Rainwater harvesting in dry environments

Training workshop on rainwater harvesting and applications
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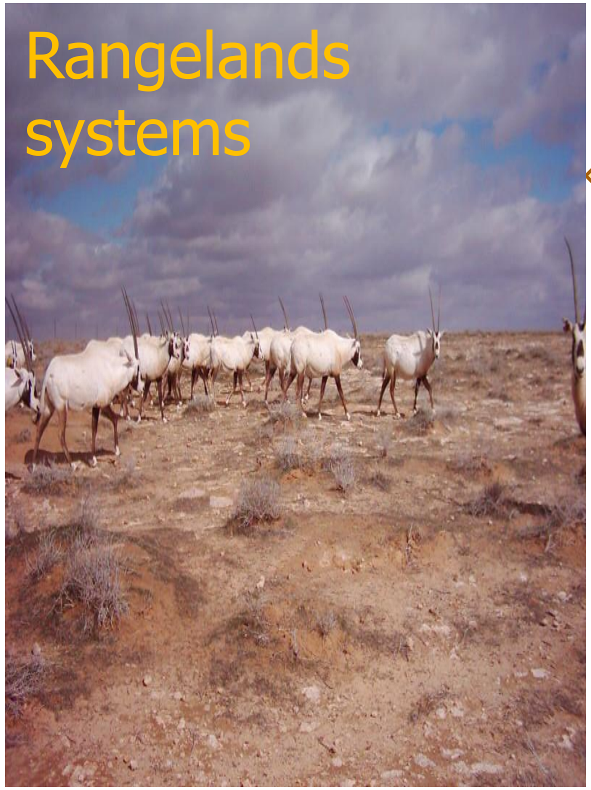
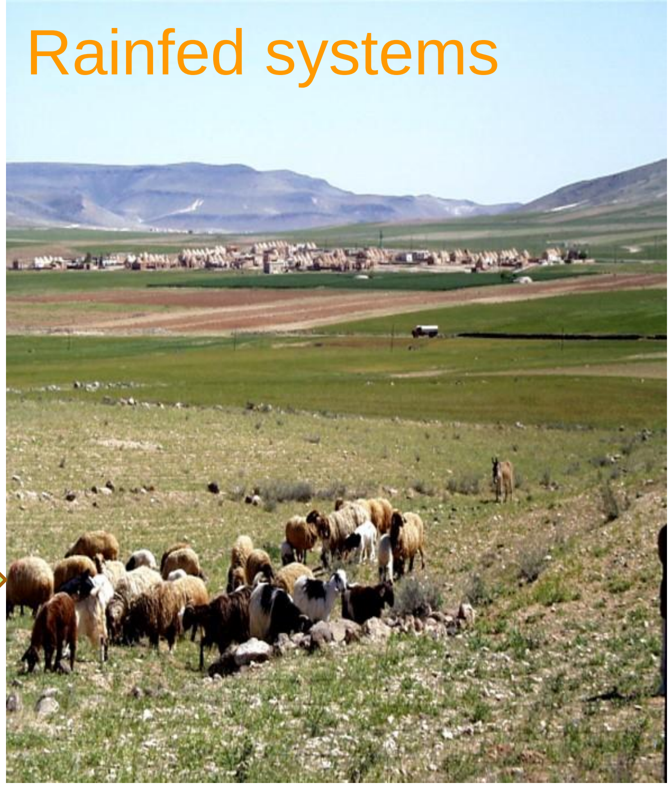
Theib Oweis
Consultant, agricultural water management
Amman, Jordan
Email: theib.y.oweis@gmail.com

Drylands (non irrigated) agroecosystems



- 100–300 mm rainfall
- Degraded rangelands, desertification
- Severe soil moisture stress
- Sparce vegetation
- Poorer communities

- 300-600 mm rainfall
- Frequent dry spells
- Moderate soil moisture stress
- Soil erosion
- Poor productivity



Rainwater mostly lost in evaporation

- High rainfall intensity
- Low soil infiltration rates
- Poor vegetation cover
- Lack of water retaining structures
- Over 90% evaporation

Runoff water mostly lost in salt sinks

- High rain intensity for extended periods
- Land slope
- Degraded surfaces
- Soil erosion
- Mostly evaporated or salinized in salt sinks

How to benefit from this water?

The concept of rainwater harvesting

No intervention

Moderate intervention

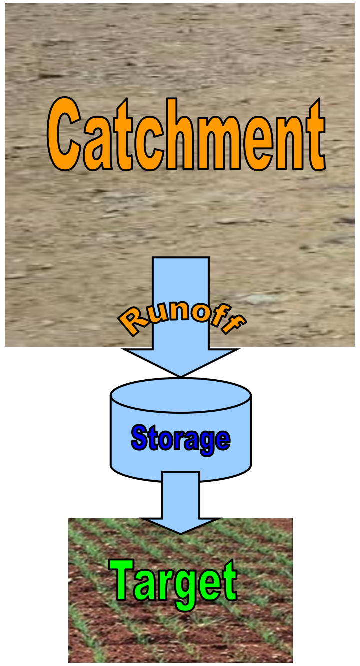
Appropriate intervention

Rainwater harvesting: definition

Concentration of rainfall from larger area into smaller one through runoff for beneficial use

Water Harvesting: system components

1. **The catchment**
   - Micro
   - Macro
2. **The runoff**
   - Natural
   - Induced
3. **The target**
   - Agriculture
   - domestic
   - industrial
   - environment
4. **The storage**
   - Surface
   - Soil
   - Ground

