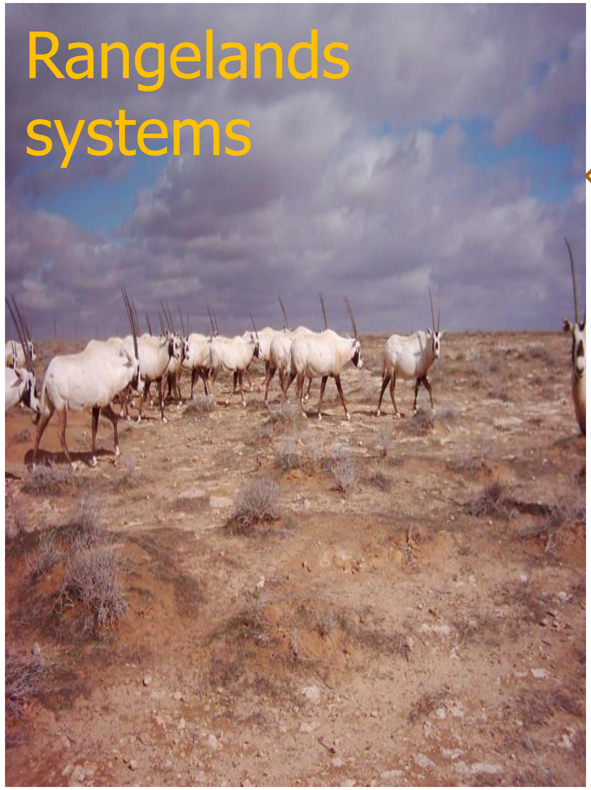
Rainwater harvesting in dry environments

Training workshop on rainwater harvesting and applications in Jordan, ESCWA event, Kempinski Hotel, Amman, Jordan, 18th. of August 2021

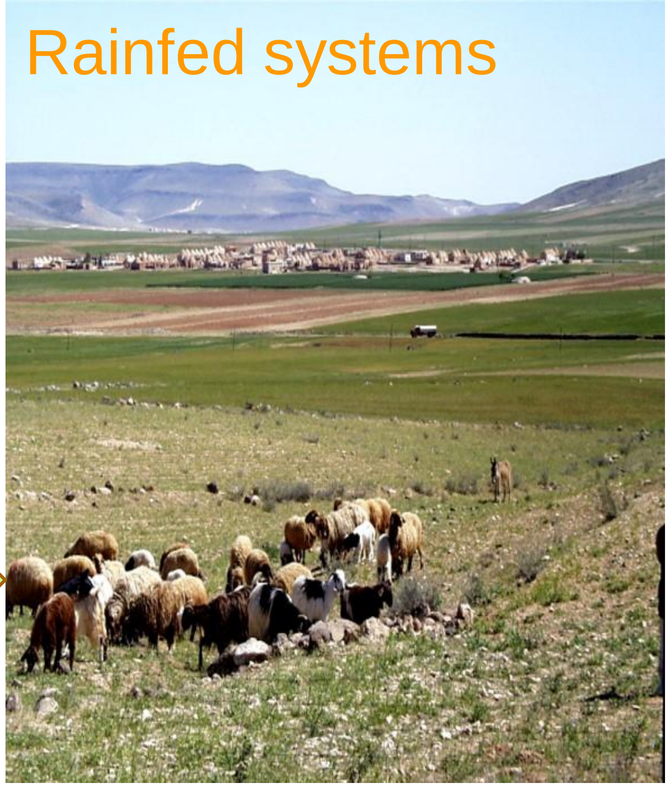
Theib Oweis
Consultant, agricultural water management
Amman, Jordan
Email: theib.y.oweis@gmail.com

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

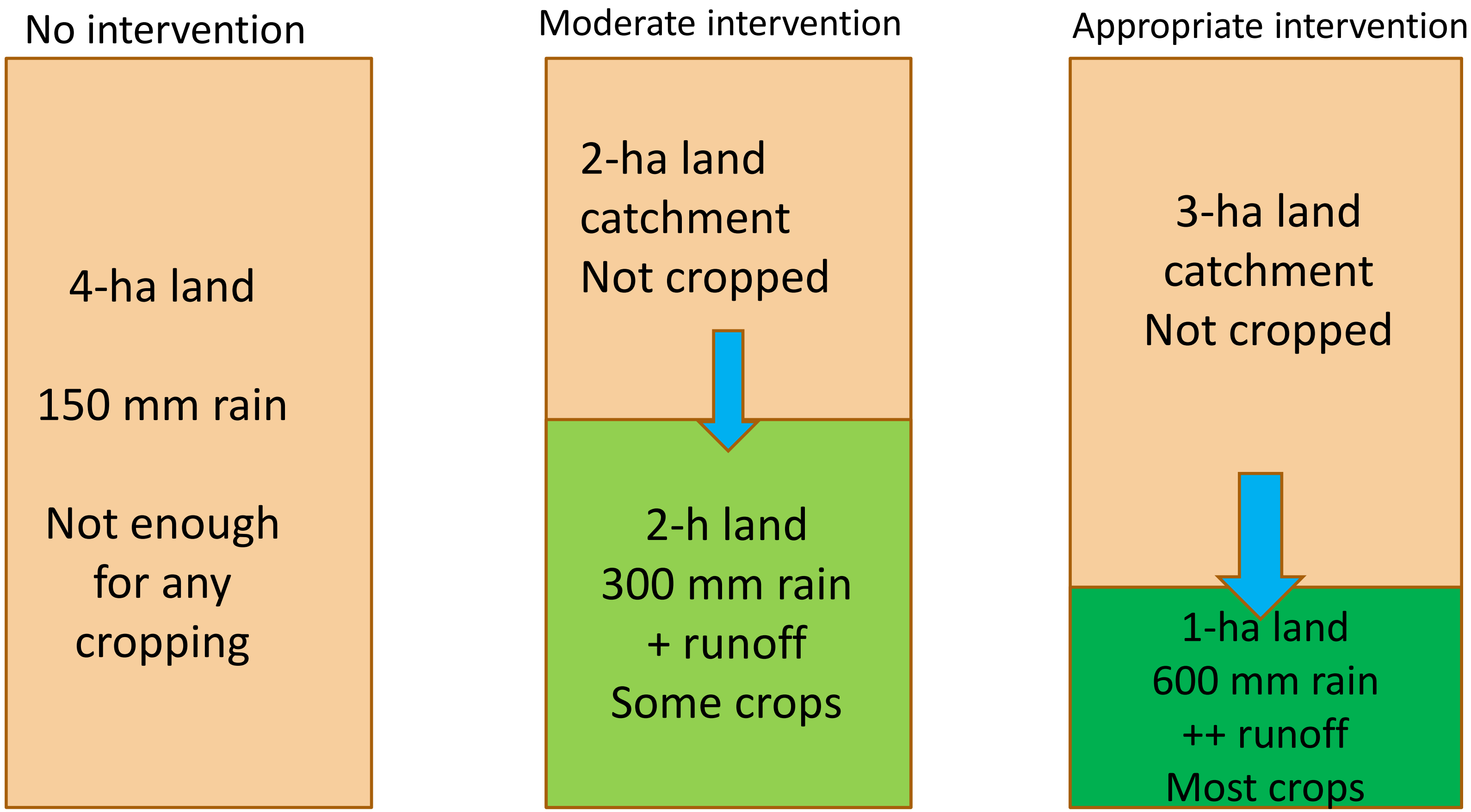
- High rainfall intensity
- Low soil infiltration rates
- Poor vegetation cover
- Lack of water retaining structures
- Over 90% evaporation

