spread on all the orchard land (4 m³ per dunum and it can be added in the whole under the seedling). Usually manure added every 3 - 4 years).
- For fertilization with macro mineral chemical fertilizers, it is advisable to use soluble fertilizers and to inject in the irrigation water in the last 30 minutes of irrigation to minimize leaching of the fertilizer outside the roots zone.

Pest and weed control

- The major apricot pests in the Middle East are: Anarsia lineatella, Capnodis carbonaria and tenebrionis, Carpophilus spp. Cerambyx dux, Ceratitis capitata, Hoplocampa flava and Hyalopterus pruni.
- For weed control, the farmers should keep maintaining the drip irrigation system to prevent any leakage which results in growth of weeds. Also, they should either spray their fields with herbicides or cultivate the land to remove the weeds. If the weeds density is not that much, weeding can be done manually by hand.
- Thinning: In some season apricot tree bear more fruits than it should be which will weaken the tree and ends with small fruits. In this regard, it is advisable to remove some of the fruits. The best time for thinning is 40 - 45 days after blooming when the diameter of the fruits is around 2 cm.

Harvesting and yield

- As in many stone fruit trees and many other woody trees, apricots are subject of moderate alternate bearing phenomenon. However, good practises and proper orchard management help in minimizing the impact of this phenomenon.
- As mentioned in the introduction, average international yield of apricots is around 800 kg/du. In the project economic calculations, we decided to do our calculation based on this average, although in Israel the figures are more optimistic (1,140 kg/du).
- The recommended varieties are: (1) Mistikawi on GF 677 root stock. (2) Ra'nana on GF 677 root stock with sandwich grafting as mentioned in the introduction.

- The harvesting season of Mistikawi apricots (like most other apricot varieties) is short. All the harvest will be in two weeks (late May to early June). Mistikawi is a soft, fleshy fruit. Shelf time is short. So, gentle handling of fruits is necessary.
- For Ra'nana, it is one of the most common varieties in Israel. The fruit size is big, and it is juicy.
- Harvesting of apricots is by hand. This is the only recommended way for the project. However, it is time consuming and labour intensive. For this method, farmers need ladders, and small boxes to put the fruits into to avoid damage of the fruits.

Irrigation

- The IMOP crop water requirement calculations show that one dunum of apricots needs about 1,128 m³ of irrigation water at 100% crop development age with a highest daily peak of 8.0 mm/d.
- Regarding irrigation systems, the Project recommends a drip irrigation with pressure-balanced (regulated) drip lines to ensure fair and regular distribution of water over all drippers. For mature trees, two drip irrigation lines should be installed for each row of trees. The distance between the drippers could be 40-75 cm. Discharge capacity could be from 1.2 - 4.0 l/h.
- Irrigation directly after planation to keep the root stock wet. (recommended quantity is about 5 - 10 m³/du)

Areas to be planted

- The proposed land area for apricots varies between 200 and 334 dunums.
- It is proposed to cultivate apricots in S1, S2 and ameliorated S3 lands.

Economic calculation, cost estimate and labour

The economic calculations of the IMOP consider the international average of 800 kg/du for apricots. Depending on the scenario, a maximum of 435 du will be cultivated, resulting in a maximum yield of 348 tons. Spread out over one month this means around 12 tons per day. This is not a big amount and could easily be absorbed in Nablus and Tulkarem markets.

The total annual variable cost of one dunum is estimated at ILS 4,340/du. This includes the annual running cost and the depreciation on the investment cost. The total benefit is estimated at ILS 8,000/du. Hence, the Net Benefit is estimated at ILS/du 3,660.

As in all fruit orchards, labour for apricots is in two parts: Machinery work and manual work. Machinery work is for land preparation, holes excavation (which also could be done manually), spreading of manure, spraying, land tilling, weeds cultivation and peeling of the seeds. Labour work is for installation and maintaining of the irrigation network, weeding, pruning, harvesting, and general field management.

For the machinery work the rate is either per working hour or per dunum. Prices of machinery depend on the kind of job. For example, for ploughing it is about 90 ILS/h while for spraying it is about 70 ILS/du.

For the labour work the daily wage is estimated by 100 ILS per working day of 8 hours i.e. ILS 12.5 per working hour.

The required number of working days per dunum is estimated at 28 days per year.

Most of the manual labour is assumed to be family work.

Marketing and value chain

As per FAO, the international interest in apricot cultivation is growing fast. It was noticed in the last decade that the international production of apricots increased from 2.9 million tons to 4.1 million tons and the land area cultivated with apricots increased from 430 thousand hectares to 0.5 million hectares. At the same time the yield has improved by 22% (from 6.7 to 8.2 tons per hectare⁶³.

As per the FAO database, Israel was the 40th country in production of apricots in 2016 and 2017 with a total production of 6,500 tons in 2016 and 8,000 tons in 2017. In the same reference, Palestine was in the 53rd position with a production of 1,111 tons in 2016 and 1,112 tons in 2017.⁶⁴

The Palestinian MoA estimated the land area cultivated with apricots in 2016/2017 at 3,500 du all over the West Bank. By matching the FAO figure for production with the MoA figure for land area, the yield is about 318 kg per dunum. This figure is almost less than half of the international average but at the same time it seems very logic as apricot cultivation in Palestine is a traditional rain-fed farming.

Israeli production is almost 7.2 times the Palestinian production. Therefore, most apricots in the Palestinian market come from Israel, except a small amount of local varieties locally produced. Expansion of fruit trees farming is of high national importance, especially as the Palestinian Government Strategy aims to minimize the bond with the Israeli economy as much as possible.

Retailer prices of apricots to the final consumer in the project area is around ILS 25/kg. Sabastiya is known for its Mistikawi apricots and farmers usually, sell their products directly to the final consumers. They fix for this purpose a shelter beside main roads closed to their orchards and sell significant portion of their product through this mechanism. This is will be considered as additional profit to the farmers who do so.

⁶³ Water Scarcity and Sustainable Agriculture in Semiarid Environment, ISBN 978-0-12-813164-0. <https://doi.org/10.1016/B978-0-12-813164-0.00005-3>

⁶⁴ Crops. FAOSTAT. Retrieved 30 April 2019, Countries-Select All; Regions-world- Apricot- 2017+2016.

FIGS

Background

The fig tree is native to the Mediterranean Basin. Spain, Turkey, Egypt and Algeria are the largest producers of fig in the world. Their production almost 58% of total production in the world. The total production of raw (fresh) fig in the world accounts for more than 1.05 million tonnes⁶⁵

Palestine was famous for fig production until the 1970s. Because of mass production at that time, a tangible amount of the product used to be dried and kept for later consumption. Fig fruit (fresh and dry) was cheap and affordable to the poor families. Therefore, dry fig fruits (*quteen*) was a main staple food for the Palestinian poor families especially in winter as a main source for body energy.

Cultivation of figs in Palestine deteriorated dramatically after the 1980s. as farmers left farming for work in Israel, which led to neglecting of their land including fig cultivation. Subsequently, supply of fig fruits decreased a lot and the prices rose. In addition, dry fruits almost disappeared from the market (except for imported Turkish dry fruit available as a luxury dry fruit). The shelf time of fresh fig fruits is short. Therefore, importing fresh figs from neighbouring countries like Turkey is not a feasible option. So, there is a certain interest to produce this fruit locally.

Some Palestinian villages still show interest in fig production. Tel village southwest of Nablus is the most famous village for fig production. The Palestinian Fig Festival conducts in this village on an annual basis. Although it is still the first village in Palestine in fig production, the land cultivated with figs decreased from 2,500 du in the past to around 500 du now⁶⁶.

Rameen village, which is one of the four villages in the project area is famous for production of figs as well. The fig farmers of Rameen are interested only in one variety called *Ihmadi*. The merchants and consumers from different areas of West Bank and Palestinian towns in Israel come to Rameen to buy figs directly from the farmers.

Land preparation

When preparing a new orchard of figs, there are several steps to be followed:

- Land cleaning by removing residues of old crops, big stones, and land levelling where and if possible.
- Orchard planning: The project plan is to plant 18 trees/ dunum. The distance between rows will be 8 meters and between trees within the row will be 7 meters. The row orientation is advised to be north/ south for more exposure to sun light.
- Holes digging: The holes will be dug by an excavator. The size should be not less than (1 x 1 x 1 m).

⁶⁵ <http://www.techno-preneur.net/technology/project-profiles/food/Fig.htm>

⁶⁶ This estimation by the Head of the village council, Agric. Eng. Jafar Ishtieh in an interview with Al Quds .com.
<http://www.alquds.com/articles/1531755960590922000/>

- Seedling plantation: The season of plantation of figs seedlings under irrigation could be along the year. However, it is better to be between January and March. The seedling should be around 18 - 24 months old. It is preferable to be in a big sack or container of 20 litre.

Pruning

- For shaping of a fig tree, it is recommended for a newly planted tree in areas with around 200 chilling hours to be on a single stem⁶⁷. Single stem should be headed at about 60 cm from the ground, and then three developing branches selected to form the initial framework. These selected branches should be shortened later to allow for further branches to develop thus allowing a strong framework to be built⁶⁸.
- Figs have two bearing seasons. The first season is early and known in Arabic under the name ***Dafour***. This usually is formed on the previous season's wood. Then the main crop which comes later, when the new wood grows its leaves and sets fruit buds. These fruits are usually formed on new annual branches. Therefore, gentle winter pruning will enhance growth of new branches which will lead to an increase of the yield of the main crop.
- Any infected or broken branches should be removed.
- Branches that goes vertically high should be cut to a suitable height.
- Some leaves should be removed to help ventilation and sun to enter the tree.

Fertilization

- usually the farmers and extension agents can recognize deficiency or toxicity of excess macro and micro minerals from the general shape of the tree and from the symptoms on the leaves. Therefore, the extension agent and the farmers should keep monitor the performance of the trees and put in place a fertilization programme accordingly.
- From the accumulated experience of Rameen farmers, they do not recommend adding manure in the first year of plantation. Usually they start manure in the second year. They add about 25 litres of fermented manure to each tree in the second year.
- Fig trees prefers alkaline medium. Required pH is between 6.5 – 8.0. For this reason, it grows very well in calcareous soil. Therefore, supplying lime to the soil to increase the pH if it is below 6.5 is necessary.
- Adding 350 - 400 g of P₂O₅ per tree per year is advisable⁶⁹.

⁶⁷ George Ray McEachern, Extension Horticulturist, Texas A & M University, College Station, Texas 77843-2134, December 9, 1996.

⁶⁸ Carey, D., Deuter, P., Zull, A., Taylor, H., White, N (2017) High Value Horticulture Value Chains for the Queensland Murray-Darling Basin Project: Activity 1 – Assessing Horticulture Crop Suitability for the Queensland Murray Darling Basin Study Area report. Queensland Government Department of Agriculture and Fisheries.

⁶⁹ LEC .24 FIG - SOIL, CLIMATE, PLANTING, VARIETIES, NUTRIENT AND WATER MANAGEMENT, SPECIAL CULTURAL OPERATIONS, PHYSIOLOGICAL DISORDERS, PESTS AND DISEASES, MANAGEMENT PRACTICES, <http://eagri.org/eagri50/HORT181/lec24.pdf>

Pest and weed control

- As per Ramin fig farmers, the major disease infecting their fig trees is the Fig rust. Rust is a fungal disease caused by *Physopella fici*⁷⁰. Its first appearing on fig leaves as yellowish orange spots. Then start to change to round brownish to black spots. Then heavy defoliation of leaves takes place. The farmers of Ramin use a fungicide called score with a concentration of 2cc/litre of water⁷¹. The spread it twice in the season. Price of 1 litre of score is around ILS 400. As alternative for score, the farmers can dust the trees with sulphur.
- The second major problem facing the farmers in Ramin is the fig fly (*Lonchae aristella*). It leads to fall of the fruits before ripe and rotting of the ripe fruits before picking. The farmers use Dimethoate with a concentration of 0.5 cc/litre of water.
- A third pest but with less importance in Ramin is the fig wax scale, which is caused by *Ceroplaster rusci*. The farmers use an insecticide called new pricide, which is with a dual use for insects and mites. The used concentration of this chemical is 1.5 cl/litre. The best time for spraying is after eggs hatching in May / June⁷².

Harvesting and yield

- Fig tree start bearing on the second year in the permanent field if the age of the seedling was 18 - 24 months old.
- In a meeting with 3 fig farmers from Ramin on 16/09/2019, the farmers estimated the yield of their trees by 20 kg/tree of 2 years old, 35 kg of 3 years old tree, 60 kg of 5 years old tree and 150 - 200 kg of a tree more than 10 years' old⁷³.
- The commercial life span of fig tree is about 30-35 years.
- The harvest season lasts from August to Mid-September.
- The shelf life for fresh fig fruits could last 5 - 7 days in a fridge temperature (5°C).
- The optimal temperature for fig fruit cultivation is above 20°C. Fig trees prefer dry climate at fruit development stage and maturity. Fruit quality start deteriorating with high temperatures above 40°C.
- Farmers of Ramin prefer one variety called Hmadi. We doubt if the farmers will accept to cultivate other varieties.
- The harvesting of fig fruits is done by hand. The farmers usually harvest figs at early morning. Harvesting is in intervals of 2 - 3 days.
- Fruits are soft, therefore, the farmers put harvested fruits in small boxes to avoid damage of the fruits.
- The farmers paint the bottom of the fruits with little oil to enhance fruits ripening.