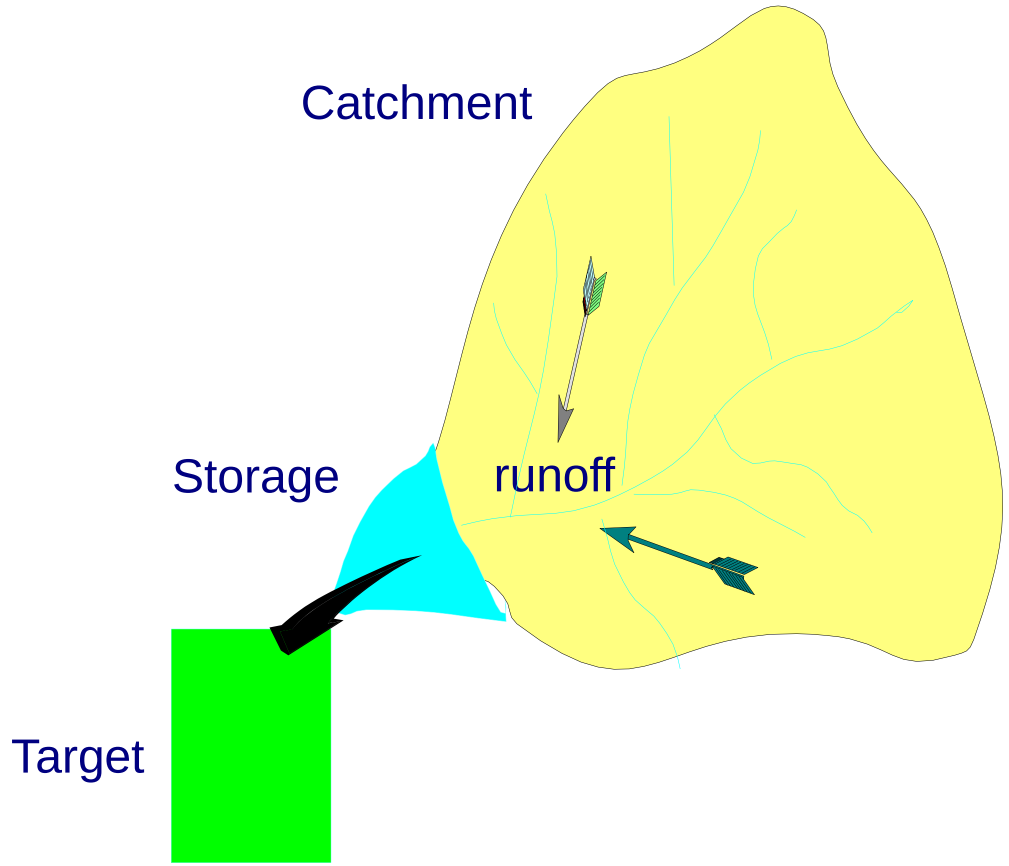


Macro & micro-catchments techniques

- Based on the size of the catchment area
- Usually off farm or on farm

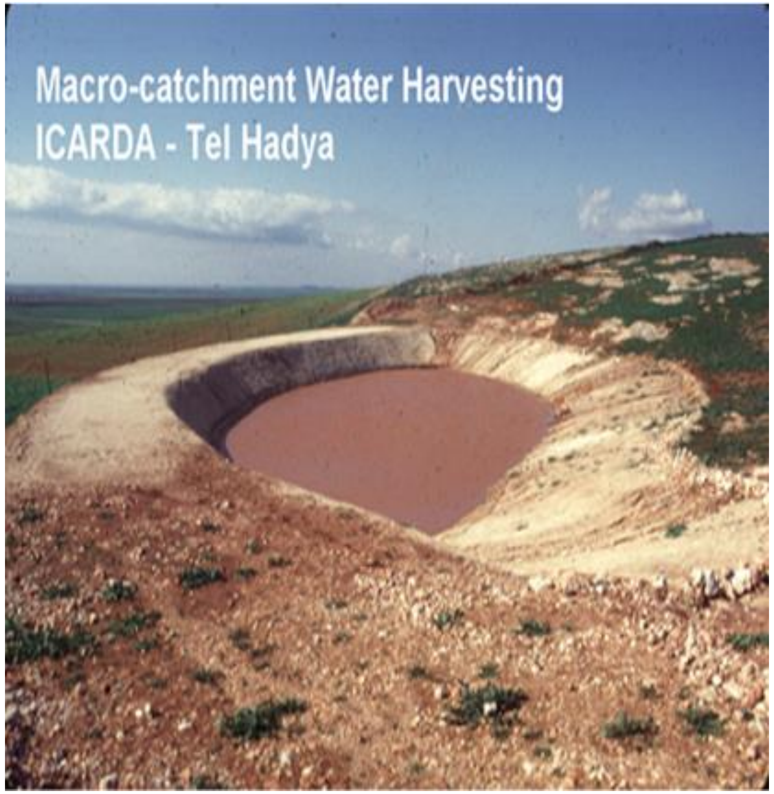
Macro-catchments rainwater harvesting

- Large catchment, usually natural terrain
- Runoff rates are not high
- Storage can be in surface reservoirs, groundwater aquifers or soil profile
- Targets can be agriculture, domestic or environment



Small farm reservoirs

- Small in size
- Dams or ponds
- Issues of sediments
- Evaporation losses



Small water harvesting reservoirs on wadi bed

- Usually earth dams
- Need a spillway
- Sediments problem
- Capacity can be increased by moving water to soil profile and refilling

