A field of cacti (ICARDA)

Cactus Fruit Plantation in Arid Dry Lands (Jordan)

DESCRIPTION

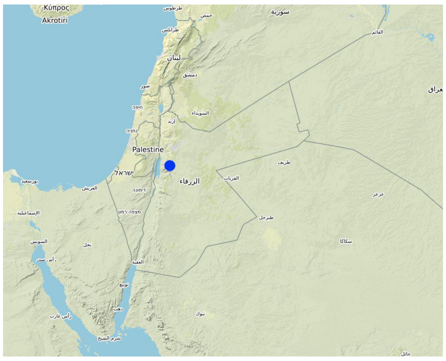
This technology is based on the natural advantages and the multi-purpose usage of spineless cactus pear (Opuntia fiscus-indica), to cultivate marginal lands in Jordan, generating environmental and socio-economic benefits.

In the arid parts of Jordan with limited rainfall, little irrigation, high water evaporation, poor soil quality and unsustainable land management result in land degradation (erosion and salinization) and productivity loss. Therefore, the International Center Agricultural Research in the Dry Areas (ICARDA) and National Agricultural Research Centre of Jordan (NARC) organized field days (started in 2014) to disseminate knowledge regarding the cultivation of the cactus pear, Opuntia ficus-indica, cactus crop. Cacti can cope with high temperatures and grow well in (semi)-arid areas with 250-600mm annual rainfall or where irrigation is available. Additionally, the plant is very resilient as it can withstand a long dry season due to its high water-content and water-use -efficiency, which are a result of its morphology (waxy cuticle, no actual leaves) and the Crassulacean Acid Metabolism (CAM). In CAM plant, stomata in the leaves remain shut during the day to reduce evapotranspiration, but open at night to collect and fix carbon dioxide (CO2). In general, cacti have multiple products that benefit local livelihoods, these are for example stable production of fodder for livestock and fruits for human consumption. Also, cactus can grow and produce requiring few inputs such as fertilizers, therefore marginal lands are well suited for cactus cultivation.

The market for cactus fruits is very promising in Jordan. Nowadays, there is high demand for cactus fruits as people grow fond of the fruits but also for medicinal uses. This documentation is focused on a farm covering roughly 10 hectares, where cactus was planted due to its socio-economic and environmental advantages i.e. the high prices for cactus fruits and the ability of cactus to grow in marginal lands with little input and cover the soil hence preventing soil erosion. However, the farm is not located ideally for cactus cultivation. Therefore, the farm is currently intensively managed in terms of fertilizer application and the irrigation. The previous land use was poor cultivation of barley to feed (grazing) sheep and goats. This led to little soil cover resulting in land degradation in the form of erosion. The farmer paid for the establishment of the cactus-plantation. The cacti are spaced by 4 meters between plants and 3 meters between rows. This spacing is specific for fruit production, in case of fodder production a higher crop density is recommended. The cacti are planted on the contours in pits (40 centimetres depth and diameter) to ensure rain-water collection and efficient fertilizer application as the farm is situated on a 15% slope. The cacti reduce erosion as the roots hold the soil together. Field preparation for the establishment of the cactus field includes: (1) soil scrapping; (2) deep soil ploughing; (3) surface soil ploughing; and (4) pit digging. No fertilizer was applied in the establishment stage. Recurrent activities and costs are weeding, applying fertilizer and organic manure, maintaining the pits and harvesting. 200 kilograms per hectare of inorganic fertilizer (NPK) is applied between March and May. A total of 4 tons per hectare of organic manure is applied in September-November. These activities are non-mechanized, and therefore labour intensive.