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

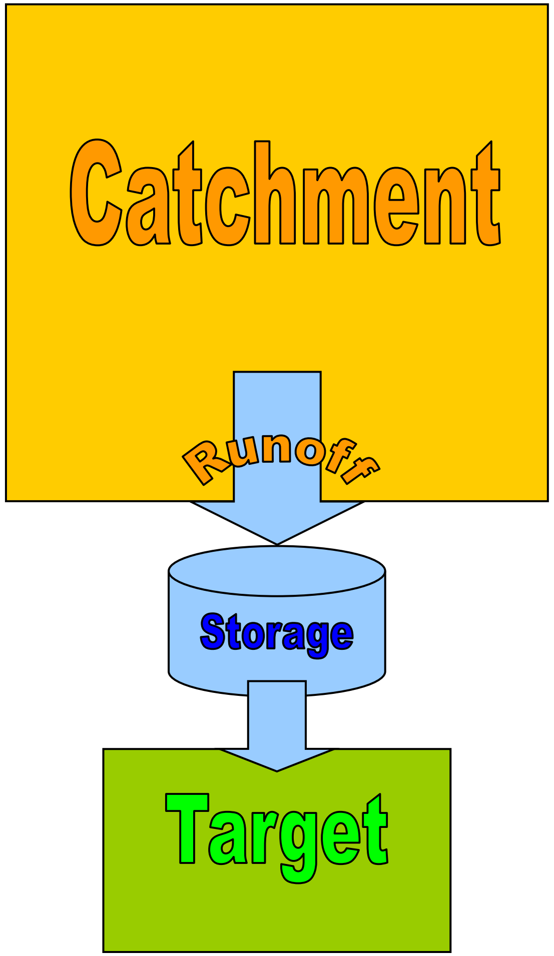


Rainwater harvesting: definition

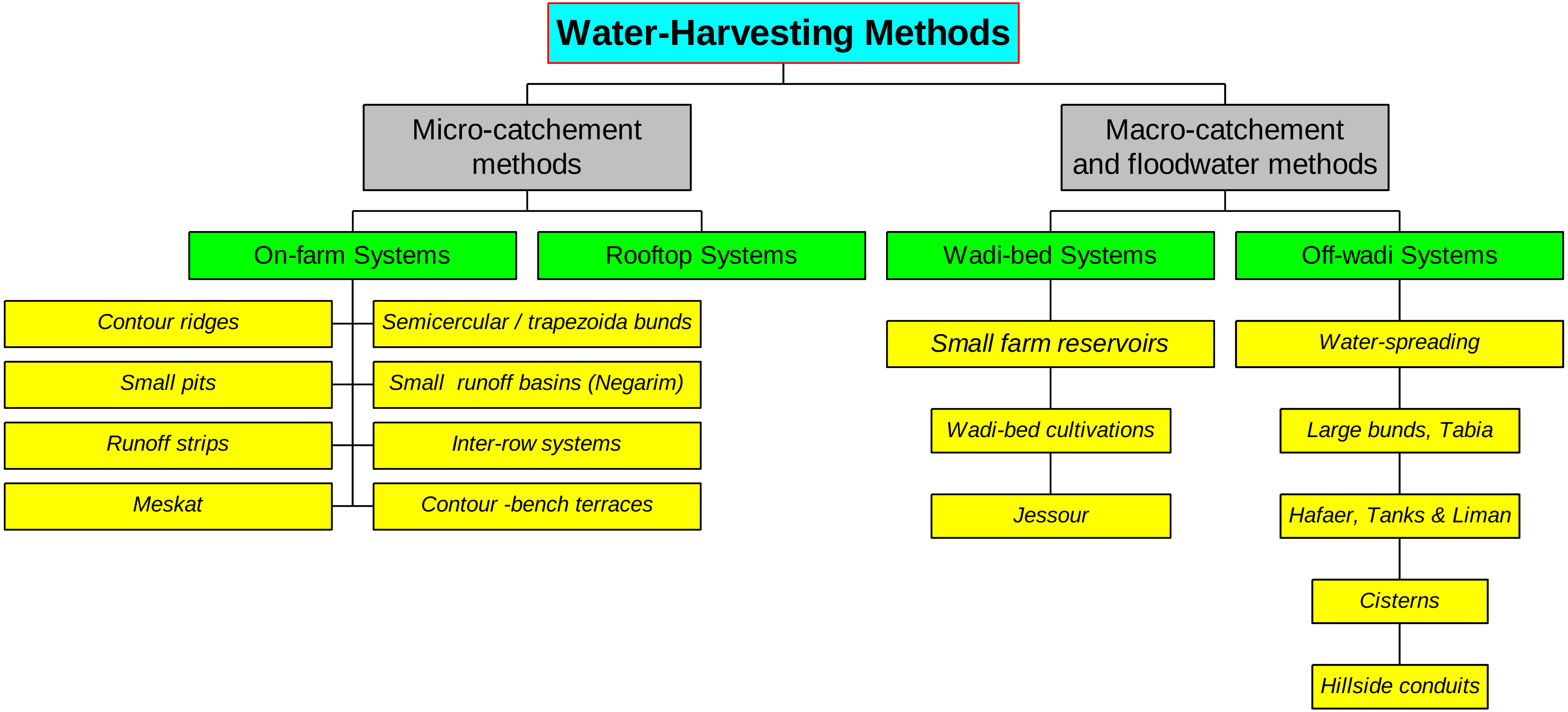
Concentration of rainfall from larger area into smaller one through runoff for beneficial use

