ADAPTATION TO CLIMATE CHANGE IN THE AGRICULTURE SECTOR (IV)

Rainwater Harvesting

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Water Harvesting (WH)

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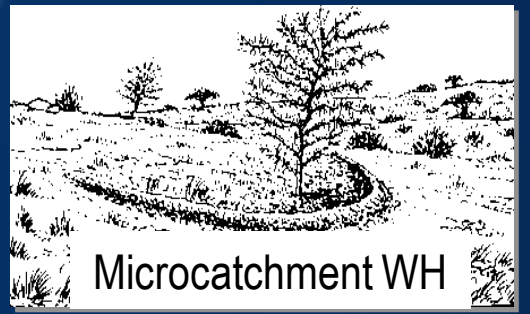
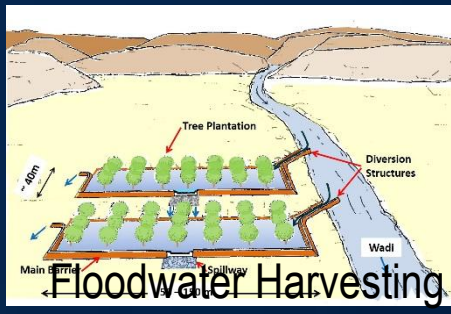


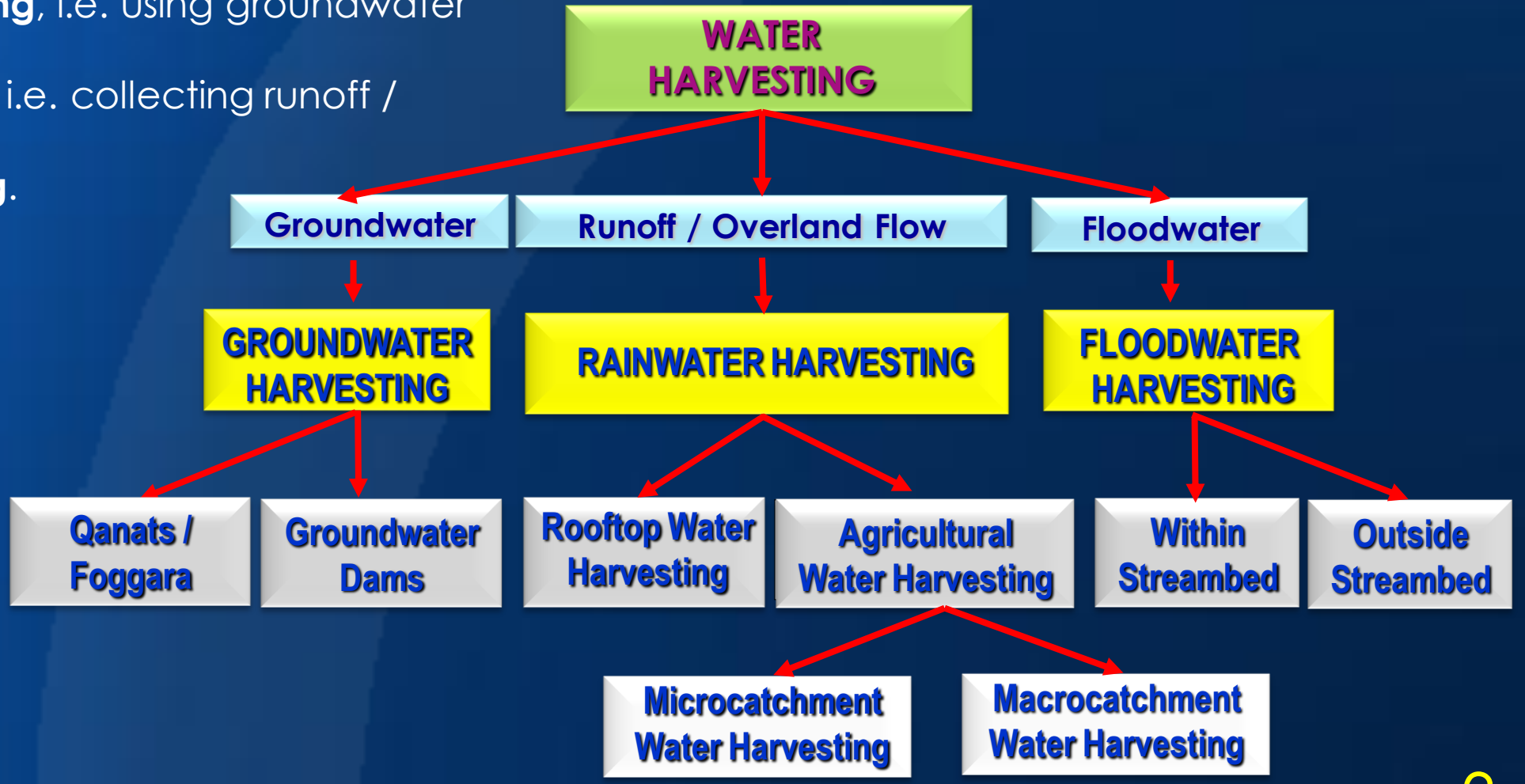


Rainwater Harvesting

Overview

The term '**Water Harvesting**' covers

- **Groundwater Harvesting**, i.e. using groundwater without lifting,
- **Rainwater Harvesting**, i.e. collecting runoff / overland flow, and
- **Floodwater Harvesting**.



Groundwater Harvesting

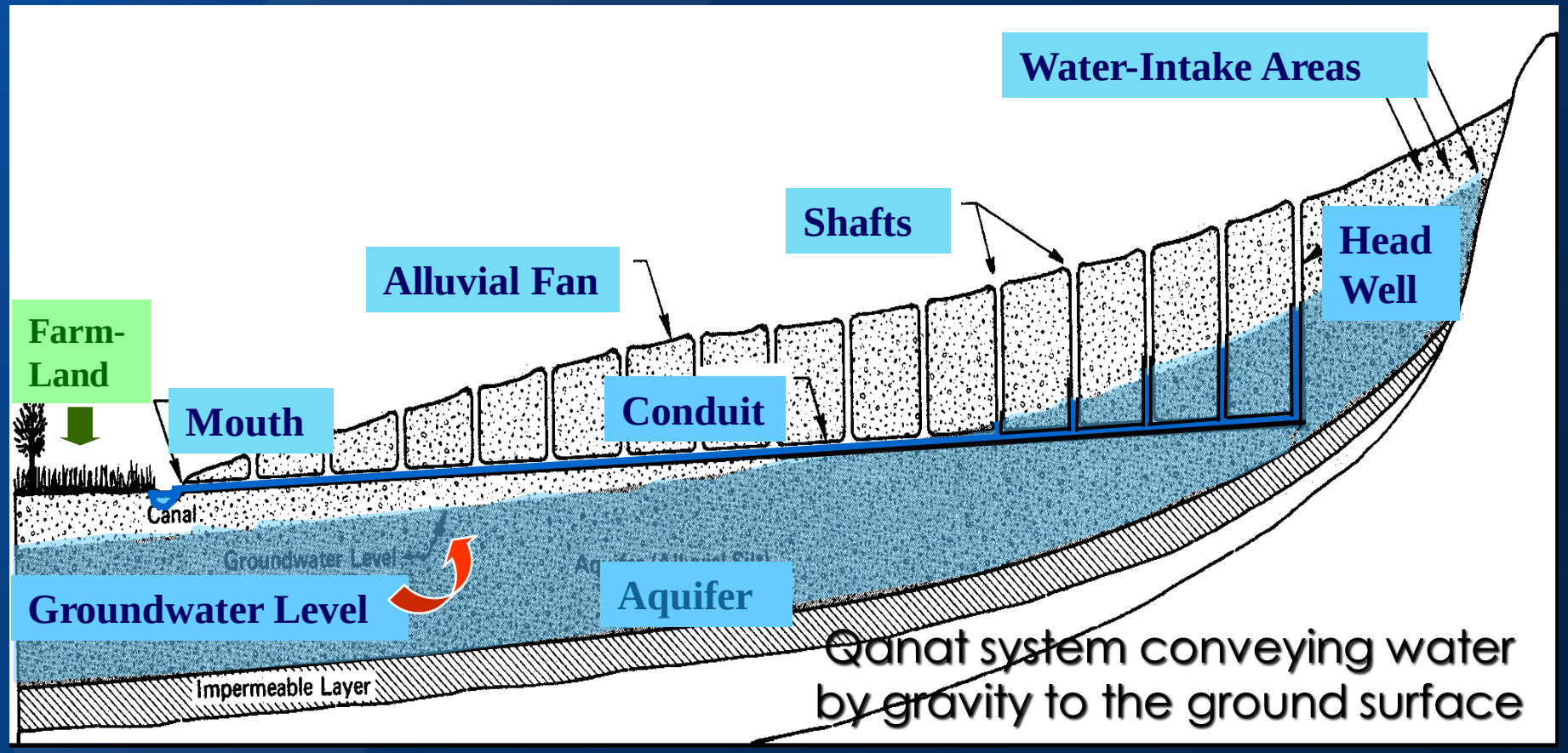
The term "Groundwater Harvesting" covers traditional and unconventional ways of groundwater extraction, e.g. by using groundwater without lifting it (Qanats) or by catching subterranean flow (Groundwater Dams).

Water Harvesting

Groundwater Harvesting / Qanats

Qanats: An ancient technique which finds renewed interest e.g. in Oman, Morocco etc.

- Qanat tunnels have a length of up to 30 km.
- Qanats can yield substantial quantities of water (5-60 l/s).
- However, many qanats have fallen dry due to a lowering of the groundwater table caused by tubewell installations.

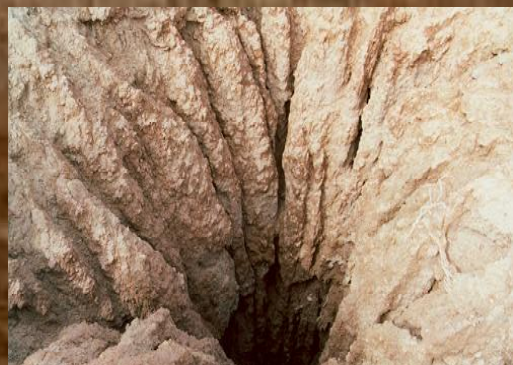


Qanat system conveying water by gravity to the ground surface

Water Harvesting

Groundwater Harvesting / Qanats: POLICY ASPECTS

- **Limiting the number of tube wells** to avoid a (further) lowering of groundwater table
- Promoting programmes to clean and **restore old qanats** (as in Oman and Morocco) and invest in their maintenance
- **Increasing the yield** of a qanat by initiating the construction of contour ditches in the **catchment** (water intake) **area** to facilitate infiltration.



Groundwater Harvesting / Groundwater Dams

Groundwater Dams

- The above-surface flow in wadis lasts for hours or days, whereas the groundwater flow within the wadi bed lasts for weeks.
- These dams offer numerous advantages of water storage e.g. very low evaporation, hardly any pollution, no breeding of mosquitoes.
- However, a precondition is that the wadi bed consists mainly of coarse sand (35 % water content), not of fine sand (5% water content).

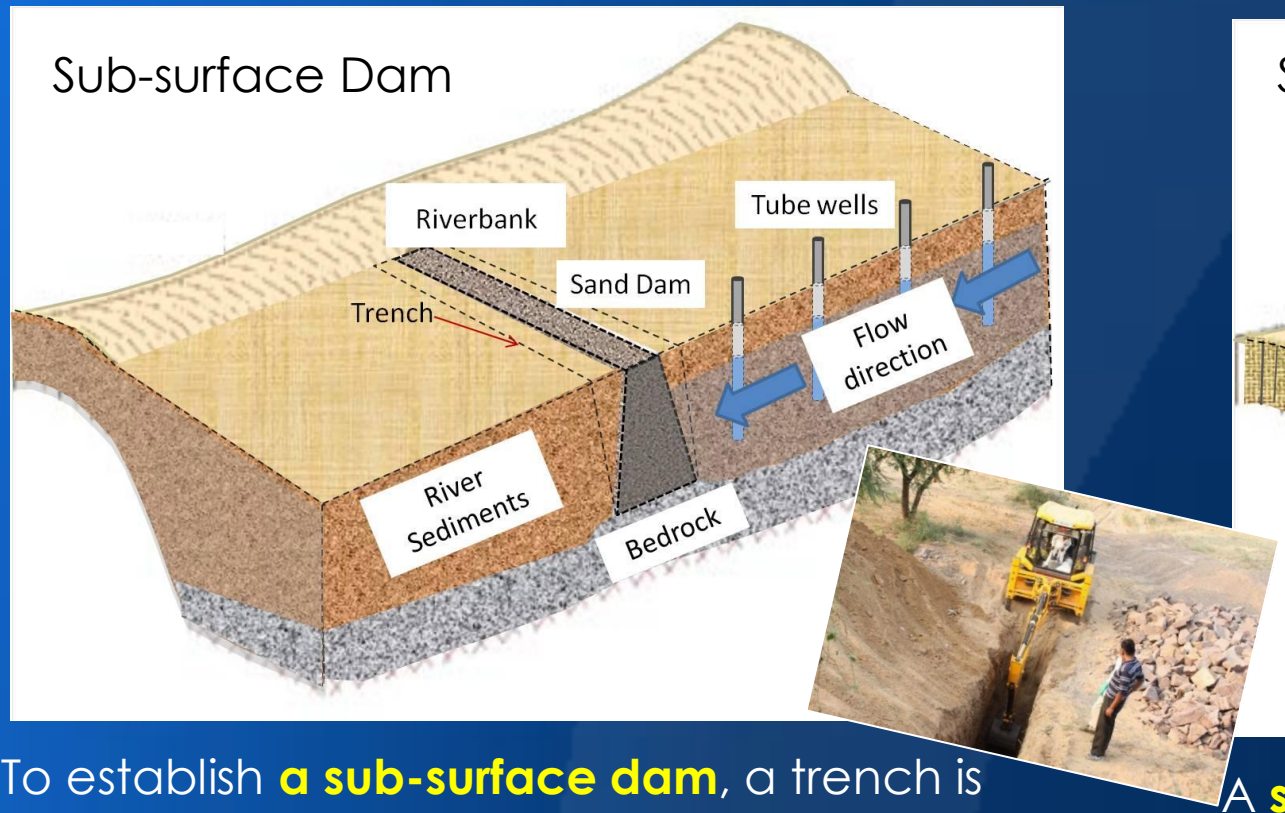
Groundwater dams are widely used in East Africa, Brazil etc., but hardly in MENA countries.

