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Continental Scale Quick Assessment Tool

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SEVENTH FRAMEWORK PROGRAMME

WAHARA
WATER HARVESTING FOR RAINFED AFRICA

DELIVERABLE 4.1
Continental scale quick assessment tool

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Introduction: water scarcity issues

Water is becoming the scarcest resource in meeting the need for increasing global food production. We therefore need to increase the efficiency of water use by useful crops, and to grow crops wherever feasible. There are a number of methods to improve water use efficiency, e.g. through selective breeding, additional input of fertiliser and water harvesting. The focus here is on water harvesting, which can be readily applied in subsistence farming contexts and perhaps has the least undesirable side-effects.

Water harvesting is able to increase crop yield per unit area and per millimetre of water applied, even when allowing for the necessity of reducing the cropped area to provide a water collecting area. In the most marginal dryland areas, arable agriculture is only possible with water harvesting. The greatest benefits of water harvesting are obtained when natural runoff coefficients are high, increasing the water harvesting potential and in most cases providing additional nutrients for cropped areas through the associated erosion of sediment from the collecting areas.

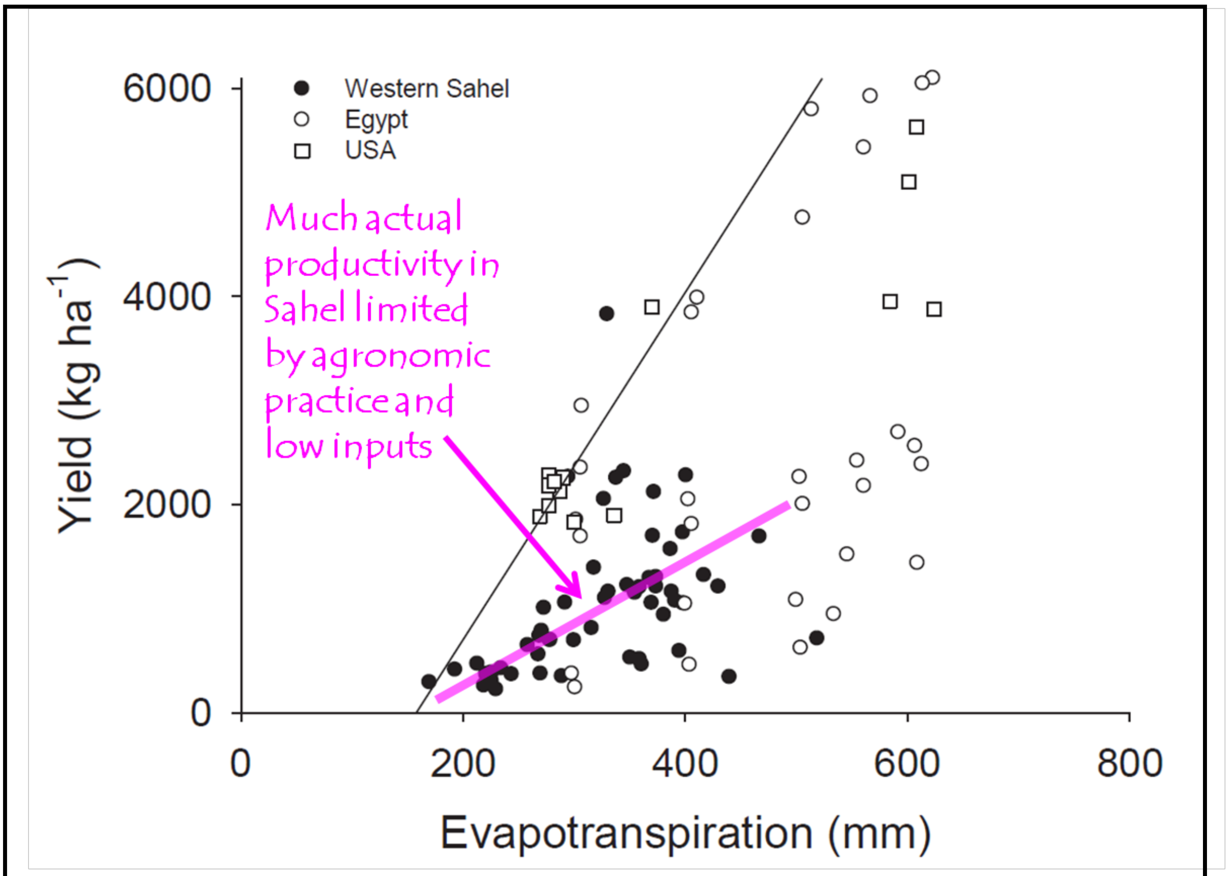


Figure 1:Water Use efficiency for millet grain (from Sadras, Grassini & Steduto, 2011: Status of water use efficiency of main crops. In: The state of world's land and water resources for food and agriculture (SOLAW). FAO, Rome and Earthscan, London, figure 11)

There are some potential negative impacts of water harvesting, and these include increased salinisation of cropped areas and diversion of water away from potential downstream users. To avoid salinisation, proper irrigation techniques should be used, while downstream impact needs to be assessed, and an agreement negotiated at catchment level. Improved downstream conditions have been observed in Ethiopia with field studies aiming to verify such a response. This field data will inform impact modelling at local/regional scale at a later stage in WAHARA (deliverables 4.2 and 4.3).

Figure 1 shows that crops in Africa are not always making best use of available water, so that better agronomic practice can improve yields, particularly through appropriate fertiliser application. The upper envelope line in figure 1 shows the optimum water efficiency of 16.7 kg.Ha^{-1} per millimetre of water, whereas cropping in the Sahel typically achieves only about half as much.

The QUICK-Scan tool

An analysis of variations in hydrology, driven by climate, allows both broad scale comparisons of water harvesting methods across Africa (or globally) and advice down to a community scale. The QuickScan tool is based on available climatic and land use data, and is also able to take account of local knowledge, comparing the opportunities for alternative harvesting methods, based either on innovative technologies or transferred from other areas with a similar hydrological regime.

Specifically, the QuickScan tool

1. makes use of publicly available climate and other data to put particular areas into their broad regional context using a water balance model, computing the shortfall of reliable rainfall for rainfed crop production and the consequently required ratio of water harvesting area to crop harvesting areas

2. provides initial advise to researchers and stakeholders on options for improving water use and sustainability of crop production by making the model applicable at a more local scale, making use of more detailed, finer scale information provided at local level, to suggest a range of possibly suitable alternative water harvesting strategies and compare them with current practice.

This brings together meteorological, topographic, soils, population and economic inputs, as sketched in Figure 2, although not all of these are fully incorporated in the tool.

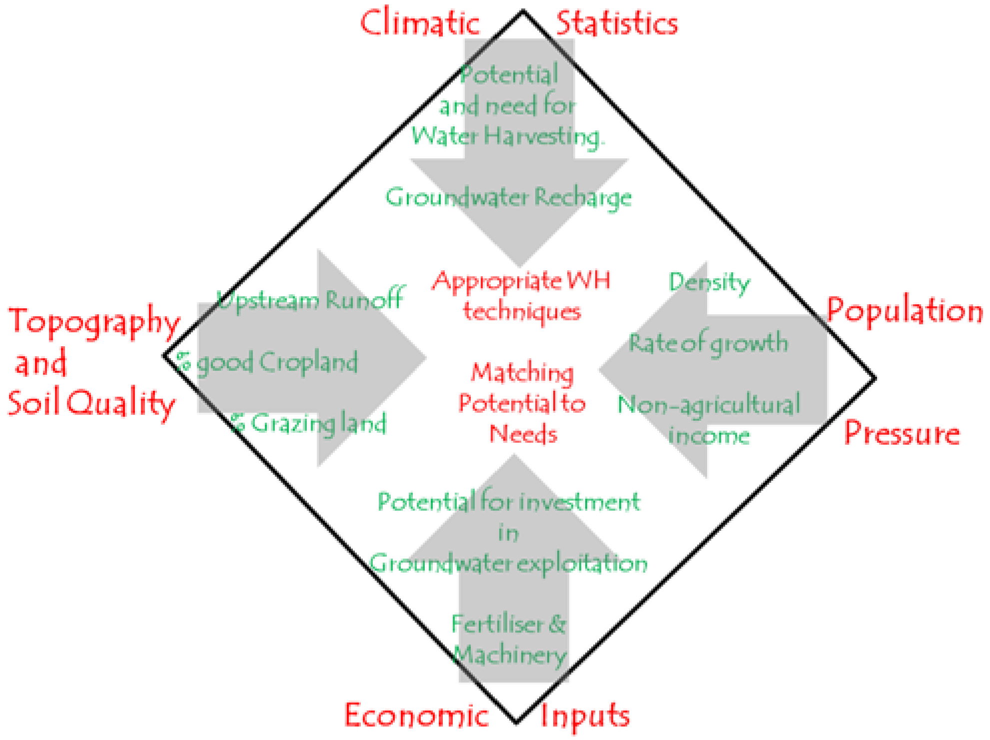


Figure 2: Outline of the QuickScan tool

Water Harvesting methods and assessment

Background is provided by the FAO survey of water harvesting principles and methods at **http://www.fao.org/docrep/U3160E/u3160e03.htm#TopOfPage** and in Critchley et al (1991)

A distinction is drawn between between '**Rainwater harvesting' (RH)** in which runoff is collected from roofs or the land surface; and '**Floodwater harvesting' (FH**) in which runoff is collected from watercourses.