The farm receives less than 200mm of annual rainfall and a public dam for irrigation is available. Therefore, the farmer invests in three water tanks to store water brought from the dam using his own truck, and in a drip irrigation system for high irrigation efficiency. The farm is irrigated by 360 cubic meter per month, divided in three events. The costs per

LOCATION



Location: Jordan

No. of Technology sites analysed: single site

Geo-reference of selected sites
- 35.80333, 31.60028
- 35.80148, 31.59935

Spread of the Technology: evenly spread over an area (0.09 km²)

In a permanently protected area?: No

Date of implementation: 2014

Type of introduction
- ☐ through land users' innovation
- ☐ as part of a traditional system (> 50 years)
- ☑ during experiments/ research
- ☑ through projects/ external interventions

cubic meter is 0.95 Jordanian Dinar (JOD) (including transportation costs). Before the realization of the drip irrigation system, the cacti were watered by hand (19991-2015). During the initial three years, cacti produce no fruits making the short-term return on investment rather negative. Currently, the cactus-plantation produces 32.5 ton/ha, equivalent to 65 kg /plant. The average net income per hectare varies between 1650 JOD to 2750 JOD. This makes the farmer relatively medium- wealthy with respect to the area. Most costs are induced by labour as the farmer uses manual weeding, harvesting and fertilizer application.

Even though the cultivation of cacti for its fruits on marginal lands has many benefits like the reduction in erosion, stable production, high output/input efficiency and good prices. There are some weaknesses, for example the relative young market of cactus products in Jordan compared to Tunisia. The Tunisian market for cactus products has a longer history, a high demand for other cactus-products like oil and juice and a better infrastructure (e.g. processing units) exist. These create more consistent prices for farmers, so less price drops during harvesting periods. Another weak point is the fact that cacti are cultivated in mono-culture. This significantly increases the risk of new pests and potential damage of the cultivated crop.

To conclude, this documentation shows that even though the selected farm does not represent an ideal site for cactus pear cultivation, the implementation of cacti is socio-economically and environmentally appropriate to cultivate dry marginal lands as cacti uses water and nutrients highly efficient while reducing land degradation. Therefore, the out-scaling of cacti is very valuable and a practical option to fight land degradation and enhance smallholder's income.

Aerial footage of the documented farm/cactus-plantation. Yellow border delineates the documented farm (10 ha) (Sawsan Hassan (Extracted from google earth 2020))

The flower of the Opuntia fiscus-indica cactus, Muchaqqer station, Jordan (Mounir Louhaichi, Sawsan Hassan (21/2/2019).)

CLASSIFICATION OF THE TECHNOLOGY

Main purpose

- ✓ improve production
- ✓ reduce, prevent, restore land degradation
- conserve ecosystem
- protect a watershed/ downstream areas – in combination with other Technologies
- preserve/ improve biodiversity
- reduce risk of disasters
- ✓ adapt to climate change/ extremes and its impacts
- mitigate climate change and its impacts
- ✓ create beneficial economic impact
- ✓ create beneficial social impact

Land use

Land use mixed within the same land unit: No

Cropland

- Tree and shrub cropping: cactus, cactus-like (e.g. opuntia)

Is intercropping practiced? No
Is crop rotation practiced? No

Water supply

- rainfed
- mixed rainfed-irrigated
- ✓ full irrigation

Purpose related to land degradation

- ✓ prevent land degradation
- ✓ reduce land degradation
- restore/ rehabilitate severely degraded land
- adapt to land degradation
- not applicable

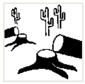
Degradation addressed

soil erosion by water - Wt: loss of topsoil/ surface erosion

soil erosion by wind - Et: loss of topsoil

chemical soil deterioration - Cs: salinization/ alkalinization

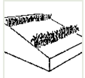
physical soil deterioration - Pk: slaking and crusting



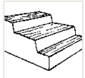
biological degradation - Bc: reduction of vegetation cover, Bq: quantity/ biomass decline

SLM group
- improved ground/ vegetation cover
- irrigation management (incl. water supply, drainage)