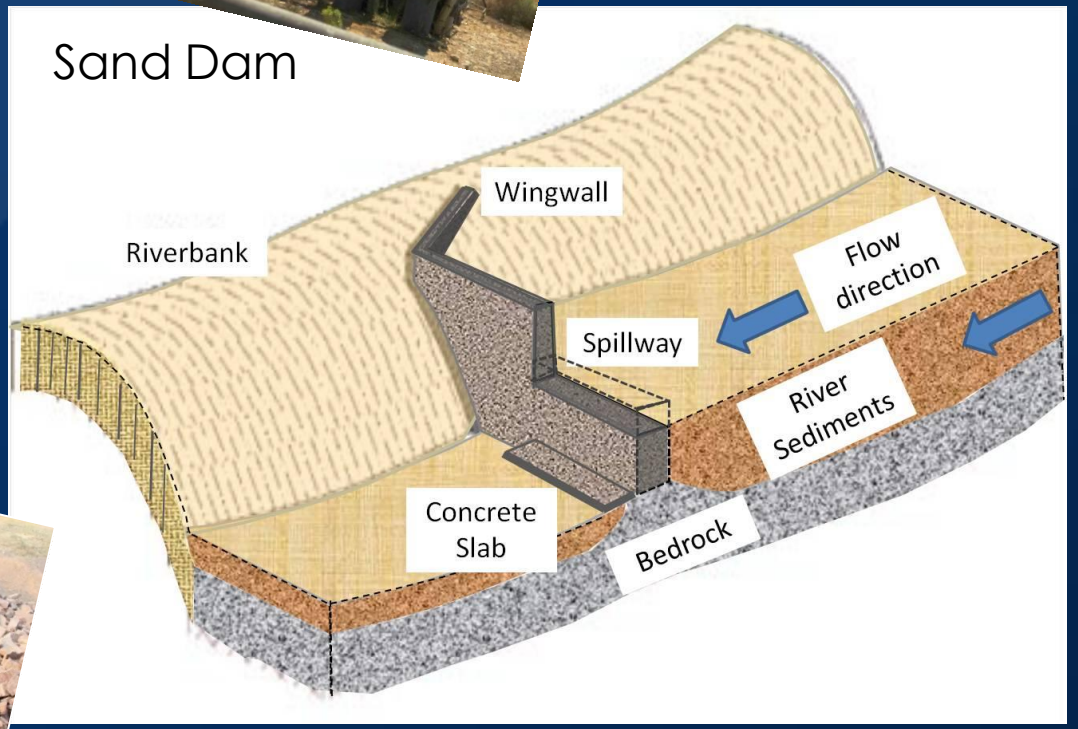
Sand Dam in Kenya
Source:
thewaterproject.org

Water Harvesting

Groundwater Harvesting / Groundwater Dams

We distinguish between two types of groundwater dams:





To establish **a sub-surface dam**, a trench is dug into the wadi sediment across a wadi bed, down to the bedrock.
The dam itself is built from stone or concrete; the work can be done by manpower or largely mechanized.

A **sand dam** is constructed in steps, generating accumulation of coarse sand upstream of the structure. An artificial aquifer is generated, which is replenished by floods in the rainy season.

Water Harvesting

Groundwater Harvesting / Groundwater Dams

An Example:
In Niger a groundwater dam was constructed by local communities under guidance and financed by an international NGO.

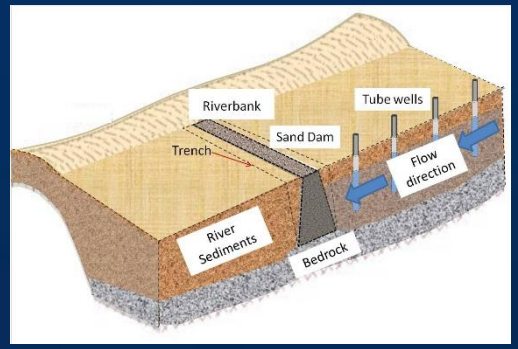
The dam was 120 m long and 2 meters high.

After a single flood, about 25000 m^3 of water had been accumulated (over a wadi length of 300 m).

Construction of a groundwater dam in Niger

Water Harvesting

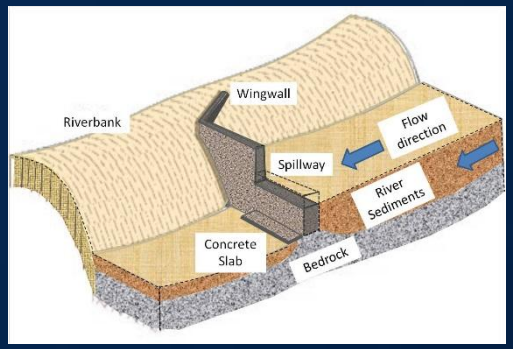
Groundwater Harvesting / Groundwater dams: POLICY ASPECTS



POLICY ASPECTS

There are good reasons to promote R&D in groundwater dams:

- Groundwater dams provide a reliable source of water for people in dry areas.
- They also help communities adapt to the effects of climate change.
- Groundwater dams can recharge groundwater levels, creating a buffer against drought in the long-term.
- The increased water table allows vegetation to grow and contributes to reverse the desertification process.



Rainwater Management

Rainwater is an underutilized resource. Too much of it evaporates unused from soil surfaces or in shallow depressions.

Rainwater Management

Introduction

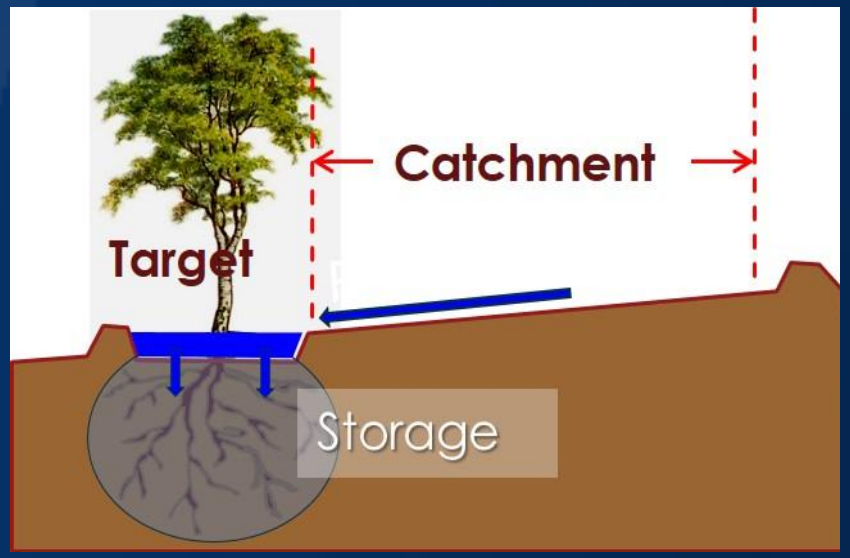
Rainwater Management

In-situ Water Conservation

Water Harvesting

The ‘in-situ’-water conservation techniques catch the rain where it falls and try to prevent any runoff

Water harvesting techniques even induce runoff to concentrate the water on part of the land.



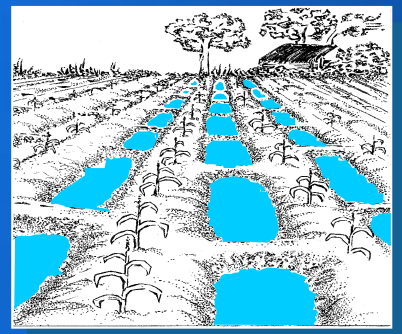
Rainwater Harvesting

Contents

Which solutions does Rainwater Management offer?

Rainwater Management

In-situ Rainwater Conservation



- Tied Ridges, Bunds and Stone Lines
- Ridges & Basins; Fanya Juu systems
- Earth basins & sunken beds, Zay technique
- Terraces

Drainage of Excess Water

- Drainage in Urban Areas
- Drainage in Rural Areas

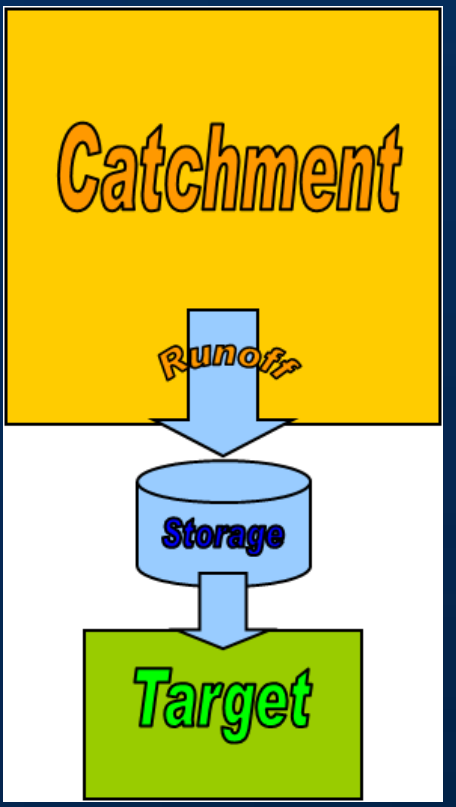
Rainwater Harvesting

- Water Harvesting in Agriculture
- Water Harvesting in Urban Areas
- Water Harvesting for GW Recharge

Rainwater Harvesting

In ‘Rainwater Harvesting’ we distinguish between:

- **Rooftop** Water Harvesting
- **Micro**catchment Water Harvesting and
- **Macro**catchment Water Harvesting,
  depending on catchment size.



Rainwater Harvesting I

Rooftop Water Harvesting

Rooftop and Courtyard Water Harvesting' describes installations on and around buildings to facilitate rainwater collection.
Uses: drinking water / domestic water, irrigation (e.g. in greenhouses) or for groundwater recharge.

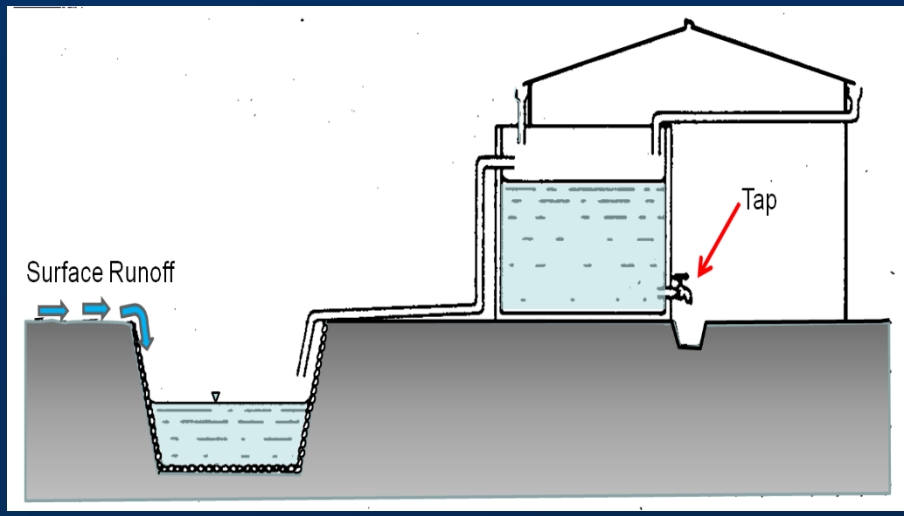
Water Harvesting

Rooftop Water Harvesting

Rooftop (and courtyard) WH systems are recommended in areas receiving an average of more than 200mm/a precipitation.

A runoff coefficient of 70 to 90 % from rooftops (including greenhouse areas), depending on roofing material and inclination, can be expected.