The general principle of water harvesting is to concentrate water onto the area for application, increasing the ratio of total area of the external water-collecting area to the cultivated area. To be useful, this ratio must be greater than zero after allowing for losses of water by infiltration, inefficient collection or delivery, transmission and evaporation.

Many simple water harvesting systems are able to transfer water from place to place. They also provide limited opportunities for transferring water over time, by storing the transferred water in the soil, to be gradually used up by the growing crops. The value of water harvesting systems is greatly increased if water can be stored in open or covered tanks or ponds, since the stored water can then be used to irrigate crops during subsequent dry periods, but the tanks themselves take up land, and losses from leakage and evaporation from open tanks can be severe.

The Appendix sets out the classification of water harvesting methods agreed within the project. Perhaps the most useful way of distinguishing water harvesting schemes without storage is through two descriptive parameters:

1: ψ is the ratio of water gathering area (including the cropped area) to cropped area ($\psi >= 1$)

2: α is the proportion of water lost from both collecting area and cropped areas through inefficient collection, transmission losses and evapotranspiration. ($\alpha <= 1$)

Classification of Water Harvesting types according to use, water source and scale.

1. Soil conservation measures to reduce runoff, $\psi=1.0$ (for crop production)
    a. Water retention in the soil
    b. Stone Lines, terraces and water retention pits
2. Micro catchments for immediate water use (for crop production)
    a. Collecting areas around each small group of plants: $\psi=2\text{-}5$
    b. Partial diversion of stream water during flow events: $\psi>10$. This may enable transfer of water from wetter adjacent uplands
    c. Small hillside catchments supplying a cultivated area: $\psi=5\text{-}10$
3. Retention in open ponds or covered tanks (for crop production)
    a. Supplied by a collecting area or stream diversion during flow events
    b. Potential to delay water use until next period of crop stress
    c. Covered tanks reduce evaporation loss during storage and disease vectors
    d. Deliberate recharge of shallow groundwater
4. Water harvesting may also be required for
    a. Drinking Water and domestic needs
    b. Watering livestock and supporting fish stocks

1a: Soil conservation through in situ water retention in the soil ($\psi=0$; α as small as possible $<<1$)
The intention here is primarily to prevent runoff so that all rainwater is available to the growing plants. This is one common component in most schemes. Some classifications of water harvesting exclude this category, but it is included here, because it is seen as lying on a continuous spectrum with other methods below.
In situ conservation methods promote local infiltration, though improving soil structure and providing ground cover (vegetation and/or stones), both of which increase infiltration rates.

1b: Field scale conservation measures. (again intended to reduce α)
Runoff is slowed, and infiltration thereby enhanced by reducing gradients through terracing. Lines of stones or lines of living or cut vegetation not only slow runoff directly, but also form the nucleus for terraces to develop as eroded soil accumulates above the lines. In combination with terracing, pits, usually along the lower edge of terraces, can also be used to encourage direct percolation deep into the soil.

2a: Micro catchments for immediate water use : Collecting areas around each small group of plants: ψ=2-5 (ψ small, usually 1-5; α variable)

Usually repeated patterns of bunds and/or pits, concentrating water to supply single trees or a small patch of crop. In some cases water is channelled into a broader field area. Patterns are usually designed to allow overspill from one patch to others down-flow In some systems collecting areas supply individual small plots or single trees, whereas in others water is collected more centrally: in that case there may be a hierarchy of receiving areas, which may be static, or varying during a single storm or between successive storms.

2b: Partial diversion of stream water during flow events: ψ>10.

With generally larger collecting areas, less attention is paid to infiltration losses within the catchment area, and the technical measures focus primarily on diverting water from the fast flowing streams and sharing it, more or less equitably, among potential stream-side recipients. There is some overlap between small systems of this kind and the larger scale versions of 2a above. Where stream levels are close to the surface, often associated with aggradation of their beds, then the engineering required to water the land is minimal, deeply incised channels present a greater challenge, with diversion canals abstracting water far upstream from the fields they are to water.

In gently sloping areas too arid for rain-fed agriculture, stream water from adjacent wetter uplands can be diverted to support cultivation.

2c: Small hillside catchments supplying a cultivated area: ψ=5-10

In some areas, an area can be dedicated to runoff gathering and the entire outflow channelled to a cultivated patch. This can be done on various scales, including the Tunisian ‘jessours’ and Nabatean agricultural practise in the Negev. Runoff collecting areas are commonly small enough to allow the application of specific methods to increase the runoff coefficient, including:

i. Clearing stones and vegetation to enhance soil crusting and minimise infiltration
ii. Maximise connectivity by channelling runoff to a dense network of surface drains
iii. Limit grazing during the rainy season, to prevent breakdown of surface crusting
iv. Encourage lichen colonisation of bare surfaces

3: Retention in open ponds or covered tanks

All of the above methods rely primarily on spreading water during and immediately after rainfall. Once applied to a cropping area, the water may be stored within the soil, but this takes place strictly within the field.

Alternatively water may be concentrated, retained off-site to be used for irrigation during a subsequent dry period. This has the advantage of spreading the application of water over time, partially protecting crops from dry periods within the growing season. However, the water retained may be subject to losses, due to unproductive leakage or evaporation, so that collected runoff water can generally only be stored for a limited time.

The simplest and most widespread method of storage is in open tanks or ponds. These can be lined with clay or plastic sheeting to minimise leakage where materials are available. Water can be collected from surface streams during rainstorm events or from smaller areas modified to enhance runoff as in 2c above. At the smallest scale, runoff from the roofs of buildings can also be used, although this is mainly used to provide domestic water etc. Open tanks have the disadvantage that they are not protected from evaporation, creating large losses over time.and providing breeding sites which may influence vector borne disease transmission.

Covered tanks are protected from evaporation, but the costs of construction are very much higher, and size is therefore usually limited. However, even small tanks provide much better assurance for crop growth over a limited area.

Lastly natural aquifers may be used for storage. They are generally at least partially protected from evaporation but may suffer leakage. Although losses may be high, the large storage capacity of aquifers offers unique advantages in providing substantial buffering capacity through drought periods. The efficacy of this method depends on the geometry of the aquifer(s), which should be accessible to wells and not losing too much to neighbouring areas. Surface water can be used to deliberately recharge aquifers, allowing water to be extracted later either directly by plant roots and/or from wells, depending on the depth to water table. Recharge occurs almost exclusively from areas that are saturated, and only while they remain saturated. Thus natural recharge in semi-arid areas is largely concentrated around streams and during floods, and measures to improve recharge generally aim to retain water in the channelways as long as possible, either through impounding water in ponds/ reservoirs or by creating multiple pits in the stream bed.

4a: Drinking water and domestic needs

For drinking water, the critical control is on water quality, particularly minimising disease vectors and faecal material. The use of wells generally provide some protection, by filtration of water through the soil, although there remains a risk of contamination from nearby disposal of inadequately treated sewage etc. In arid areas, the sustainable use of wells requires provision of adequate recharge. Because the quantities required for domestic use are relatively small, wells can also mine non-renewable fossil water for a long time.

If surface water is to be used, it requires full control of the collecting area, with exclusion of livestock and a high runoff coefficient (low α). Rooftop collection is widely used, but may be less appropriate where there are high levels of contaminants in rainfall, for example from heavy metal pollution or dust in urban or industrial settings. There may also be periodical high natural sediment loads in rainfall from wind-blown material, but this can generally be removed by settling, filtration or exclusion of affected rainfalls. Collected water can be stored, provided that precautions are taken to minimise contamination.

4b: Water for livestock and/or fish

Many of the same considerations apply to provision of water for livestock, or to maintain fishponds, although lower water quality standards may be applied. In many cases, animal needs are met through creating ponds or providing facilities around well heads. Requirements for designing stock ponds are similar to those for 1b(i) and 1b(ii) above, but with the additional requirement that the ponds are well sealed beneath, and have an adequate supply to maintain them constantly through a sufficient part of the year. Dry periods can be managed if stock are able to migrate seasonally or have access to alternative water supplies. Evaporation is unavoidable from open water, and some systems make use of covered tanks to minimise this loss.

Criteria for a regional assessment of water harvesting potential.