Hafaer/ livestock ponds

- Natural medium size catchments
- Seasonal ponds, mainly for livestock
- Pollution, health and safety issues

Cisterns/ underground reservoirs

- Both the catchment and the reservoir are small in size
- Cover eliminates evaporation
- Cost is high for digging and plastering
- Used for domestic, animals and home gardening

Ancient cisterns - renovation

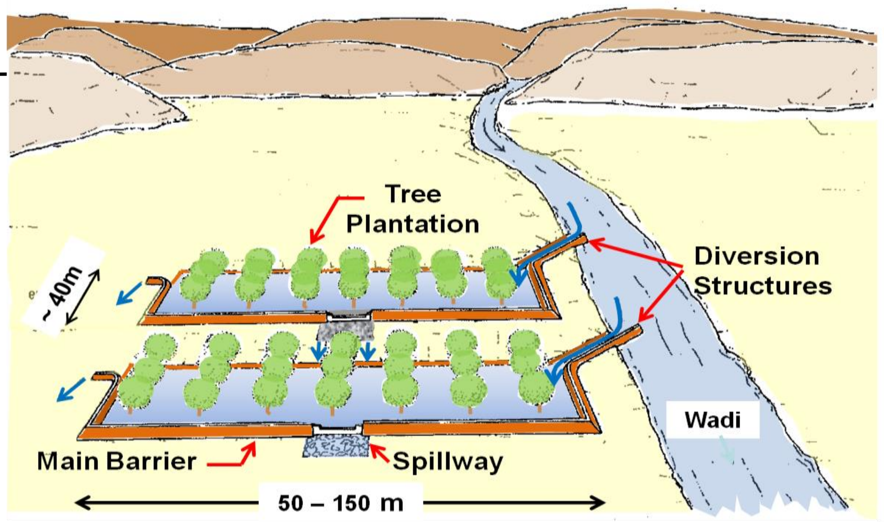
- Clearing or compacting the catchment
- Digging out the sediments inside the cistern
- Constructing a settling basin & a gravel filtering system
- Flushing first runoff and settling basin and filtering is essential
- Can install pump and refill the cistern if needed

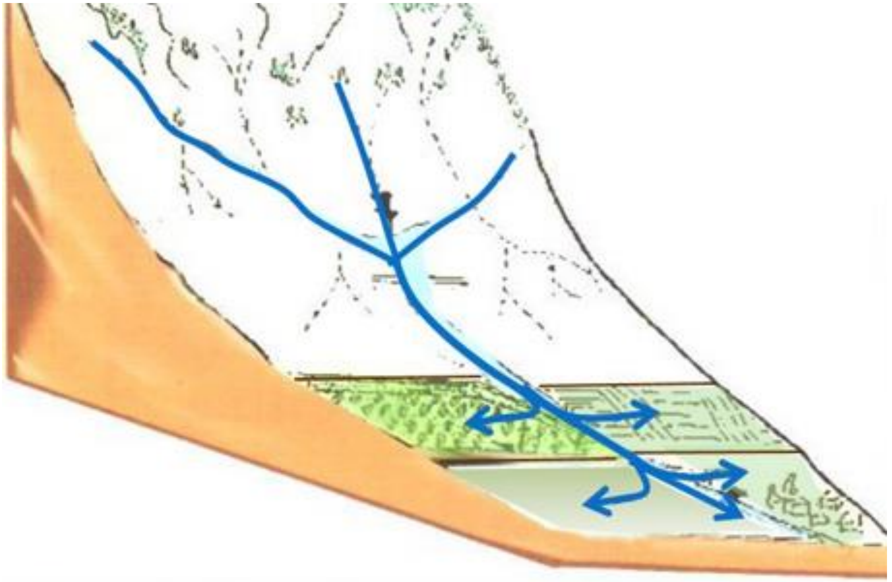
Wadi-bed systems

- Constructing wall across the wadi with a spillway
- Eroded fertile sediments accumulate behind the wall
- Crops grown in deep soils
- Example: Jessour in Tunisia