The storage tank:
Exclusion of vermin and mosquitoes
Exclusion of light to prevent algal growth
Some ventilation to prevent anaerobic decomposition of washed-in matters
Sufficient structure strength and easy access for cleaning



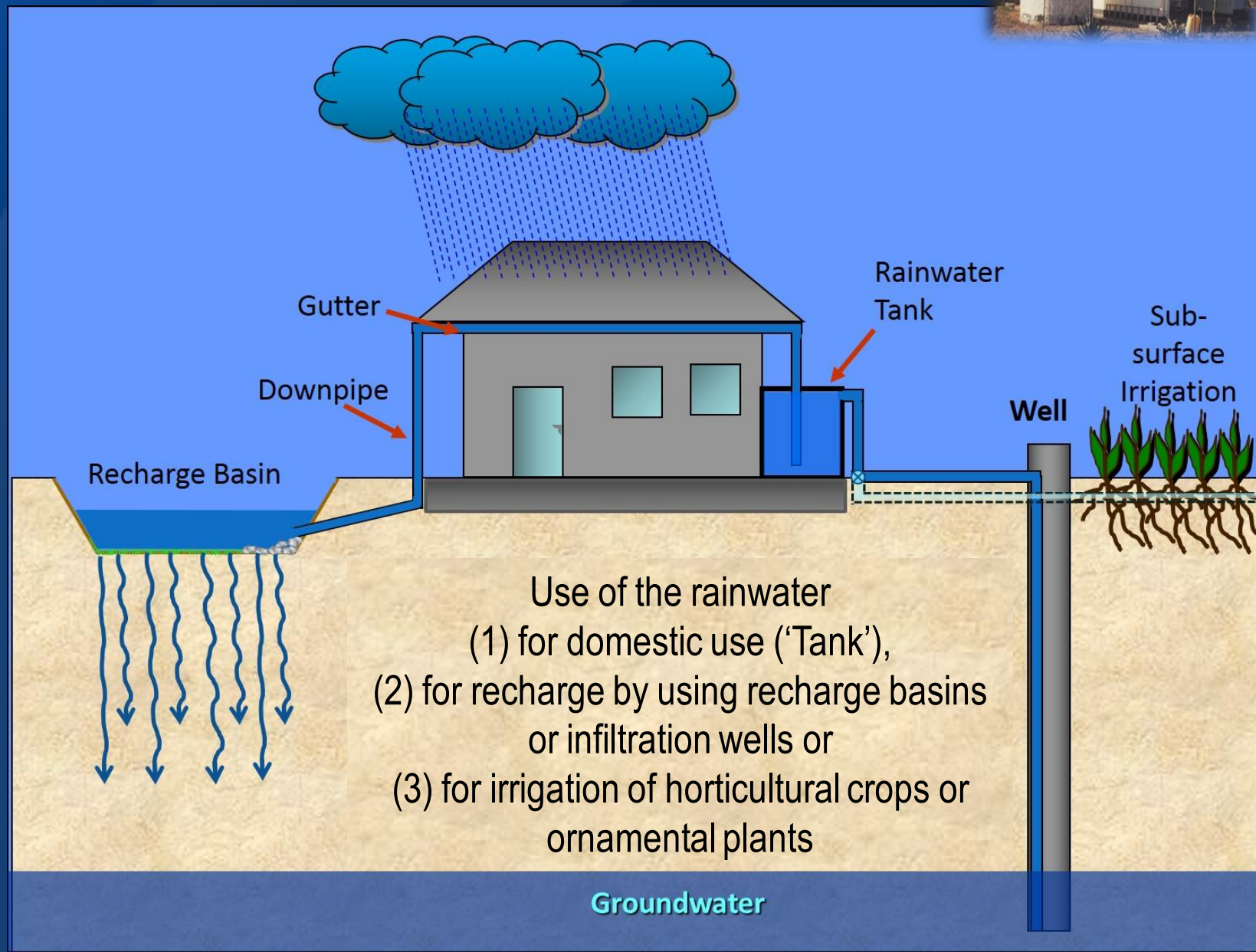
Two-tank system used to store water harvested from house roofs for domestic use and water from courtyard surfaces for gardening purposes

Source: Pacey and Cullis (1986).

Water Harvesting

Rooftop Water Harvesting

Rainwater from rooftops can be used for a variety of purposes as shown in this schematic drawing.



If the water is not used for irrigation or recharge, but e.g. for domestic purposes, a ‚first-flush' device has to be installed.

Water Harvesting

Rooftop Water Harvesting

Rainwater Harvesting for outdoor purposes – a simple calculation

Assumptions

Area of the roof (A) = 100 m^2

Average annual rainfall (R) = 300 mm = 0.3m

Runoff coefficient (C) = 0.85

Annual water harvesting potential
= A*R*C = 100*0.3*0.85 = 25.5 m^3

Dry period of the year = 245 days; = 104 l/day available

There are no specific water quality requirements in regard to rainwater use for outdoor purposes.

Water Harvesting

Rooftop Water Harvesting

Greenhouses are very well suited for harvesting rainfall. The rain can be stored in tanks or in ponds.

Rainwater tank collecting rain/runoff from greenhouses (Lebanon).

The location is NE of Jounieh, Central Lebanon, 300 – 350 m asl.

Rainwater from greenhouse-tops is collected in this lined pond. The stored water is used for greenhouse drip irrigation (Lebanon)

Water Harvesting

Rooftop Water Harvesting: POLICY & CCA ASPECTS.

POLICY & CCA ASPECTS

Information and incentives are needed to equip as many buildings as possible, particularly new ones, with WH devices (1) to secure water supply and (2) to avoid floods by stormwater.

Climate Change Adaptation (CCA): Larger tanks for water storage to bridge dry spells are needed.

Rooftop WH has got a potential to cope better with the impacts of climate change.
Preconditions are:

- Suitable laws and regulations
- Credits or subsidies or tax exemption
- Storage tanks and other devices at an affordable price
- Demonstrations and applied research
- Skilled personnel for the hydrological & engineering planning
- A well trained and motivated Agricultural Extension Service.

- If water is supplied by Government at very low cost, hardly any farmer or city dweller will invest in water harvesting..

Rainwater Harvesting II

Agricultural Water Harvesting

- **The basic principle of agricultural water harvesting:**
- to capture precipitation falling on **one part of the land** and
- transfer it to another part (**'target area'**),
- thereby increasing the amount of water available to the **latter part**.

Water Harvesting

Agricultural Water Harvesting

- There is a long tradition of Rainwater Harvesting (RWH) in MENA countries

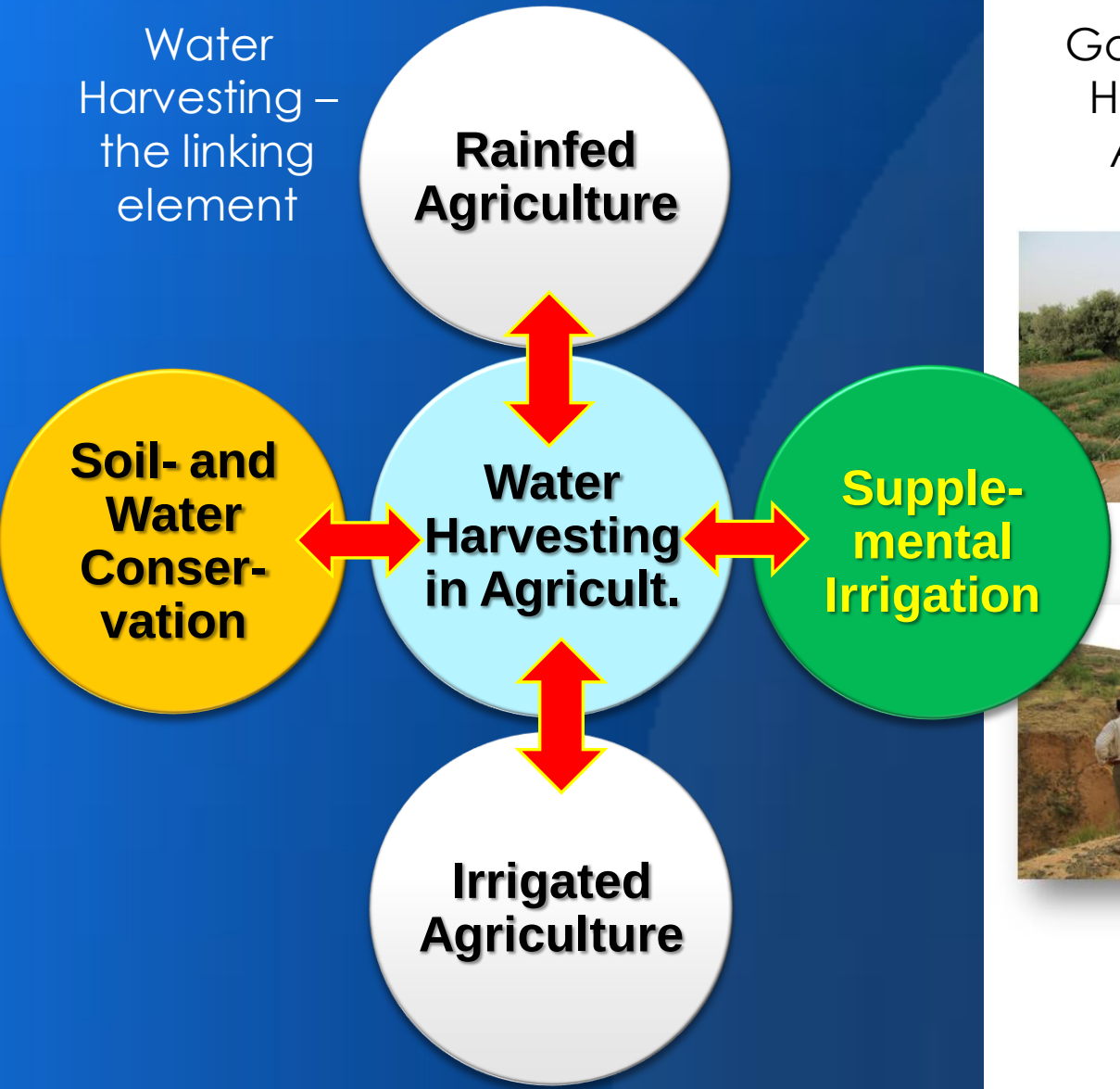
The earliest water harvesting structures are believed to have been built 9000 years ago in the Edom Mountains in southern Jordan to supply drinking water for people and animals