The water needs for crop growth can be approximately estimated as the potential evapotranspiration over the growing season, multiplied by a ‘Water Use Efficiency’ or ‘crop factor’ which is generally less than 1.0 (equivalent to the kc factor in Critchley et al, 1991) , and may be as low as 0.5 for drought-tolerant crops. The amount of water required is usually in the range 500-1200 mm, spread over a growing period of 90-150 days that depends on the crop type.

Arable crop growth normally requires a period of at least four months to complete the cycle from sowing to harvest, with an average requirement of about 70% of potential evapotranspiration (pot ET) over this period. Conditions for rain-fed agriculture can therefore be assessed on the basis of the wettest consecutive four months of the year, with ‘wetness’ defined as the ratio of Pot ET to precipitation. This assessment is initially made for average conditions, defining areas with adequate conditions for crop growth.
Tree crops require some water throughout the year, but, in marginal conditions, are usually grown with a lower proportion of crown cover, i.e. with more widely spaced trees allowing roots to gather water over the entire area.

Maintenance of an open stock pond should allow for 100% of Pot ET over the pond area for the whole year, and so is somewhat more demanding than crop growth in water requirement.

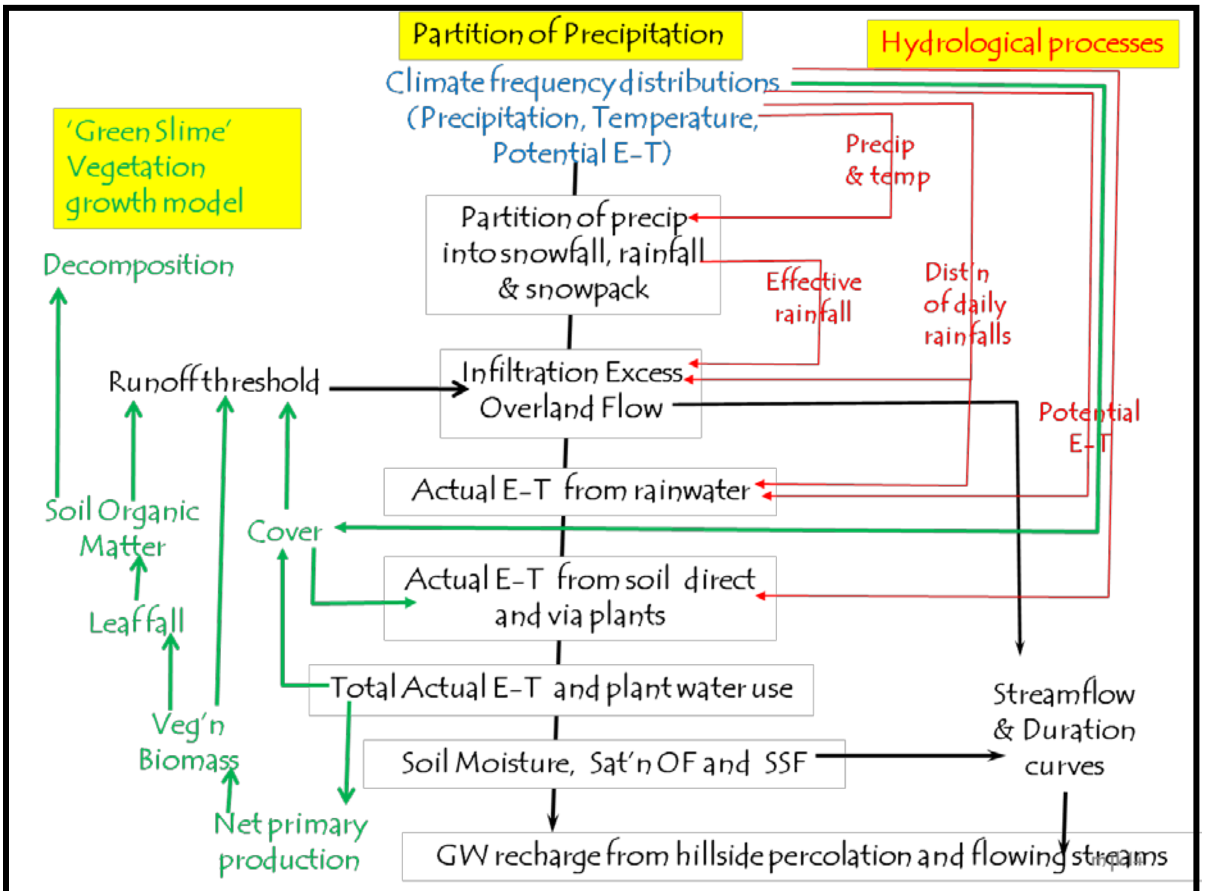


Figure 3: Biophysical model scheme for QuickScan tool

Calculations, using climate data within a realistic simple water balance model can estimate the ratio of available water for the wettest four months, or over the entire year, and compare the available water to the water needs of each use. If this ratio, ϕ, is greater than 1.0, then water supply is adequate for rain-fed use in an average year. If $\phi<1$, then water harvesting for a crop area of A needs to deliver a depth of water RA/ϕ for a region with rainfall R over the growing season. ψ is the ratio of total collecting area, including the cropped area itself, to the crop area. So that the water collected is ψA.R. Allowing for a fractional loss of α, the water delivered is ψA.R.(1- α). The required ratio of total collecting area to utilised crop area is therefore given by, $\psi = \frac{1}{\phi(1-\alpha)}$.

As well as looking at conditions in an average year, it is relevant to look at the range of conditions over a number of years. This can be assessed, either for conditions at a fixed percentile representing, say the worst10% of years, or as the standard deviation (or coefficient of variation) around the average value.

These calculations are made in the QuickScan model through estimating the monthly water balance for any given climate, initially estimating the runoff, evapotranspiration, soil water and groundwater recharge components of the water balance from climate data. Figure 3 shows a schematic of the biophysical model for partitioning the water balance. The 'Green

Slime' model refers to a simple generic (i.e. not crop specific) vegetation growth model. The climatic data are assimilated as frequency distributions, allowing stochastic realisations of 50-year monthly weather sequences, either related to the current climate or perturbed to provide scenarios for potential future climate change. For these simulated time series, the hydrological sub-model estimates overland flow runoff, soil moisture and actual evapo-transpiration, together with water available for recharge to groundwater. Runoff is analysed via flow duration curves. QuickScan is based on the hydrological principles developed in the PESERA model (Kirkby et al, 2008).

The actual evapotranspiration is then used to interactively drive a simple growth model for natural vegetation, which provides some of the hydrological parameters, particularly those for overland flow runoff, based on vegetation cover and soil organic matter. The model is initialised by running the first year repeatedly until the hydrology and vegetation stabilise, before running the full 50-year sequence. This method of 'spinning-up' the model minimises the requirement for additional parameters.

Analysis of regional differences between WAHARA study sites.

The model outlines above has been applied for the current climates associated with the four study sites, in Ethiopia, Burkina Faso, Zambia and Tunisia. The first of these is set out in greater detail to illustrate the stages in developing the regional QuickScan analysis.

Climate data has been obtained from interpolated global gridded climate data at a spatial resolution of 10 arc minutes (approximately 15 km) produced by the Climatic Research Unit (New et al, 2002). These data do not include potential evapotranspiration, which has been estimated using the modified Hargreaves method (Hargreaves and Samani, 1982), for which the data are available. For precipitation, the model requires monthly data for total precipitation, mean rain per rain day and the coefficient of variation of non-zero daily rainfalls. The latter parameter is not included in the New et al compilation, and has been estimated from a global correlation with mean rain per rain day.

Figure 4 shows the average climatic conditions for Mekele, Ethiopia. In this figure temperature and precipitation are raw data from New et al (2002), potential evapotranspiration is derived directly from these data together with humidity and cloudiness raw data, using the modified Hargreaves method, and actual evapo-transpiration is an output from the QuickScan model. The rainfall shows a strong peak July and August, and actual evapotranspiration, in this semi-arid climate, is strongly constrained by the availability of rain.