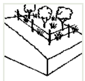
SLM measures



vegetative measures - V1: Tree and shrub cover



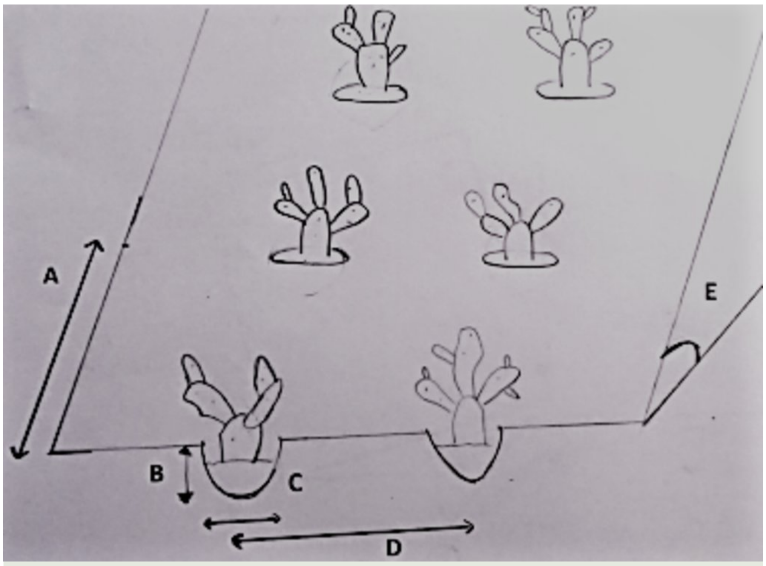
structural measures - S7: Water harvesting/ supply/ irrigation equipment



management measures - M1: Change of land use type

TECHNICAL DRAWING

Technical specifications
The rows are placed 3 meters apart (A), and are located on the contour for rainwater collection as the farm field has a slope of 15% (E). The interspace is 4 meters (D). The cacti are planted in pits that have a diameter of roughly 40 centimeters (C) and a depth of 40 centimeters (B).



Author: Meike Kleinlugtenbeld & Joren Verbist

ESTABLISHMENT AND MAINTENANCE: ACTIVITIES, INPUTS AND COSTS

Calculation of inputs and costs
- Costs are calculated: per Technology area (size and area unit: **9.1 hectare**)
- Currency used for cost calculation: **JOD**
- Exchange rate (to USD): 1 USD = 0.71 JOD
- Average wage cost of hired labour per day: 20

Most important factors affecting the costs
On the farm most work (e.g. weeding) is done manually. Therefore, the cost of labour contributes significantly to the total cost.

Establishment activities
1. Soil scrapping (Timing/ frequency: Prior to planting)
2. Deep soil ploughing (Timing/ frequency: Prior to planting)
3. Surface soil ploughing (Timing/ frequency: Prior to planting)
4. Pit digging (Timing/ frequency: Prior to planting)
5. Planting cacti (Timing/ frequency: Last third of the dry season (August - October))
6. Establishment of drip irrigation (Timing/ frequency: If feasible (This case 2015))

Establishment inputs and costs (per 9.1 hectare)

Specify input	Unit	Quantity	Costs per Unit (JOD)	Total costs per input (JOD)	% of costs borne by land users
Labour					
Pit Digging & Planting	Person Hour	47.0	100.0	4700.0	100.0
					100.0
					100.0
Equipment					
Soil Scrapping (Jackhammer)	Machine-Hour	35.0	200.0	7000.0	100.0
Deep Soil Ploughing (Tractor)	Machine-Hour	9.0	250.0	2250.0	100.0
Surface Soil Ploughing	Machine-Hour	9.0	250.0	2250.0	100.0
Plant material					
Cactus Pads	Pad	5000.0	0.1	500.0	100.0
Construction material					
Drip Irrigation (including labour for installation: 14 person days)	Whole System	1.0	13700.0	13700.0	100.0
Water Tanks (including labour for construction: 10 person days)	Tank	3.0	500.0	1500.0	100.0
Total costs for establishment of the Technology				**31'900.0**	
Total costs for establishment of the Technology in USD				*44'929.58*	