Water spreading systems

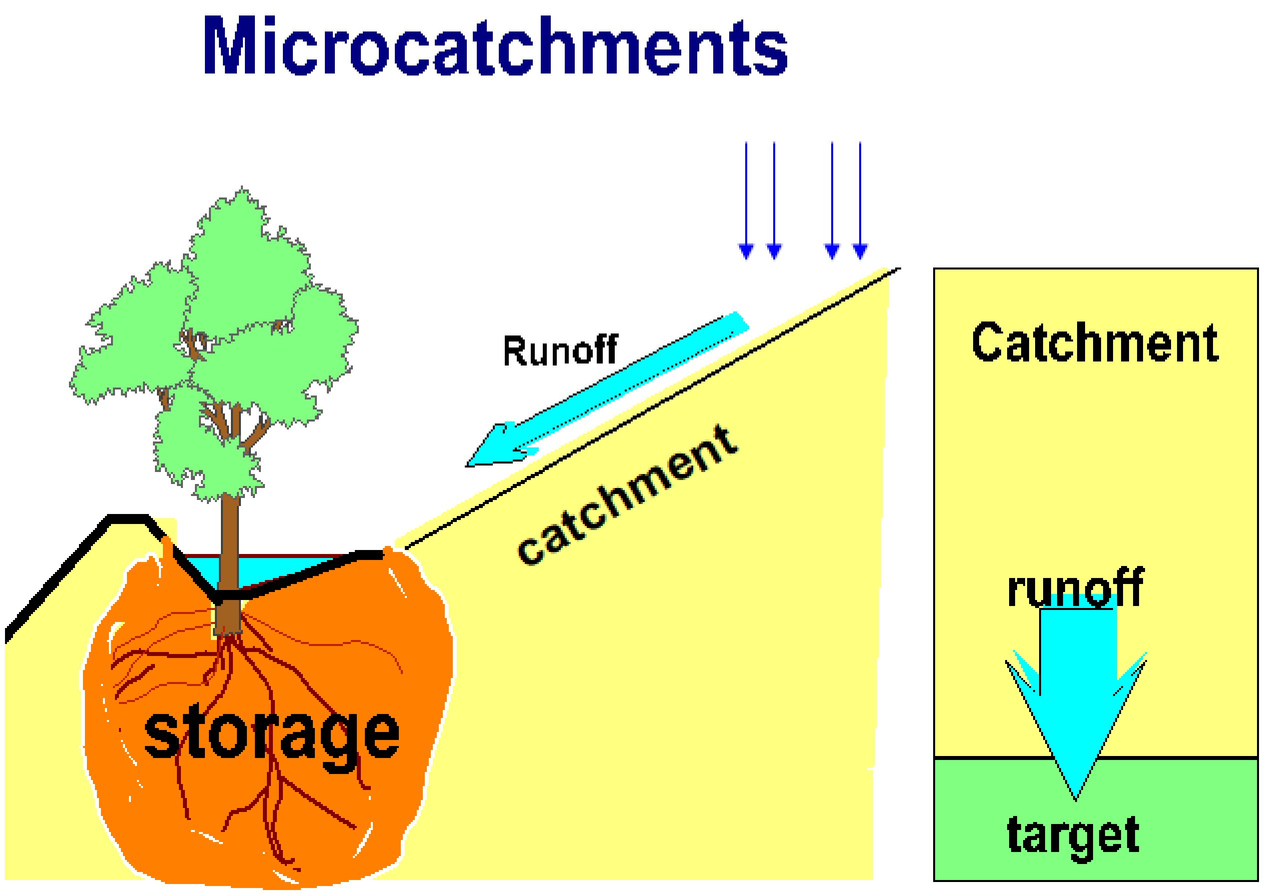
- Diversion structure to raise water level and divert
- Directing part or all of the water right and/or left
- Convey to agricultural lands on the side(s)
- Sediment can block the diversion canal inlet
- Check for upstream-downstream water rights





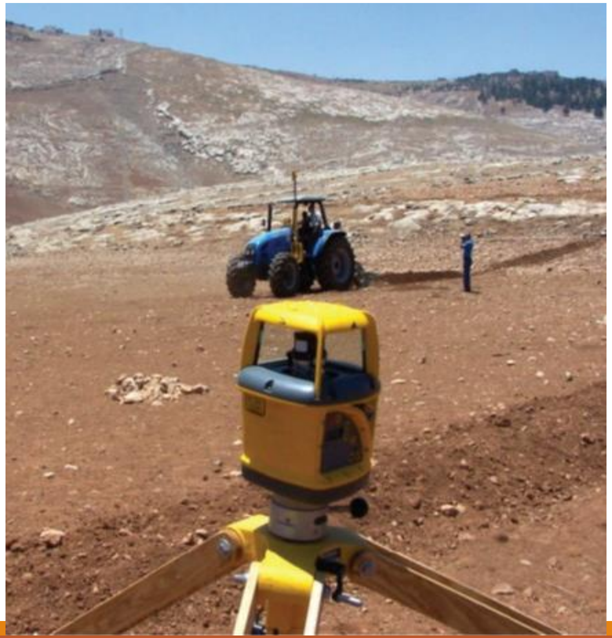
Micro catchment water harvesting techniques

- Small catchment area (10-100 m2)
- Short runoff runs, more efficient
- Water storage is in soil profile
- Usually on farm systems



Contour ridges

- Bunds constructed on contour lines
- Manual construction high cost of labor
- Plants grow in the bund
- Spacing vary with rainfall, slope, crop & water requirements



Contours identification

- Water can flow and break ridges if not precisely on contour lines
- Using leveling machine is costly
- Simpler use of transparent hose
- Laser guiding is most effective and lower in cost

Semicircular bunds

- Bund faces slope upwards
- Bund may be Hight enough to retain maximum runoff
- Used mainly for shrubs and fruit trees
- Manually constructed, now also mechanized

Mechanization of contour ridges and bunds

- Adapting the Vallerani implement
- Providing contour laser guiding
- Can construct up to 50 hectares a day
- Cost about 30 USD/ha



Small runoff basins (negarim)

- Rectangular/diamond shapes
- Max slope should be along the diagonal
- Trees & shrubs planted at the lowest corner
- Usually done permanently. Issues of weeds control with no plowing
- The size depend of the slope, rainfall and crop water requirements