Irrigation

- The IMOP crop water requirement calculations show that one dunum of figs need about 861 m³ of irrigation water at 100% crop development age with a daily peak of 5.6 mm/d.

⁷⁰ George Ray Mc Eachern, Extension Horticulturist, Texas A & M University, College Station, Texas 77843-2134, December 9, 1996.

⁷¹ Fig farmer from Ramin, Mr. Sakher Salman over phone call on 19/5/2020.

⁷² An article on figs plantation in Palestine in Arabic on The Palestinian News and Information Agency (WAFA). http://info.wafa.ps/ar_page.aspx?id=8619.

⁷³ Meeting report is available in the project and contact information of interviewed farmers are within the report.

- Regarding irrigation systems, the Project recommends a drip irrigation with pressure-balanced (regulated) drip lines to ensure fair and regular distribution of water over all drippers. Two lines of drip irrigation lines to be installed for each row of trees. Distance between drippers could be from 40-75 cm. discharge capacity could be from 1.2 - 4.0 l/h.
- Irrigation directly after plantation to keep the root stock wet (recommended quantity is about 5 - 10 m³/dunum).

Areas to be planted

- Figs grow well in arid and semiarid climate.
- Fig tree can survive temp. up to 45 °C. Optimal temperature for growth is 15 - 21 °C.
- Soil: The best soil is medium to heavy calcareous soil. Soils having a high lime content produce fruits of better quality suitable for drying.
- It must be well drained soil. Avoid sites and soils where water stands for more than 24 hours after a rain. In areas of poor drainage, roots receive insufficient oxygen, which results in stunted growth and eventual death of the tree.
- Fig tree is one of the most salt tolerant crops among fruit trees. It tolerates high level of sulphate and chloride salt.
- The proposed land area for figs varies between 200 and 334 du.

Economic calculation, cost estimate and labour

- The total annual variable costs are estimated at ILS 4,286/du. This includes the annual running cost and the depreciation on the investment cost. The total benefit is estimated at ILS 8,400/du. The Net Benefit is estimated at ILS 4,114/du.
- After more than 5 years of plantation the expected production under the first scenario is expected to be around 522 tons. If the harvesting season will last for 45 days, the average daily supply will be 11.2 tons.
- As in all fruit orchards, labour for figs is in two parts: Machinery work and manual work. Machinery work is for land preparation, holes excavation, spraying, land tilling and weeds cultivation. Labour work is for installation and maintaining of the irrigation network, weeding, pruning, harvesting, and general field management.
- The required number of working days per dunum is estimated at 30⁷⁴.
- Most of the manual labour is assumed to be family work.
- Farmers of other villages in the project did not show interest in cultivation of figs for two reason as they said: 1) Needs a lot of work especially in the harvesting season. 2) their experience is limited. Therefore, the project focus for figs should be on Rameen farmers.
- There are 16 farmers from Rameen cultivating 590 fig trees on land beside the main road to Tulkarem opposite to Ennab Junction. These farmers irrigate their trees from the water coming out from Nablus WWTP discharged into the Wadi. Those farmers have raised their concern than when the project become functional, the wadi will become dry and they will not find water to irrigate their trees.

⁷⁴ Harvesting and painting the fruits with oil will consume reasonable part of the working days.

Marketing and value chain

- Some current producers of figs from Rameen raised their concern if the area increased it could affect the prices. This concern is reasonable to some extent. But also, it could be the opposite, by attracting more merchants from different areas to come for Rameen figs.
- The yield of one dunum considered in the economic calculation of the IMOP is 1,200 kg/du (i.e. 67 kg per tree) and the farm gate price is ILS 7/kg. The retailer price to final consumers in the supermarket varies from ILS 35/kg at the beginning of the season to ILS 12-15 at the end of the season.
- The Hmadi variety which Ramin farmers cultivate is a table fruit. Drying or processing is not an option for the farmers at this stage.
- The competition on Nablus market is coming from Tel village/ south Nablus which cultivate around 2,500 du of figs.

GRAPES

Background

Grapes is one of the most famous crops in Palestine; it is part of the heritage. It is widely spread in many districts, especially in Hebron and Bethlehem districts and the Northern – Western villages of Jerusalem. Also, it is rare not to find a grape tree in any home garden all over the West Bank. The Gaza Central District is also famous for its grapes. Most of the Palestinian grape varieties are traditional ones. These varieties in above mentioned areas are almost under rain-fed farming and their fruits become ripe in a short season. It was noticed in the last decades that grape farming has been expanded to other districts such as the Jordan Valley, Tubas and Tammoun areas in Tubas District and in some areas in Jenin district. New varieties have been introduced to these areas.

The comparative advantage of these new varieties lay in its early ripening season (before the traditional season of grapes between August and October). Also, some of these introduced varieties are seedless. In addition, the storage period for some of these varieties is much longer and could last for 2 - 3 months in cool stores, which help in price elasticity and improve farmers' resilience. Farming of these new varieties in these new areas are under irrigation. Beside the fruit production, a new market for vine leaves has opened, noticeably in the last years; many farmers now grow grapes only for leaves production.

Land preparation

When preparing a new orchard of grapes, there are several steps to be followed:

- Land cleaning by removing residues of old crops, big stones, and land levelling where and if possible.
- Deep ploughing: the land should be turned over to a depth up to 60 - 90 cm by using special mouldboard ploughs. This should be between September and November:
- Spreading of fermented manure: Adding fermented manure is necessary for improving the soil physical characteristics and its water holding capacity beside its value as organic fertilizer. The average quantity is about 6- 8 m³ per dunum. The manure should be properly fermented which helps in killing the pathogens, and the weed seeds. Also, fermentation is important for fast decomposition of the manure and absorption by the plants.
- Land smoothing and bed preparation: This is important for levelling the field and it is advisable to be done by a rotary tiller. It is preferable to undertake this operation when the soil have a good (but not too moisture content). This will help in minimizing the dust and crushing big blocks of soil.
- Orchard planning: It is recommended to make a proper plantation bed. The bed will be around 1.2 m-wide and 25-50 cm high with gentle slope of 1-1.5%. The beds orientation must be north-south giving more light to the trees. The distance between the rows is 3 m and the distance between the trees should be 2 m. Hence, the number of seedlings will be 167 trees per dunum.
- Holes digging: The holes can be dug either manually or by an excavator. The size should be suitable with a diameter not less than 30 cm and depth not less than 40 cm.

- Seedling plantation: There are two recommended seasons for plantation of grapes seedling in a permanent orchard. The first in summer in July and the second in winter in November. It is important to add primary fertilizer in the bed (such as multicote) in the hole (10 - 20 gram per hole. Then plant seedling and support with a bamboo stick (130 cm long and 20 - 30 mm thick). Add carton or plastic protection to protect the seedling

Pruning

- Pruning of grapes was comprehensively presented in the “**Manual for Table Grapes Cultivation 2019, Australian Aid, PARC and Oxfam**” (Arabic guide manual)
- As per above manual, there are two types of pruning. (1) for training of new seedlings and (2) the normal winter pruning of grapes trees.
- For training pruning they propose three stages:
 - usually at the second year of plantation the farmer should put the posts which they will fix the trellis on. The distance between the posts is 4 - 6 m. Then they fix an iron wire along the posts at 120 cm high and they tie the seedling to the wire with a rubber tie. Beside the main branch, another two selected secondary branches should be kept while other branches will be removed. The growth of the three branches should be assessed and when they reach a height of 10 cm above the wire (120 cm), they should select the strongest one and remove the other two.
 - If the diameter of the selected stem is less than 14 mm, it is advisable to cut the stem by leaving two buds only. This action should be in the winter pruning time when the tree still in the dormancy.
 - In the third stage, the canopy / crown of the tree will be cut leaving two branches on each side above the cordon. The branches will be tied to the trellis.
 - Winter pruning: There are different strategies for winter pruning depending on the variety, purpose of cultivation (for fruits or for leaves or for both), and kind of husbandry (Y-shape trellis, full trellis, height of trellis...etc.). In this regard the WUA agricultural engineer and the MoA extension agents must advise the farmers on the best approach for their fields. Also, the farmers field schools will undertake this subject in detail.

Fertilization

- Usually the farmers and extension agents can recognize deficiency of macro and micro minerals from the general shape of the tree and from the symptoms on the leaves.
- Fertilization is essential in grapes orchards for increasing the yield and for improving the quality of the fruits. In addition, it is essential for improving the chemical and physical characteristics of the soil and for improving the resilience of the grape trees for the fungus diseases and pests as well.
- The annual requirements of grape tree from the essential macro nutrients are: 14 - 22 kg of nitrogen, 7.5 kg of phosphorus in the form of P_2O_5 , 6 kg of MgO , 11 kg of CaO and 19 kg of K_2O . This is beside the microelements such as ferrous, manganese, zinc, and copper. This is to show to which extent fertilization is essential for grapes orchards. However, it does not mean that the farmers will add all these required quantities of nutrients as many of them are available in the soil. For example, treated water is rich with nitrogen. Therefore, maybe, no need for nitrogen fertilizer.

- There are several methods to calculate the proper amounts of required fertilizer. One of these methods is to compensate the consumed amount for production of fruits. In grapes for each one ton of fruits the farmers can add 0.9 kg of Nitrogen, 0.3 kg of P₂O₅, 1.9 kg of K₂O and 0.09 kg of MgO.

Pest and weed control

- Irrigated orchards are more vulnerable to some diseases and pests, especially the fungal disease. Therefore, there are general principle should be part of any integrated pest management programme:
 - Select resistant cultivars and root stocks suitable for the area.
 - Give enough sun light and ventilation. Therefore, the trees rows orientation should North / South.
 - Select a suitable location with well-drained soil.
 - Follow proper orchard management in regard of training, pruning, balanced leaves picking, irrigation and fertilization programmes and all other practises.
 - Treat diseases and pests on time.
- The most common fungus diseases of grapes are powdery mildew, downy mildew, dead arms eutypa dieback, gray mold and black rot.
- The most common pests are moth berry grape, mealybug grape, thrips, and grape vine cicada.
- The most common viral diseases are: fanleaf virus, leafroll virus and rugose wood complex
- For new orchards, it is very important to have seedlings from a trustful licenced nursery and under direct supervision of MoA to assure provision of healthy and disease free seedlings as nurseries are a main source of infection if the seedlings have come from infected nursery.
- For usage of chemical pesticides before harvesting, it is important to use chemicals with lower toxicity and to take in consideration the safety period of each pesticide could be used as some of the chemical residues will appear in the oil and it will have harm impact on the oil and consumers.
- For weed control, the farmers should keep maintaining the drip irrigation system to prevent any leakage which results in growth of weeds. Also, they should either spray their fields with herbicides or cultivate the land to remove the weeds. If the weeds density is not that much, weeding can be done manually by hand.

Harvesting and yield

- Commercial bearing of grapes trees is in the third year of planting in the permanent field.
- The commercial life span of grape trees is about 15 years.
- Fruits yield under irrigation varies from 2 - 4.5 ton/du highly depends on management and variety. And yield of leaves varies from 200 - 400 kg/du. In the IMOP, our calculation was based on average yield of 3,000 kg/du of fruits and 300 kg/du of leaves.
- The harvest season in the project area is highly depending on the cultivars as many cultivars are early and many others are within the common season of grapes while others are late cultivars. However, when you compare the different areas, Jordan valley will be the first, Tubas and Jenin follow and then our project area will be after them. Hebron and Bethlehem districts which are the main areas will come later except the western villages

of Hebron such as Beit Ula and Kharas which are warmer than other areas in Hebron. This helps in selecting the suitable varieties in regard of marketing considerations.

- The shelf life for fresh grapes is long in comparison with other proposed fruits for the project area. For some cultivars it could be more than two months. This gives the farmers good room to organize their supply. Also, this helps in exporting grapes to neighbouring countries and abroad.
- The optimal temperature for harvesting grapes is around 20°C and the proper harvesting time is in the morning.
- It is advisable in dewy days to delay harvesting until the dew dries.
- Farmers should avoid harvesting by hands and should use scissors for this purpose. Also, by using scissors, they should remove bad fruits.
- For transportation of grapes, it must be in cool containers with a temperature between 15 - 17 °C.
- Storage could last from 30 - 90 days depending on the variety. Optimal temperature for storage is between 0 - 5 °C and optimal humidity is above 90%.

Irrigation

- The IMOP crop water requirement calculations show that one dunum of grapes need about 1,034.27 m³ of irrigation water at 100% crop development age with a highest daily peak of 7.2 mm/d.
- Regarding irrigation systems, the Project recommends a drip irrigation with pressure-regulated drip lines to ensure equal distribution of water over all emitters. Two lines of drip irrigation lines to be installed for each row of trees. Distance between drippers could be from 40 - 75 cm. discharge capacity could be from 1.2 - 4.0 l/h.

Areas to be planted

- Grapes grow well in soils with good drainage.
- Farmers must avoid planting grapes in calcareous soil as grapes are sensitive to active lime content.
- Grapes are sensitive to salinity.
- High organic matter content is good for improving the soil texture. Therefore, it is advisable to add enough quantities of fermented manure.
- The proposed land area for grapes varies between 86 and 330 du.