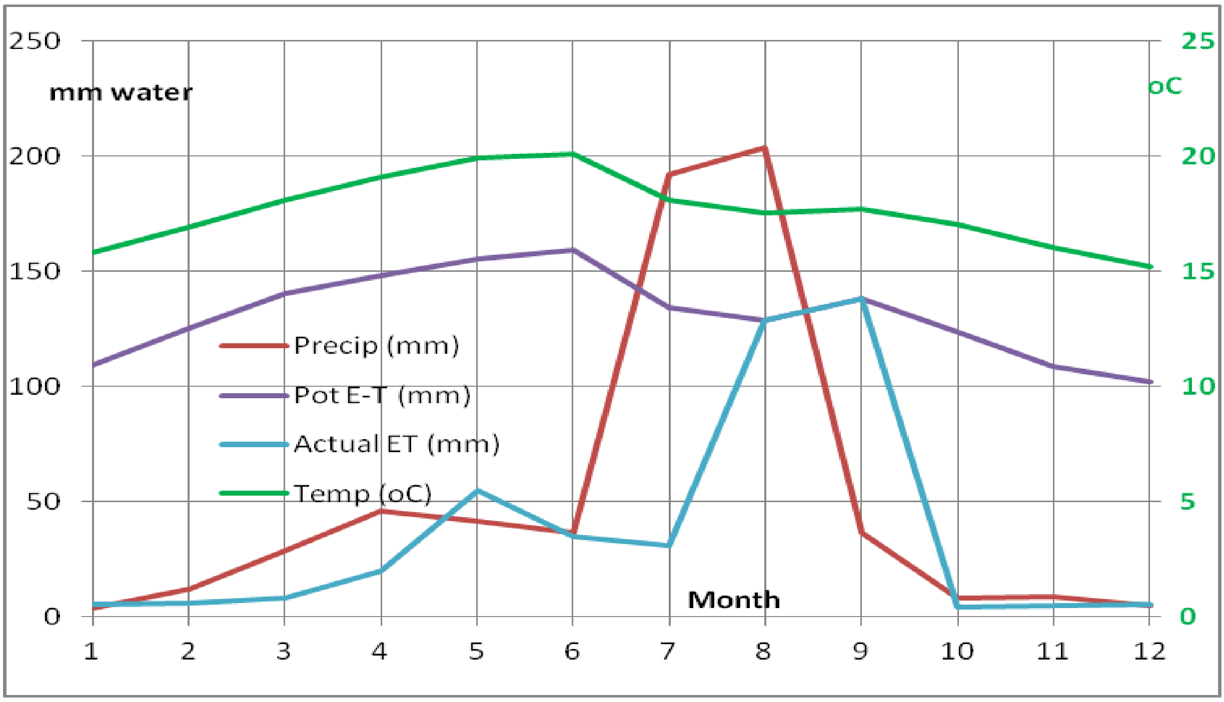


Figure 4: Average monthly climate for Mekele, Ethiopia.(13.49^{o}N: 39.47^{o}E).

In an average year, the water deficit is the difference (in mm) between the water required to grow a good crop and the water available, both from direct rainfall and from harvested water, after allowing for losses. This is expressed as a percentage of the total water need over the growing season. The total ratio of harvested water to direct rainfall, is obtained as the Cropped Area Ratio, CAR = $\psi(1-\alpha)$. In this expression ψ is the ratio of total collecting area to cropped area (including the cropped area itself), and α is the fractional water loss through inefficient collection or transmission and through evaporation within the external collecting area.

CAR values less than 1.0 corresponds to agriculture with some conservation measures and no water harvesting, where overland flow runoff escapes from the plot and is lost to the crop. This is clearly the worst-case base line scenario for rain-fed agriculture, and generates the highest deficits. Values of CAR between 0 and 1.0 represent conditions where there is no water harvesting (i.e. $\psi = 1$) and varying degrees of in-field conservation, reducing some of the losses. Within the cropped area, evapotranspiration is not a loss since it directly drives crop growth. Losses within the cropped area reflect failures to retain runoff, so that a CAR of zero indicates that all runoff is lost, and a CAR of 1.0 indicates that it has all been retained through conservation measures.

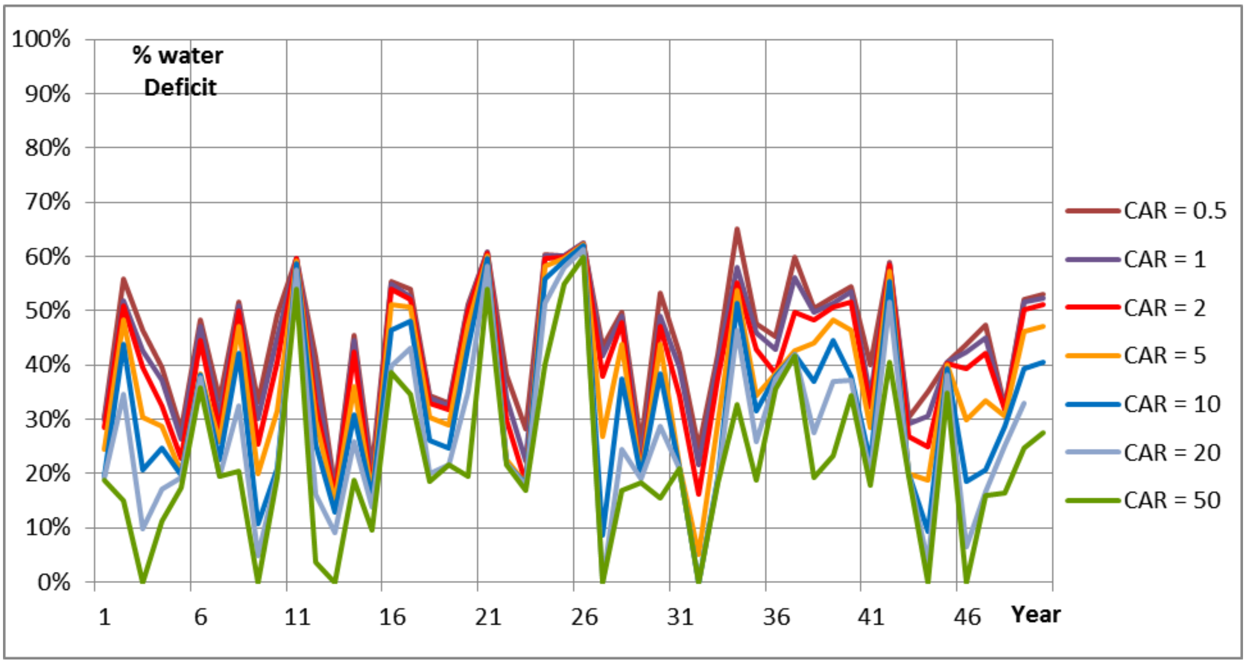


Figure 5. Mekele, Ethiopia. Annual water deficit as a percentage of total water need for each year in a 50-year realisation of current climate, for a range of values of the Cropped Area Ratio (CAR) given by CAR = $\psi(1-\alpha)$.

Values of CAR greater than 1.0 reflect various levels of water harvesting ($\psi > 1$) and a conservative estimate is that the external collecting area delivers only the overland flow runoff, although it is recognised that this may be increased above ‘normal’ levels through management to increase runoff. Figure 5 illustrates how the CAR modifies the number of years with growing season deficits above any given level. For this example, with no water harvesting and no conservation measures (CAR=0), there is a deficit of more than 40% in 37 years out of 50. With conservation measures to contain and store runoff, this falls to 31 years, and with water harvesting systems (CAR=5), the number of years with at least 40% deficit falls to 21. In this climatic setting, it is therefore clear that there are some benefits in establishing good conservation practice, and clear additional benefit in modest water harvesting collector systems.

This analysis can also be expressed by plotting the various levels of water deficit, as a percentage of total water need (estimated as potential E-T multiplied by a water use efficiency of 70%), against the number of years in which conditions are worse. From Figure 6, it can be seen that the conclusions drawn for a 40% deficit apply to other levels, and that even partial conservation measures, with CAR in the range 0.6-1.0, show some benefit in reducing the number of years in which crops might suffer from water shortage.

Table 1: Sites for which QuickScan analysis is presented.

Area	Latitude (^{o}N)	Longitude (^{o}E)	Annual Precipitation (mm)	Annual Potential E-T (mm)	Mean Annual Temp (^{o}C)
Mekele, Ethiopia	13.5	39.5	621	1571	17.6
Medenine, Tunisia	33.2	10.7	175	1363	20.8
Ouagadougous, Burkina-Faso	12.4	-1.5	778	1957	28.9
Lusaka, Zambia	-15.4	28.3	840	1585	20.5

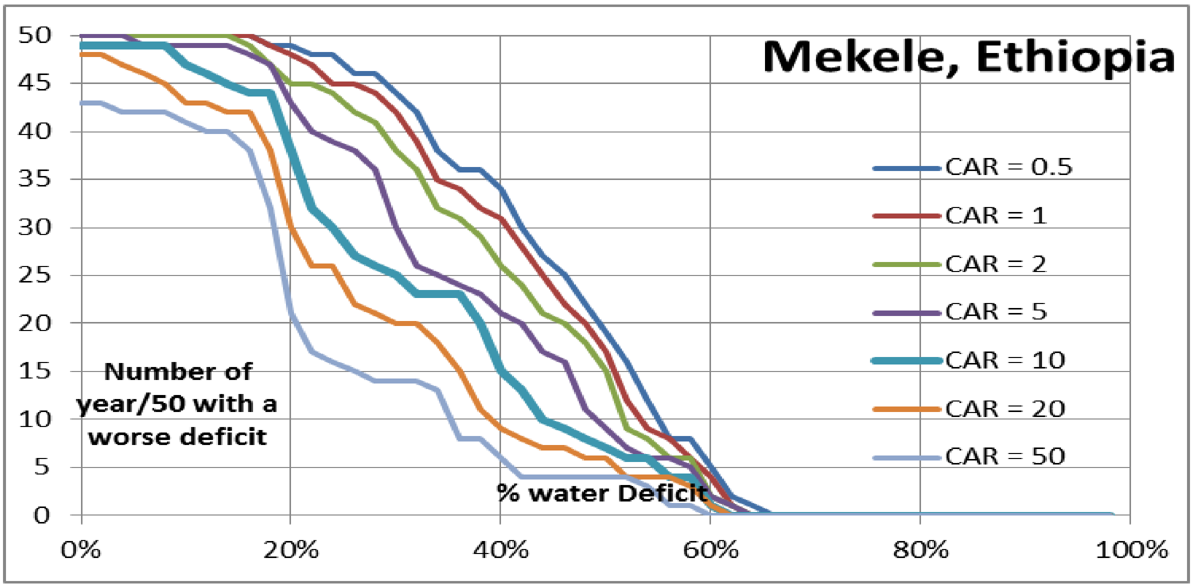


Figure 6. Mekele, Ethiopia. Frequency distribution for different severities of water deficit, according to the conservation and water harvesting methods applied, as indicated by the Cropped Area Ratio (CAR).