Maintenance activities
1. NPK Fertilizer (1x) (Timing/ frequency: March - May)
2. NPK Fertilizer (1x) (Timing/ frequency: September - November)
3. NPK Fertilizer (1x) (Timing/ frequency: December - February)
4. Organic Manure Application (Timing/ frequency: September - November)
5. Manual Weeding (2x) (Timing/ frequency: March - May)
6. Maintenance of planting pits (Timing/ frequency: April)
7. Harvesting (Timing/ frequency: August - September)

Maintenance inputs and costs (per 9.1 hectare)

Specify input	Unit	Quantity	Costs per Unit (JOD)	Total costs per input (JOD)	% of costs borne by land users
Labour					
NPK Fertilizer Application	Person-Day	9.0	20.0	180.0	100.0
Organic Manure Application	Person-Day	7.0	20.0	140.0	100.0
Total Weeding	Person-Day	200.0	15.0	3000.0	100.0
Harvesting / Fruit Grabbing	Person-Day	280.0	20.0	5600.0	100.0
Equipment					
Irrigation Management	Person Hour	252.0			100.0
Fertilizers and biocides					
NPK Fertilizer	Ton	2.0	1000.0	2000.0	100.0
Organic Manure	Ton	40.0	30.0	1200.0	100.0
Other					
Pit Maintenance	Per Pit	4550.0	0.25	1137.5	100.0
Water for Irrigation (360m3 per month)	Kubic Metre	4320.0	0.95	4104.0	100.0
Total costs for maintenance of the Technology				**17'361.5**	
Total costs for maintenance of the Technology in USD				*24'452.82*	

NATURAL ENVIRONMENT

Average annual rainfall
- [x] < 250 mm
- [ ] 251-500 mm
- [ ] 501-750 mm
- [ ] 751-1,000 mm
- [ ] 1,001-1,500 mm
- [ ] 1,501-2,000 mm
- [ ] 2,001-3,000 mm
- [ ] 3,001-4,000 mm
- [ ] > 4,000 mm

Agro-climatic zone
- [ ] humid
- [ ] sub-humid
- [x] semi-arid
- [x] arid

Specifications on climate
Average annual rainfall in mm: 200.0

Slope
- [ ] flat (0-2%)
- [ ] gentle (3-5%)
- [ ] moderate (6-10%)
- [ ] rolling (11-15%)
- [x] hilly (16-30%)
- [ ] steep (31-60%)
- [ ] very steep (>60%)

Landforms
- [ ] plateau/plains
- [ ] ridges
- [ ] mountain slopes
- [x] hill slopes
- [ ] footslopes
- [ ] valley floors

Altitude
- [ ] 0-100 m a.s.l.
- [ ] 101-500 m a.s.l.
- [x] 501-1,000 m a.s.l.
- [ ] 1,001-1,500 m a.s.l.
- [ ] 1,501-2,000 m a.s.l.
- [ ] 2,001-2,500 m a.s.l.
- [ ] 2,501-3,000 m a.s.l.
- [ ] 3,001-4,000 m a.s.l.
- [ ] > 4,000 m a.s.l.

Technology is applied in
- [ ] convex situations
- [ ] concave situations
- [x] not relevant

Soil depth
- [ ] very shallow (0-20 cm)

Soil texture (topsoil)
- [ ] coarse/ light (sandy)

Soil texture (> 20 cm below surface)

Topsoil organic matter content
- [ ] high (>3%)

- shallow (21-50 cm)
- ✓ moderately deep (51-80 cm)
- ✓ deep (81-120 cm)
- very deep (> 120 cm)

- ✓ medium (loamy, silty)
- ✓ fine/ heavy (clay)

- coarse/ light (sandy)
- ✓ medium (loamy, silty)
- ✓ fine/ heavy (clay)

- medium (1-3%)
- ✓ low (<1%)

Groundwater table
- on surface
- < 5 m
- ✓ 5-50 m
- > 50 m

Availability of surface water
- excess
- good
- medium
- ✓ poor/ none

Water quality (untreated)
- good drinking water
- ✓ poor drinking water (treatment required)
- for agricultural use only (irrigation)
- unusable