Economic calculation, cost estimate and labour

- The total annual variable cost of growing grapes is estimated at 11,336 ILS/du. This includes the annual running cost and the depreciation on the investment cost. The total benefit is estimated at 22,500 ILS/du. The Net Benefit is estimated at 11,164 ILS/du.
- At the full maturity age, the expected production under the first scenario will be around 1,305 tons. If the supply to the market will last for 60 days, the average daily supply will be 22 tons.
- In the IMOP, the calculation was done based on the 10th Scenario for cultivation of 296 dunum. Under this scenario the estimated annual production will be 888 tons and the daily supply to the market will be around 15 tons.

- As in all fruit orchards, labour for grapes is in two parts: Machinery work and manual work. Machinery work is for land preparation, holes excavation, spraying, land tilling and weeds cultivation. Labour work is for installation and maintaining of the irrigation network, weed-ing, pruning, harvesting, and general field management.
- The required annual working days is estimated at 70⁷⁵ working days per dunum.
- Most of the manual labour is assumed to be family work.

Marketing and Value chain

- Grapes in Palestine are considered one of the best cash crops. The cost benefit analysis carried out shows that grapes Net Benefit is the highest among all other selected crops, three times higher than any other fruit tree.
- As per an article published by the Palestinian News and Information Agency (WAFA)⁷⁶, grapes farming in Palestine covers around 12% of the total agricultural production which estimated by 80 thousand tons of fruits. And it is the second crop after olives in regard of production. The same article, with a reference to PCBS, estimated the land area cultivated with grapes in 2010 by 80,000 du, Hebron District was the largest with around 45,000 du and Bethlehem was the second largest with around 15,000 du.
- On 27 September 2017, Al Iqtisadi Magazine published an article on grapes. For that article they interviewed the head of horticulture department at MoA, Eng. Odeh Sabarneh. Eng. Sabarneh estimated the lands cultivated with grapes at 46,000 dunums, of which 36,000 du in Hebron and Bethlehem, 3,000 dunums in the Northern districts of West Bank and 7,000 du in Gaza⁷⁷. Similar figures on the land areas of grapes has been confirmed by the director of the Hebron Directorate of Agriculture, Eng. Usama Jarrar, who estimated the land area of grapes in Hebron in 2018 by 29,000 dunums⁷⁸.
- It is clear from the above that the land areas cultivated with grapes are deteriorating. Also, it important to know that around 50% of grapes production in Hebron and Bethlehem goes for processing of molasses, jam, dry grapes and other products such as malban. Also, as per the head of Hebron Chamber of Commerce on 16 September 2015, the statistics of the Chamber of Commerce has shown that at least 40% of grapes production is Hebron district was consumed locally in the district itself, 35% in the remaining districts of West Bank and Gaza while 25% was exported to Israel⁷⁹.
- From the above we can conclude that there is good marketing potential for grapes in Palestine.

⁷⁵ Harvesting and leaves picking will consume reasonable part of the working days.

⁷⁶ http://info.wafa.ps/ar_page.aspx?id=8157

⁷⁷ <https://www.aliqtisadi.ps/article/49623/>

⁷⁸ http://www.alhayat-j.com/ar_page.php?id=40d69e5y67987941Y40d69e5

⁷⁹ <https://www.palestineconomy.ps/ar/Article/33a8d8y3385560Y33a8d8/35-%D9%85%D9%84%D9%8A%D9%88%D9%86-%D8%AF%D9%88%D9%84%D8%A7%D8%B1-%D8%B3%D9%86%D9%88%D9%8A%D8%A7-%D8%A5%D9%86%D8%AA%D8%A7%D8%AC%D9%8A%D8%A9-%D9%85%D8%AD%D8%B5%D9%88%D9%84-%D8%A7%D9%84%D8%B9%D9%86%D8%A8-%D8%A7%D9%84%D8%AE%D9%84%D9%8A%D9%84%D9%8A>

- One of the main challenges farmers could face is the high investment cost required for grapes cultivation. Due to the required high investment, cash flow is negative in the beginning; up to 25,000 ILS/du. However, the payback period does not differ from other fruit trees, i.e. around 5 years.

ALFALFA

Background

Alfalfa is a perennial flowering legume from the legume family *Fabaceae*. Its economic value comes from the fact that it is a well-known forage crop in wide areas along the globe. Its nutritional value is excellent with high value of protein and fibre. Therefore, it is an advisable ration for livestock (cattle, sheep, and goats) especially the dairy herds as forage rations are essential for milking livestock. In addition, alfalfa can be given to animals in many forms: either direct grazing, dry hay, and or silage.

Alfalfa has a deep root system that could go down to more than four meters. Therefore, it should be cultivated in a very deep soil. For proper field management, alfalfa cultivation should be fully mechanized, and for this purpose the alfalfa field size should be wide enough to be suitable for the machine to move freely.

Land preparation

When preparing a new field of alfalfa, there are several steps to be followed:

- Site selection:
 - The selected site must be flat or with very gentle slope. The active depth of the soil should not be less than one meter under any circumstances. In addition, it should be well drained soil.
 - Soil acidity: avoid growing alfalfa in acidic soils. Optimal pH for growing alfalfa is between 6.5 and 7. If pH is below this, limestone must be added⁸⁰.
- Land cleaning by removing residues of old crops, big stones and land levelling where needed.
- Deep ploughing: the land should be turned over to a depth up to 60 cm by using special mouldboard ploughs. This should be between September and November.
- Land smoothing and seedbed preparation: This is one of the most important steps for successful establishment of new alfalfa field. It is preferable to undertake this operation when the soil have a good (but not too moisture content). This will help in minimizing the dust and crushing big blocks of soil.
- Installation of the subsurface drip irrigation system: depth of the pipes must be between 25 - 40 cm. and distance between laterals must be between 70 - 80 cm.
- Seeds sowing: It could be done either manually or by drill sowing machine. Amount of seeds in manual hand spreading is 2.5-3.0 kg/du. While in machinery sowing it could be around 2 - 2.5 kg/du.
- Seedbed firming: The depth of alfalfa seed should be around 1 cm. for this purposed the seedbed should be firmed to prevent deep sowing. This can be done with a compaction roll after surface sowing or before machinery sowing by drill sowing machine.
- Weeds control: to prevent growing of weeds, it is necessary to use pre-emergence herbicides before sowing alfalfa⁸¹.

⁸⁰ Doo-Hong Min, Michigan State University Extension - March 31, 2011, planting method for successful alfalfa establishment. https://www.canr.msu.edu/news/planting_methods_for_successful_alfalfa_establishment

⁸¹ The same previous reference.

- Germination irrigation by sprinklers. The first 2 - 3 irrigations must be by using sprinklers⁸² to help in germination of the seeds.

Fertilization

- Liming: As mentioned in the land preparation section, adding lime is essential if the pH is less than 6.5. However, as per the lab analysis of 27 samples representing all soils of the project area, pH ranges from 7.1 - 8.2. Therefore, liming is not needed in our case. Instead fertilization management programme is needed. When soil pH values are calcareous (7.4 and higher), the best strategy is to concentrate on appropriate management of fertilizer⁸³ as soil pH above pH 7.2 or below about 6.5 reduces the amount of P that is available to alfalfa⁸⁴.
- Nitrogen: No need for any nitrogen fertilizers because alfalfa is a legume crop and it is known that legumes fix nitrogen in the soil. Also, the treated wastewater is rich with nitrogen.
- Phosphorus and Potassium: Alfalfa requires high amounts of P and K as each harvested dry matter ton of alfalfa removes approximately 11 pounds of P_2O_5 and 53 pounds of K_2O ⁸⁵. The required amounts of P_2O_5 and K_2O to be added can be calculated based on soil analysis and expected yield.
- Sulphur (S): sulphur fertilizer needed only if the soil is a sandy soil which is not the case in our project or if the organic matter content is less than 3%⁸⁶.
- Boron: It is known that soil with high pH suffers boron deficiency⁸⁷. Therefore, in our case boron fertilizing programme should be taken in consideration.
- Copper (Cu): alfalfa is highly responsive to Cu. Cu toxicity will cause root damage and prohibits absorption of P. In this regard Cu availability/ deficiency should be monitored.

Pest and weed control

There are several insects damaging alfalfa. The most damaging insects are:

- Alfalfa weevil (occurs primarily in late winter), Aphid complex (occurs in spring, summer, and fall), Summer worm complex (armyworms, alfalfa caterpillars, etc.), and Leafhoppers (can occur at various times)⁸⁸. The harmful damage of these insects is when they are in the larva (caterpillar) stage as they feed on alfalfa leaves in this stage of their growth. Using insecticides must be the last option when the infection is high. Keeping natural enemies is a good choice as part of integrated pest management programme.

⁸² As the sprinklers use is only for the first 2-3 irrigations, it is not necessary to install sprinklers irrigation network for all the project area. Instead, a network for few dunums can be used by moving it from parcel to another.

⁸³ Daniel E. Kaiser, Extension nutrient management specialist, University of Minnesota Extension. <https://extension.umn.edu/crop-specific-needs/alfalfa-fertilizer-recommendations>

⁸⁴ Spectrum analytic Inc., Fertilizing alfalfa, https://spectrumanalytic.com/support/library/pdf/Fertilizing_Alfalfa.pdf

⁸⁵ Doo-Hong Min, Michigan State University Extension - March 31, 2011, planting method for successful alfalfa establishment. https://www.canr.msu.edu/news/planting_methods_for_successful_alfalfa_establishment

⁸⁶ The organic matter content in the analyzed 27 soil samples ranges from 1.09-2.87%. Only one sample was above 3%. It was 3.76%.

⁸⁷ Spectrum analytic Inc., Fertilizing alfalfa, https://spectrumanalytic.com/support/library/pdf/Fertilizing_Alfalfa.pdf

⁸⁸ <http://ipm.ucanr.edu/PMG/r1900111.html>

- Viral diseases: The most common viral disease in alfalfa is Alfalfa Mosaic Virus (AMV). There no treatment for viral diseases. Therefore, farmers should select resistant varieties.
- Fungus diseases There are several fungus diseases that attack alfalfa in certain weather conditions. The main fungus diseases are: Anthracnose (*Colletotrichum trifolii*), common leaf spot (*Pseudopeziza medicaginis*), downy mildew (*Peronospora trifoliorum*), Fusarium wilt and lepto leaf spot. The best treatment to control fungus diseases is early harvest before heavy spread of the disease.
- Parasite plants: Alfalfa is a host for the invasive dodder (*Cuscuta*) plants⁸⁹, which spread in the project area.
- Weeds: Weeds are a serious problem for alfalfa either in establishment phase of alfalfa field as it can domain the field and domain alfalfa germinated seeds or in already established field. Weeds can be annual weeds or perennials. Impact of weeds is in regard of reducing the yield and affecting the hay quality. One of the weeds appears in the project area and has a high risk of spreading in the area is the ragweed which is a flowering plant of the genus *Ambrosia*. It has heavily spread in the project area. It grows much higher than alfalfa and its stem is thick and too hard that animals can chew it. Beside this it is harmful to human beings as it causes skin allergy. It causes about half of all cases of pollen-associated allergic rhinitis in North America, where ragweed is most abundant and diverse⁹⁰.

Harvesting and yield

- The only available information about yield of alfalfa in Palestine has come from the recent experience of Marj Ibin Amer Agricultural Cooperative in Jenin⁹¹:
 - From their experience, each dunum has given 9 cuts in the first year. The period between two cuts was 24 - 30 days. Each cut produced 20 - 22 bales of sun dry hay. Weight of bales was about 15 - 18 kg. This means that the yield of one dunum was around 3 tons of sun dry hay which considered relatively high.
 - In the second year, the cuts decreased to 8 and number of bales of each cut was between 18 - 20 bales/du.
 - In the third year, the cuts were 8 and number of bales of each cut was between 15-18 bales/du`.
 - In the fourth year, 80 dunums out of 218 cultivated dunums. have been scrapped because of spread of dodder and low yield.
 - The quality of first cut of each year is so bad as high ration of it was winter weeds.
- In the outside scheme, 30 du were cultivated with stand-alone alfalfa and 14.3 du intercropped with alfalfa and pecan. As per the draft completion report (T4.2 Reuse Outside Scheme), "harvest and income of alfalfa were far below expectation"⁹²

⁸⁹ Dodder, (genus *Cuscuta*), is a genus of about 145 species of leafless, twining, parasitic plants in the morning glory family (*Convolvulaceae*). They are widely distributed throughout the temperate and tropical regions of the world, and many species have been introduced with their host plants into new areas and are considered invasive species.

⁹⁰ <https://en.wikipedia.org/wiki/Ragweed>

⁹¹ The given information on alfalfa production in Jenin has been gotten from the Director of Marj Iben Amer Cooperative/ Engineer Majdi Abu Naim

⁹² T4.2 Reuse Outside Scheme Completion Report (draft version). Page 28: Section 5.2: Conclusion.

- Harvesting of alfalfa is fully mechanized. In good conditions, alfalfa can give 8 - 10 cuts per year. The interval between two cuts is 24 - 30 days. Harvest will be by mower. The harvest will be left for 4 - 5 days for sun drying before baling.
- The IMOP B/C calculations were based on yield estimation of 160 bales per du.
- Sharp depreciation in yield is highly possible. Therefore, risk of making losses is rather high.