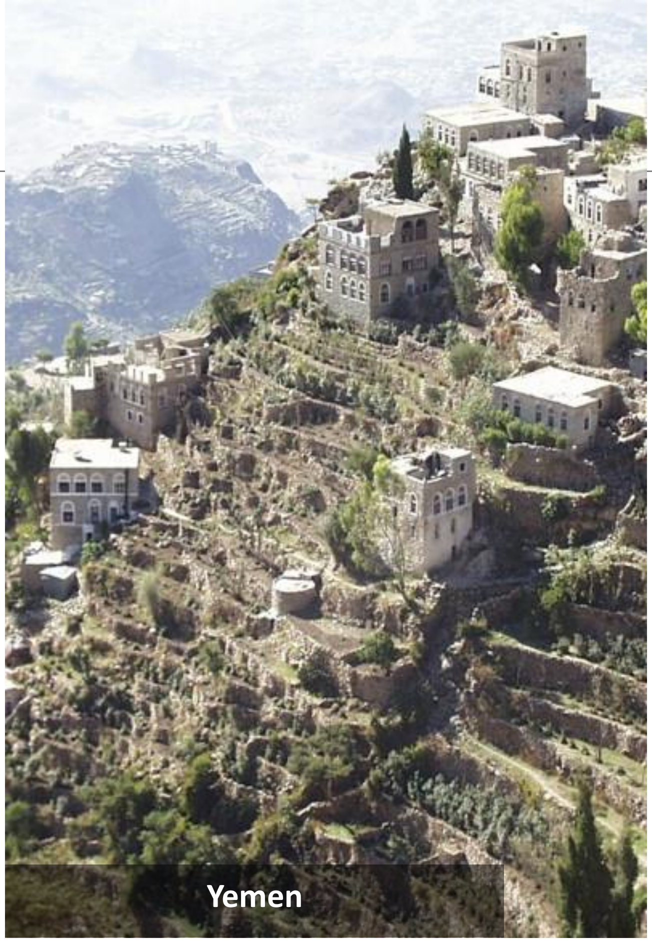


Runoff strips

- Strips of alternate catchment and cropped areas
- Runoff inducement may be needed
- Used for field crops in areas with less than 350 mm annual rainfall
- Width and ratios depend on slope, rainfall, crop water requirement
- Issues of water application uniformity across the cropped area

Roaded catchments

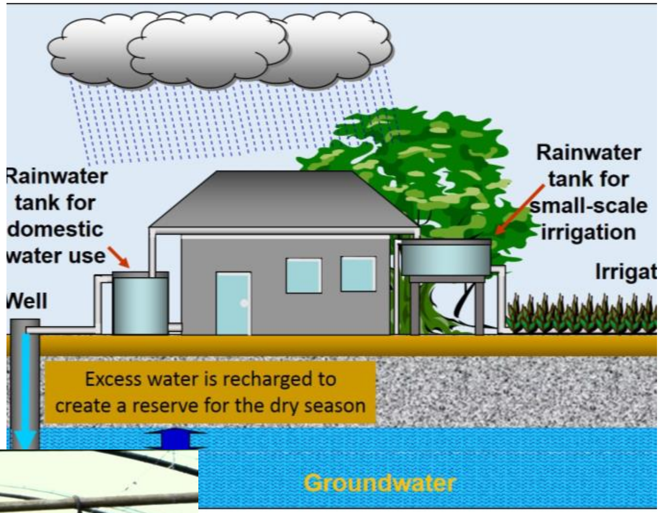
- Artificial slope is created in flat lands to induce runoff
- Normally compaction of lose soils is needed at construction
- Generally harvested water is used for agriculture



Contour bench terraces

- Constructed on very steep slopes
- Narrow terrace are constructed usually at contour lines and supported by a wall
- Terases are grown with trees but catchment is usually left natural with little disturbance
- Famous in Yemen and Tunisia

Rooftop water harvesting



- Paved and clean house roofs with slope provide near 100% runoff coefficient
- First rain to flush out
- Gutters convey rainwater runoff to a storage tanks
- Purification/filtering of water is essential before using in households
- Green house roofs can provide water for protected agriculture

Planning and designing micro catchment water harvesting

General considerations:

1. Determine the need for a rainwater harvesting system
   - Rainwater is not enough for crop water requirements & no irrigation water available
   - Livestock or households need drinking water
2. Involve local communities early in the planning to insure ownership
3. Ensure that runoff is possible and catchment is available
4. Ensure that the project creates no conflict of interests (i.e. Upstream downstream)
5. Institution/people with capacity available to operate and maintain the system
6. Funds are available for implementation and follow up

Planning, designing and implementing water harvesting projects

Determining runoff coefficients

- Runoff Coefficient (RC%) = $\dfrac{\text{Volume of runoff}}{\text{Volume of rainfall}} \times 100$
- Runoff Coefficient (RC%) = $\dfrac{\text{Volume of runoff (m3)}}{\text{Rainfall (mm)/1000 x area (m2)}} \times 100$

RC value depends on:

- Land slope (the steeper the higher the RO)
- Rain intensity (the more intense rain the higher RC
- Surface smoothness (the smoother the surface the higher RC)
- Soil Infiltration rate (he higher infiltration rate the lower RC)
- The length of the catchment (the longer the run the lower the RC)

Planning, designing and implementing water harvesting projects

Micro-catchments for agriculture : Runoff inducement

Increasing runoff coefficient by:

- Land clearing / smoothing
- Surface cover (plastic, concrete, asphalt, etc.)
- Compaction
- Use of chemicals (salts, water repellants)
- Increase slope

Planning, designing and implementing water harvesting projects

Selection of water harvesting techniques

Guidelines for selection of micro and macro catchments systems in:

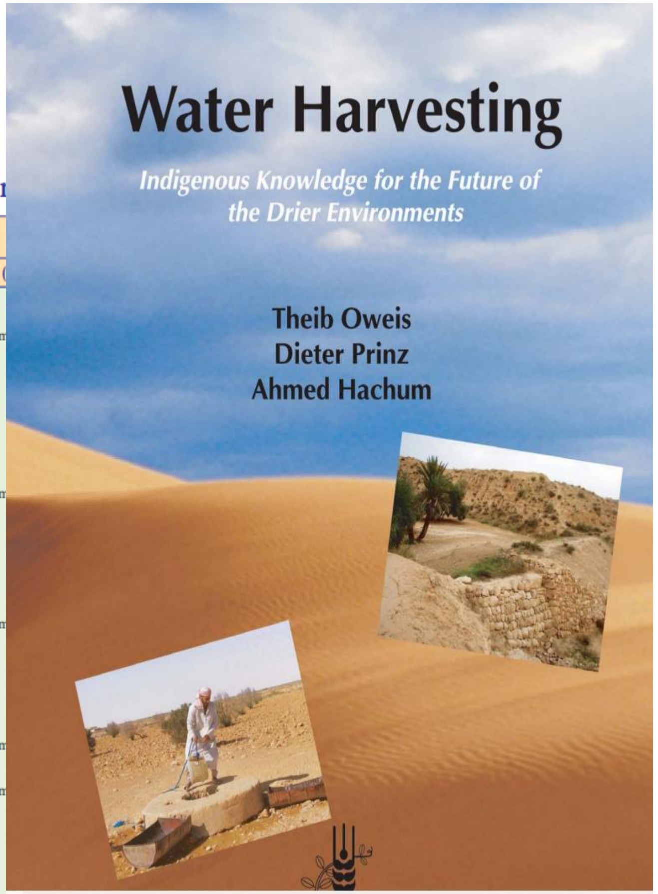
Oweis, T., D. Prinz, and A. Hachum. 2001. Water harvesting: Indigenous knowledge for the future of the drier environments. ICARDA, Aleppo, Syria. 40pp.

Document will be provided

Guidelines for Selecting Water-Harvesting Techniques in the Drier Environ

Technique	Crop	Soil		Land	Land Cover		Socio-economics				
		Depth (1)	Texture	Slope (2)	Vegetation	Stoniness (4)	Farm size (5)	Capital (6)	Labor		
Micro-catchments											
On-farm systems											
Contour ridges	range field trees vegetable	variable med.,deep deep med.,deep	variable " med.,heavy "	med.,steep medium low,med. "	poor,med. poor poor,med. "	low-med. low " "	variable small,med. " small	low " " "	medium " " "		
Semi-circular bunds (trapezoidal triangular)	range field trees vegetable	" " deep "	variable med.,heavy " "	" " " "	poor " poor,med. "	low,med. " low "	variable small,med. " small	" " " "	high " " "		
Small pits	field range	" shallow,med.	" "	" "	poor poor,med.	" low,med.	variable "	" "	medium "		
Small basins (Negarim)	range trees	med.,deep deep	" "	" low	poor poor,med.	" "	small small,med.	" "	high "		
Runoff strips	range field	variable med.,deep	" "	low,med. "	poor poor,med.	" "	" "	" "	low "		
Inter- row system (roaded catchment)	trees vegetable field	deep medium "	" variable "	Low " "	poor " "	low " "	large " med.,large	high " "	medium " "		
Meskat (Khushkaba)	trees field	deep medium	med., heavy "	low,med. "	poor,med. poor	" "	variable small,med.	low "	" low		
Contour bench terraces	trees field	deep medium	" "	Steep "	" "	" "	" "	high "	medium "		
Rooftops	drinking vegetable	na variable	na variable	na "	na "	na "	small "	" "	medium "		
Macro-catchments											
Wadi-bed systems											
Small farm reservoirs	all crops	variable	"	low,med.	variable	variable	med.,large	high	high		subsurface
Wadi-bed cultivation	trees/ vegetable	med.,deep	med., heavy	"	poor	Low	small,med.	medium	med.,high	local	surface/soil profile
Jessour	trees	"	"	med.,steep	variable	variable	small	"	high	local/training	"
Off-wadi systems											
Water spreading	field/trees	"	"	low,med.	poor	low,med.	variable	"	medium	external skill	soil profile
Large bunds	trees field range	deep medium shallow,med.	" " variable	" " "	poor,med. poor med.,dense	" low variable	med.,large medium med.,large	" " "	" " "	local/training " "	" " "
Tanks and hafair	*all crops*	variable	med., heavy	low	variable	"	"	med.,high	"	external skill	surface/subsurface
Cisterns	drinking/ trees/vegetable	deep	rock	all slopes	poor,med.	variable	small,med.	medium	high	local/training	subsurface
Hillside runoff systems	field/trees	med.,deep	med.,heavy	low,med.	poor,med.	low	small,med.	"	high	local/training	soil profile