Similar analyses can be applied for any site in Africa with the QuickScan tool. Here the differences are illustrated with respect to the four study areas of WAHARA. Their climatic characteristics are summarised in Table 1. Figure 7 shows the distribution of deficit for the three other sites listed in Table 1, and can be compared with Figure 6. It can be seen that there is a spectrum of increasing crop reliability from Medenine to Mekele to Ouagadougou to Lusaka, and that Medenine shows greater year to year variability than the other sites, as the range of deficits that occur is largest.

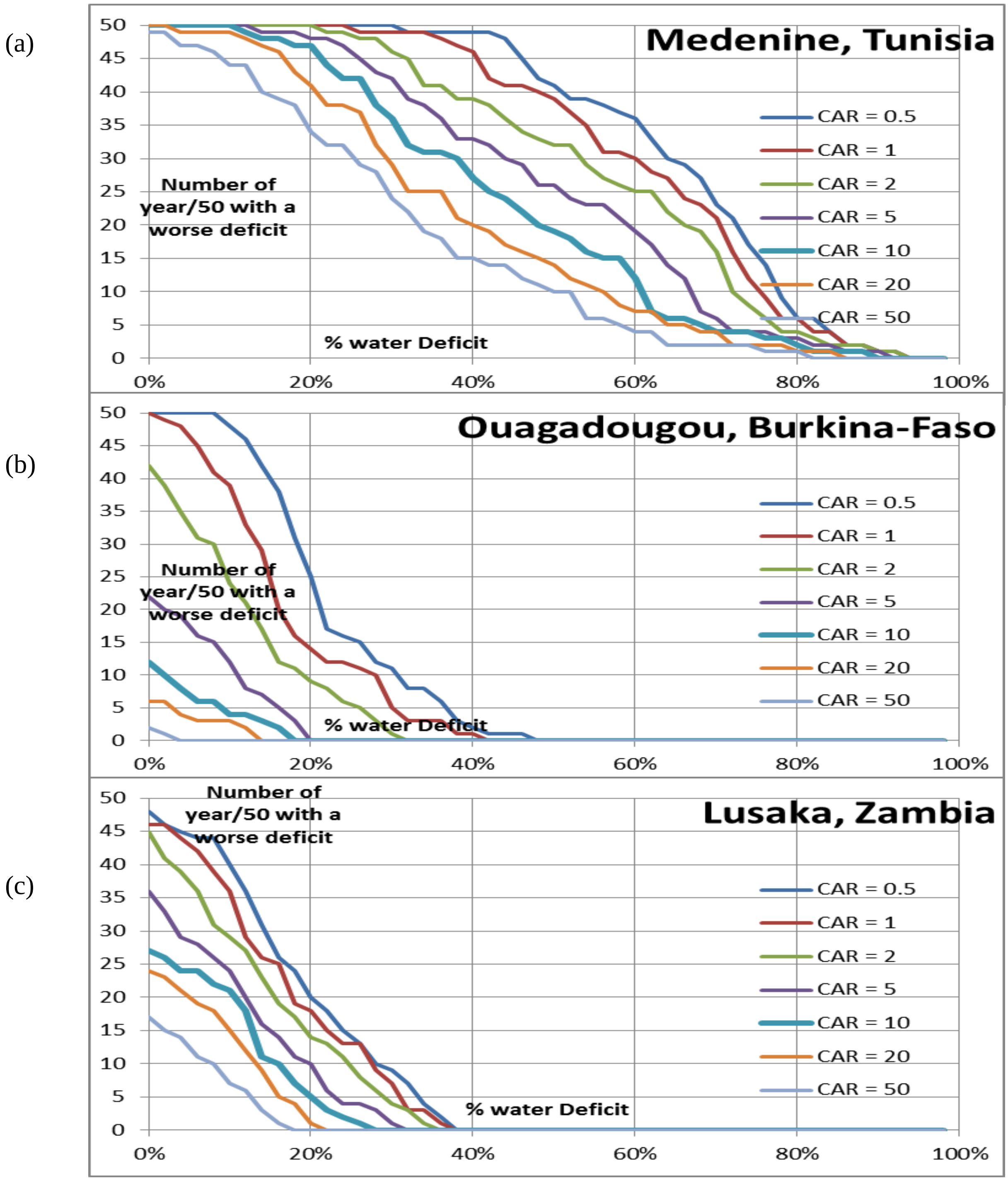


Figure 7. Distribution of water deficit for a range of water harvesting strategies, indicated by choice of Cropping Area Ratio (CAR). CAR<1 represent conservation measures andCAR>1 water harvesting measures. (a) Medenine, Tunisia. (b) Ouagadougou, Burkina-Faso. (c) Lusaka, Zambia.

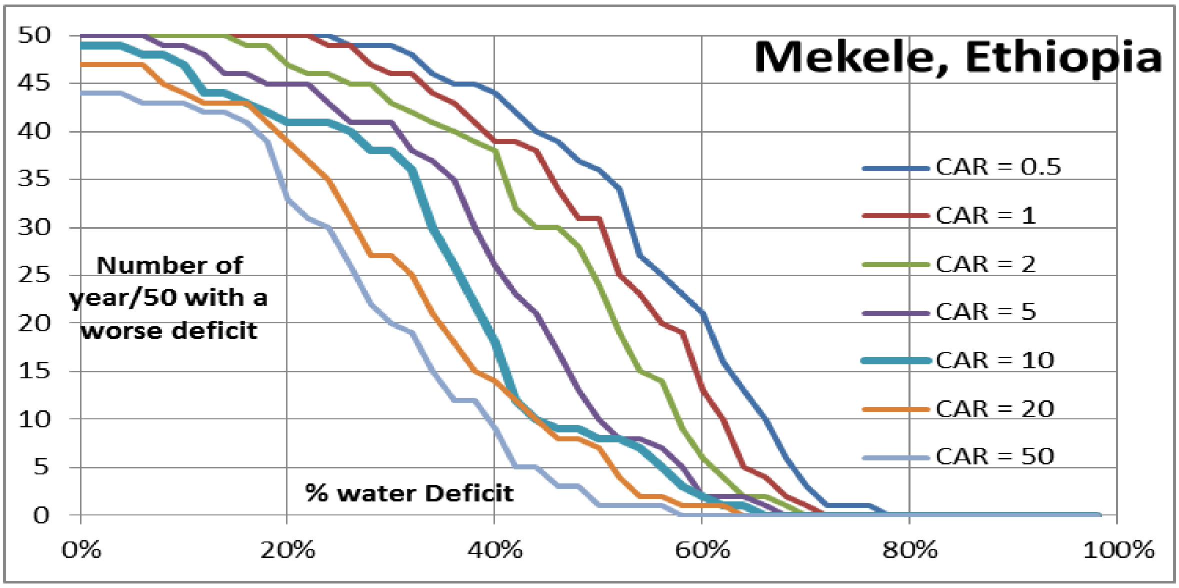


Figure 8: Distribution of deficit for growing season according to Crop Area Ratio (CAR) for Mekele, but with temperatures 2^{o}C warmer, and 20% less rainfall, but with no reduction in intensity, Comparing with figure 6, there is a clear worsening of conditions for crop growth

Figure 8 shows how a future climatic scenario may be applied. Here the climatic data for Mekele have been modified, following possible climate changes over the next 50 years, to provide a 2^{o}C rise in temperature and a 20% reduction in rainfall through less rain days, but with unchanged intensities. It can be seen, for example, that the frequency of a 40% seasonal water deficit with conservation measures in place (CAR=1.0) is increased from 31 to 39 years in the 50 year period, and the risk of a 60% failure, which was previously insignificant, has risen to 13 years in 50 with conservation measures (CAR=1),

Another way to compare the impact of water deficits in a more precise way is by converting water deficits to yields, following linear relationships like those shown in Figure 1. from figure 1 it can be seen that for optimum agronomic and fertiliser conditions, the yield can be expressed as:

$$Y_{max} = 16.7(PE - 158) * \text{kg/Ha},$$

and for more typical conditions with low fertiliser and agronomic inputs:

$$Y_{ave} = 6.0\ (PE - 158)\ \text{kg/Ha},$$

Where PE is the potential evapotranspiration in the growing season (in mm) and Y is the consequent millet yield. Similar relationships can be applied for other crops. Assuming a 70% water use efficiency, PE can be replaced by (Water Need)/0.7, so that

$$Y_{ave} = 8.6\ (\text{Water Need} - 110)\ \text{kg/Ha}.$$

Figure 9a shows estimated grain yields, calculated for millet within the cropped area, for the four site areas. It can be seen that increasing the collecting area (CAR) has a modest effect on yields, and more so in the more arid areas. However, if allowance is made for the sacrifice of cropping area to collect runoff, then there is rarely a gain in net yield, averaged over the entire area (cropped area and collecting area). Figure 9b shows that while conservation

(CAR=1) shows a positive return, the use of larger collecting areas does not generally provide a net benefit in terms of total crop yield.