NW Libya

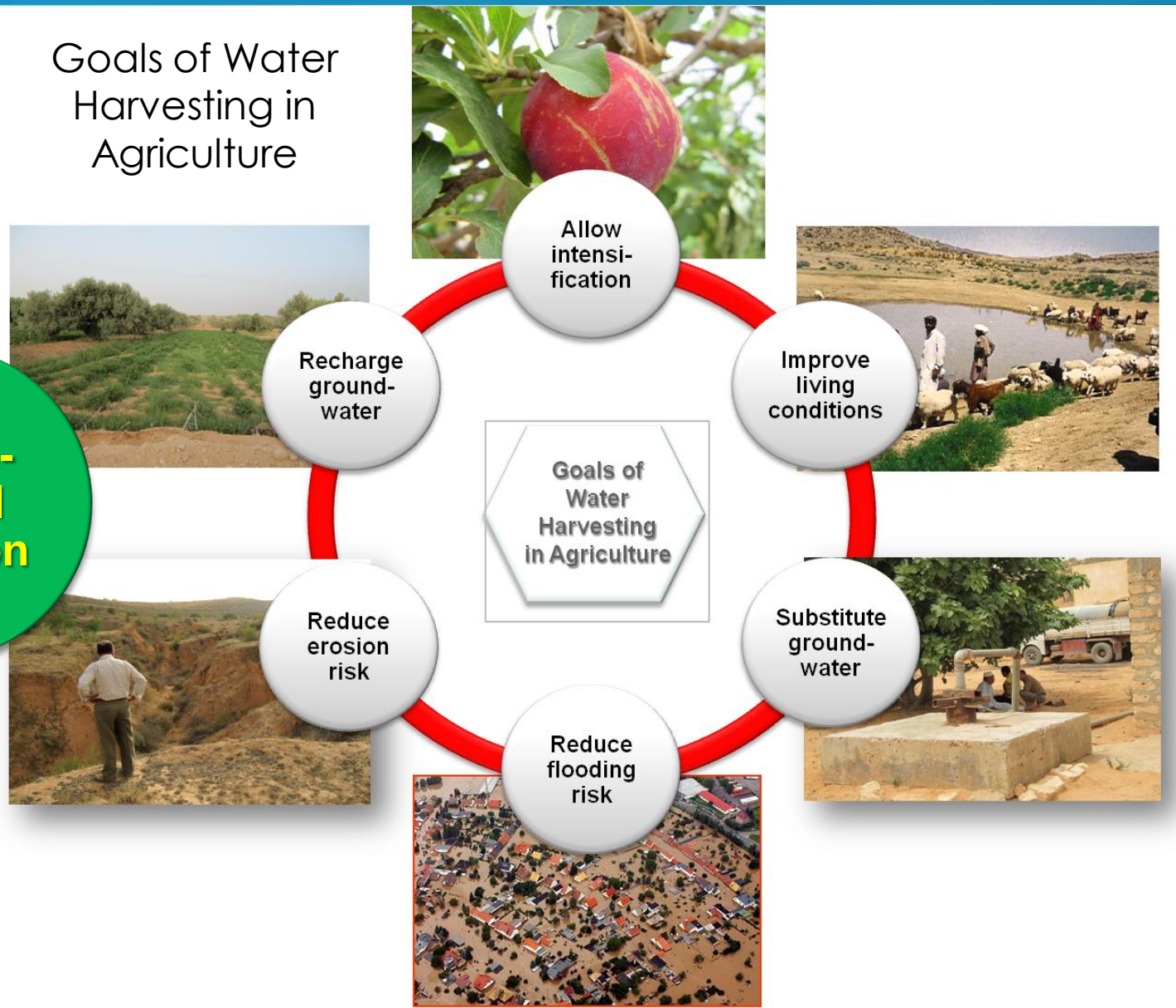
Water Harvesting

Agricultural Water Harvesting

Water Harvesting – the linking element

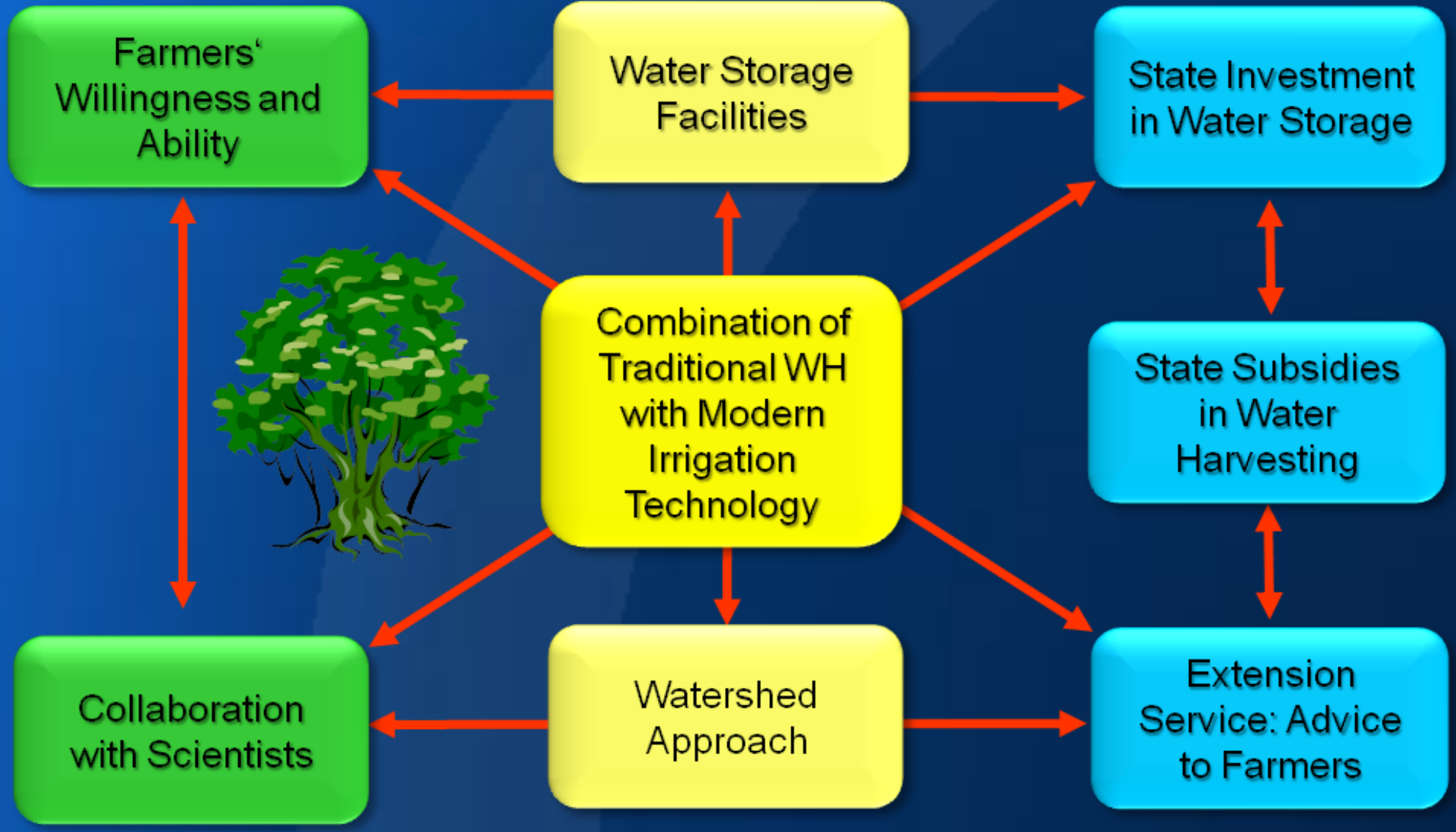


Goals of Water Harvesting in Agriculture



Water Harvesting

Agricultural Water Harvesting

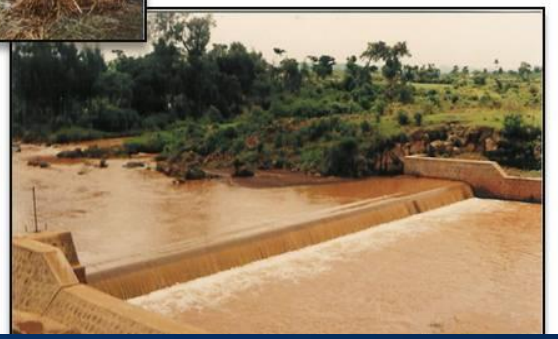


Water Harvesting Overview

Water Harvesting Methods

Method : **Microcatchment** Water Harvesting , mainly from solid surfaces (house tops, greenhouses, roads , etc.)
Catchment Size: ~ 100 – 500 m^2, on-farm types ≤ 1000 m^2
Storage Types: Tanks, cisterns , ponds

Method: **Macrocatchment** WH; surface runoff is collected at foot of slope
Catchment Size: 0.1 – 200 hectares
Storage Types: Ponds, hafirs , hill lakes



Method: **Floodwater Harvesting** (Spate Irrigation); Floodwater is diverted from wadi
Catchment Size: ≥ 200 hectares
Storage Type: Reservoirs

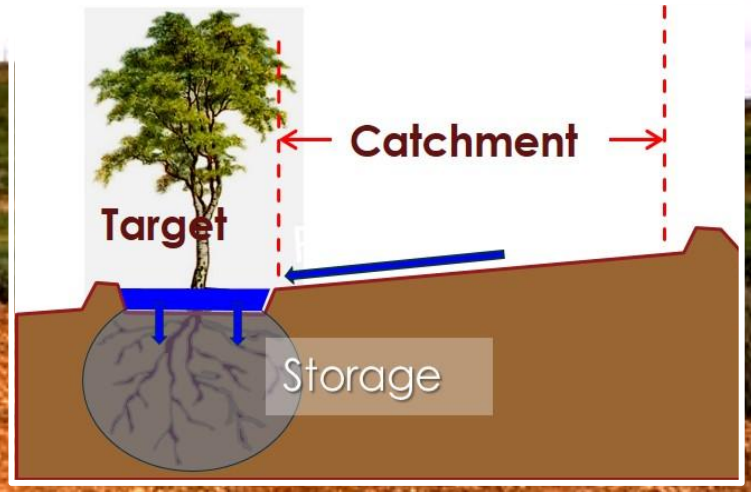
Rainwater Harvesting II

Microcatchment Water Harvesting

'**Microcatchment WH**' comprises a wide range of on-farm, small-scale agricultural WH techniques.

Water Harvesting

Microcatchment Water Harvesting



- **Surface runoff from a small catchment area is stored in the root zone of an adjacent infiltration basin.**
- **Basin is planted with a single tree/ bush or with annual crops.**
- **Size of catchment is 2 m² - 500 m² and**
- **Catchment to Cropping area Ratio (CCR) is from 1 : 1 to 25 : 1**

- **Simple** in design
- May be constructed **at low cost**
- Techniques are **easily replicable** and adaptable
- They have **higher runoff efficiency** than macro-catchment systems
- No **water conveyance** system is needed.
- There are **systems suitable** to any slope and crop

- **Treatment of catchment surface:** Compacted, treated with chemicals or covered with plastic sheets

Negarim WH Technique

Water Harvesting

Microcatchment Water Harvesting

Advantage : The farmer has got the control within his farm over both the catchment and the target areas

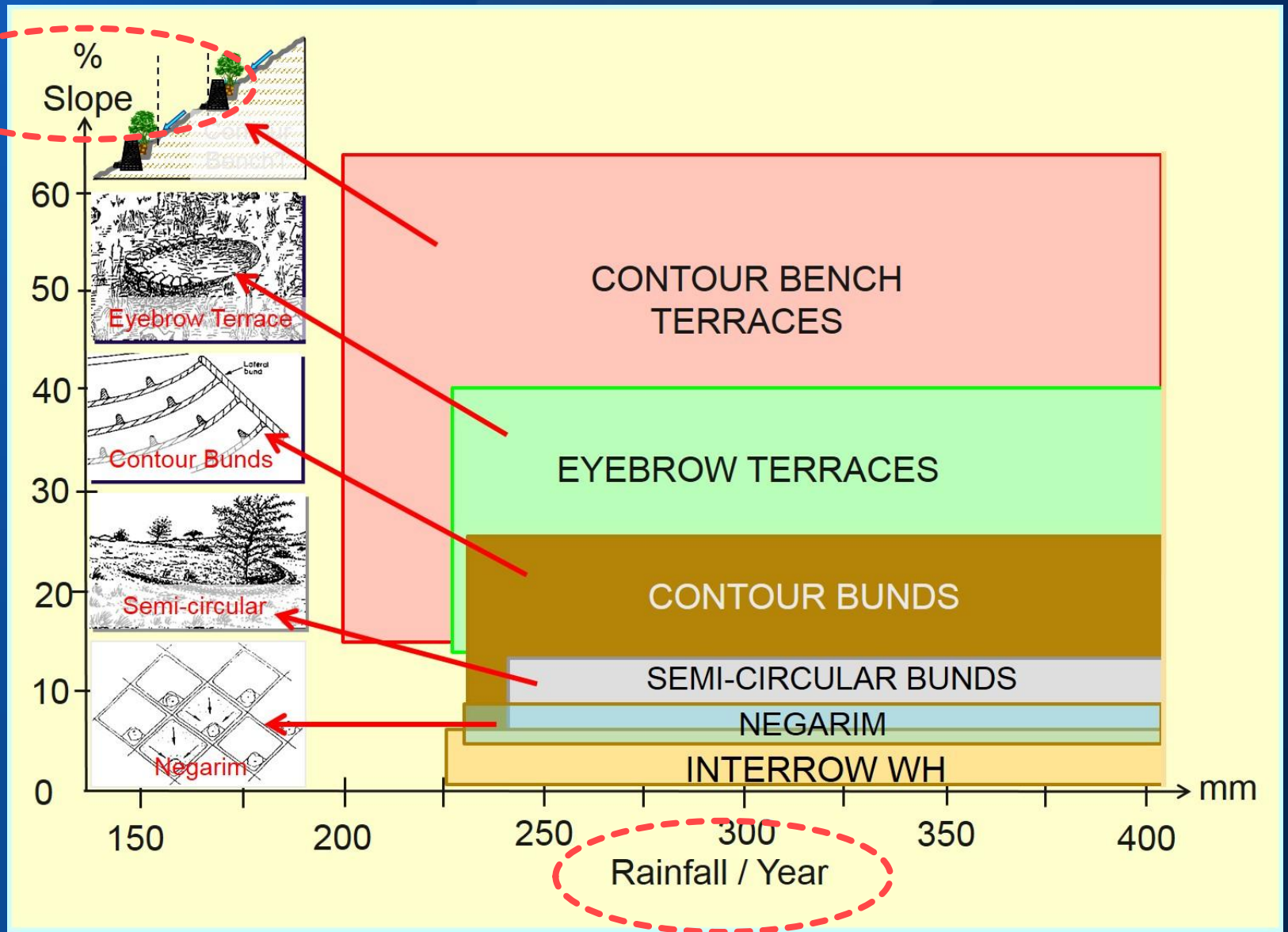
Disadvantages: The catchment in this system occupies part of the farm area, and farmers will accept this only in drier environments.

There are techniques, which need a **high labour input** in construction and maintenance (e.g. **Semicircular Bunds**‘)

The ‚**Vallerani-WH** Technique‘ however needs **high capital input** for the fully mechanized construction, but little maintenance.