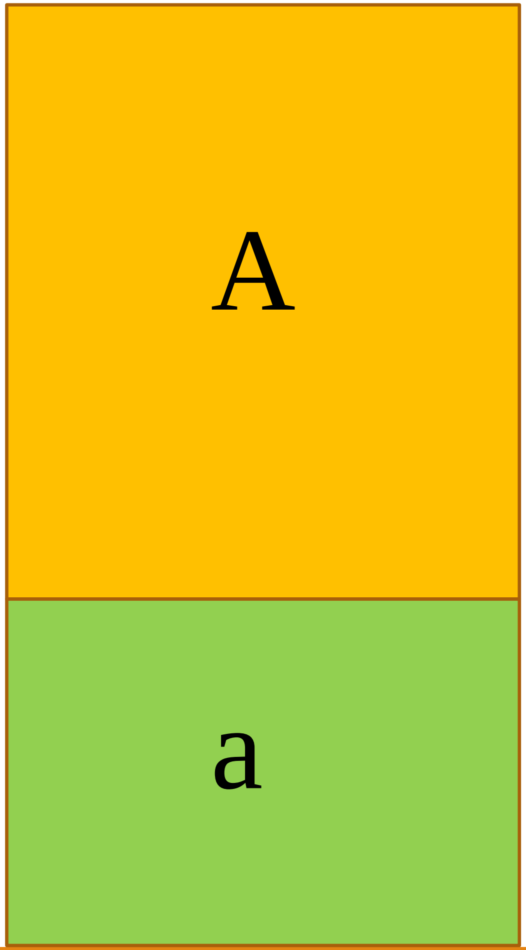
(1) shallow < 50 cm, medium: 50-100 cm, deep> 100 cm; (2) low < 4%, medium: 4-12%, steep > 12%; (3) poor < 15%, medium: 15-30%, dense > 30% ow < 10%, medium: 10-25%, high> 25%; (5) small<5 ha, medium:5-25 ha, large> 25 ha; (6) low < $ 25/ ha, medium: $ 25-100/ ha, high > $ 100/ ha;
(7) low < 5 man-day/ ha, medium: 5-20 man-day/ ha, high > 20 man-day/ ha; na : not applicable.

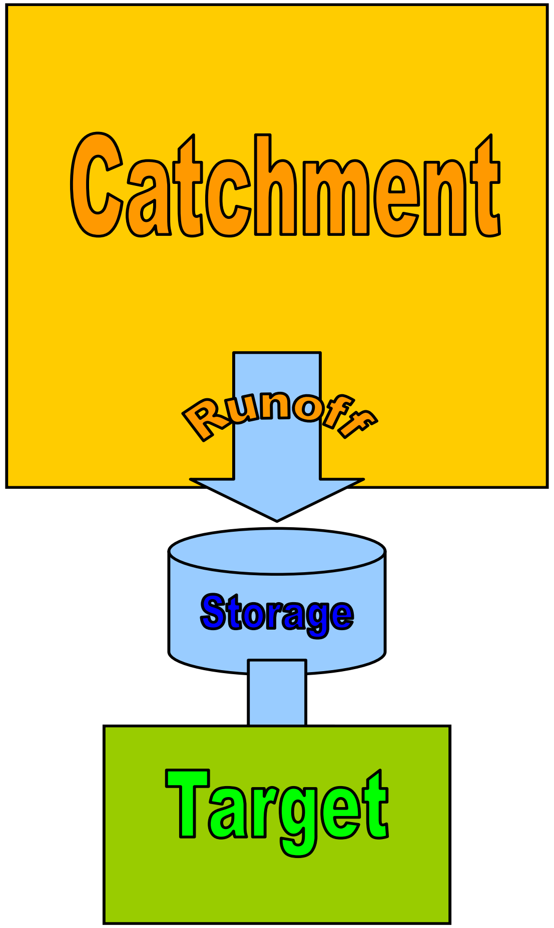


Determining Catchment-Target areas ratio

Data required

- Runoff coefficient
- Crop water requirements
- Annual rainfall amounts
- Soil water holding capacity





Determining Catchment-Target ratio

V = Volume (annual)
ET = Evapotranspiration (annual)
R = rainfall (annual)
a = cultivated area
A = catchment area
Rc = Runoff coefficient

$V_{deficit}$ = (ET – R) * a .... (1)

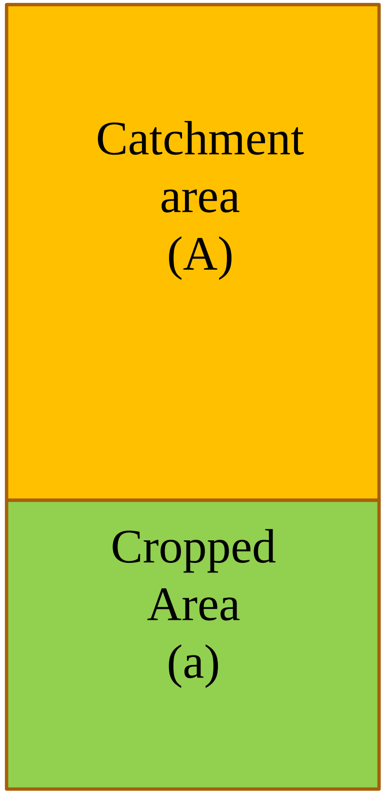
$V_{harvested}$ = A * R * Rc .... (2)

By equating (1) and (2):

A * R * Rc = (ET – R) * a ....(3)

A/a = (ET-R)/(R*Rc) ....(4)

Total seasonal depth of water supplied to the cropped area = Direct Rain on the cropped area + (Volume of harvested water / cropped area)



Design steps

Step 1: determine the need and potential for a water harvesting system

Step 2: Select the technique suitable for the site

Step 3: Determine crop water requirements (ET)

Step 4: Determine design annual rainfall (R)

Step 5. Determine design water storage capacity

Step 6: determine design runoff coefficient (RC)

Step 7: Determine catchment/target ratio (A/a)

Step 8. Check if the soil storage capacity can accommodate the runoff

Table 5. Average soil water holding capacity and plant available water in various textured soils