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



Classification of water harvesting methods

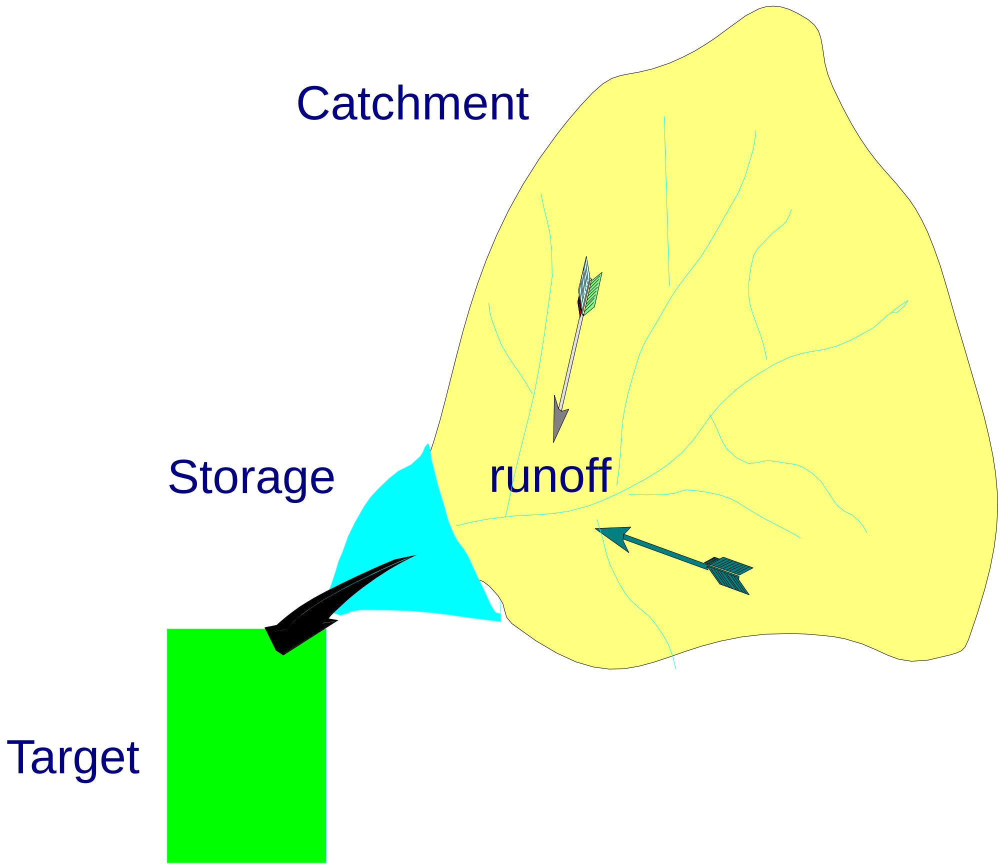


Macro & micro-catchments techniques

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

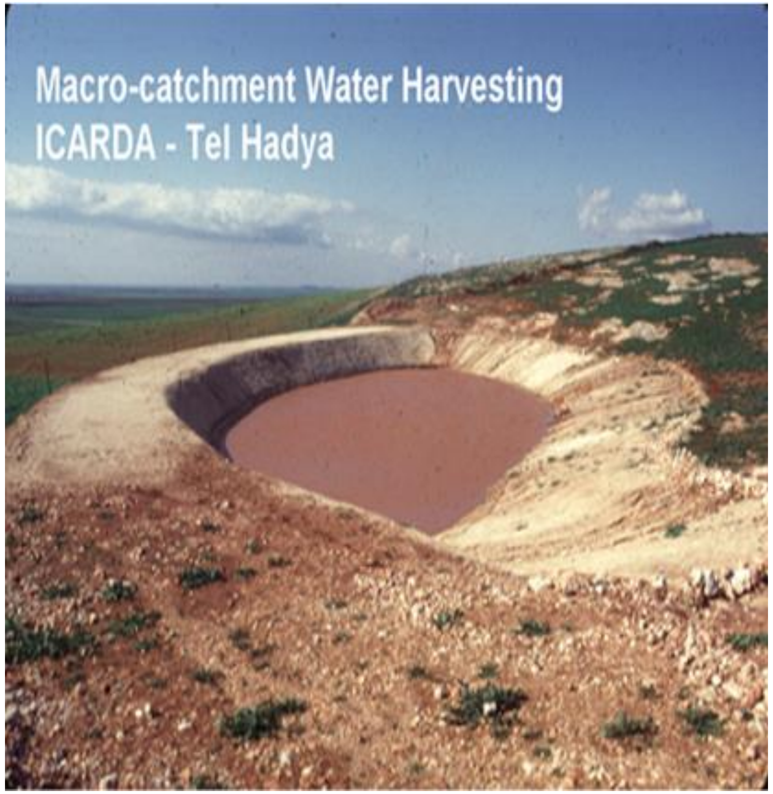
Macro-catchments rainwater harvesting

- 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

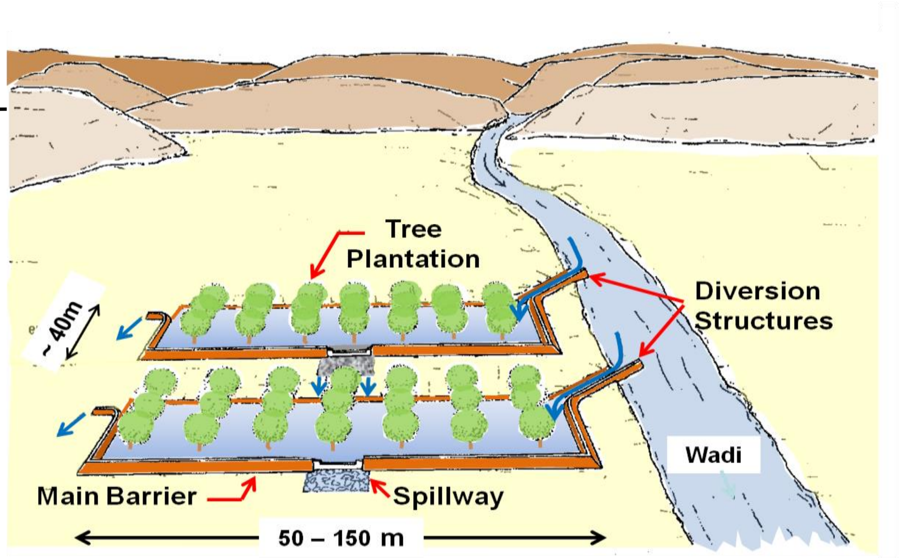
- Clearing or compacting the catchment
- Digging out the sediments inside the cistern
- Constructing a settling basin & a gravel filtering system
- Flushing first runoff and settling basin and filtering is essential
- Can install pump and refill the cistern if needed