Water Harvesting

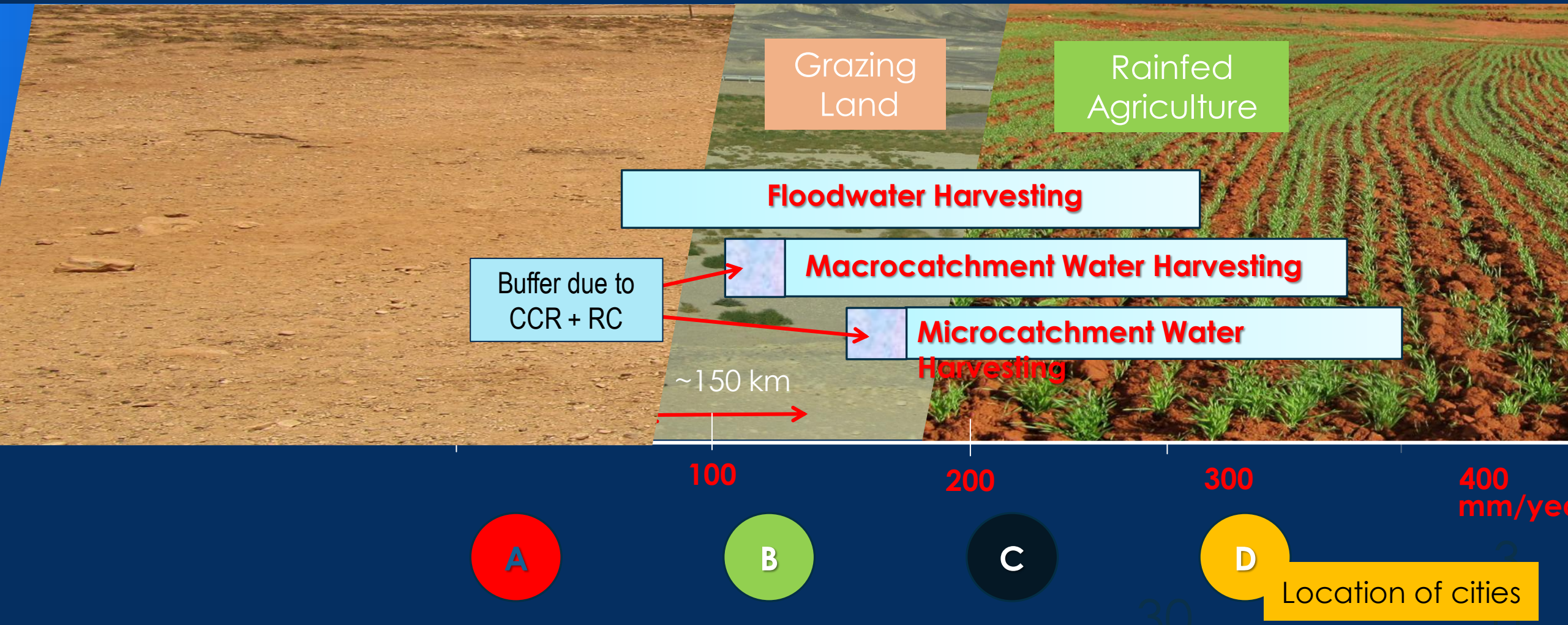
Microcatchment Water Harvesting



Suitability of some Microcatchment Water Harvesting Techniques according to Rainfall and Slope Conditions

Movement of ecological belts within the next 50 years

WH techniques can retard the impacts of climate change due to the ‚buffer' of larger Catchment to Cropping Area Ratios (CCR) and a higher Runoff Coefficient (RC)



Water Harvesting

Microcatchment Water Harvesting

- **CCR:** Under the impacts of climate change, the **ratio between catchment and cropping area** (CCR) has to be enlarged, proportional to the **increase in temperature** and the irregularity of rainfall.

- **The enlarged CCR** contributes to **a retardation of climate change impacts.**

- **RC:** A high **runoff coefficient (RC in %)** is of utmost importance.
- **The runoff coefficient** is the percentage of precipitation that appears as runoff; it depends on rainfall characteristics, soil surface, soil type, slope, and vegetation.

- **Lower annual rain amounts and higher rain intensities,** as predicted for the coming decades, **demand well compacted catchment areas,** which will need careful maintenance

Water Harvesting

Microcatchment Water Harvesting

- **The minimum annual rainfall** amounts under winter-rainfall (Mediterranean) conditions are **200 - 250 mm/a.**

- Availability of **Supplemental Irrigation** reduces the cropping risk, rendering the use of **micro- and macrocatchments possible at lower minimum rainfall amounts** and allowing **a wider choice of crops.**

- **Minimum soil depth for annual crops should be 0.6 m, for trees 1.0 – 1.5 m.**

- The **stronger** the impacts of **climate change**, **the deeper and more fertile the soil** of the selected site should be to allow **more water to be stored,** and growing conditions to make best use of the available water.

Water Harvesting

Microcatchment Water Harvesting

Eyebrow Terraces

Terrace?

Terrace?

Combination with Soil & Water Conservation measures

Optimizing the use of rainfall is **impossible without incorporating soil and water conservatio**n in the planning process

Rainfall and overland flow has to be **caught and stored**, but may never accumulate in the valley to cause soil erosion

As the risk of **soil erosion** rises with augmenting impacts of climate change, a **conjunctive use** of **soil & water conservation** (SWC) and **water harvesting**, coupled with **storage** of excess water, becomes indispensable.

Water Harvesting

Microcatchment Water Harvesting

Preconditions for the implementation of Microcatchment WH are:

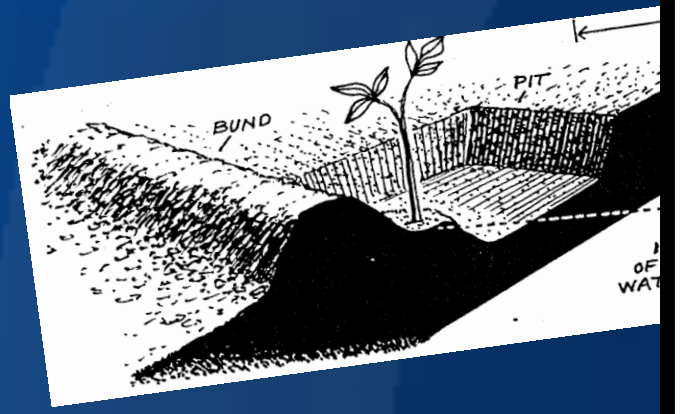
- **Willingness of the farmers to protect the land and to make optimal use of land and water resources**
- **Financial capacity of the farmers to invest and long-term economic profitability of the implemented measures**
- **Knowledge of the farmers regarding the adequate application of the various measures, on improved farming methods (fertilization, pest control etc.) and finally on marketing of the harvested produce.**
- **Availability of well motivated and well trained agricultural extension staff for training and organization**
- **Cooperation within the watershed to join forces in stabilizing the deep erosion gullies and to overcome the problem of soil erosion within the watershed in general.**

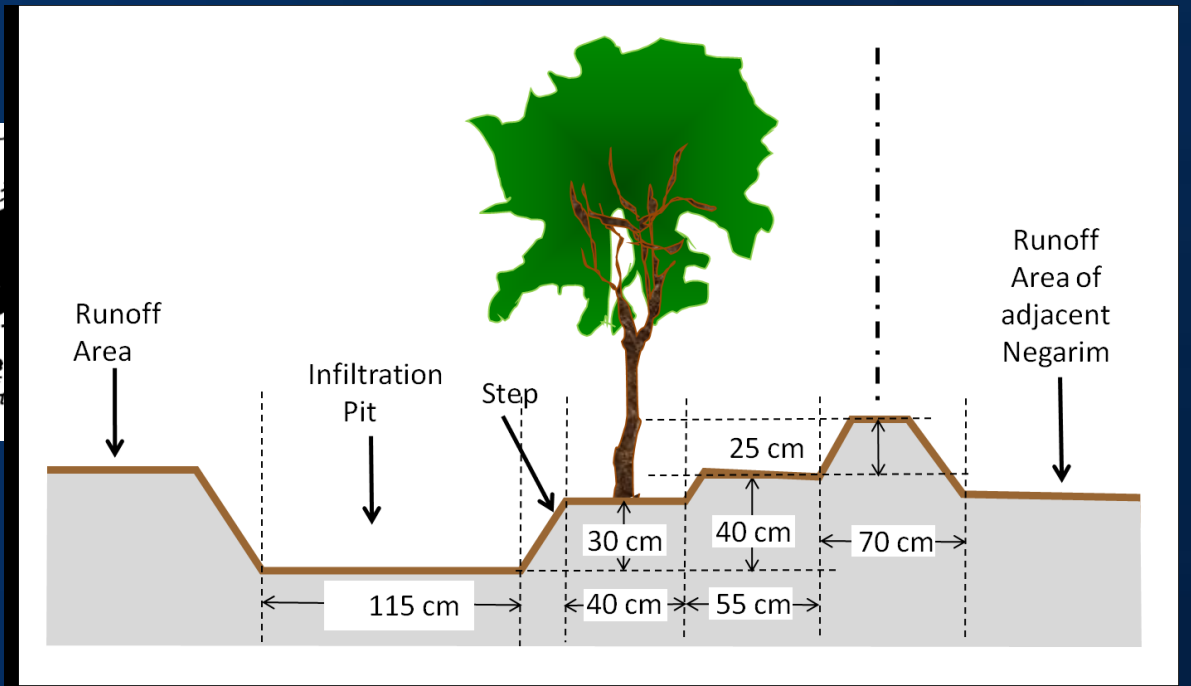
Water Harvesting

Microcatchment Water Harvesting: Policy & CCA Aspects

Climate Change Adaptation (CCA):

Higher rain intensities and **more erratic rainfall** will demand
(a) application of more soil conservation measures within and around the micro-catchments,
(b) raised and strengthened bunds,
(c) trees to be planted on steps to avoid waterlogging,
(d) perpendicular bunds in contour systems to avoid break of contour bunds,
(e) a larger soil depth than presently to increase water storage capacity.
(f) The application of more soil conservation measures within and around the macro- and microcatchments





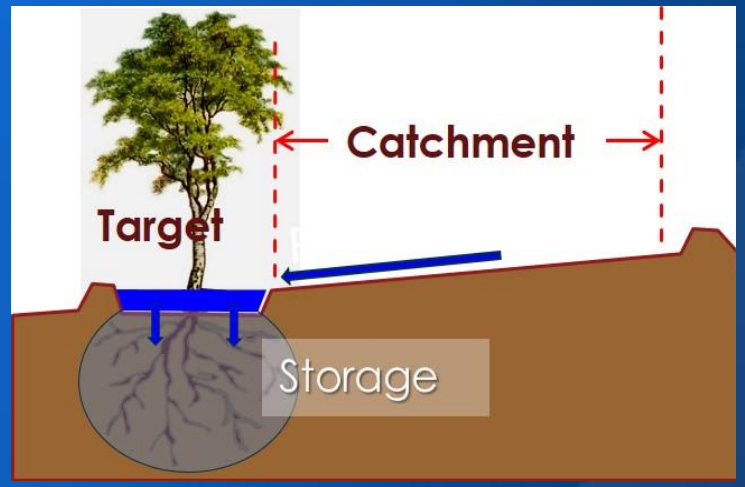
Rainwater Harvesting

Macrocatchment Water Harvesting

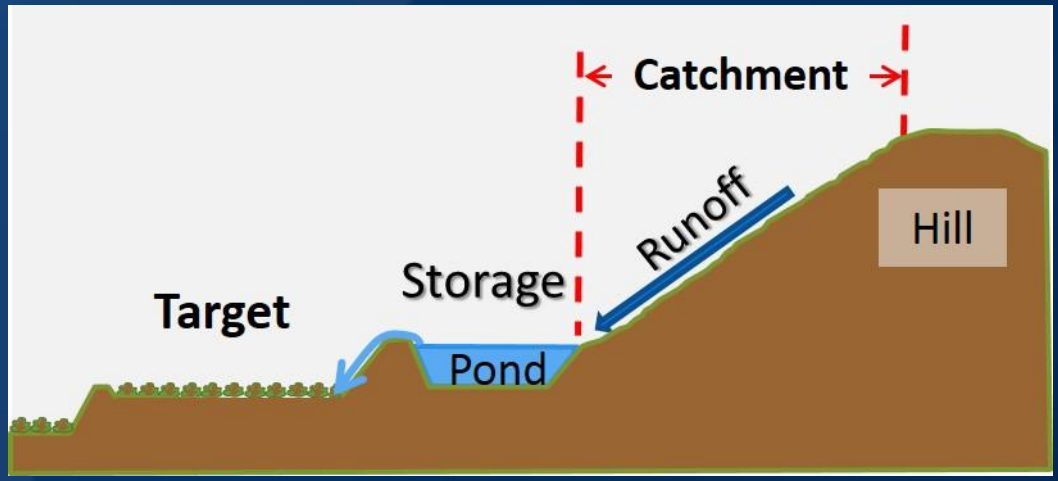
This method is also called "water harvesting from long slopes" or "harvesting from external catchment systems". Runoff from hillslopes is conveyed to the cropping area located at the hill foot on flat terrain.