This conclusion from simple modelling should however, be viewed with considerable caution for a number of reasons. First the labour expended to cultivate a crop is more efficiently concentrated within a small area. Second, it has been assumed that runoff from the collecting area is the same as in the general area, whereas the runoff coefficient can be greatly increased through suitable management, raising possible runoff levels from 20-50% up to about 80%. Third, the collecting area may not be suitable for cultivation because it is too steep or rocky, so that no cropland need be sacrificed to increase the collecting area. These limitations help to constrain the optimal conditions for applying water harvesting methods.

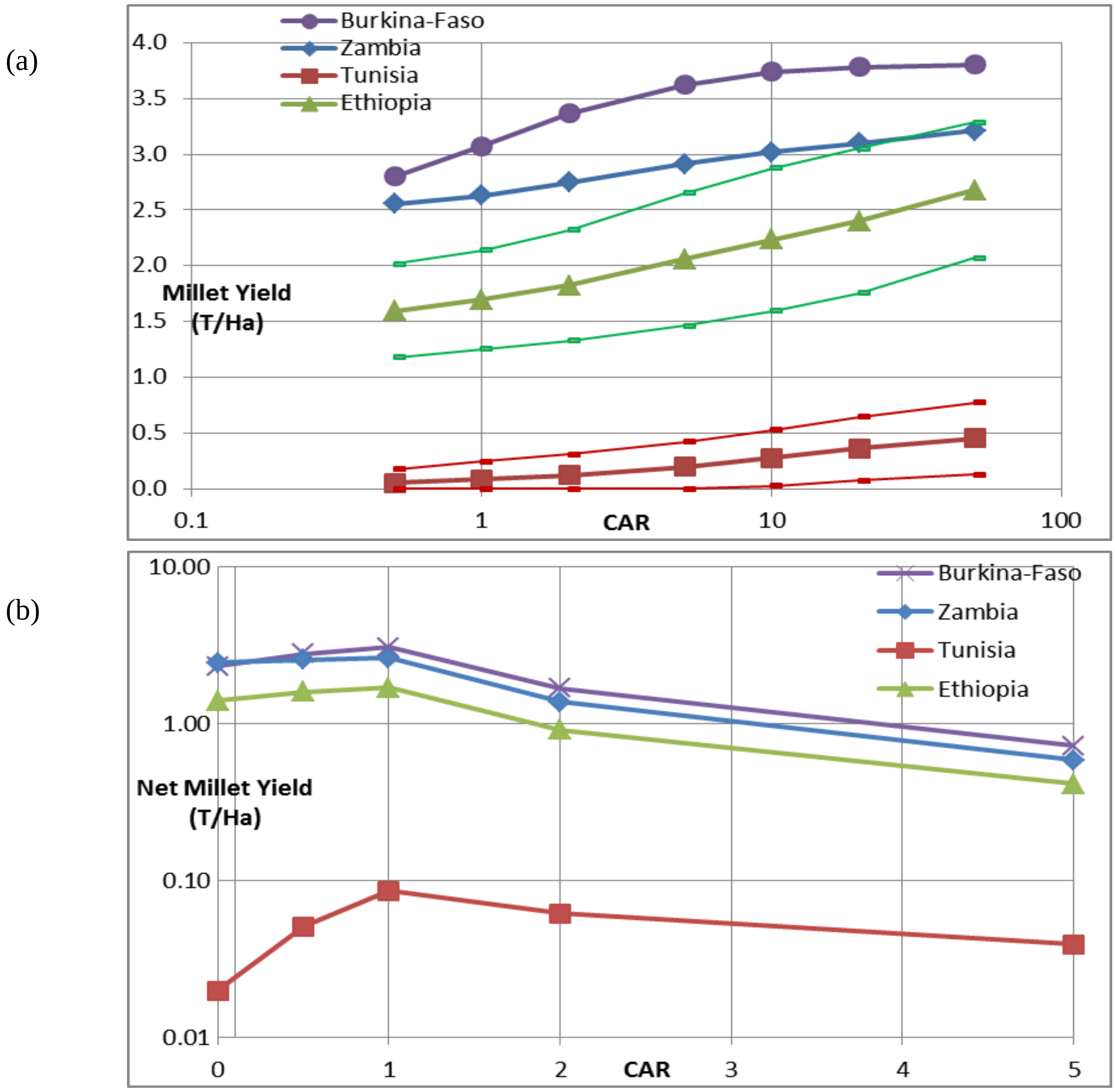


Figure 9: (a) shows forecast grain yields from the cultivated area, based on data for millet, for different cropped area rations (CAR). (b) shows the same data, converted to mean net yield, taking account of the unproductive area used to collect water

QuickScan also allows estimation of the value of storage tanks, with or without covers to prevent evaporation. The model compares tanks with different ratios of collecting area to cropped area, but assuming that collected water surplus to immediate crop needs is stored in a tank, and used for irrigation when required. Figure 10 shows the distributions of deficit using a storage tank for covered and open tanks, for the Ouagadougou climate.