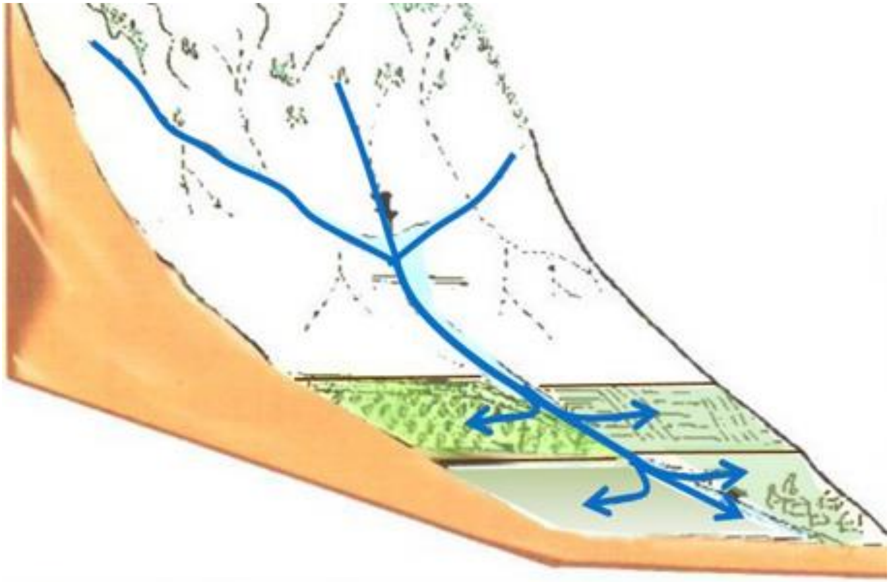
Wadi-bed systems

- 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

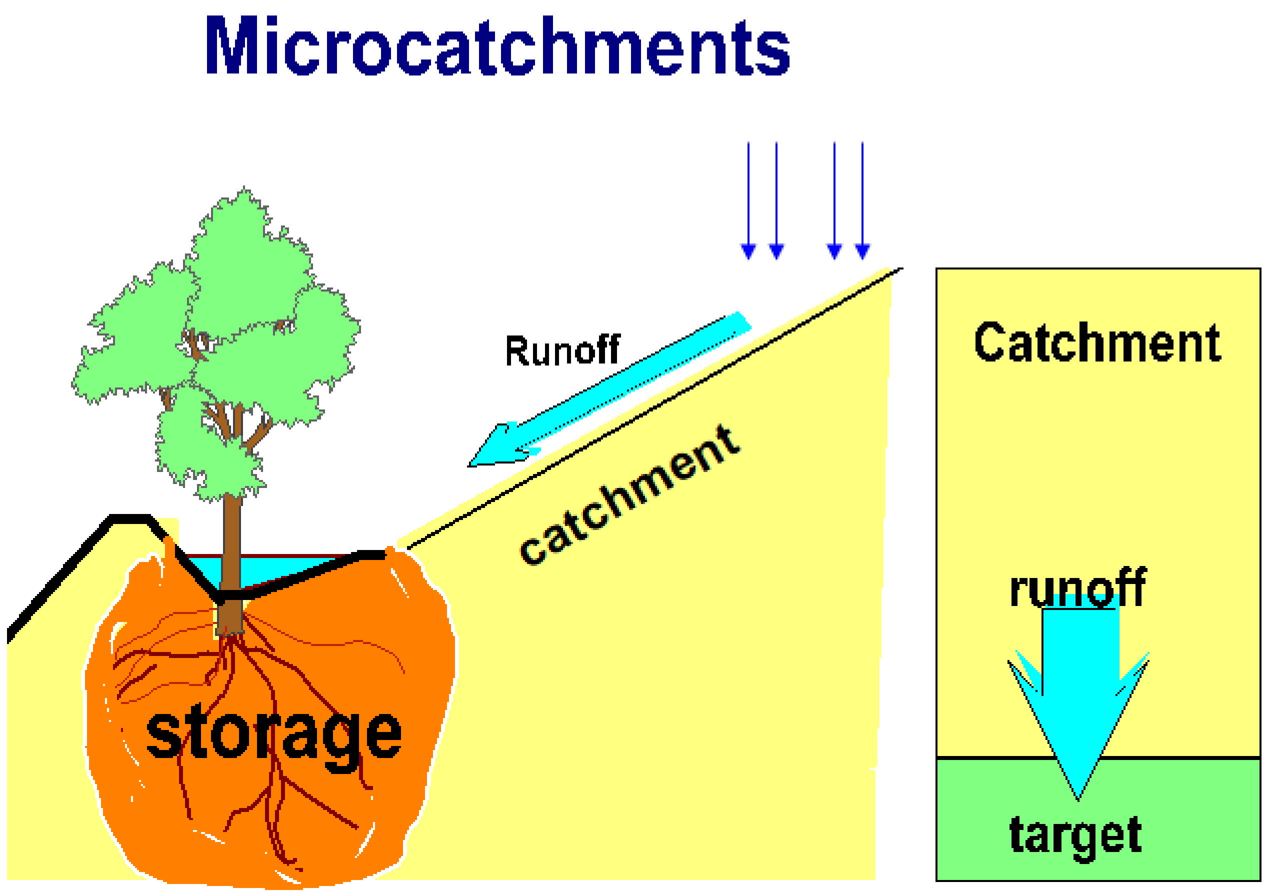
- Diversion structure to raise water level and divert
- Directing part or all of the water right and/or left
- Convey to agricultural lands on the side(s)
- Sediment can block the diversion canal inlet
- Check for upstream-downstream water rights