Water Harvesting

Macrocatchment Water Harvesting



Microcatchment WH

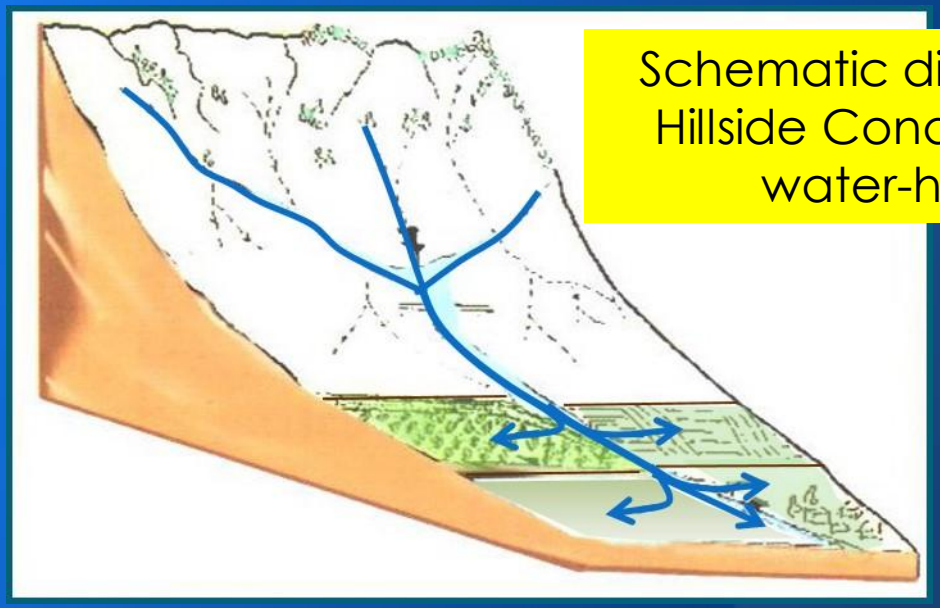


Macrocatchment Water Harvesting

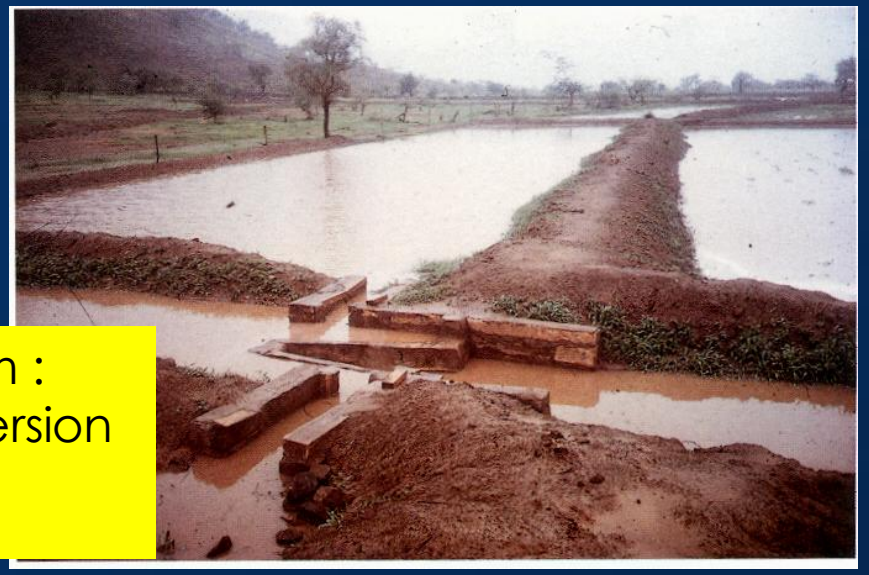
In **Macrocatchment systems**, the collected **water** is normally **stored in the soil**. **Alternatively** a **pond or a small reservoir** may catch the runoff and store it for **supplemental irrigation** either during long dry spells within the rainy season or to **prolong** the growing season.

Size of catchment is from **1000 m²** to **200 ha;** CCR: 10:1 - 100:1

Macrocatchment Water Harvesting: Hillside Conduit Systems



Schematic diagramme of a typical Hillside Conduit macrocatchment water-harvesting system.



Hillside conduit system : Flooded fields with a diversion structure

Source: Klemm 1990

- The method can be used **for nearly any crop**
- Hillside conduit schemes **require proper design** and **high labour input** and probably **the assistance of consultants**
- Hillside conduits need **provision for disposal of surplus water**

Water Harvesting

Macrocatchment Water Harvesting: The Liman Type

The Liman Type

Liman in Tunisia. The bund has a height of about 1.3 m

A flooded liman (150 mm/a)
The trees
(*Eucalyptus occidentalis*)
are 4 years old
Source: H. Loewenstein

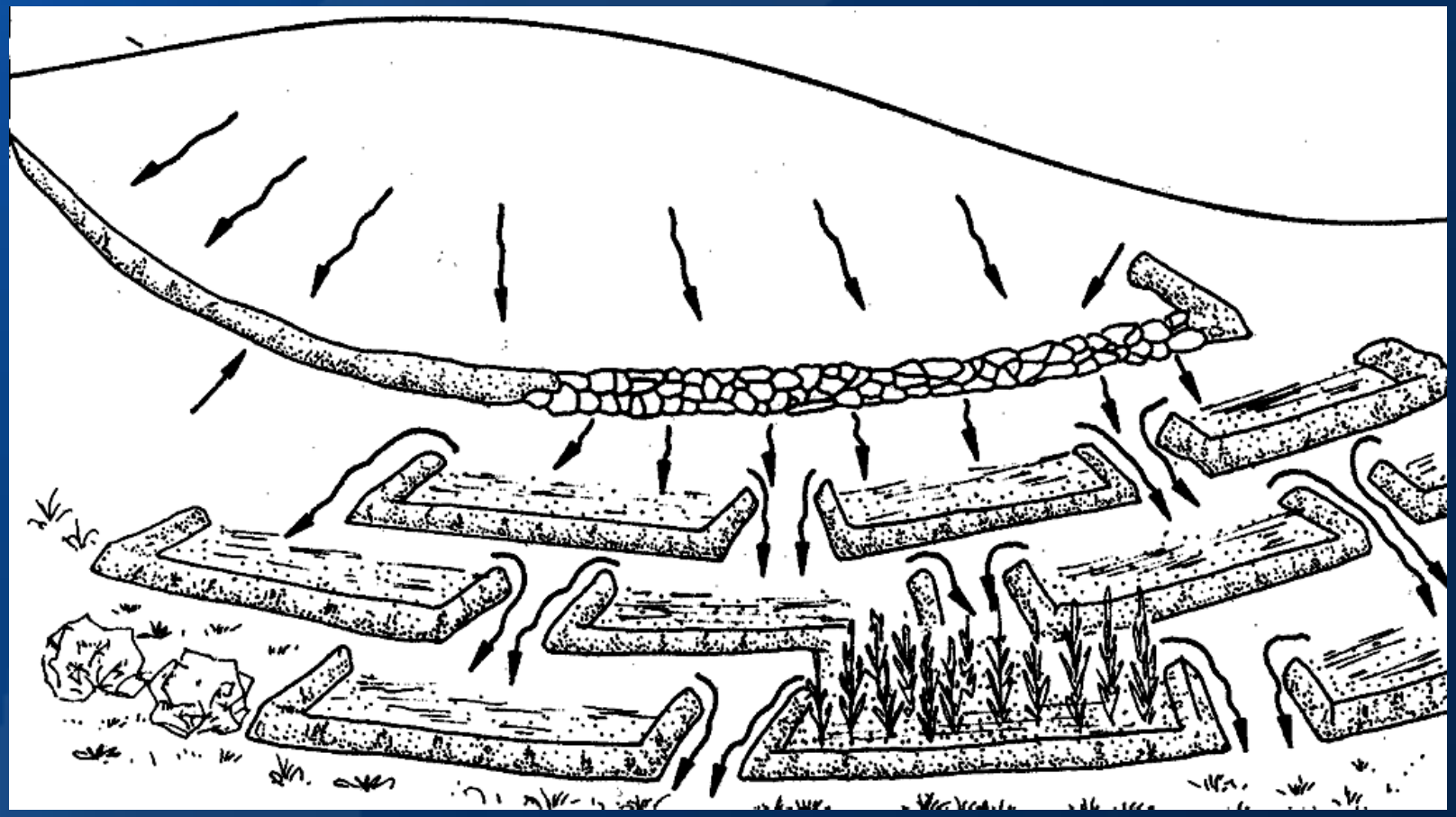
The plants must withstand drought and flooding (up to 1 week)

5 year old liman
Source: H. Loewenstein

Water Harvesting

Macrocatchment Water Harvesting

There are many more macrocatchment techniques in use, also combinations of macro- and microcatchment systems



Combining macro- and microcatchment systems

Source: Tabor and Djiby 1987

Macrocatchment Water Harvesting: CCA Aspects

CCA ASPECTS

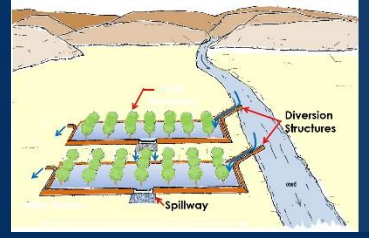
There is a wide range of **possible adaptation measures** for macrocatchments:

Higher **water demands** of people, crops & livestock due **to higher temperatures** have to be met

- by an **increase in catchment area** and/or by increasing runoff coefficients on catchment areas
- by a **higher water use efficiency** (e.g. using an efficient water supply system, cultivating crops in greenhouses, keeping other **growing conditions** (e.g. soil fertility) at high level, covering the soil (in the cropping area) with plastic or organic mulch etc.)
- by an **increase in storage volume**.

Higher rain intensities and a more **erratic rainfall** demand

- a larger **catchment-to-cropping-area ratio** and
- a **strengthening / raising of water harvesting structures** (diversion structures, bunds, dams, walls)
- provision of **more water storage in ponds** for **supplemental irrigation**.



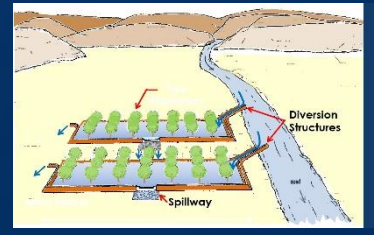
Rainwater Harvesting

Floodwater Harvesting

Floodwater harvesting systems require more complex structures of dams and distribution networks and a higher technical input than the other two water harvesting methods.

Water Harvesting

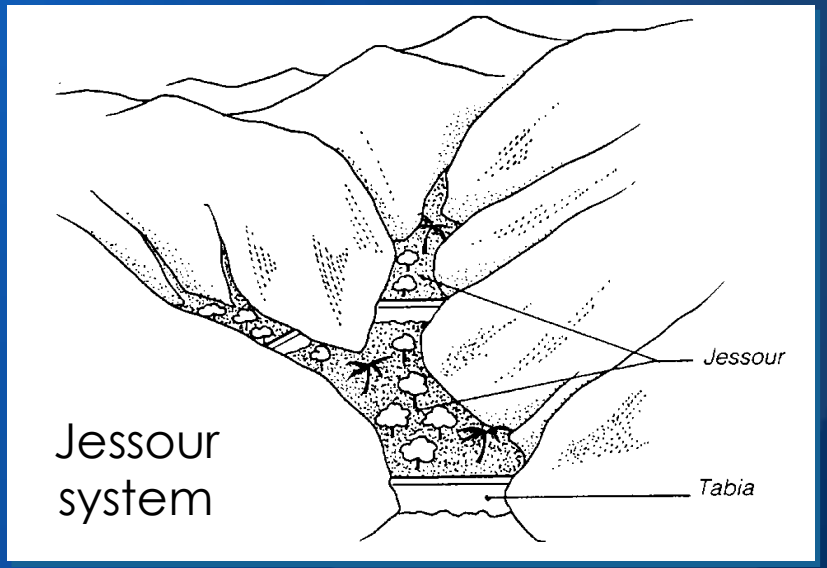
Floodwater Harvesting



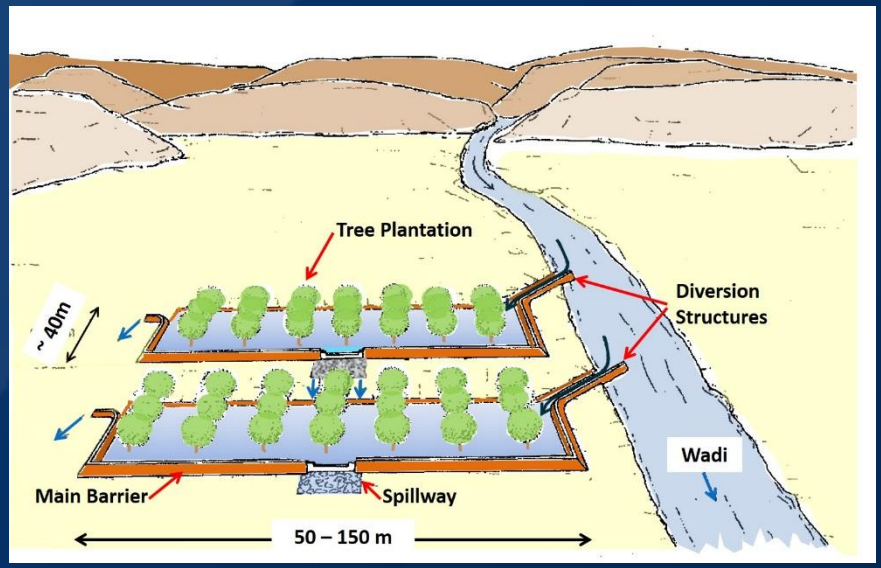
Two types of Floodwater Harvesting are distinguished:

‚**Wadi-bed Floodwater Systems**‘:

Common in wadi beds with mild slopes.