Table 7. Potential runoff coefficients (RC) for various land uses, soil types and land slopes in the Arab region rainfed and rangelands environments

A/a = (ET-R)/(R*RC)

Where:

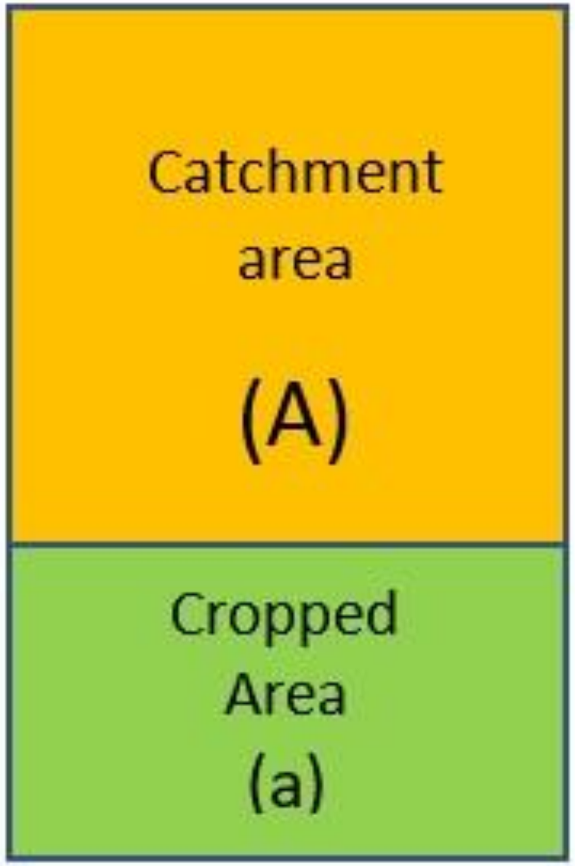
A: is the Catchment area

a: is the Target area

ET: is the crop water requirements

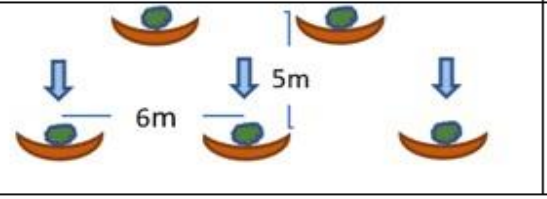
R: is the Design Rainfall

RC: is the Runoff Coefficient



cereals	1.0	Continuous
legumes	0.6	Continuous
vegetables	0.7	Rows of 1.0 m wide
grasses	0.5	Continuous

Table 9. Practical design example 2. Olive orchard with semicircular bunds & small basins

Step 1	Determine the need and potential for water harvesting	Olives trees in Jerash areas is grown in annual rainfall zone of 300-400 mm at times when olive trees need 500 mm annually. Trees survive the deficit but yields are low and fluctuate greatly from one year to the other. Availability of supplemental water through water harvesting will improve yields and provide more stable income and higher oil quality.
Step 2	Select the technique and the suitable site	A site in Jarash area with mean annual rainfall of 400 mm is selected on land with a slope of 5% having deep (1.5 m) clay loam soils. Consulting with table 1 suitable techniques are semicircular bunds and small basins (negarim)
Step 3	Determine crop water requirements and water deficit	From table 2. trees ET is around 500 mm. Rainfall of 400 mm the deficit would be 100 mm
Step 4	Determine design annual rainfall	Annual rainfall at 67% probability in the area was calculated by the equation to be 320 mm
Step 5	Determine design water storage capacity	- From table 5. A clay loam soil has 20% available water. - Olive matured trees is 3 m diameter (7m2 area) and 1.5 m soil depth. - Available water per tree = 7.0m2* 1.5m * 20%= 2.1 m3
Step 6	Determine design runoff coefficient	For clay loam soil with slope of 5%, from table 7 Orchards similar to forest RC = 21% is suitable.
Step 7	Determine catchment /target ratio (A/a)	Applying the equation: A/a = (ET-R)/(R*RC) - ET= 500 mm, Design R= 320, RC= 21% - A/a = (500-320)/(320*0.21)= 2.7, may be rounded to 3 then A/a = 3:1 - As the target area/tree is 7m2 then the catchment area should be 21m2 - Total area of catchment and target =7+21=28 m2 so best-rounded tree spacing = 6m x 5 m
Step 8	Check if the soil storage capacity can accommodate the expected runoff and rainfall	- Catchment area= Total tree area-Target area=(5m*6m)-(7.0 m2)= 23m2 - Runoff volume= Catchment * rainfall * Runoff coefficient= 23.0m2*0.32m*.20= 1.47 m3 - Rainwater volume on target= Rainfall depth * area = 0.32 m*7m2= 2.24 m3 - Total water expected at target = Runoff volume + Rainfall volume = 1,47+ 2.24= 3.71 m3 - Storage capacity in soil profile= tree area*soil depth*available WHC = 7.0m2*1.5m*0.2=2.1m3. - Depleted ET volume from November to April Table 2 = ET (0.170m)*tree area (7.0m2)= 0.17m*7.0m2=1.19m3 - Total storage available=available WHC + depleted ET= 2.1+1.19 m3= 3.29 m3. This is a bit short of 3.71 m3 of water expected but within the error margin
Summary		Olive trees planted at spacings on 5x6 meters with semicircular bunds/small basins would provide the trees with supplemental water to cover the deficit between rainfall and crop ET.