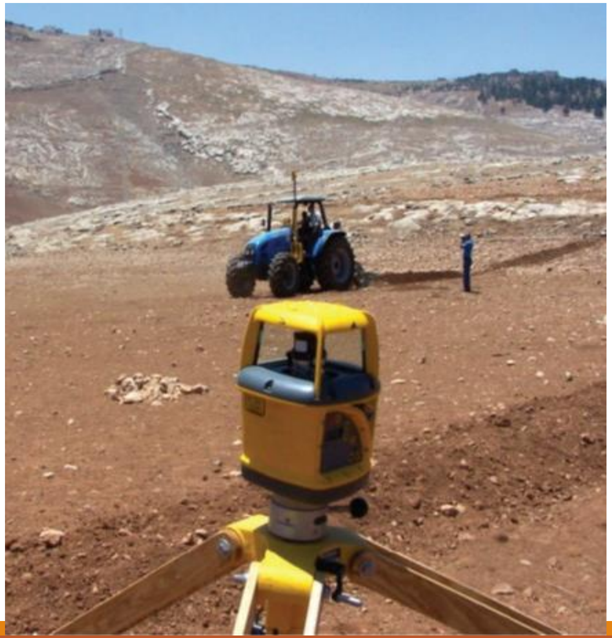
Micro catchment water harvesting techniques

- 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)

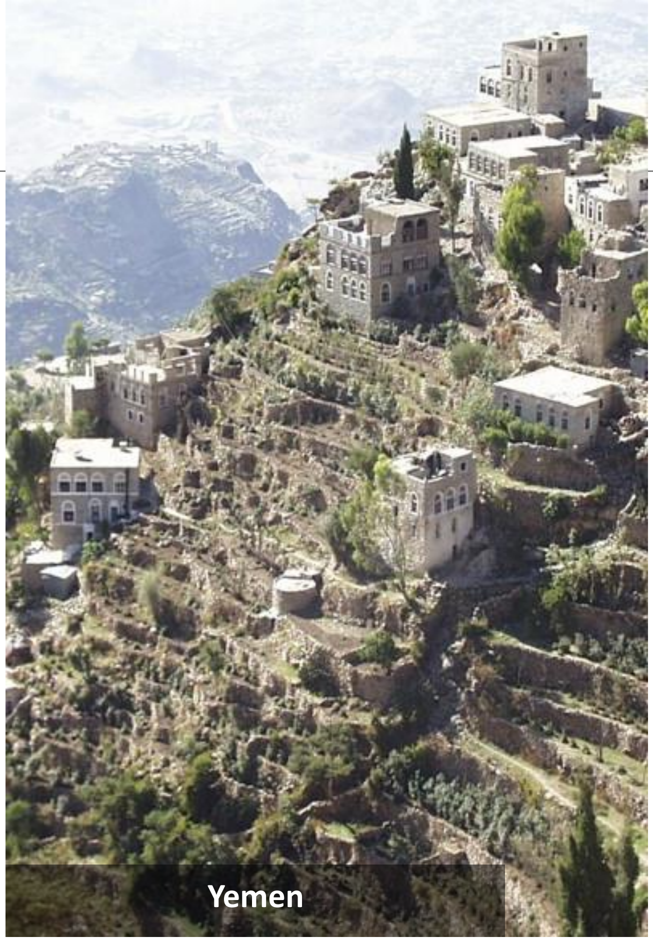
- Rectangular/diamond shapes
- Max slope should be along the diagonal
- Trees & shrubs planted at the lowest corner
- Usually done permanently. Issues of weeds control with no plowing
- The size depend of the slope, rainfall and crop water requirements

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

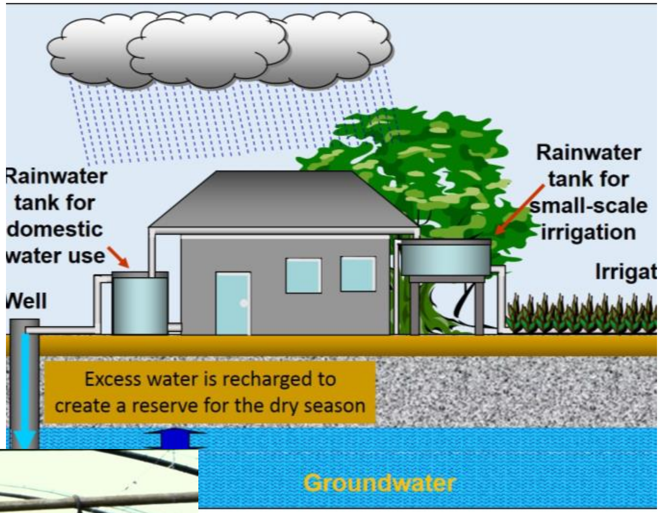
Roaded catchments

- 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

Review questions (1)

check all correct answers

A. Rainwater harvesting system is defined by:

1. Availability of a catchment
2. Occurrence of runoff
3. Having a mean of storage
4. Having a use for the water
5. All of the above

B. The following water harvesting systems can support agriculture?

1. Rooftop water harvesting
2. Contour ridges
3. Cisterns
4. Runoff strips
5. All of the above

C. Mechanization of micro-catchment water harvesting is good:

1. To reduce cost
2. To save water
3. To improve precession
4. To speed implementation
5. To enhance employment

Part 2:
Planning, designing and implementing water harvesting projects

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:

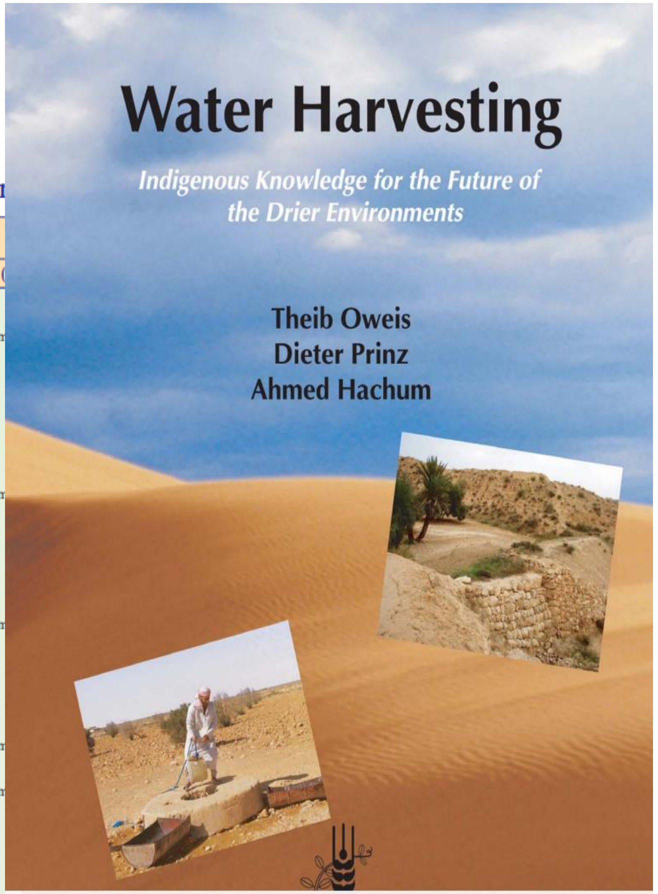
Oweis, T., D. Prinz, and A. Hachum. 2001. Water harvesting: Indigenous knowledge for the future of the drier environments. ICARDA, Aleppo, Syria. 40pp.