Source: El Amami 1983



Source: Adapted from GTZ/DGF (1993)

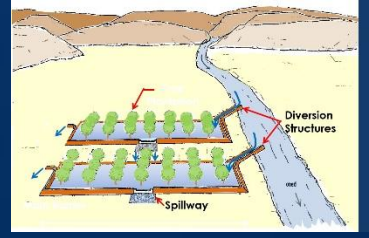
‚**Floodwater Diversion Systems**‘or ‚**Spate Irrigation**‘:

Agric. land may be graded & divided into basins by levees.

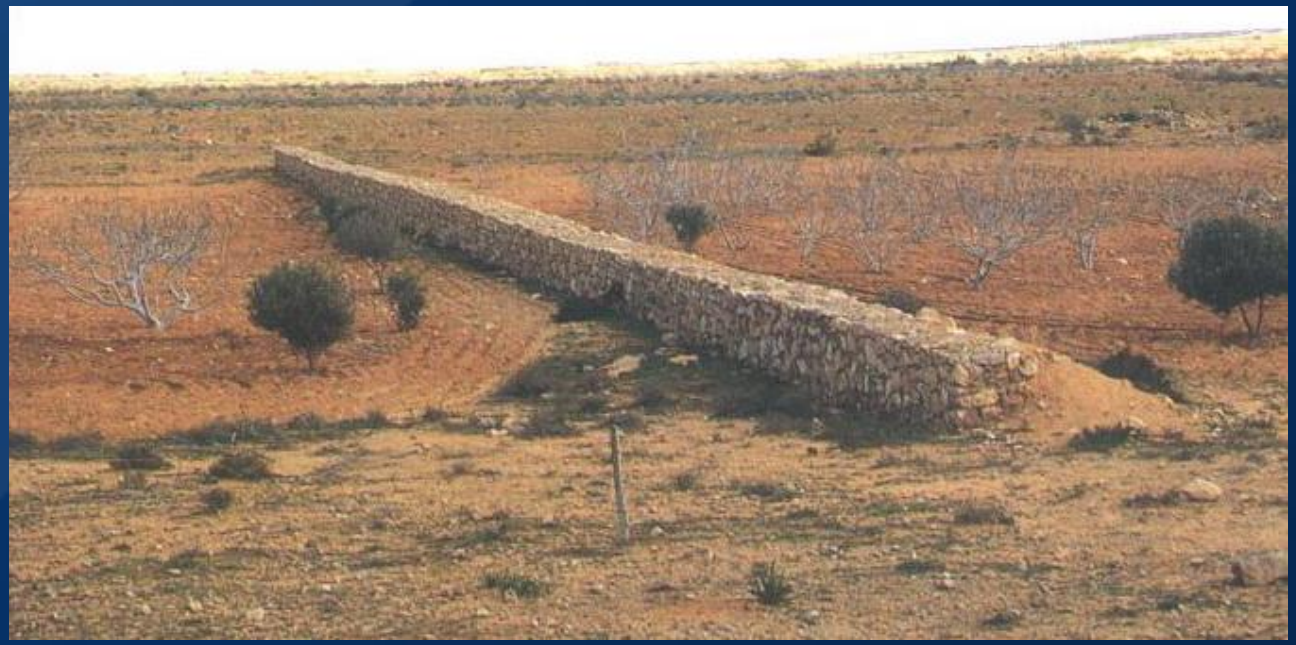
- Size of catchment: > 200 ha
  Flow type: channel flow; complex structures needed
- CCR: 100:1 - 10,000 :1 (and more)
- Precipitation: from 100 to 400 mm / year
- Cropping area is terraced or in flat terrain.

Water Harvesting

Floodwater Harvesting: Wadi – bed Systems



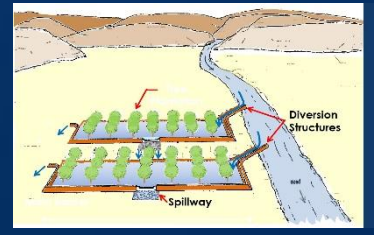
A *wadi*-bed water harvesting system in Tunisia.
Photo: T. Oweis/ICARDA.

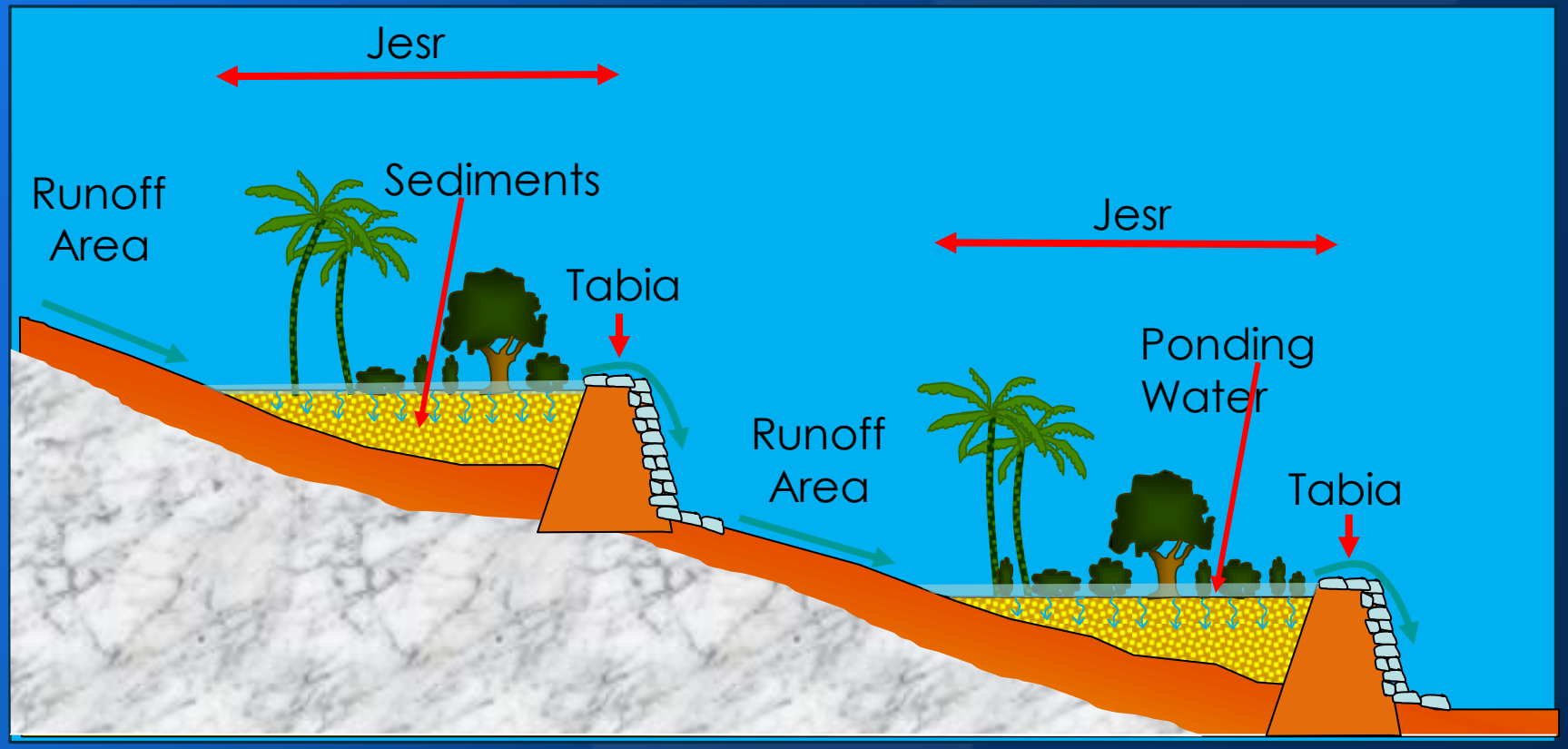


A masonry dam for harvesting floodwater in a *wadi* in NW Egypt. The water is used for supplemental irrigation of field crops and groundwater recharge..
Photo: T. Oweis/ICARDA.

Water Harvesting

Floodwater Harvesting: Wadi – bed Systems





Schematic drawing of a series of *jesr (jesr = singular, jessour = plural)* built along a steep *wadi* bed

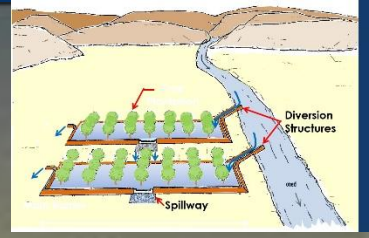
Source: Prinz

Jessour in Tunisia

Source: Missaoui

Water Harvesting

Floodwater Harvesting: Wadi - bed Systems

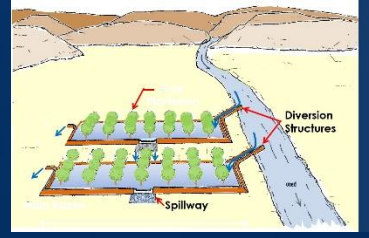


Within-bed rock dams are spaced in such a way that the crest of a dam is at the same level as the base of the next one upstream.

- Cross-valley dams are constructed with stone, earth or both
- Behind the dam, accumulation of sediment takes place
- Cross-valley dams are equipped with spillways
- The structures are suitable for trees or bushes (fig, olive, date palm)
- Problems: Building & maintaining the tabias is costly; reduced runoff

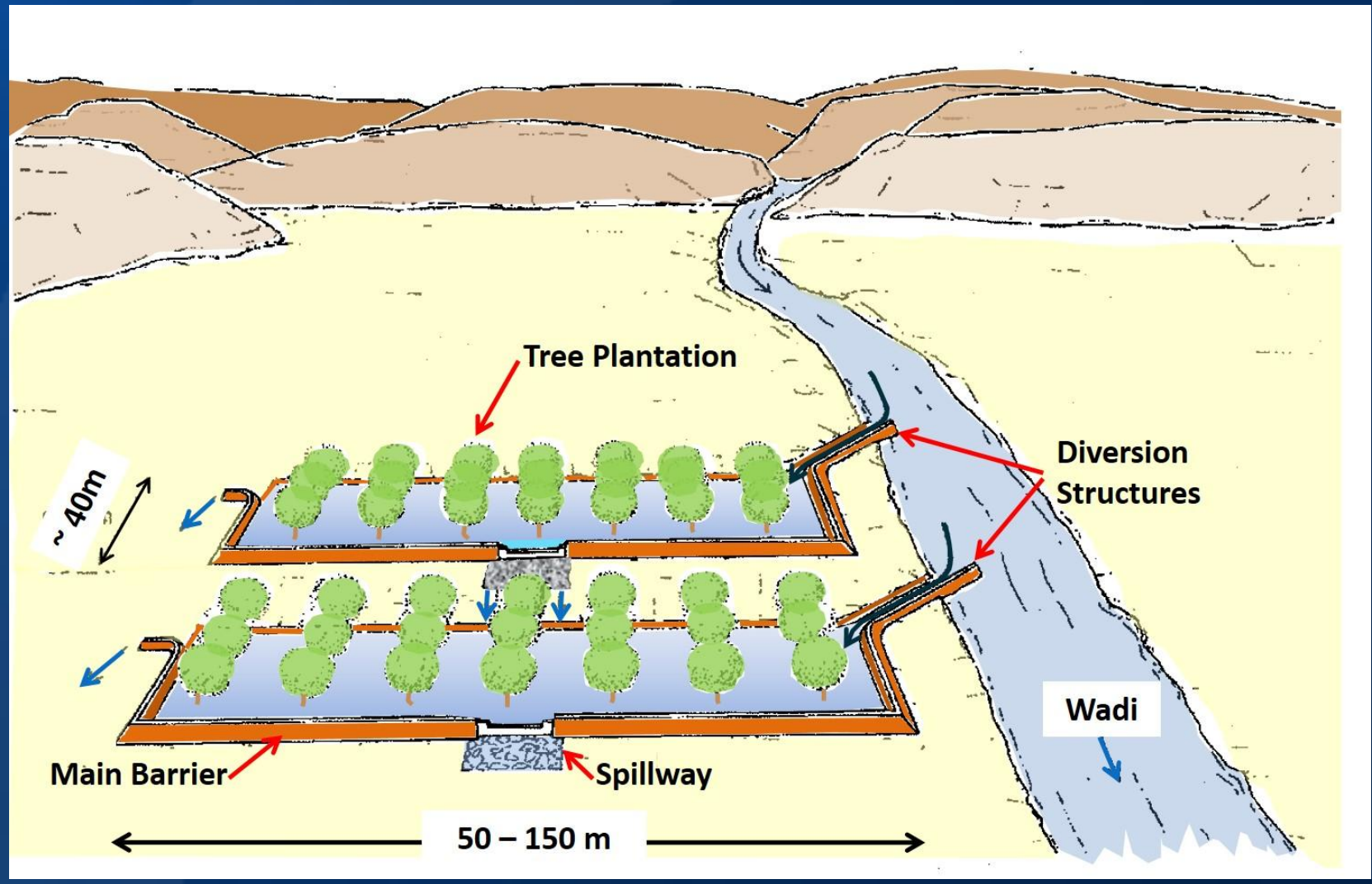
Source: Wolfer

Floodwater Harvesting: Floodwater Diversion Systems



Floodwater Diversion Systems

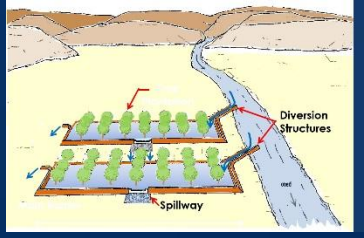
- Floodwater diversion directs water from wadis to the cropping areas by means of stone or concrete structures.
- Floodwater diversion is suitable for almost any crop;
- Levees assure the distribution of water within the cropping area.