Water quality refers to: both ground and surface water

Is salinity a problem?
- ✓ Yes
- No

Occurrence of flooding
- Yes
- ✓ No

Species diversity
- high
- medium
- ✓ low

Habitat diversity
- high
- medium
- ✓ low

CHARACTERISTICS OF LAND USERS APPLYING THE TECHNOLOGY

Market orientation
- subsistence (self-supply)
- ✓ mixed (subsistence/ commercial)
- commercial/ market

Off-farm income
- less than 10% of all income
- ✓ 10-50% of all income
- > 50% of all income

Relative level of wealth
- very poor
- poor
- ✓ average
- rich
- very rich

Level of mechanization
- ✓ manual work
- ✓ animal traction
- mechanized/ motorized

Sedentary or nomadic
- ✓ Sedentary
- Semi-nomadic
- Nomadic

Individuals or groups
- ✓ individual/ household
- groups/ community
- cooperative
- employee (company, government)

Gender
- women
- ✓ men

Age
- children
- ✓ youth
- ✓ middle-aged
- elderly

Area used per household
- < 0.5 ha
- 0.5-1 ha
- 1-2 ha
- 2-5 ha
- ✓ 5-15 ha
- 15-50 ha
- 50-100 ha
- 100-500 ha
- 500-1,000 ha
- 1,000-10,000 ha
- > 10,000 ha

Scale
- small-scale
- medium-scale
- ✓ large-scale

Land ownership
- state
- company
- communal/ village
- ✓ group
- individual, not titled
- individual, titled

Land use rights
- open access (unorganized)
- communal (organized)
- leased
- ✓ individual

Water use rights
- open access (unorganized)
- ✓ communal (organized)
- leased
- individual

Access to services and infrastructure

health	poor			✓	good
education	poor			✓	good
technical assistance	poor			✓	good
employment (e.g. off-farm)	poor			✓	good
markets	poor			✓	good
energy	poor			✓	good
roads and transport	poor			✓	good
drinking water and sanitation	poor			✓	good
financial services	poor			✓	good

IMPACTS

Socio-economic impacts

Crop production	decreased						✓		increased
crop quality	decreased						✓		increased
demand for irrigation water	increased			✓					decreased
expenses on agricultural inputs	increased			✓					decreased
farm income	decreased						✓		increased
diversity of income sources	decreased					✓			increased

Socio-cultural impacts

food security/ self-sufficiency	reduced						✓		improved
SLM/ land degradation knowledge	reduced					✓			improved

Ecological impacts

soil moisture	decreased					✓			increased
soil cover	reduced					✓			improved

soil loss	increased					✓			decreased
nutrient cycling/ recharge	decreased					✓			increased
soil organic matter/ below ground C	decreased					✓			increased
biomass/ above ground C	decreased						✓		increased
drought impacts	increased							✓	decreased

Off-site impacts

COST-BENEFIT ANALYSIS

Benefits compared with establishment costs

Short-term returns	very negative			✓					very positive
Long-term returns	very negative					✓			very positive

Benefits compared with maintenance costs

Short-term returns	very negative					✓			very positive
Long-term returns	very negative					✓			very positive

The Net Income per hectare varies between 1650 and 2750 JOD.

CLIMATE CHANGE

Gradual climate change

annual temperature increase	not well at all					✓	very well

Climate-related extremes (disasters)

local hailstorm	not well at all		✓				very well
local snowstorm	not well at all		✓				very well
heatwave	not well at all					✓	very well
cold wave	not well at all		✓				very well
extreme winter conditions	not well at all		✓				very well
drought	not well at all					✓	very well
epidemic diseases	not well at all		✓				very well

ADOPTION AND ADAPTATION

Percentage of land users in the area who have adopted the Technology

- [ ] single cases/ experimental
- [x] 1-10%
- [ ] 11-50%
- [ ] > 50%

Of all those who have adopted the Technology, how many have done so without receiving material incentives?