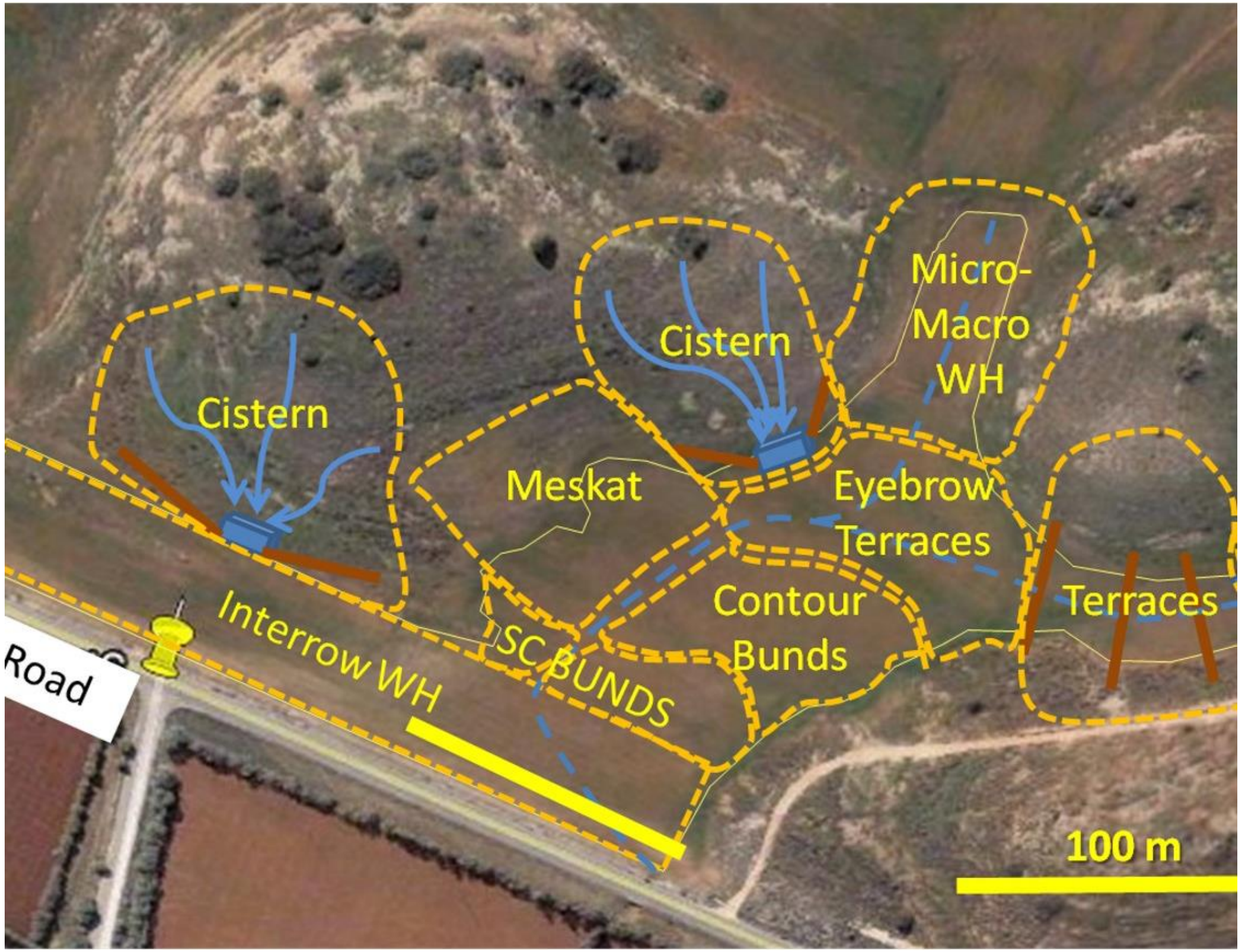
Document will be provided

Guidelines for Selecting Water-Harvesti[ng] Techniques in the Drier Enviro[nments]

Technique	Crop	Soil: Depth (1)	Soil: Texture	Land: Slope (2)	Land Cover: Vegetation (	Land Cover: Stoniness (4)	Socio-economics: Farm size (5)	Socio-economics: Capital (6)	Socio-economics: 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% [l]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.





Planning, designing and implementing water harvesting projects

Using google maps for planning water harvesting techniques

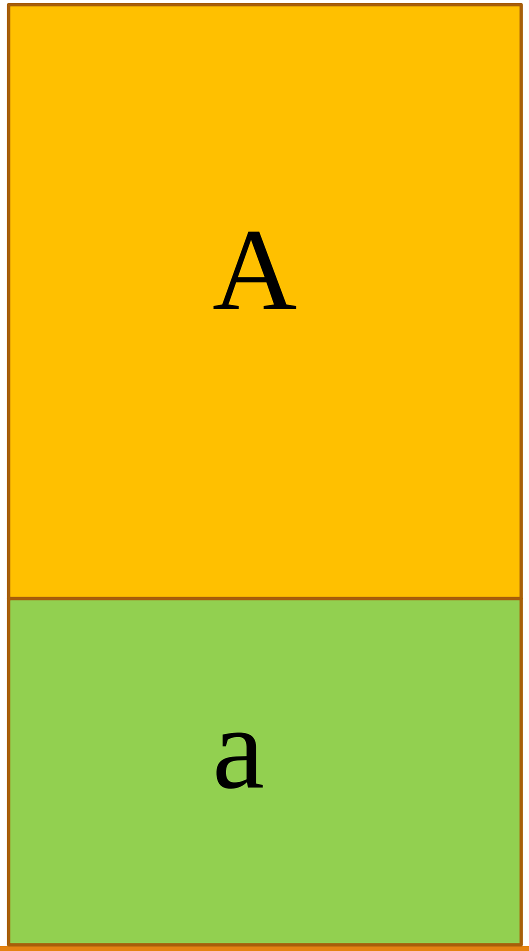
- On farm or at landscape scales
- Information on:
  - Topography
  - Crops
  - Rainfall storms amount and intensity
  - Soils physical properties
  - Runoff coefficients