Irrigation

- When decided on the irrigation system to be used for irrigation of alfalfa, it should be taken in consideration the free movement of the machines. Therefore, the best irrigation system for alfalfa is either big overhead sprinklers (gun sprinklers) or a subsurface irrigation system. However, the Palestinian Standard No. 742-2015 put limits on using sprinklers for irrigation with treated wastewater. For irrigation with Grade "A" treated wastewater by sprinklers, a buffer zone of at least 50 meters should be assured. As the Project did not receive any official answer from the Palestinian Standard Institution (PSI) on the definition of feeder roads within the project area (consideration as public roads), it was agreed with the MoA to exclude sprinklers⁹³ and thus opt for subsurface irrigation only.
- Using subsurface irrigation for alfalfa has some limitations:
 - The technology is quite expensive in comparison with surface and sprinklers irrigation systems.
 - Subsurface irrigation is suitable for deep soils with very few stones.
 - Subsurface irrigation is not recommended for use in clay soils, which are reacting with cyclical movements when soil moisture changes and produce cracks when drying, leading to damages to pipes.
 - Depth of the pipes must be between 25-40 cm. and distance between laterals must be between 70-80 cm. To achieve this, the field should be properly prepared before installation of the irrigation network, which implies additional cost.
 - Subsurface irrigation systems cannot be used for germination of seeds. Therefore, the first two irrigation rotations should be carried out with micro sprinklers, which also implies additional costs.
- The IMOP crop water requirement calculations show that one dunum of alfalfa under subsurface irrigation needs about 1,333 m³/year of irrigation with a highest daily peak of 7.2 mm/d.

Areas to be planted

- It was noticed from the Land Suitability Assessment, that the suitable areas for alfalfa⁹⁴ in the project irrigation area is limited and does not exceed 110 du in area S1 and eventually 216 du in area S2.
- High suitable lands will be reserved for alfalfa as alfalfa needs deep flat soils with few stones.

⁹³ This was confirmed by the Head of the Marginal Water Use department in MoA, Eng. Emad Khelif via email exchange on 15 April 2020.

⁹⁴ Suitable land for are alfalfa under subsurface irrigation within the project irrigation areas is the land, which is considered as highly suitable regarding depth, gentle slope and with a minor content of stones (less than 10 percent).

- For intercropped alfalfa with pecan, the distance between pecan rows should be enough to allow machinery movement for harvesting and baling of the hay. In the IMOP, we have recommended to have 10 meters distance between trees rows. And a buffer area of 80 cm from each side of pecan trees to be empty. In this regard the area for alfalfa will be 8.4 meter between two rows of pecan trees.
- Literature on intercropping alfalfa with pecan nut or other fruit trees is conservative in regard of shade, competition for water and nutrients since trees and alfalfa have deep competing root systems
- Intercropping of fruit trees with Alfalfa was moderately popular about 100 years ago as the alfalfa provided nitrogen. With the arrival of cheap chemical fertilizer, intercropping lost interest.
- Irrigation rotations for alfalfa and trees are different, therefore irrigation systems should be separated: One subservice irrigation system for alfalfa and another service drip irrigation system or micro sprinkler system for the trees, which complicates irrigation management.

Economic calculation, cost estimate and labour

- The IMOP estimated the annual variable cost of alfalfa at 2,996 ILS/du and the total benefit at 3,840 ILS/du. Therefore, the Net Benefit will be 844 ILS/du and B/C ratios for alfalfa as presented in Chapter 4 of this study was 1.3. However, any farmer should think twice cultivating a crop with a B/C ratio below 1.5 as a low B/C ratio presents high risks.
- As alfalfa is almost a fully mechanized crop, it will not create many jobs.

Marketing and Value chain

Cultivation of alfalfa in Palestine is limited. It has been started more than 40 years ago in Jericho by The Arab Development Society (ADS). ADS maintains more than 400 du of alfalfa to feed their dairy cattle. A few years ago, ANERA has introduced cultivation of alfalfa in partnership with the Marj Ben Amer Society as part of the Reuse Project of Treated Wastewater from the Jenin WWTP (approx. 280 du of cultivation). Nablus Municipality has demonstrated cultivation of 44.4 du of alfalfa in the outside scheme (30 du stand-alone crop and 14.4 du. intercropped with pecan)

Advanced full computerized dairy farms are a growing business in Palestine. In the last two decades several big dairy farms with more than 500 milking cows were established. Some of them have more than 2,000 heads. Animal feed represents the major input and the costliest. At least 95% of the feed, either concentrate or hay or silage comes from Israel or imported via Israel. The cost of hay from Israel with cost of transportation added leaves a low margin of profit for the Palestinian farmers. Therefore, producing of alfalfa has a high marketing potential. However, at the same time it associated with a high risk as the local knowledge is limited and as clarified in B/C ratio, the business is not encouraging and risk of making losses is too high.

One of the comparative advantages of alfalfa in addition to the high demand in the local market is its fast cash flow. The first cut of alfalfa could be after 3 - 4 months of seeding.

Because of this comparative advantage, it was planned in the Request for Tender Document (RFT) to plant a round 1,500 du of alfalfa (600 du to be intercropped with pecan nut) and

another 900 du of stand-alone fields. Even more, agriculture equipment for alfalfa cultivation have been purchased with support by KfW. The plan is to handover this equipment to the WUA to provide support to the alfalfa farmers. The feasibility studies did however not consider that most of the land in the project area is not suitable for growing alfalfa.

With all constrains and difficulties mentioned in this essay, we are very hesitant to recommend the cultivation of alfalfa

PECAN

Background

Pecan is a large deciduous tree that can reach heights of up to 35 m. It has a deep root system, will not grow well on soils less than 1 m deep and need even deeper soils (2 m at least) to develop well.

Literature on intercropping alfalfa with pecan is conservative regarding shade, competition for water and nutrients since pecan trees and alfalfa have both deep competing root systems and both prefer deep soil with good drainage. Adequate lands with deep soils in the project area are scarce,

Land preparation

There are several steps to be followed for establishment a new orchard of pecan:

- Site selection:
 - For best rooting and good production, soils should be deep, fertile, and well-drained, with good water holding capacity⁹⁵.
 - Soil acidity: avoid growing alfalfa in acidic soils. Optimal pH for growing alfalfa is between 6.5 and 7. If pH is below this limestone must be added⁹⁶.
- Land cleaning by removing residues of old crops, big stones and land levelling where needed.
- Deep ploughing: the land should be turned over to a depth up to 60 cm by using special mouldboard ploughs. This should be between September and November.
- Land smoothing. It is preferable to undertake this operation when the soil has a good (but not too high) moisture content. This will help in minimizing the dust and in crushing big blocks of soil.
- Orchard design and holes digging: The most common design is the square pattern with a distance between trees not less than 10 m, as root spread of pecan trees can be twice that of the branches and extend into areas beneath the canopy of adjacent trees⁹⁷.
- A diagonal pattern is possible by inserting another tree in the cross centre of each square diagonal which will double the number of trees per dunum. This technique used for early bearing varieties with a condition to remove the additional trees that are cultivated in the centre of diagonal after 16 - 22 years of plantation⁹⁸. In such case distance between rows should not be less than 12 m.
- The plantation holes' can be dug either manually by hand or by auger. The depth and diameter should be larger than the seedling pocket (container)

⁹⁵ Lenny Wells, UGA Extension Horticulturist – Pecans, Establishing of Pecan Orchard, published by the University of Georgia in cooperation with Fort Valley State University, the U.S. Department of Agriculture, and counties of the state. Bulletin 1314, Revised January 2017, page 2

⁹⁶ Doo-Hong Min, Michigan State University Extension - March 31, 2011, planting method for successful alfalfa establishment. https://www.canr.msu.edu/news/planting_methods_for_successful_alfalfa_establishment

⁹⁷ The same previous reference. Page 2

⁹⁸ The same previous reference. Page 3

- It is much better to plant containerized seedlings than bare root seedlings. Plantation of containerized seedlings can be any time in the year. However, it is much better to be in the dormancy stage (in winter).
- After removing the pocket, the pot-bound and twisted roots should be cut with a sharp knife.
- Pecan trees should have around 10 percent pollinator trees within each orchard. It is advisable to have more than one pollinator variety which will help in good constant annual bearing to avoid the alternate bearing phenomenon.
- Recommended cultivars for Palestine are *Delmar*, *Bounty* and *Chico*.
- To protect the seedling trunk from cold damage in the first three years of plantation, it should be painted with white latex paint or insert a growing tube.
- To protect pecan trees intercropped with alfalfa from damage when harvesting alfalfa, it is advisable to leave a buffer zone of 80 cm from each side of the tree. This means the area for alfalfa between two trees will be 8.4 m and the buffer zone along the trees row will be 1.6 m. This will help also in pest management of the pecan tree seedlings.

Pruning

- The best pruning system to be followed for training pecan trees is the central leader pruning system or modified central leader system⁹⁹. This kind of pruning will help in developing a strong, well wind resistant, medium-sized pecan tree.
- In such kind of training, the scaffold limbs should be well-spaced, and widely angled, and emerging in a spiral shape¹⁰⁰.
- For earlier production, it is not advisable to go to heavy pruning of pecan trees as heavy pruning of trees could delay production¹⁰¹.

Fertilization

- Do not add any fertilizer to the hole when transplanting trees.
- The level of P_2O_5 in the soil should not be less than 9 kg/du. The difference after soil tests should be added as a fertilizer.
- The level of K_2O in the soil should not be less than 17 kg/du; the difference after soil test should be added as a fertilizer.
- The level of magnesium should be 11 kg/du; the difference should be added.
- To be noted that pecan is sensitive for salinity, sodium and boron.

Pest and weed control

- Weed competition is the most limiting factor to the growth of young pecan trees. Weeds can rob young trees of soil moisture and nutrients, reducing growth by as much as 50 percent in the first 3 years¹⁰². Research indicates that a 7 x 7-foot area around the tree should be kept free of weeds during the first year of establishment and at least a 10 x 10-

⁹⁹ Richard Heerema, Training young pecan trees, College of Agricultural, Consumer and Environmental Sciences, New Mexico State University. https://aces.nmsu.edu/pubs/_h/H605/welcome.html

¹⁰⁰ The same previous reference

¹⁰¹ The same previous reference.

¹⁰² The same previous reference. Page 9

foot area is required in subsequent years for optimal growth and yield¹⁰³. Therefore, intercropping with weed or legume crops is not advisable.

- Pecan trees and nuts are subject to many fungus, bacterial, and viral diseases, and nematodes. Also, it is subject to deficiency of some minerals.
- The main fungus diseases are: scab which caused by the fungus: *Cladosporium caryigenum* and powdery mildew caused by the fungus *Microsphaera alni*. Scab symptoms appear on the nuts and vegetative part of pecan trees as small, dark, circular, olive to black spots. It is the most serious disease affecting pecan¹⁰⁴. There are tolerant and resistant cultivars to scab. Keep proper ventilation and air circulation and good drainage to get rid of excessive humidity helps a lot in minimizing the opportunity of growing of fungus diseases. Fungicide spraying programme is essential.
- The most common bacterial disease is the Crown Gall which caused by the bacterium *Agrobacterium tumefaciens*. It is a soil borne disease. The pecan seedlings should be bought from a trustful certified nursery. Seedlings should be checked before transplantation in the permanent location.
- Nematodes: Pathogenic root-knot nematodes (*Meloidogyne* spp.) invade small roots of the pecan tree and cause small galls to form on the roots. Pecan roots are also susceptible to infection by a ring nematode (*Criconomella rusium*)¹⁰⁵. For management of nematodes, farmers must follow the same measures followed for crown gall control.
- Minerals deficiency: The most serious mineral deficiency is Zinc deficiency which is known under the name Rosette. Zinc deficiency is common in alkaline soils¹⁰⁶. It can be corrected by adding zinc fertilizers to the soil or by spraying the trees.

Harvesting¹⁰⁷ and yield

- The most optimistic estimate on yield found in literature speaks about 4,000 kg per hectare. Most estimates from the USA, Mexico and South Africa speak about an average of 1,500 – 2,000 kg per hectare. Israeli Palestinian experts estimate the yield level at 280 - 350 kg/du. The potential yield levels indicated in the feasibility study of 2016 (2,000 kg/du) are overestimated by factor 10.
- Pecan trees bear fruits at the age of 8 years. However, commercial bearing will not be before 9 years after planting. Full maturity and maximum harvest will not be before the age of 25 years.
- Harvesting season of pecan nuts is Autumn (between September and November); depends on the cultivar and climate.
- There are several indications of ripeness of pecan nuts. The first indication is the shift in colour of husk from green to brown as it becomes dry. Then start crack to split from the shell. After that the grower will notice that some nuts start falling beneath the tree.

¹⁰³ The same previous reference. page 9

¹⁰⁴ Sharon von Broembsen, Professor Emeritus of Plant Pathology, Oklahoma State University, Oklahoma Cooperative Extension Service, EPP-7642, Pecan diseases: prevention and control. <http://pods.dasnr.okstate.edu/docushare/dsweb/Get/Document-1030/EPP-7642web2013.pdf>

¹⁰⁵ The same previous reference

¹⁰⁶ The same previous reference.