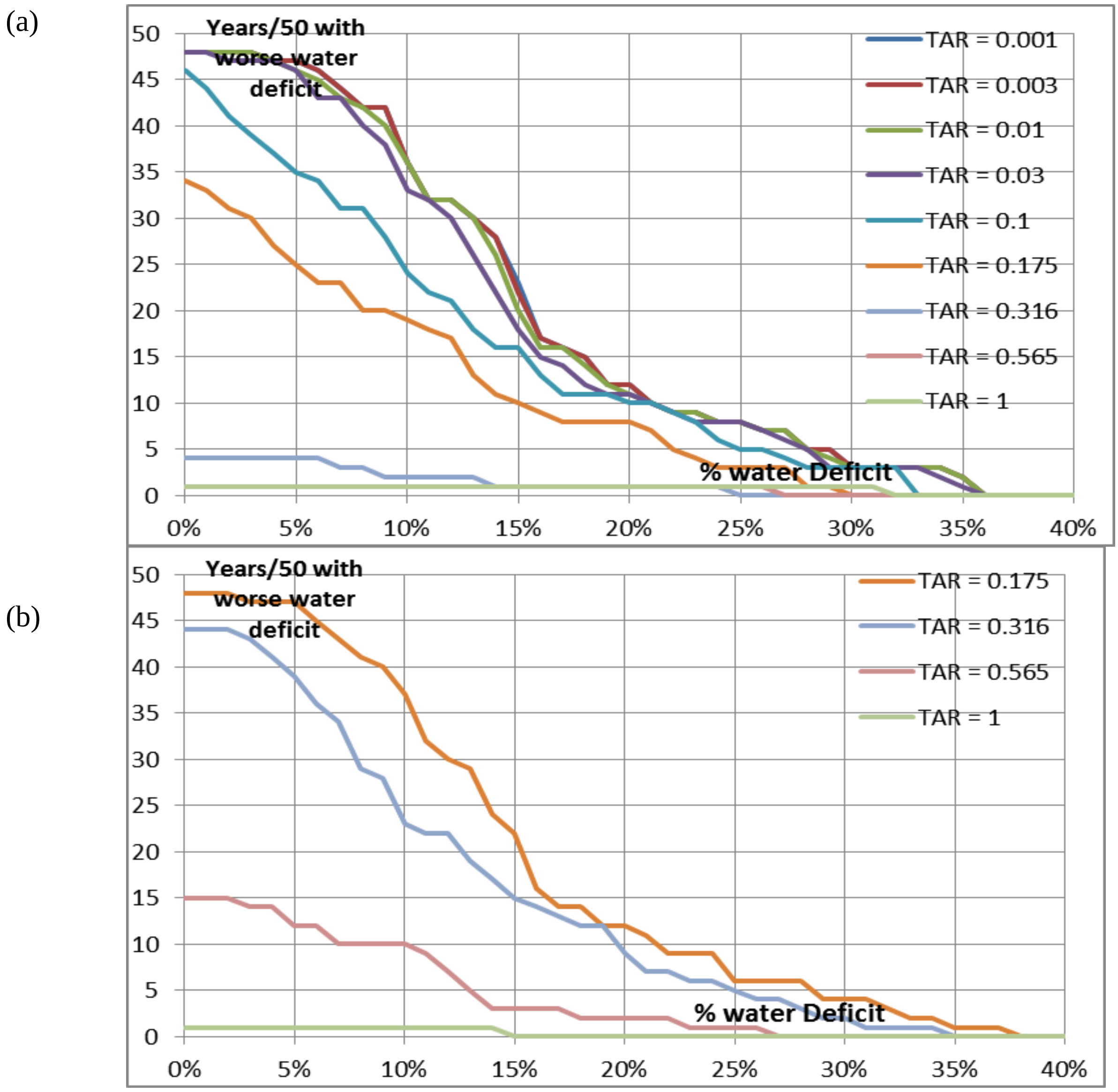


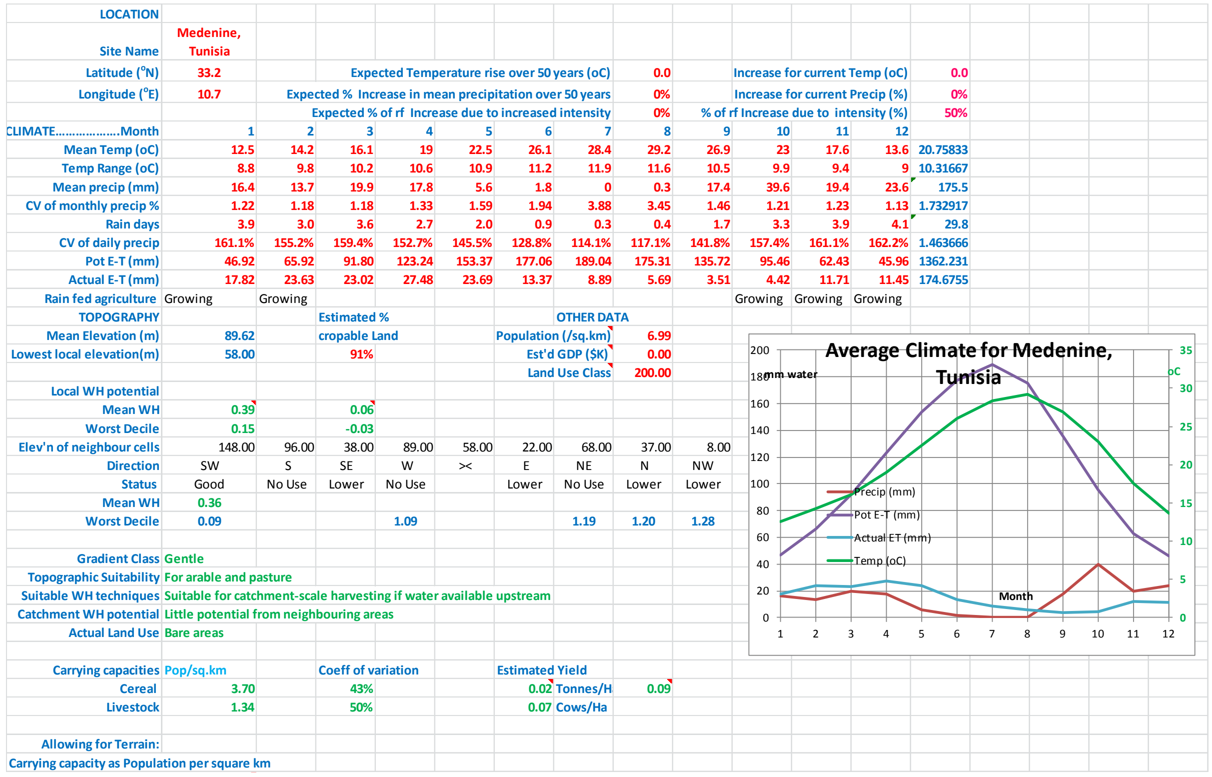
Figure 10: Distribution of deficit risk, using collecting areas filling a tank, which then provides irrigation water when needed. TAR = ratio of collecting area to cropped area. is for a covered tank and (b) for an open tank, with surface area 5% of the cropped area. In comparing TAR and CAR, note that TAR includes only the collecting area feeding the tank or pond, whereas CAR also includes the cultivated area itself

The effectiveness of storage-based systems can be compared with direct rain water harvesting. For effective conservation (CAR=1), Figure 7b shows that there will be a 20%

water deficit for 13 years in 50. With an external collecting area equal to the cropped area (CAR =2), this level of deficit is reduced to 8 years in 50. To achieve a similar level of reliability with an open pond, as shown in Figure 10b, the external collecting need only be 32% of the cropped area, and with a covered tank only a 20% collecting area is needed. In both cases rainfall variability requires a pond/tank storage volume of 1000-1200 m^3 per hectare of cultivation. This is more economically achieved with an open pond. Taking account of the areas unavailable to crops, either as collecting areas or as the pond itself, there seem to be gains in net yields and their reliability for the dryer areas (Ethiopia and Tunisia), and these appear to increase for collecting areas equal to or greater than the cropped/ irrigated area.

Using the QuickScan tool: current utility

The QuickScan tool is embodied in an Excel spread-sheet (QuickSCAN_v2.xlsm) with supporting macros. Figure 11 shows the main landing sheet for the tool, which will be made freely available to potential users through the WAHARA web site. The tool should be supported by an additional Excel spreadsheet that contains background data for Africa (Africa_CRU.xlsm) that provides recommended, but not essential regional data.



LOCATION													
Site Name	Medenine, Tunisia												
Latitude (°N)	33.2						Expected Temperature rise over 50 years (oC)	0.0				Increase for current Temp (oC)	0.0
Longitude (°E)	10.7						Expected % Increase in mean precipitation over 50 years	0%				Increase for current Precip (%)	0%
							Expected % of rf Increase due to increased intensity	0%				% of rf Increase due to intensity (%)	50%
CLIMATE……………….Month	1	2	3	4	5	6	7	8	9	10	11	12	
Mean Temp (oC)	12.5	14.2	16.1	19	22.5	26.1	28.4	29.2	26.9	23	17.6	13.6	20.75833
Temp Range (oC)	8.8	9.8	10.2	10.6	10.9	11.2	11.9	11.6	10.5	9.9	9.4	9	10.31667
Mean precip (mm)	16.4	13.7	19.9	17.8	5.6	1.8	0	0.3	17.4	39.6	19.4	23.6	175.5
CV of monthly precip %	1.22	1.18	1.18	1.33	1.59	1.94	3.88	3.45	1.46	1.21	1.23	1.13	1.732917
Rain days	3.9	3.0	3.6	2.7	2.0	0.9	0.3	0.4	1.7	3.3	3.9	4.1	29.8
CV of daily precip	161.1%	155.2%	159.4%	152.7%	145.5%	128.8%	114.1%	117.1%	141.8%	157.4%	161.1%	162.2%	1.463666
Pot E-T (mm)	46.92	65.92	91.80	123.24	153.37	177.06	189.04	175.31	135.72	95.46	62.43	45.96	1362.231
Actual E-T (mm)	17.82	23.63	23.02	27.48	23.69	13.37	8.89	5.69	3.51	4.42	11.71	11.45	174.6755
Rain fed agriculture	Growing	Growing								Growing	Growing	Growing	
TOPOGRAPHY			Estimated %				OTHER DATA						
Mean Elevation (m)	89.62		cropable Land				Population (/sq.km)	6.99					
Lowest local elevation(m)	58.00		91%				Est'd GDP ($K)	0.00					
							Land Use Class	200.00					
Local WH potential													
Mean WH	0.39		0.06										
Worst Decile	0.15		-0.03										
Elev'n of neighbour cells	148.00	96.00	38.00	89.00	58.00	22.00	68.00	37.00	8.00				
Direction	SW	S	SE	W	><	E	NE	N	NW				
Status	Good	No Use	Lower	No Use		Lower	No Use	Lower	Lower				
Mean WH	0.36												
Worst Decile	0.09			1.09			1.19	1.20	1.28				
Gradient Class	Gentle												
Topographic Suitability	For arable and pasture												
Suitable WH techniques	Suitable for catchment-scale harvesting if water available upstream												
Catchment WH potential	Little potential from neighbouring areas												
Actual Land Use	Bare areas												
Carrying capacities	Pop/sq.km		Coeff of variation			Estimated Yield							
Cereal	3.70		43%			0.02	Tonnes/H	0.09					
Livestock	1.34		50%			0.07	Cows/Ha						
Allowing for Terrain:													
Carrying capacity as Population per square km													

Figure 11: Main landing sheet for the QuickScan tool. Example shown is for Medenine, Tunisia

The background data provides publicly available data at spatial resolution of 10 Arc minutes (approximately 15 km) for monthly meteo (rainfall, rain days, temperature, temperature range, relative humidity, sun hours, frost days, wind speed and potential evapo-transpiration), together with derived data on water harvesting potential and actual evapo-transpiration; Additional files show population density, land use and GDP.