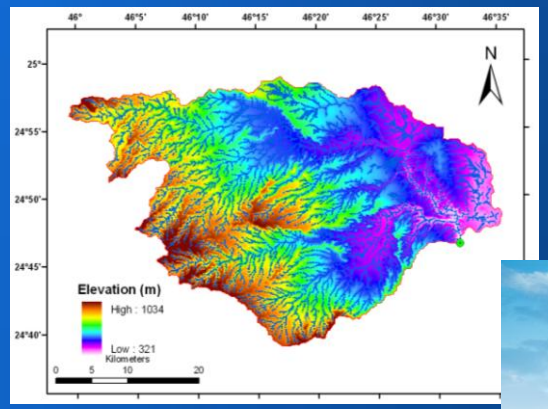
Example of floodwater diversion as applied in Tunisia.

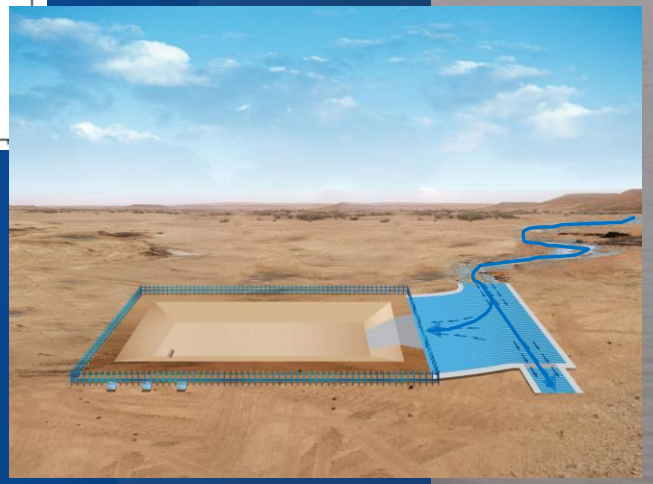
Water Harvesting

Floodwater Harvesting: Floodwater for Groundwater Recharge



Storage of water in aquifers: Floodwater used for groundwater recharge in Saudi Arabia

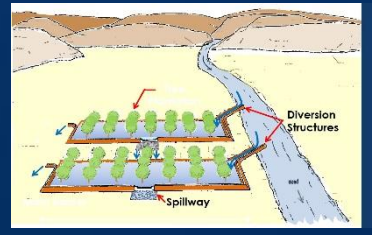


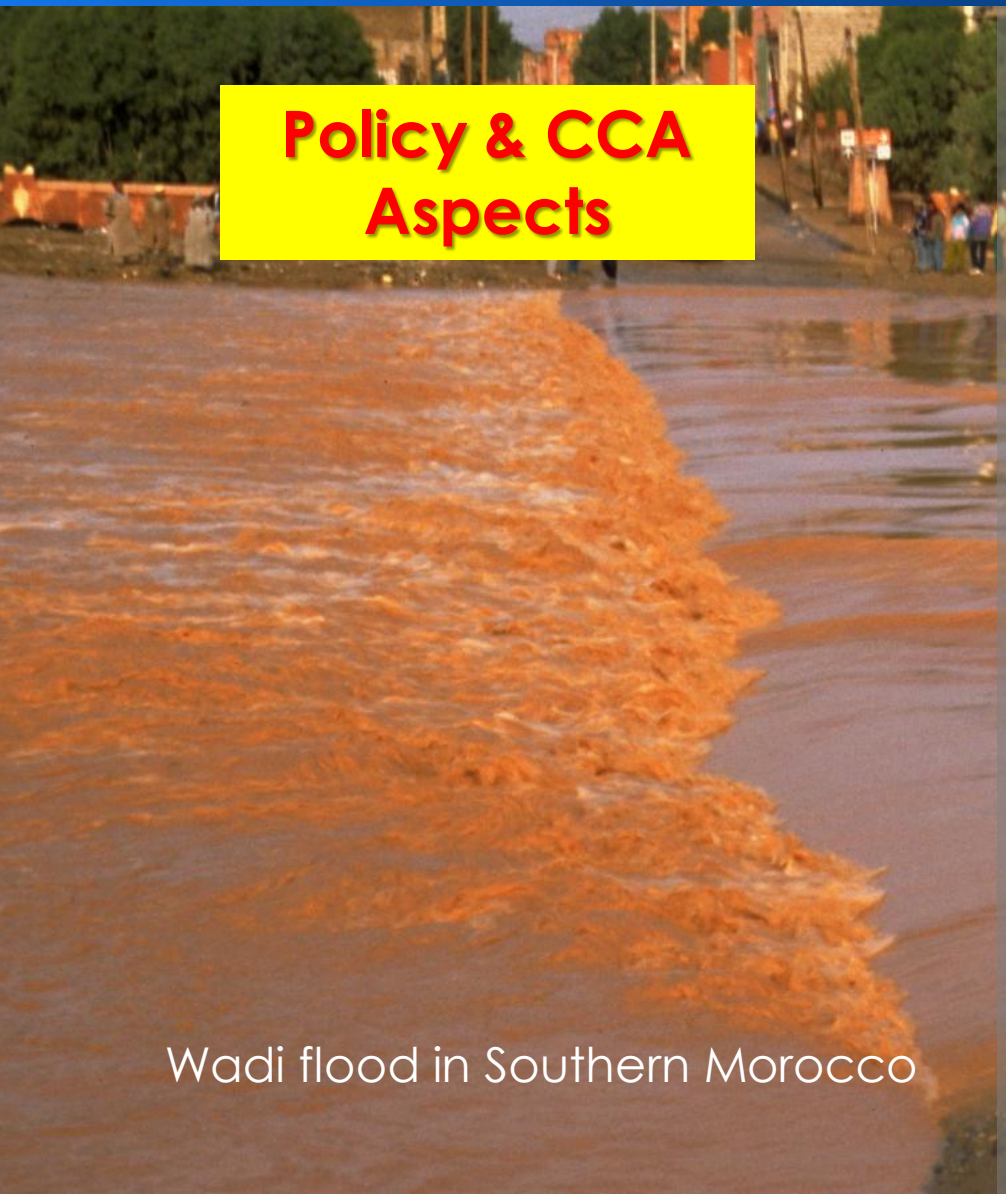


Source: Al Torbak (2011)

Water Harvesting

Floodwater Harvesting: Policy & CCA Aspects





Policy & CCA Aspects

Wadi flood in Southern Morocco

Adaptation to more/larger **floods** can be achieved e.g.

- by increasing **size of structures** for water diversion,
- by enlarging the **impoundment** and
- by designing **larger / stronger spillways** to evacuate excess water.

The drier the area, the more there is the need for **supplemental irrigation**, i.e. storage of water for life-saving irrigation.

Interannual water storage above ground or **in aquifers** is necessary to deal with longer-lasting droughts.

Floodwater harvesting will in future experience a **smaller number of floods**, but these will be **even more voluminous** (and presumely more destructive).
Floodwater harvesting has to be extended to become **floodwater management**. **In peri-urban areas** it has to become part of **excess water management**, i.e. the converting of stormwater to an asset and element of the water budget by catching and storing it..

Water Harvesting

Summary

Rainwater harvesting can support people in MENA region to cope better with the impacts of climate change by securing rural water supply, reducing flood and soil erosion risk and improving agricultural production.

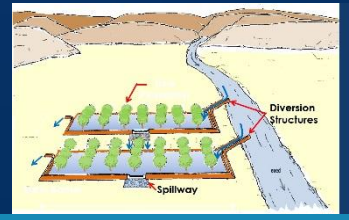
We distinguish five water harvesting methods (1) Groundwater Harvesting, (2) Rooftop Water Harvesting, (3) Microcatchment Water Harvesting, (4) Macrocatchment Water Harvesting and (5) Floodwater Harvesting, also called Spate Irrigation.

Changes are needed in planning and design to meet future climatic conditions: Higher temperatures and more erratic rainfall demand **larger catchments and/or a higher runoff coefficient**. Longer dry spells demand **larger storage volumes** in ponds or reservoirs. Drought endurance asks for more water being **stored in aquifers**.

Climate change impacts demand a raising of height and strengthening of **all** WH structures (e.g. bunds, dams); the systems have to be newly designed to deal with higher rain intensities. Floodwater harvesting has to be extended to become floodwater management. **In peri-urban areas** it has to become part of **excess water management,** i.e. the converting of stormwater to an asset and part of the water budget by catching and storing it.

Rainwater Harvesting

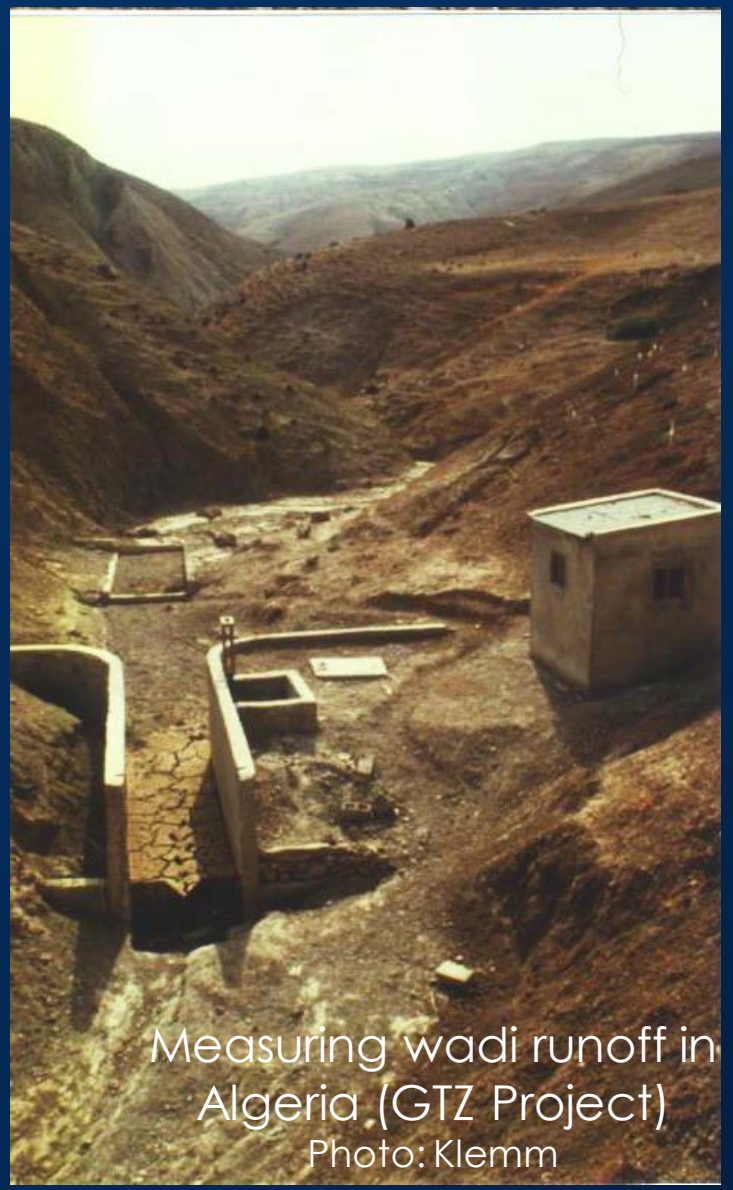
Water Harvesting: Policy & CCA Aspects



Policy & CCA Aspects

A **general problem** of planning water harvesting schemes is the **lack of data**.
Causes: Missing meteorological stations and water harvesting research stations or ‚hiding' of data.

Runoff measured by using a gauge (EU Project) Photo: Klemm



Measuring wadi runoff in Algeria (GTZ Project)
Photo: Klemm

Any policy intending the promotion of water harvesting has to include investments in collection of data on climatic and runoff parameters.
Applied research on all aspects of water harvesting is another necessity in MENA region.

شكرا

THANK YOU !

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