¹⁰⁷ The information regarding harvesting have been taken from: <https://www.wikihow.com/Harvest-Pecans>

- Harvesting pecan nuts usually done naturally by letting the nuts falling beneath the tree. This requires from the growers to prepare the site to be able to visualize the fallen nuts to be able to collect them.
- Preparing the ground beneath the tree could be done by removing the weeds and fallen leaves. Using leaf rake or leaf blower are good practices for preparing for harvesting.
- For collection of the nuts it could be done manually by bending or crawling to collect the nuts or by using simple tools like simple pickers or rolling pickers.
- Before storage, to maintain good quality nuts with good aroma and taste, the nuts must have cured well. The nuts should be dried before they are put in storage. Drying can usually be accomplished by placing the pecans in a shallow layer in a warm, dry area for two weeks. Adding fans and heat can speed drying¹⁰⁸.
- Storage for short time could be in a cool dry place (fridge). Freezing could keep nuts fresh for two years¹⁰⁹.

Irrigation

- Drought stress is a main cause for seedling mortality. So, the new planted seedlings should be irrigated frequently to keep the soil around the seedling as wet as could as possible.
- The IMOP crop water requirement calculations show that one dunum of pecan needs about 1,358 m³ of irrigation water at 100% crop development age with a highest daily peak of 9.5 mm/d.
- Regarding irrigation systems, the Project recommends a surface drip irrigation with pressure-balanced (regulated) drip lines to ensure fair and regular distribution of water over all drippers. Two lines of drip irrigation lines to be installed for each row of trees.
- As the irrigation rotation schedule is different for alfalfa and pecan, two irrigation system should be installed: i) a surface drip irrigation system for pecan, and ii) a subsurface irrigation system for alfalfa.

Areas to be planted

- Based on the estimate given in the feasibility study, the “Draft Institutional and Social Assessment Report, Potential for Reuse Expansion to 2,000 du” report, June 2017, by CDM Smith, proposed pecan nut was as the only tree crop in supplement to the existing olives and a small area of almonds not exceeding 12 du. The proposed land area to be cultivated with pecan as in the above-mentioned report was 600 du. This area was proposed to be intercropped with alfalfa for the first four years to resolve the problem of cash flow. The incorrect estimate of the feasibility study required the Project to investigate other options more favourable than pecan.
- As mentioned in the alfalfa section, the suitable land for alfalfa does not exceed 336 du in S1 and S2 lands (at least 1 m soil depth required and low slopes). It is also not advisable to cultivate pecan as a stand-alone crop. Its capital needs are around 7,500 ILS/du, contrary to 2,500 ILS/du when intercropped with alfalfa; see Chapter 4 on farm economics.

¹⁰⁸ https://www.lsuagcenter.com/portals/our_offices/research_stations/pecan/features/consumer_advice/proper-harvesting-and-storage-of-pecans-improves-quality#:~:text=Pecans%20often%20contain%20excessive%20moisture,and%20heat%20can%20speed%20drying.

¹⁰⁹ <https://www.wikihow.com/Harvest-Pecans>

- Soil pH for pecan cultivation should be within 6.5-7.0 range which is available in the project site.
- Orchard site topography should be level or gently sloping and free of areas that hold water. Surface water should drain quickly from the land after heavy rains. Standing water in the orchard will cause waterlogging, which deprives pecan roots of oxygen
- The water table should remain 6 feet below the soil surface for good pecan growth¹¹⁰.

Economic calculation, cost estimate and labour

- The IMOP estimated that for, mature crops, the annual variable costs of pecan at 2,940 ILS/du and the total benefit at 5,000 ILS/du with assumption that the average yield at maturity age will be 250 kg/du and the farm gate price of pecan nuts will be 20 ILS/kg. Therefore, the Net Benefit will be 2,060 ILS/du. and B/C ratios for pecan as presented in Chapter 4 of this study was 1.7.
- Pecan cultivation will not create many jobs. Estimated annual workdays will not exceed 10-12 d/du.

Marketing and Value chain

Cultivation of pecan and walnut in Palestine is insignificant; there are scattered trees here and there. To our knowledge there is no commercial orchards in Palestine to refer to. Demand in the local market is high and all the supply is imported. Retailer price of shelled pecan to the final consumer could exceed 60-80 ILS/kg and for walnut 36-45 ILS/kg. While retailer price of pecan nut with the shell is around 40-50 ILS/kg. Therefore, pecan production will not struggle with any marketing problem. Also, as nut product, farmers can control supply if they manage to store their product properly. In addition, as the production is rare in Palestine, it has potential to sell it to the final consumer directly for better prices.

The main problem for pecan production is the delayed cash flow. As mentioned earlier, commercial production will not be before 9 years after planting. In this regard, it is not attractive from the economic point of view for farmers to cultivate pecan unless as a hobby. Also, it was approved in this essay that intercropping pecan with alfalfa or any weed crop to enhance cash flow is not recommended either from economic point of view or from technical point of view.

With all constraints and difficulties mentioned in this essay, we are very hesitant to recommend cultivation of pecan and do not recommend any cropping pattern including pecan.

¹¹⁰ Lenny Wells, UGA Extension Horticulturist – Pecans, Establishing of Pecan Orchard, published by the University of Georgia in cooperation with Fort Valley State University, the U.S. Department of Agriculture, and counties of the state. Bulletin 1314, Revised January 2017, page 2

Crop: Existing Olives	
Strengths: 1. Minimal efforts to shift to irrigated olives as the trees already exist 2. Net Benefit¹¹¹ in comparison with non-irrigated (before the project) is very high (Shifts from around 185 to 634 ILS/du) 3. Investment cost is very low (only for irrigation network) 4. Available local knowhow and farmers' willingness	Weaknesses: 1. Net Benefit in comparison with other crops is low (634 ILS/du) 2. Olive trees under full irrigation need more follow up from the farmers especially for keep cutting the stems that grow from the root stock 3. MoA does not prefer shifting to full irrigation 4. Conversion ratio to olive oil will decrease as the water content in the fruits will be high 5. As per some studies, oil quality will be affected under full irrigation 6. Clear positive impact of shifting and peak yield will be clear after 3 - 4 years (When the trees build a completely new root system)
Opportunities: 1. Fully irrigated olive fruits will be suitable for pickles. So, farmers will earn more money if they sell their fruits for pickles rather than for oil 2. Full irrigation will reduce the effect of alternate (biennial) bearing	Threats: 1. MoA could resist shifting to full irrigation 2. Reputation of the oil could be affected as it is irrigated with treated wastewater

Crop: Intercropping olives within half-dense existing olives	
Strengths: 1. Available local knowhow and experience 2. Investment cost is not high 3. Net Benefit¹¹² in comparison with non-irrigated (before the project) is very high (Shifts from 185 to 956 ILS/du)	Weaknesses: 1. The trees will be at different ages and the services for young trees could be different than for old trees within the same orchard
Opportunities: 1. Introducing new varieties good for pickles will improve the marketing and the Net Benefit as the price of 1 kg of olives for pickles is double the price for oil	Threats: 1. MoA could resist shifting to full irrigation 2. Reputation of the oil could be affected as it is irrigated with treated wastewater

¹¹¹ Net Benefit is calculated at full maturity age when the yield at peak. This is of course different from the accumulative benefit average, which takes in consideration the plant performance along the plant lifecycle.

¹¹² Net Benefit is calculated at full maturity age when the yield at peak. This is of course different from the accumulative benefit average, which takes in consideration the plant performance along the plant lifecycle.

Crop: New olives	
Strengths: 1. Introduce new varieties good for pickles which will improve the marketing and the Net Benefit as the price of 1 kg of olives for pickles is much higher than the price for oil 2. The Net Benefit of new olives is expected to be more than double the Net Benefit of the existing olives	Weaknesses: 1. New varieties with intensive farming system require machinery work (harvesting) which is not available yet. 2. New varieties need more care and knowledge than the farmers traditionally have
Opportunities: 1. Success in introducing new varieties could lead to shifting in the crop pattern on the long run 2. Help the MoA in applying strategy to find local alternatives for imported olives from Israel	Threats:

Crop: Alfalfa	
Strengths: 1. Cash flow period is very short (few months) 2. Demand in the Palestinian market is very high 3. Net Benefit is good if irrigated with sprinklers (1,187 ILS/du) 4. Equipment (mower and baler) are already supplied by the project	Weaknesses: 1. Requires very good soils (very deep, no stones, light) which may be limited in the project area. 2. The land tenure system is so complicated and land ownership is fragmented while alfalfa requires land consolidation (the field must be large enough for proper mechanisation) 3. Requires a lot of regular supervision. 4. Limited experience available in the area. Alfalfa requires experienced full-time farmers 5. Restrictions on irrigation methods 6. Market demand is high only for good quality alfalfa balers
Opportunities: 1. Farmers can establish a kind of cooperative for alfalfa producers 2. Livestock husbandry in the area could increase because of the affordable prices of forages 3. Water requirement is quite high, which contributes to achieving the first objective of the project in minimizing the water flow across the borders	Threats: 1. Area infected with Ambrosia, which will domain the crop if spread in the field and it will reduce the quality of the forage 2. Alfalfa is suitable host for dodder, which spreads in the area 3. Sharp depreciation in yield is highly possible. Therefore, risk of making losses is very high

Crop: Figs	
Strengths: 1. Well known tree in the area. Rameen farmers have the experience and the willingness to cultivate figs 2. Land and climate suitability are very good for cultivating figs 3. Cash flow period is short in comparison with other fruit trees. 4. Net Benefit is the third highest among the analysed crops (4,136 ILS/du)	Weaknesses: 1. Only Rameen farmers show interest in cultivation of figs 2. Rameen farmers are interested only in one variety (for table) called Ahmadi
Opportunities: 1. Farmers are now using tap water for irrigating figs within the village which is very expensive in comparison with the price of treated wastewater. So, cost of irrigation will decrease a lot and the farmers can provide their trees with proper amount of irrigation water 2. Suitable for processing (drying and packing)	Threats: 1. Value chain analysis is needed to know the limits on expansion of cultivated land area and the potential negative effects on market prices when the supply is increased

Crop: Almonds	
Strengths: 1. High market demand 2. Storage for long periods 3. Net Benefit is very good (2,212 ILS/du) 4. Available farmers experience in the area 5. Tree adaptability to the project area	Weaknesses: 1. Almond is labour intensive crop and hard to cultivate without machinery 2. Alternate bearing phenomenon 3. Sensitive for many diseases and pests 4. Limited local knowhow and experience
Opportunities:	Threats: 1. Farmers could neglect their orchards if they feel they are not able to control the pests or not able to harvest. In this regard, risk of making losses instead of making profit is expected

Crop: Apricots	
Strengths: 1. Net Benefit is the fourth highest among the analysed crops (3,770 ILS/du). 2. Harvesting season is very short. So, the farmers can intensify their work in a short period.	Weaknesses: 1. Requires good quality soils. 2. Some varieties require high chilling hours which may not be available in all project areas. (need to be investigated before coming to a conclusion) 3. Sabastiya farmers are the only farmers who are interested and have experience in the cultivation of apricots. 4. The local experience of the farmers is limited to one variety only (Local Variety: Mistikawi), which is not good for full irrigation. So, shifting to a new variety may face resistance or unacceptance by farmers. Also, may need kind of value chain analysis. 5. Although, shelf life for other varieties rather than the local variety is longer. But it is still short.
Opportunities: 1. Suitable for processing (Drying and packing)	Threats: 1. Competition with products of other areas could be high and risk of marketing problems are expected

Crop: Grapes	
Strengths: 1. Net Benefit is the first highest among all other analysed crops (11,326 ILS/du) 2. Cash flow period is short in comparison with other fruit trees 3. Diversity of suitable high yield varieties 4. Investment could be attractive for private sector investors as the return is high	Weaknesses: 1. Investment cost is very high, and it could be beyond the capacity of ordinary small farmers 2. Needs full time experienced farmers, while the local experience in the project area is very limited 3. Needs intensive pest management plan 4. Expansion of grapes cultivation in other areas rather than Hebron, Tubas and Jordan valley could be against the strategy of MoA
Opportunities: 1. Market demand for fruits and leaves is high 2. Expansion of grapes cultivation creates job opportunities	Threats: 1. Bad management could lead to high financial losses

Crop: Pecan	
Strengths: 1. Net Benefit is good (2,227 ILS/du) (based on yield of 250 kg/du) 2. Life span is excellent (Peak yield could last for more than 40 years after the full maturity age of 20 years) 3. Shelf life of the produce is very long and storage for long time is easy. 4. Demand in the local market is high 5. The water requirement is quite high which contribute for achieving the first objective of the project in minimizing the water flow cross the borders	Weaknesses: 1. Cash flow is very slow (Positive after 17 years). 2. Accumulative benefit average is low because of long time required to reach full maturity age (366 ILS/du) 3. The commercial production starts at 10 years' age. But the peak production will not be before 20 years' age. 4. Requires good quality deep soil which could be limited in the project area 5. Have alternate bearing phenomenon
Opportunities:	Threats:

Crop: Avocado	
Strengths: 1. Net Benefit is the second highest among the analysed crops (4,427 ILS/du) 2. Shelf life is reasonable and storage for some time is possible.	Weaknesses: 1. Sensitive to frost 2. Knowhow and local experience are limited 3. MoA is against cultivation of avocado under irrigation with treated wastewater. 4. Needs more management than other fruit trees (more harvests per year)
Opportunities: 1. Demand is very high in the local market	Threats: 1. Project area maybe exposed to frost although the meteorological data of the last 10 years did not show that (one 3-day period of -2 °C in Nablus) 2. Export of avocado from other areas (Qalqilya and Tulkarem) is promising - cultivation of avocado under irrigation with treated water could have negative impacts on export (especially to the Gulf)

ANNEX 7

CALCULATION OF EVAPORATION (ET_o) AND EFFECTIVE RAINFALL

Annex 7 Calculation of Evaporation (ET_o) and Effective Rainfall

ET _o -Nablus	ET _o -Wadi Shaeer	E _o -Wadi Shaeer decade	rain (average year)	REFF
mm/d	mm/d	mm/dec.	mm/dec.	mm/dec.
				0.65
1.28	1.37	13.7	60.0	37.2
1.44	1.54	15.4	32.9	20.4
1.64	1.75	17.5	40.3	25.0
2.03	2.17	21.7	38.2	23.5
2.05	2.19	21.9	63.7	39.2
2.41	2.57	25.7	27.5	16.9
2.98	3.16	31.6	16.3	6.2
2.85	3.03	30.3	15.3	5.8
3.49	3.70	37.0	13.9	5.3
4.04	4.27	42.7	11.8	2.7
4.34	4.58	45.8	9.6	2.2
5.00	5.27	52.7	5.6	1.3
5.19	5.46	54.6	2.0	0.0
5.51	5.79	57.9	1.3	0.0
5.76	6.05	60.5	0.3	0.0
6.03	6.32	63.2	0.0	0.0
6.17	6.46	64.6	0.0	0.0
6.26	6.55	65.5	0.0	0.0
6.39	6.69	66.9	0.0	0.0
6.34	6.63	66.3	0.0	0.0
6.27	6.55	65.5	0.0	0.0
5.71	5.97	59.7	0.0	0.0
5.62	5.87	58.7	0.0	0.0
5.22	5.46	54.6	0.0	0.0
4.66	4.88	48.8	0.0	0.0
4.46	4.67	46.7	0.2	0.0
3.93	4.12	41.2	1.1	0.0
3.50	3.67	36.7	2.4	0.5
3.19	3.35	33.5	3.9	0.8
2.64	2.78	27.8	18.4	3.6
2.26	2.39	23.9	20.1	8.2
2.04	2.16	21.6	17.5	7.1
1.77	1.88	18.8	14.1	5.7
1.58	1.68	16.8	44.3	27.7
1.34	1.43	14.3	42.1	26.4
1.32	1.41	14.1	50.7	31.7

ANNEX 8

CALCULATION OF CROP WATER REQUIREMENTS

Annex 8 Calculation of Crop Water Requirements

alfalfa subsurface			alfalfa sprinkler			pecan			olives, oil				olives, pickles			
0.08	(Leaching coeff.)		0.08			0.20			0.12				0.12			
kc	WC decade	WC daily peak	kc	WC decade	WC daily peak	kc	WC	WCpeak	kc	deficit	WC	WCpeak	kc	deficit	WC	WCpeak
0.90	0.0	1.49	0.90	0.0	1.91	0.00	0.0	0.00	0.00	1.00	0.0	0.00	0.00	1.00	0.0	0.00
0.90	0.0	1.67	0.90	0.0	2.15	0.00	0.0	0.00	0.00	1.00	0.0	0.00	0.00	1.00	0.0	0.00
0.90	0.0	1.90	0.90	0.0	2.45	0.00	0.0	0.00	0.00	1.00	0.0	0.00	0.00	1.00	0.0	0.00
0.90	0.0	2.35	0.90	0.0	3.02	0.00	0.0	0.00	0.00	1.00	0.0	0.00	0.00	1.00	0.0	0.00
0.90	0.0	2.37	0.90	0.0	3.05	0.00	0.0	0.00	0.00	1.00	0.0	0.00	0.00	1.00	0.0	0.00
0.90	7.5	2.78	0.90	9.0	3.58	0.00	0.0	0.00	0.00	1.00	0.0	0.00	0.00	1.00	0.0	0.00
0.90	26.8	3.43	0.90	32.1	4.40	0.00	0.0	0.00	0.30	1.00	4.1	1.18	0.30	1.00	4.1	1.18
0.90	25.8	3.28	0.90	31.0	4.22	0.00	0.0	0.00	0.30	1.00	4.1	1.13	0.30	1.00	4.1	1.13
0.90	33.7	4.01	0.90	40.4	5.16	0.00	0.0	0.00	0.30	1.00	7.2	1.38	0.30	1.00	7.2	1.38
0.90	43.1	4.63	0.90	51.7	5.96	0.00	0.0	0.00	0.32	1.00	13.6	1.70	0.32	1.00	13.6	1.70
0.90	47.0	4.97	0.90	56.4	6.39	0.40	21.4	2.44	0.37	1.00	18.3	2.10	0.37	1.00	18.3	2.10
0.90	55.6	5.72	0.90	66.7	7.35	0.40	26.3	2.80	0.40	1.00	24.6	2.61	0.40	1.00	24.6	2.61
0.90	59.2	5.92	0.90	71.1	7.62	0.75	54.4	5.44	0.45	1.00	30.5	3.05	0.45	1.00	30.5	3.05
0.90	62.8	6.28	0.90	75.3	8.07	1.06	81.5	8.15	0.49	0.75	26.4	2.64	0.49	1.00	35.2	3.52
0.90	65.6	6.56	0.90	78.7	8.43	1.07	86.0	8.60	0.54	0.50	20.3	2.03	0.54	1.00	40.5	4.05
0.90	68.6	6.86	0.90	82.3	8.81	1.08	90.7	9.07	0.58	0.50	22.7	2.27	0.58	1.00	45.5	4.55
0.90	70.1	7.01	0.90	84.2	9.02	1.07	91.9	9.19	0.63	0.40	20.2	2.02	0.63	1.00	50.5	5.05
0.90	71.1	7.11	0.90	85.3	9.14	1.07	93.2	9.32	0.67	0.35	19.1	1.91	0.67	1.00	54.4	5.44
0.90	72.5	7.25	0.90	87.0	9.32	1.07	95.1	9.51	0.68	0.35	19.7	1.97	0.68	1.00	56.4	5.64
0.90	71.9	7.19	0.90	86.3	9.25	1.07	94.3	9.43	0.67	0.35	19.3	1.93	0.67	1.00	55.1	5.51
0.90	71.1	7.11	0.90	85.3	9.14	1.07	93.2	9.32	0.67	0.35	19.1	1.91	0.67	1.00	54.5	5.45
0.90	64.7	6.47	0.90	77.7	8.32	1.06	84.1	8.41	0.67	0.35	17.4	1.74	0.67	1.00	49.6	4.96
0.90	63.7	6.37	0.90	76.5	8.19	1.05	82.0	8.20	0.66	0.40	19.2	1.92	0.66	1.00	48.1	4.81
0.90	59.2	5.92	0.90	71.1	7.61	1.04	75.4	7.54	0.65	0.50	22.0	2.20	0.65	1.00	44.0	4.40
0.90	52.9	5.29	0.90	63.5	6.80	1.04	67.4	6.74	0.65	0.50	19.7	1.97	0.65	1.00	39.3	3.93
0.90	50.6	5.06	0.90	60.8	6.51	1.05	65.1	6.51	0.65	0.75	28.2	2.82	0.65	1.00	37.6	3.76
0.90	44.7	4.47	0.90	53.6	5.74	1.04	56.9	5.69	0.65	1.00	33.2	3.32	0.65	1.00	33.2	3.32
0.90	39.3	3.98	0.90	47.1	5.12	0.95	45.7	4.64	0.70	1.00	31.3	3.19	0.70	1.00	31.3	3.19
0.90	35.4	3.63	0.90	42.5	4.67	0.79	34.1	3.51	0.64	1.00	25.6	2.66	0.64	1.00	25.6	2.66
0.90	25.8	3.01	0.90	31.0	3.88	0.64	18.9	2.36	0.64	1.00	17.6	2.21	0.64	1.00	17.6	2.21
0.90	16.1	2.59	0.90	19.3	3.33	0.00	0.0	0.00	0.61	1.00	7.9	1.81	0.61	1.00	7.9	1.81
0.90	14.8	2.34	0.90	17.8	3.01	0.00	0.0	0.00	0.60	1.00	7.2	1.60	0.60	1.00	7.2	1.60
0.90	13.5	2.04	0.90	16.2	2.62	0.00	0.0	0.00	0.60	1.00	6.9	1.40	0.60	1.00	6.9	1.40
0.90	0.0	1.82	0.90	0.0	2.34	0.00	0.0	0.00	0.60	1.00	0.0	1.25	0.60	1.00	0.0	1.25
0.90	0.0	1.55	0.90	0.0	2.00	0.00	0.0	0.00	0.00	1.00	0.0	0.00	0.00	1.00	0.0	0.00
0.90	0.0	1.53	0.90	0.0	1.97	0.00	0.0	0.00	0.00	1.00	0.0	0.00	0.00	1.00	0.0	0.00
maximum (mm/day):		7.25	maximum (mm/day):		9.32	maximum (mm/day):		9.51	maximum (mm/day):		3.32		maximum (mm/day):			5.64
yearly amount (mm):		1,333	yearly amount (mm):		1,600	yearly amount (mm):		1,358	yearly amount (mm):		505		yearly amount (mm):			843

grapes			figs			apricots			almonds			avocado			intercropping pecan & alfalfa		
0.17			0.12			0.23			0.23			0.27					
kc	WC	WCpeak	kc	WC	WCpeak	kc	WC	WCpeak	kc	WC	WCpeak	kc	WC	WCpeak			
0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.49	0.0	0.95		0.00	0.74
0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.49	0.0	1.07		0.00	0.84
0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.49	0.0	1.21		0.00	0.95
0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.49	0.0	1.50		0.00	1.18
0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.54	0.0	1.67		0.00	1.19
0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.62	0.0	2.24		3.73	1.39
0.00	0.0	0.00	0.00	0.0	0.00	0.40	8.8	1.73	0.40	8.8	1.73	0.69	22.0	3.07		13.40	1.71
0.00	0.0	0.00	0.00	0.0	0.00	0.40	8.6	1.66	0.40	8.6	1.66	0.77	24.7	3.29		12.91	1.64
0.00	0.0	0.00	0.00	0.0	0.00	0.43	14.5	2.18	0.44	15.0	2.23	0.80	34.2	4.17		16.85	2.00
0.30	13.2	1.67	0.40	17.8	2.12	0.50	25.6	2.93	0.53	27.3	3.10	0.81	45.0	4.88		21.53	2.32
0.30	15.0	1.79	0.40	20.0	2.27	0.57	32.8	3.58	0.60	34.6	3.76	0.81	49.2	5.23		34.21	3.70
0.36	23.1	2.47	0.43	26.5	2.81	0.64	44.5	4.62	0.68	47.3	4.90	0.81	58.4	6.02		40.96	4.26
0.49	34.9	3.49	0.50	33.9	3.39	0.71	53.2	5.32	0.76	56.8	5.68	0.82	63.2	6.32		56.84	5.68
0.63	47.5	4.75	0.57	40.9	4.09	0.77	61.1	6.11	0.83	65.7	6.57	0.82	66.9	6.69		72.16	7.22
0.76	59.9	5.99	0.65	48.8	4.88	0.84	69.6	6.96	0.87	72.0	7.20	0.82	69.9	6.99		75.78	7.58
0.83	68.4	6.84	0.68	53.3	5.33	0.87	75.4	7.54	0.88	76.1	7.61	0.83	74.0	7.40		79.64	7.96
0.83	69.9	6.99	0.68	54.5	5.45	0.87	77.1	7.71	0.87	77.0	7.70	0.82	74.8	7.48		81.03	8.10
0.83	70.8	7.08	0.68	55.3	5.53	0.88	79.0	7.90	0.87	78.0	7.80	0.82	75.8	7.58		82.11	8.21
0.83	72.3	7.23	0.68	56.4	5.64	0.87	79.7	7.97	0.88	80.5	8.05	0.83	78.3	7.83		83.80	8.38
0.83	71.7	7.17	0.68	55.9	5.59	0.87	79.1	7.91	0.87	78.9	7.89	0.82	76.7	7.67		83.11	8.31
0.83	70.9	7.09	0.68	55.3	5.53	0.87	78.2	7.82	0.87	78.0	7.80	0.82	75.8	7.58		82.16	8.22
0.83	64.5	6.45	0.68	50.3	5.03	0.87	71.2	7.12	0.87	71.0	7.10	0.82	69.0	6.90		74.40	7.44
0.82	62.8	6.28	0.68	49.6	4.96	0.86	69.3	6.93	0.86	69.1	6.91	0.81	67.1	6.71		72.84	7.28
0.82	58.3	5.83	0.68	46.0	4.60	0.85	63.6	6.36	0.85	63.5	6.35	0.80	61.6	6.16		67.33	6.73
0.81	51.5	5.15	0.68	41.1	4.11	0.80	53.5	5.35	0.85	56.7	5.67	0.80	55.0	5.50		60.14	6.01
0.82	49.9	4.99	0.68	39.4	3.94	0.73	46.7	4.67	0.85	54.3	5.43	0.80	52.7	5.27		57.89	5.79
0.82	44.0	4.40	0.68	34.7	3.47	0.65	36.7	3.67	0.85	47.9	4.79	0.80	46.5	4.65		50.80	5.08
0.75	35.3	3.59	0.66	29.5	3.01	0.00	0.0	0.00	0.74	36.5	3.72	0.79	40.2	4.09		42.50	4.31
0.64	26.9	2.79	0.61	24.4	2.53	0.00	0.0	0.00	0.67	29.7	3.07	0.79	36.2	3.73		34.77	3.57
0.53	14.5	1.92	0.56	14.9	1.93	0.00	0.0	0.00	0.59	17.5	2.24	0.76	24.7	2.98		22.36	2.69
0.40	1.8	1.24	0.52	5.3	1.54	0.00	0.0	0.00	0.00	0.0	0.00	0.75	13.7	2.52		8.03	1.29
0.00	0.0	0.00	0.47	3.7	1.26	0.00	0.0	0.00	0.00	0.0	0.00	0.73	12.2	2.22		7.40	1.17
0.00	0.0	0.00	0.43	2.9	1.00	0.00	0.0	0.00	0.00	0.0	0.00	0.71	10.7	1.88		6.73	1.02
0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.69	0.0	1.63		0.00	0.91
0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.66	0.0	1.33		0.00	0.78
0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.63	0.0	1.25		0.00	0.76
maximum (mm/day):		7.23	maximum (mm/day):		5.64	maximum (mm/day):		7.97	maximum (mm/day):		8.05	maximum (mm/day):		7.83	maximum (mm/day):		8.38
yearly amount (mm):		1,027	yearly amount (mm):		861	yearly amount (mm):		1,128	yearly amount (mm):		1,251	yearly amount (mm):		1,379	yearly amount (mm):		1,345