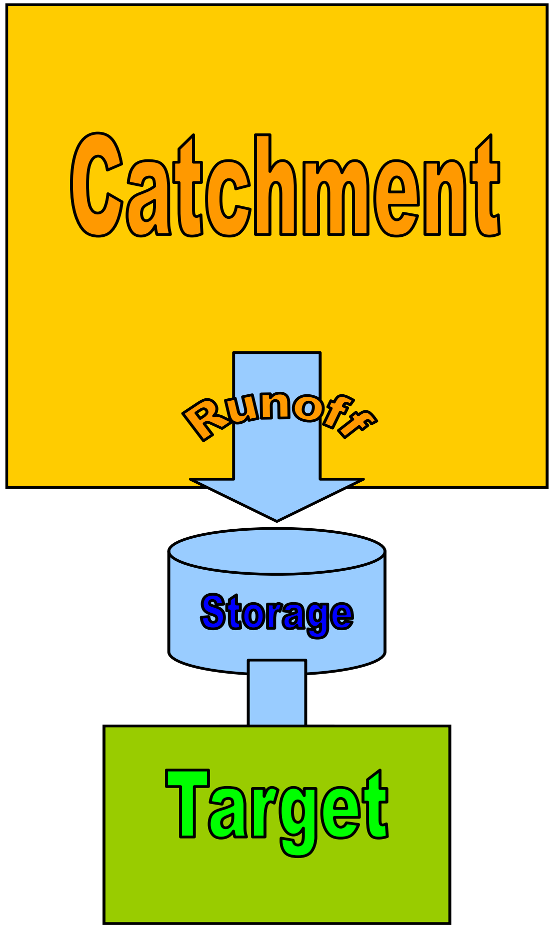
Planning, designing and implementing micro-catchments water harvesting projects

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)

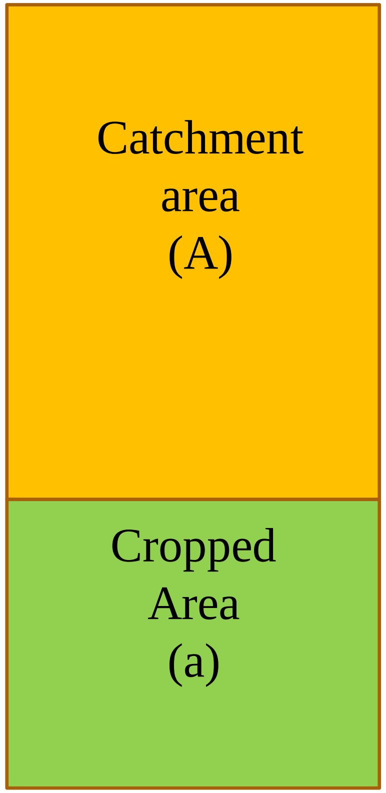
$V_{harvested} = A * R * Rc$ .... (2)

By equating (1) and (2):

$A * R * Rc = (ET – R) * a$ ....(3)

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

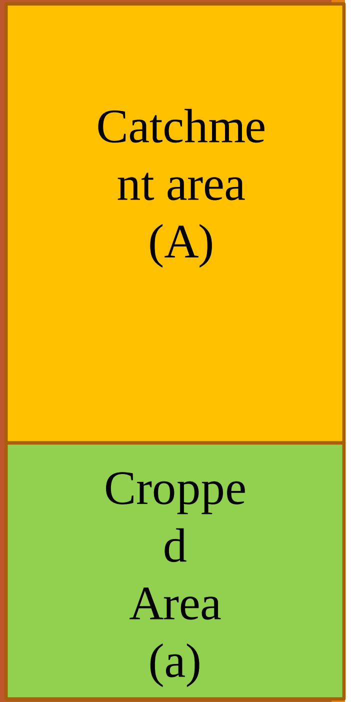
Total seasonal depth of water supplied to the cropped area = Direct Rain on the cropped area + (Volume of harvested water / cropped area)



Determining Catchment-Target ratio

Area ratio (A/a) for micro-catchment water harvesting:

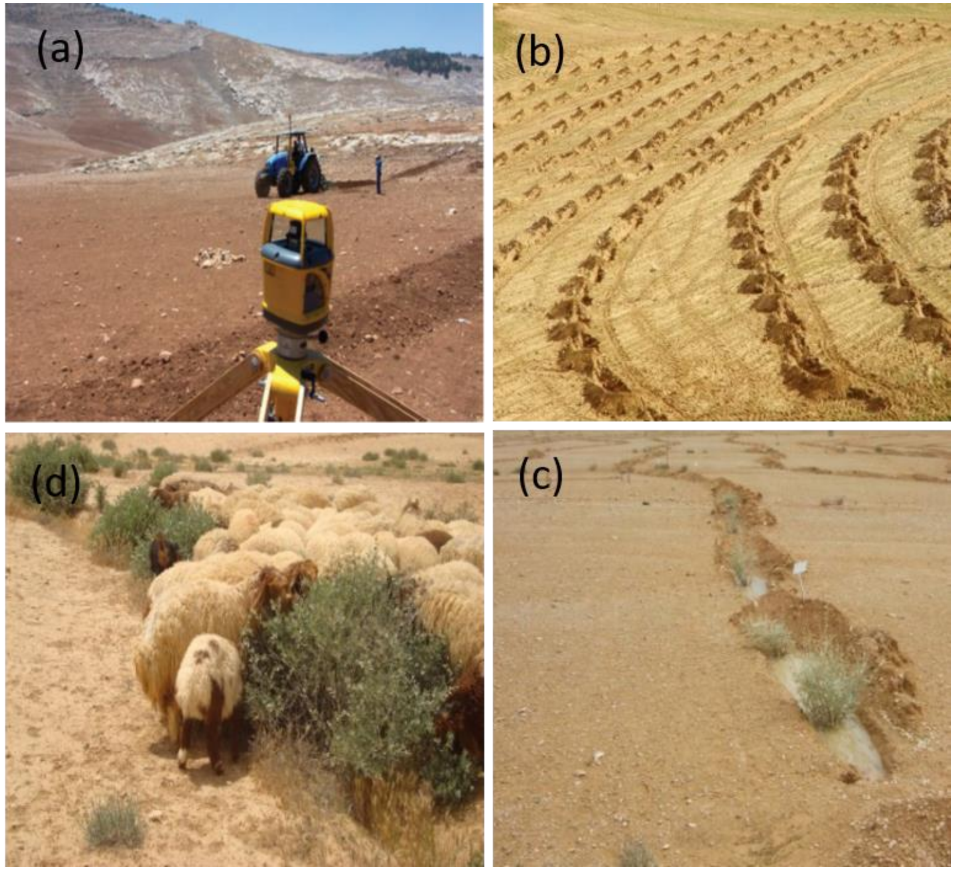
- 400 mm crop seasonal consumptive
- 160 mm mean seasonal rainfall
- Different runoff coefficients