- [ ] 0-10%
- [ ] 11-50%
- [ ] 51-90%
- [x] 91-100%

Number of households and/ or area covered

200 ha

Has the Technology been modified recently to adapt to changing conditions?

- [x] Yes
- [ ] No

To which changing conditions?

- [ ] climatic change/ extremes
- [x] changing markets
- [ ] labour availability (e.g. due to migration)

The market demands increase for cactus pears. This results in different crop-spacing because cactus for pear production requires wider spacing, while cactus for fodder production can be planted more dense. Hence, changing market demands for the different products of cactus require different agronomic practices.

CONCLUSIONS AND LESSONS LEARNT

Strengths: land user's view

- The cacti are highly productive with minimum inputs.
- It does not require much water, which is important as irrigation water availability is a bottleneck for the farmer as well as for most areas in Jordan.
- The cacti are even productive in poor soil and by growing cacti on these soils, it also reduces erosion.
- The reduced risk of drought deteriorated yields is important as climate change leads to more extreme weather event, such as droughts. This will only increase in the future. Therefore the cactus's ability to cope with climate change (resilience to climate fluctuations) is a great advantage and increasingly important.

Strengths: compiler's or other key resource person's view

- Due to the suitability of cacti to be cultivated in marginal lands, the soil is partly covered permanently by vegetation in these areas which protects these degraded lands. Therefore, cacti cultivation could offer incentive to prevent land degradation.
- The technology offers increased resilience of the environment and its involved livelihoods. This is because cacti are more

Weaknesses/ disadvantages/ risks: land user's view → how to overcome

- The significant cost related to labour. → According to the farmer there were no alternatives.
- Marketing can be considered a weakness as during harvest, the supply of cactus fruits was high and thus the selling-prices were low. → By investing in manufacturing/ processing the cacti and stably provide the market with other cactus-products, such as the Tunisian market.
- The increased risk of new pests. → More awareness is required so the new pests can be identified, allowing proper and timely action.
- The absence of agro-industrial processing units. Currently, the market demand is mostly related to the cactus fruits. However, cacti offer more such as seeds for oil extraction (such as the Tunisian cactus value chain) . → Investments to enhance cactus-value chain as is done in Tunisia.

Weaknesses/ disadvantages/ risks: compiler's or other key resource person's view → how to overcome

- The possible knowledge gap for farmers to switch from their resilient to climate change induced effects such as increased droughts and increasing (summer) temperatures, as result of their high-water content and efficiency. Therefore, this technology is better suited for the future.

conventional/traditional agricultural practices to a more innovative one could be a bottleneck for out-scaling the technology. → This bottleneck can be overcome, by developing social capital such as (e.g.) institutions or farmers networks to disseminate knowledge. A good example is the field days for farmers organized by NARC and ICARDA.

- The risks of pests and diseases is a weakness of the cacti as these plants are vulnerable to this. Also, due to the density and mono-cropping of the cacti, the pest/ disease may spread easily and rapidly over the field. Eventually, risking the production of the cacti, thus possibly reducing the income of local farmers. → A solution may be found in changing the agricultural activities. An example of such a possible solution is the introduction of intercropping, this could increase bio-diversity and reduce the potential loss of income in case of a pest-outbreak.

REFERENCES

Compiler
Joren Verbist

Reviewer
Rima Mekdaschi Studer

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Resource persons
Mounir Louhaichi - Research Team Leader of Rangeland Ecology and Forages
Sawsan Hassan - Research Associate Coordinator of Forage Systems

Full description in the WOCAT database
https://qcat.wocat.net/en/wocat/technologies/view/technologies_5847/

Linked SLM data
n.a.

Documentation was faciliated by
Institution
- International Center for Agricultural Research in the Dry Areas (ICARDA) - Lebanon

Project
- ICARDA Institutional Knowledge Management Initiative

Links to relevant information which is available online

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