year	available WW	crop development factor									procentual area planted and irrigated								
		alfalfa	olives			almonds	figs	apricots	grapes	intercrop	alfalfa	olives			almonds	figs	apricots	grapes	intercrop
		SSI	existing	scattered	new						SSI	existing	scattered	new					
2019		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2020	12,250	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2021	12,475	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2022	12,708	100.0%	100.0%	60.0%	20.0%	40.0%	40.0%	40.0%	25.0%	60.0%	100%	80.0%	80.0%	80.0%	80.0%	80.0%	80.0%	80.0%	100.0%
2023	12,950	100.0%	100.0%	61.5%	23.0%	50.0%	60.0%	50.0%	50.0%	65.0%	100%	81.0%	81.0%	81.0%	81.0%	81.0%	81.0%	81.0%	100.0%
2024	13,200	100.0%	100.0%	63.0%	26.0%	60.0%	80.0%	60.0%	75.0%	70.0%	100%	82.0%	82.0%	82.0%	82.0%	82.0%	82.0%	82.0%	100.0%
2025	13,458	100.0%	100.0%	64.5%	29.0%	70.0%	90.0%	70.0%	100.0%	75.0%	100%	83.0%	83.0%	83.0%	83.0%	83.0%	83.0%	83.0%	100.0%
2026	13,826	100.0%	100.0%	66.0%	32.0%	80.0%	100.0%	80.0%	100.0%	80.0%	100%	84.0%	84.0%	84.0%	84.0%	84.0%	84.0%	84.0%	100.0%
2027	14,203	100.0%	100.0%	67.5%	35.0%	90.0%	100.0%	90.0%	100.0%	45.0%	100%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	100.0%
2028	14,589	100.0%	100.0%	69.0%	38.0%	100.0%	100.0%	100.0%	100.0%	55.0%	100%	86.0%	86.0%	86.0%	86.0%	86.0%	86.0%	86.0%	100.0%
2029	14,985	100.0%	100.0%	70.5%	41.0%	100.0%	100.0%	100.0%	100.0%	65.0%	100%	87.0%	87.0%	87.0%	87.0%	87.0%	87.0%	87.0%	100.0%
2030	15,391	100.0%	100.0%	72.0%	44.0%	100.0%	100.0%	100.0%	100.0%	75.0%	100%	88.0%	88.0%	88.0%	88.0%	88.0%	88.0%	88.0%	100.0%
2031	15,807	100.0%	100.0%	73.5%	47.0%	100.0%	100.0%	100.0%	100.0%	80.0%	100%	89.0%	89.0%	89.0%	89.0%	89.0%	89.0%	89.0%	100.0%
2032	16,234	100.0%	100.0%	75.0%	50.0%	100.0%	100.0%	100.0%	100.0%	85.0%	100%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	100.0%
2033	16,671	100.0%	100.0%	76.5%	53.0%	100.0%	100.0%	100.0%	100.0%	90.0%	100%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	100.0%
2034	17,119	100.0%	100.0%	78.0%	56.0%	100.0%	100.0%	100.0%	100.0%	95.0%	100%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	100.0%
2035	17,578	100.0%	100.0%	79.5%	59.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	100.0%
2036	18,049	100.0%	100.0%	81.0%	62.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	100.0%
2037	18,531	100.0%	100.0%	82.5%	65.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	100.0%
2038	19,026	100.0%	100.0%	84.0%	68.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	100.0%
2039	19,532	100.0%	100.0%	85.5%	71.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	100.0%
2040	20,052	100.0%	100.0%	87.0%	74.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	100.0%
2041	20,585	100.0%	100.0%	88.5%	77.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	100.0%
2042	21,130	100.0%	100.0%	90.0%	80.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	100.0%
2043	21,690	100.0%	100.0%	91.5%	83.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	100.0%
2044	22,263	100.0%	100.0%	93.0%	86.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	100.0%
2045	22,851	100.0%	100.0%	94.5%	89.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	100.0%
2046	23,454	100.0%	100.0%	96.0%	92.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	100.0%
2047	24,071	100.0%	100.0%	97.5%	95.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	100.0%
2048	24,704	100.0%	100.0%	99.0%	98.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	100.0%
2049	25,353	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	100.0%
2050	26,018	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	100.0%
2051	26,700	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	100.0%

ANNEX 9

DATA SOURCES

Annex 9 Data Sources

Alfalfa

1. Interview with Eng. Majdi Abu Naim, Head of Marj Ibin Amer Cooperative in Jenin
2. UGA Extension, Clover Management in Pecan Orchards, Lenny Wells, Department of Horticulture
3. Field visit to alfalfa field in the outside scheme and the WWTP
4. Field visit to the alfalfa fields in Jenin
5. Interviews with Mr. Sameer Junaidi/ The contractor of the outside scheme and Eng. Hamza Ghazal the Agricultural supervisor of the project from the contractor side.
6. NETAFIM website, irrigation guidelines. <https://www.netafim.com/en/>

Almonds

1. Interview with Mr. Eyad Mash'al/ Head of Merimis Company for Technology and Development
2. Interview with Eng. Odeh Sabarneh/ Head of Horticulture Department
<https://www.facebook.com/merimisps>
3. نشرة اللوز والتغير المناخي، مسودة نشرة إرشادية لزراعة اللوز، مقدمة من المهندس عودة صبارنة
4. Irrigated Almond Cultivation Manual 2018, Palestine, As part of "Enhancing profits of small scale farmers through better market connections", AMENCA 3 program in partnership between Union Aid Abroad-APHEDA and MA'AN Development Center, Bethlehem University Institute for Community Partnership and Palestinian Businesswomen's Association-Asala.
5. NETAFIM website, irrigation guidelines. <https://www.netafim.com/en/>

Apricots

1. National yield statistics of Turkey
2. National yield statistics of France
3. <https://www.africanfarming.com/fresh-production-basic-guidelines-apricot-production/>
4. <http://userspecial.com/apricot-fruit-farming/>
5. Danida and Oxfam, Integrated Market Development Programme Across the Occupied Palestinian Territory, Stone Fruits Value Chain Analysis Report, August 2018
6. شجرة المشمش، إعداد الإدارة العامة للإرشاد والتنمية الريفية، دائرة البستنة الشجرية، مهندس عودة صبارنة ومهندس خلدون غضيان
7. Interview with Eng. Odeh Sabarneh/ Head of horticulture Department/ MoA

Avocado

1. <http://www.israelagri.com/?CategoryID=453&ArticleID=978>
2. <https://www.israel21c.org/europe-to-israel-more-avocado-please/>
3. زراعة الأفوجادو، إعداد المهندس الزراعي صبحي عيد والمهندس الزراعي محمد فطائر
4. Meeting with Apricots farmers from Sabastiya
5. Field visit to apricot farms in the Wadi Shaeer Area
6. NETAFIM website, irrigation guidelines. <https://www.netafim.com/en/>

Figs:

1. Interviews with fig farmers from Rameen
2. Field visit to fig farms in Rameen
3. Field visit with Rameen Farmers to Wadi Shaeer Area
4. NETAFIM website, irrigation guidelines. <https://www.netafim.com/en/>

Grapes:

1. دليل زراعة العنب 2019، A manual for Table Grapes Cultivation 2019, Australian Aid, PARC and Oxfam
2. Interview with Eng. Majdi Abu Naim, Head of Marj Ibin Amer Cooperative in Jenin and Mr. Eyad Misha'al Head of Meramis Company
3. Interview with Eng. Odeh Sabarneh/ Head of horticulture Department/ MoA
4. NETAFIM website, irrigation guidelines. <https://www.netafim.com/en/>

Olives

1. Interviews with Wadi Shaeer farmers
2. Interview with Dr. Usama Odeh/ Olive Expert and owner of olive oil press and olive oil marketing company
3. Interview with MoA head of Olive Department, Eng. Rames Obaid
4. National yield statistics of Spain
5. كتيب إرشاد مقدم من فرع الزيتون، وزارة الزراعة الإسرائيلية، إعداد المهندس مغيرة بديع يونس، مكتب الإرشاد الزراعي قسم الأشجار
6. <https://en.excelentesprecios.com/picual-olive-tree>
7. <https://www.groworganic.com/olive-picual-std-tr.html>
8. https://en.wikipedia.org/wiki/Manzanilla_olive
9. <https://www.moonvalleynurseries.com/trees/manzanillo-olive>
10. <https://onegreenworld.com/product/manzanillo-olive/>
11. Interview with Mr. Yasser/ owner of Yasser Nursery in Jenin in the presence of Engineers Baha' Khader and Bara' Al Ghoul from MoA
12. NETAFIM website, irrigation guidelines. <https://www.netafim.com/en/>

Pecan

1. Oklahoma Cooperative Extension Services, HLA-6247, Establishing of Pecan Orchard, Becky Carroll, senior agriculturist and Michael W. Smith research horticulturist.
2. Oklahoma Cooperative Extension Service, OSU Extension Fact Sheet, Fertilizing Pecan and Fruit Trees, February 2017
3. UGA Extension, Clover Management in Pecan Orchards, Lenny Wells, Department of Horticulture
4. UGA Cooperative Extension Bulletin 1314, Establishing a Pecan Orchard, Lenny Wells
5. A Double Row system for Establishing Pecans, William Reid, Pecan Experiment Field, Kansas State University, Chetopa, KS 67336. <http://www.centerforagroforestry.org/pubs/pecansdouble.pdf>