Runoff Coefficient “ Rc”	Area Ratio A:a	Catchment Area “ A” per 100 m2 plot	Cropped area “a” Per 100m2 plot
0.5	3 :1	75 m2	25 m2
0.3	5 : 1	83.3 m2	16.7 m2
0.2	7.5 : 1	88.2 m2	11.8 m2

Implementation:
The rangelands restoration package development

- Package developed through research by ICARDA in partnership with NARC and local communities
- Based on mechanizing contour bunds and ridges by adapting the Vallerani implement to the badia conditions
- Laser guiding was added to avoid manual contour identification and cost
- 20-4 ha/day was possible to construct
- Cost per ha was 32 US$ when completed.



Implementation:
The rangelands restoration package elements

1. Site selection:
   - Annual rainfall from 100 to 250 mm
   - Soil depth of more than 60 cm
   - Slope from 1%-20%
   - Vegetation less than 25%

2. Agreements with farmers/land owners before bunds and contour ridges design (spacings) and construction is done before the onset of rain

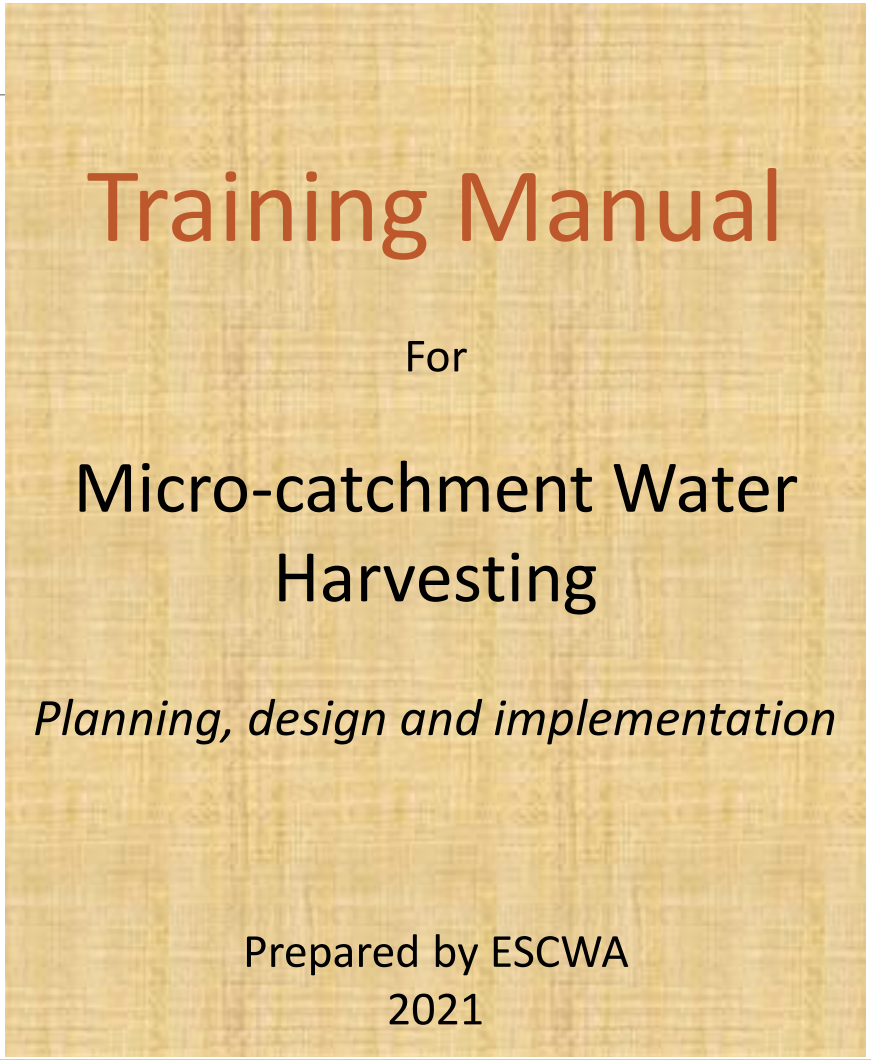
3. Indigenous shrubs seedlings be prepared in nurseries during the development year (should not exceed on year of age) and planted in the bunds immediately after the first rain and runoff

4. Site should be protected from grazing by farmers/owners for 2 years

5. After two years herds can be allowed with gradual numbers according to shrubs developing carrying capacity

Training manual for planning, design and implementation of Micro-catchment water harvesting

- Under development & should be ready in a month
- Will focus on planning, design and implementing micro catchment systems for agriculture
- Will use step by step procedure with examples from the region including:
  - Selecting the appropriate site
  - Collecting required information
  - Determining suitable crops and techniques
  - Determining runoff coefficients
  - Determining catchment target ratios
  - Layout of the system
  - Implementation
  - Maintenance
- Will include relevant illustrations



Review questions (2)
check all correct answers

A. Runoff coefficient is higher with:
1. Sandy soils
2. Steeper slope
3. Higher infiltration rates
4. Larger catchment
5. Longer period of rain

B. Spacings between contour ridges should be larger when:
1. Runoff coefficient is higher
2. Slope is larger
3. More livestock grazing
4. Rainfall is lower
5. All of the above

C. Vallerani rangelands restoration package may not perform well unless:
1. The site is properly selected with annual rainfall greater than 100 mm
2. The seedlings age is less than one year
3. The planting is made after the occurrence of first runoff
4. The site is protected for 2 years with proper grazing management afterwards
5. All of the above