ANNEX 10

ECONOMIC BASE DATA ON POTENTIAL CROPS

Annex 10 Economic Base Data on Potential Crops

	Olive dense, existing	Olive new pickles	Olive scattered, gaps filled	Apricots	Almonds	Figs	Grapes	Pecan	Alfalfa SSI	Inter-cropping
Yields										
estimated yield fruits [kg/du]*	700	900	700	800	225	1,200	3,000	250	160	0
estimated yield alfalfa [bales/du]									160	
estimated yield grape leaves[kg/du]*							300			
farm gate price fruits [ILS/kg]	5.33	6.50	5.33	10.00	25.00	7.00	6.00	20.00		20.00
farm gate price alfalfa bales [ILS/kg]									24.00	24.00
farm gate price grape leaves [ILS/kg]							15.00			
Product yields [ILS/du]	3,731	5,850	3,731	8,000	5,625	8,400	22,500	5,000	3,840	1,920
Estimated future area [du]	889	318	288	322	225	322	277	0	0	0
Planting										
seeds, ILS/kg or per seedling	0	30	70	40	40	15	15	100	70	
Seedlings, number /Dunum	0	40	15	30	30	18	150	10		
seeds, kg/dunum									5	
seed/plant cost (grapes ILS 10 per hole)	0	1,200	1,050	1,200	1,200	270	2,400	1,000	350	1,263
Grape poles +wiring							9,940			
planting/seeding [ILS/du]		600	250	200	400	300	3,200	200	7	105
Planting cost ILS/dunum	0	1,800	1,300	1,400	1,600	570	15,540	1,200	357	1,368
Replacement period [years]	50	20	50	30	30	20	15	50	5	50
Linear annual depreciation [ILS/du]	0.0	90.0	26.0	46.7	53.3	28.5	1,036.0	24.0	71.4	27.4
Irrigation system										
Connection pipe ILS/dunum	25	25	25	25	25	25	25	25	25	25
Drippers ILS/Dunum	400	400	400	400	400	400	1,200	200	2,350	1,963
Labor for installation ILS/dunum	100	100	100	100	100	100	150	100	800	700
Investment cost on field irrigation	525	525	525	525	525	525	1,375	325	3,175	2,663
Replacement period years	5	5	5	5	5	5	5	5	5	10
Linear annual depreciation	105	105	105	105	105	105	275	65	635	266
Farm head works	616	616	616	616	616	616	616	616	616	616
Replacement period years	15	15	15	15	15	15	15	15	15	15
Linear annual depreciation	41	41	41	41	41	41	41	41	41	41
Total linear annual depreciation	146	146	146	146	146	146	316	106	676	307
Irrigation m3/season/dunum	505	843	505	1,128	1,251	861	1,027	1,340	1,333	1,345
Irrigation water cost/dunum	505	843	505	1,128	1,251	861	1,027	1,340	1,333	1,345
fertilizer, ILS/dunum	30	50	30	50	50	50	450	50		
pesticides/herbicides [ILS/du]	45	250	45	300	300	300	500	200	77	139
Agrochemical cost [ILS/du]	75	300	75	350	350	350	950	250	77	164
plowing, harrowing, cleaning h/dunum	3	4	3	3	3	3	8	3	0	2
Soil preparation cost/dunum	225	360	225	270	270	270	675	270	0	135
Harvest machines, hours/dunum									7	5
Machinery cost harvest/dunum									490	368
Labour costs										
man lab weed terraces h/dunum	6	12	6	6	6	6	6	6		3
manual labour hours/dunum	12	18	12	42	42	42	240	4	24	14
manual harvest hours/dunum	86	110	86	120	50	135	300	50		25
Manual work, cost/dunum	1,294	1,750	1,294	2,100	1,225	2,288	6,825	750	300	525
Oil pressing cost	311		311							
other cost [ILS/du]		90		300	300	300	500	200		
* final yield when fully established										
Total cost [ILS/du]*	2,557	3,579	2,583	4,341	3,595	4,243	11,329	2,940	2,948	2,940
Total benefit [ILS/du]	3,731	5,850	3,731	8,000	5,625	8,400	22,500	5,000	3,840	5,000
Net Benefit [ILS/du]	1,174	2,271	1,148	3,659	2,030	4,157	11,171	2,060	892	2,060
benefit/cost ratio against uncultivated	1.46	1.63	1.44	1.84	1.56	1.98	1.99	1.70	1.30	1.70
labour-based benefit/cost ratio	1.98	2.05	2.00	2.07	2.93	1.85	1.66	3.92	9.83	5.60
benefit/cost ratio against wheat/barley		1.72		1.95	1.64	2.11	2.03	1.83	1.34	1.83
benefit/cost ration against olive traditional	1.70		1.67							
* including depreciation										
All valus are undiscounted										
All monetary values are in ILS										
General unit cost										
Machinery cost harvest, ILS/hour**		70								
Machinery cost soil preparation, ILS/hour**		90								
Manual labour ILS/hour (ILS 100 for 8 hour day)		12.5								
Water price per m3 ILS		1.00								
**including machinery driver										

ANNEX 11

LIST OF PLOTS TO BE CLUSTERED

Annex 11 List of plots to be clustered

Village	Block number	Total area after merging	Merging proposal	Village	Block number	Total area after merging	Merging proposal
Sabastia	4	6.56	1+2	Deir Sharaf	12	10.44	33+34+35
Sabastia	4	9.22	3+4+7	Deir Sharaf	12	7.03	36+37
Sabastia	4	3.29	12	Deir Sharaf	12	6.79	38+39
Sabastia	4	8.47	15+16+17	Deir Sharaf	12	5.37	40+41
Sabastia	4	7.11	18+19	Deir Sharaf	12	4.76	no merging
Sabastia	4	6.12	21+22+23	Deir Sharaf	12	6.21	43+44
Sabastia	4	14.53	4/26+4/27+21/20+21/21	Deir Sharaf	12	5.99	45+46
Rameen	8	2.15	14	Deir Sharaf	12	6.42	47+48
Rameen	8	8.67	16+17	Deir Sharaf	12	4.1	no merging
Rameen	8	2.64	no merging	Deir Sharaf	12	7.89	51+52+53
Rameen	8	2.98	71+72	Deir Sharaf	12	4.68	no merging
Rameen	8	2.64	77+78	Deir Sharaf	12	7	57+58
Rameen	9	1.99	no merging	Deir Sharaf	14	3.33	no merging
Rameen	9	8.34	8+9+12	Deir Sharaf	14	2.37	no merging
Rameen	9	6.37	17+18	Deir Sharaf	14	6.95	10+11
Rameen	9	3.69	20+21	Deir Sharaf	14	8.76	13+14
Rameen	9	10.66	9/25+9/26+22/82+22/83	Deir Sharaf	14	2.41	no merging
Rameen	9	5.1	37+38+39	Deir Sharaf	14	3.58	no merging
Rameen	9	6.46	40+41	Deir Sharaf	16	6.15	1+2
Rameen	9	2.92	no merging	Deir Sharaf	16	4.43	4+5
Rameen	9	6.17	44+45	Deir Sharaf	16	2.68	no merging
Rameen	9	3.68	no merging	Deir Sharaf	16	14.16	no merging
Rameen	9	2.94	no merging	Burqa	18	3.84	no merging
Rameen	9	4.4	no merging	Burqa	18	3.91	no merging
Rameen	9	10.8	59+62+68	Burqa	19	2.77	no merging
Rameen	9	3.58	no merging	Burqa	21	13.12	4/26+4/27+21/20+21/21
Rameen	9	2.69	59+62+68	Burqa	21	6.47	23+24
Rameen	9	6.28	76+77+78+79	Burqa	21	6.74	25+26
Rameen	9	7.86	80+81+82	Burqa	21	9.23	27+28+29
Rameen	9	5.43	83+84+85+86	Burqa	21	2.32	no merging
Rameen	9	10.02	87+88+101	Burqa	21	2.47	no merging
Rameen	9	6.06	89+90	Burqa	21	3.66	no merging
Rameen	9	2.8	no merging	Burqa	21	4.12	no merging
Rameen	9	5.11	93+94	Burqa	21	8.7	49+50
Rameen	9	4.64	96+97	Burqa	21	3.79	no merging
Rameen	9	3.4	no merging	Burqa	21	3.72	no merging
Deir Sharaf	10	6.59	89+90+91+92+93+94	Burqa	21	9.65	no merging
Deir Sharaf	10	11.85	95+96+97+119	Burqa	21	2.67	no merging
Rameen	11	3.97	8+9+12+14	Burqa	21	8.31	68+69+70
Rameen	11	4.58	15+16+17+18+21+22	Burqa	21	2.04	no merging
Rameen	11	5.24	23+24+25+26	Burqa	22	5.86	6+7
Rameen	11	6.68	28+29+30+38+39+40+41	Burqa	22	4.82	no merging
Rameen	11	6.63	31+32+34+37	Burqa	22	5.81	10+11
Deir Sharaf	12	7.96	3+4	Burqa	22	5.32	12+13+14
Deir Sharaf	12	8.83	6+7	Burqa	22	11.34	15+16+17+18+20
Deir Sharaf	12	4.57	no merging	Burqa	22	9.71	25+26+27+28+29
Deir Sharaf	12	4.97	15+16	Burqa	22	13.99	31+32+33+34
Deir Sharaf	12	6.39	20+21	Burqa	22	4.68	no merging
Deir Sharaf	12	9.28	22+23+24	Burqa	22	6.25	45+46
Deir Sharaf	12	5.44	26+27	Burqa	22	7.23	48+49
Deir Sharaf	12	7.08	28+29	Burqa	22	8.05	54+55+56+57+58
Deir Sharaf	12	8.15	31+32	Burqa	22	3.62	62+63

ANNEX 12

**MAXIMUM DAILY WATER USE COMPARED WITH
AVAILABILITY OF TREATED WASTEWATER OVER THE PERIOD
2022-2051**

Annex 12 Maximum daily water use compared with availability of treated wastewater over the period 2022-2051

year	outlet flow WWTP	used for pilots	available for irrigation area	scenario 1	scenario 2	scenario 3	scenario 4	scenario 5	scenario 6	scenario 7	scenario 8	scenario 9	scenario 10	scenario 11	scenario 12
	[m3/d]	[m3/d]	[m3/d]	[m3/d]	[m3/d]	[m3/d]	[m3/d]	[m3/d]	[m3/d]	[m3/d]	[m3/d]	[m3/d]	[m3/d]	[m3/d]	[m3/d]
2019	13,000	750	12,250												
2020	13,325	850	12,475												
2021	13,658	950	12,708												
2022	14,000	1,050	12,950	4,519	6,231	5,475	5,555	4,857	6,631	5,861	5,955	5,328	7,161	6,364	6,486
2023	14,350	1,150	13,200	5,425	6,903	6,255	6,585	6,062	7,567	6,920	7,250	6,775	8,286	7,639	7,969
2024	14,708	1,250	13,458	6,427	7,590	7,093	7,639	7,362	8,526	8,029	8,575	8,273	9,437	8,940	9,486
2025	15,076	1,250	13,826	7,340	8,189	7,842	8,573	8,532	9,383	9,036	9,764	9,634	10,485	10,138	10,866
2026	15,453	1,250	14,203	7,993	8,658	8,462	9,245	9,264	9,931	9,734	10,517	10,473	11,140	10,943	11,725
2027	15,839	1,250	14,589	8,511	9,031	7,783	9,784	9,843	10,364	9,116	11,115	11,153	11,675	10,427	12,426
2028	16,235	1,250	14,985	9,039	9,411	8,463	10,332	10,432	10,805	9,857	11,724	11,847	12,221	11,273	13,139
2029	16,641	1,250	15,391	9,214	9,560	8,912	10,526	10,612	10,960	10,313	11,925	12,082	12,429	11,782	13,394
2030	17,057	1,250	15,807	9,389	9,709	9,362	10,722	10,795	11,117	10,770	12,128	12,318	12,640	12,293	13,651
2031	17,484	1,250	16,234	9,567	9,861	9,664	10,920	10,979	11,274	11,078	12,332	12,557	12,853	12,656	13,911
2032	17,921	1,250	16,671	9,746	10,014	9,967	11,120	11,164	11,434	11,387	12,538	12,798	13,068	13,022	14,172
2033	18,369	1,250	17,119	9,817	10,085	10,189	11,196	11,225	11,495	11,599	12,605	12,898	13,168	13,272	14,278
2034	18,828	1,250	17,578	9,888	10,157	10,411	11,273	11,287	11,557	11,811	12,672	12,998	13,268	13,523	14,383
2035	19,299	1,250	18,049	9,960	10,228	10,632	11,350	11,349	11,619	12,023	12,739	13,099	13,368	13,773	14,489
2036	19,781	1,250	18,531	10,031	10,300	10,704	11,427	11,410	11,680	12,085	12,806	13,199	13,469	13,873	14,594
2037	20,276	1,250	19,026	10,103	10,371	10,775	11,504	11,472	11,742	12,146	12,873	13,299	13,569	13,973	14,700
2038	20,782	1,250	19,532	10,174	10,442	10,847	11,580	11,534	11,804	12,208	12,940	13,399	13,669	14,073	14,805
2039	21,302	1,250	20,052	10,246	10,514	10,918	11,657	11,596	11,865	12,270	13,007	13,499	13,769	14,173	14,910
2040	21,835	1,250	20,585	10,317	10,585	10,990	11,734	11,657	11,927	12,332	13,074	13,599	13,869	14,273	15,016
2041	22,380	1,250	21,130	10,388	10,657	11,061	11,811	11,719	11,989	12,393	13,141	13,699	13,969	14,373	15,121
2042	22,940	1,250	21,690	10,460	10,728	11,132	11,887	11,781	12,051	12,455	13,208	13,799	14,069	14,473	15,227
2043	23,513	1,250	22,263	10,531	10,799	11,204	11,964	11,842	12,112	12,517	13,275	13,899	14,169	14,573	15,332
2044	24,101	1,250	22,851	10,603	10,871	11,275	12,041	11,904	12,174	12,578	13,343	13,999	14,269	14,673	15,438
2045	24,704	1,250	23,454	10,674	10,942	11,347	12,118	11,966	12,236	12,640	13,410	14,099	14,369	14,774	15,543
2046	25,321	1,250	24,071	10,745	11,014	11,418	12,195	12,028	12,297	12,702	13,477	14,199	14,469	14,874	15,649
2047	25,954	1,250	24,704	10,817	11,085	11,490	12,271	12,089	12,359	12,763	13,544	14,299	14,569	14,974	15,754
2048	26,603	1,250	25,353	10,888	11,157	11,561	12,348	12,151	12,421	12,825	13,611	14,399	14,669	15,074	15,859
2049	27,268	1,250	26,018	10,936	11,204	11,609	12,399	12,192	12,462	12,866	13,656	14,466	14,736	15,140	15,930
2050	27,950	1,250	26,700	10,936	11,204	11,609	12,399	12,192	12,462	12,866	13,656	14,466	14,736	15,140	15,930
2051	28,649	1,250	27,399	10,936	11,204	11,609	12,399	12,192	12,462	12,866	13,656	14,466	14,736	15,140	15,930