On the QuickScan landing page, the minimum required data is the site name and its latitude and longitude. These data are used to search the background data files to extract information for the site, which is then tabulated on the landing page, and the meteo data presented as a summary graph. If the user has access to better data, then any of the values in red can be replaced by user data. The user is also invited to enter simple climate scenarios for precipitation and temperature, as a fixed offset from the tabulated values, and/or imposing a trend of change over the next 50 years.

The values entered are then used to run the underlying model that generates a 50-year realisation of climate on a monthly basis, and interpret it for water harvesting potential, crop yields etc, generating a number of summary graphs, of which Figures 5-10 are examples. The results are also summarised in a series of text statements which can form the basis of a dialogue at local level referring to the conditions for agriculture with reference to water availability, the potential of local topography to collect water for harvesting and soil conditions.

The QuickScan tool requires a laptop PC (currently running under WINDOWS 7), but no internet connection, so that it can be taken into the field. Each run of the program with altered input data takes a few seconds, so that a local dialogue can explore a number of what-if alternatives. Although the tool is freely available to all users, it is recommended for implementation by a person with some prior training. Further development is still in progress, both in refining the algorithms and parameterisation and in enhancing user feedback. The current version of the tool can be downloaded from the WAHARA website.

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Appendix: WHT classification for QuickScan tool

The general classification of WHT here has already been presented within the project:

- In situ soil moisture conservation methods;
- Microcatchment methods;
- Macrocatchment methods;
- Flood water harvesting methods; and
- Atmospheric water harvesting methods.

However, we might end up with techniques that belong to two main categories in further sub-dividing the WHT. These are mainly storage systems that can either be macrocatchments or flood water harvesting based on the source of water, either runoff or flood. Accordingly, we propose further sub-division by primarily classifying the WHT into two broad categories, namely, techniques that facilitate the infiltration and subsequent storage of rainfall/runoff in the soil profile and systems that collect and store runoff/flood in storage mediums.,

A WHT that store rainfall/runoff in the soil profile

1 In situ moisture conservation methods

These systems are more suitable in dry sub-humid climates where the amount of rainfall is relatively sufficient to meet the crop water demand but water scarcity is aggravated due to large proportion of runoff loss. The techniques required in such situation need to avoid runoff and encourage the infiltration of rainfall where it falls. These systems can best be divided based on the soil type they best perform.

1.1 Techniques used in heavy soils

The two most important undesirable problems in heavy soils are waterlogging and poor workability when wet and induration when dry. As a result, the WHT implemented should be able to facilitate drainage of excess water and create a friable bed for cultivation (***Example: Broad Bed and Furrows***).

1.2 Techniques used in medium and light soils

Since waterlogging is not as such a problem in these soils, a technique that collects as much rainfall as possible can be used (***Example: Tied ridges***).

Broad Bed and Furrows

Tied ridges

2 Microcatchment methods

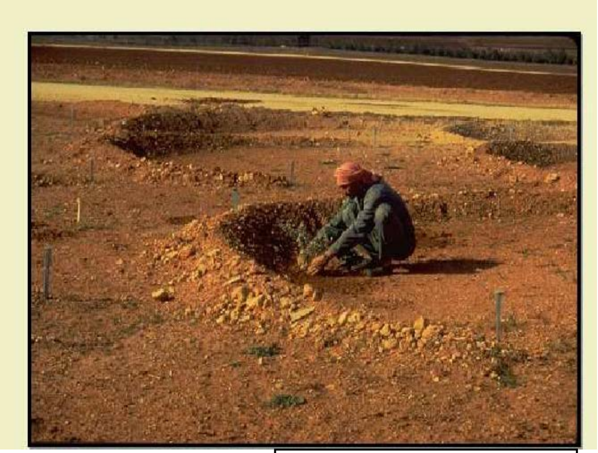
These systems are generally characterized by a catchment to cultivated area ratio (C:CA) of 1:1 – 3:1. They collect runoff from a short catchment area left between adjacent structures. They are more suitable to wetter semi-arid areas and are best sub-categorized based on the landuse/cropping system they better suit.

2.1 Techniques used for crop production (*Example: Contour ridges*)

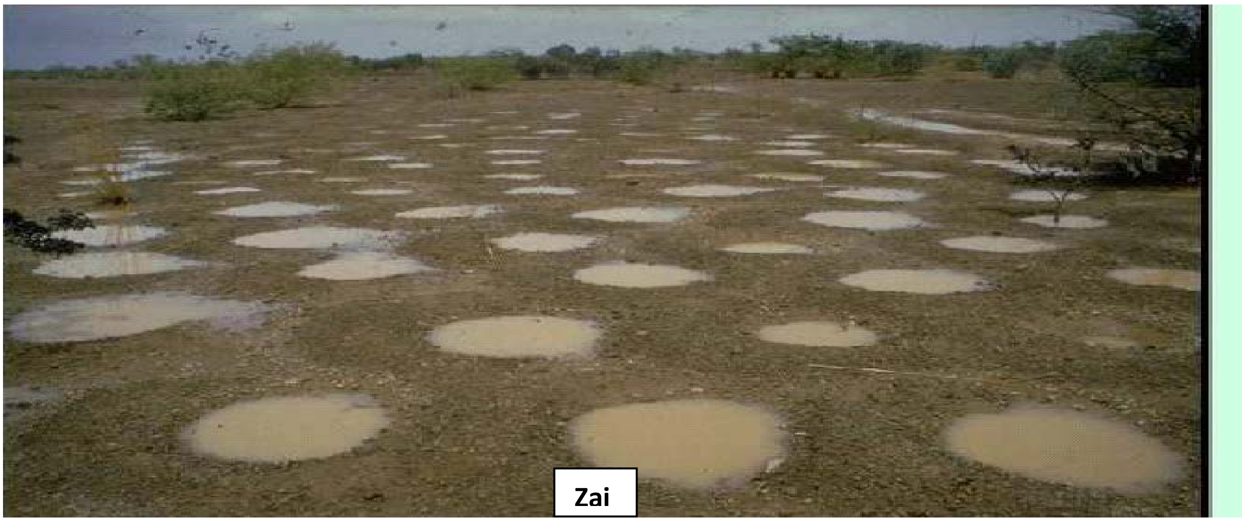
2.2 Techniques used for fruit production (*Example: Semi-circular bunds*)

2.3 Techniques used for rehabilitation of degraded/range lands (*Example: Zai*)

Contour ridges



Semi-circular bunds



3 Macrocatchment methods

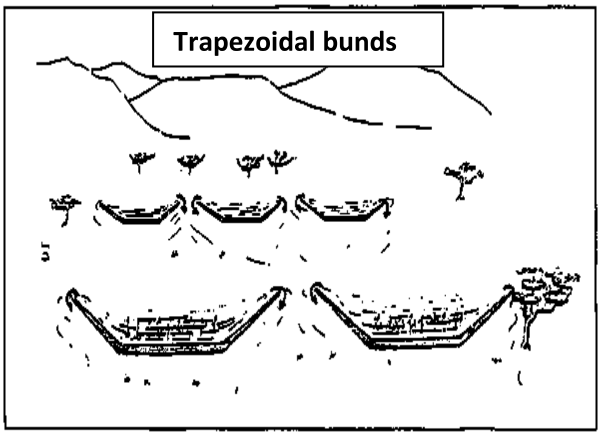
These systems are generally characterized by C:CA of 3:1 – 10:1 and are more suitable in drier semi-arid areas. The best way to sub-divide these systems is based on the source and management of the runoff.

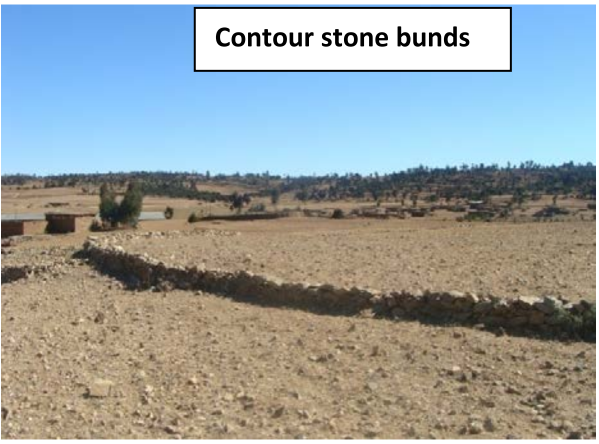
3.1 Techniques used on cultivated areas adjacent to hillsides

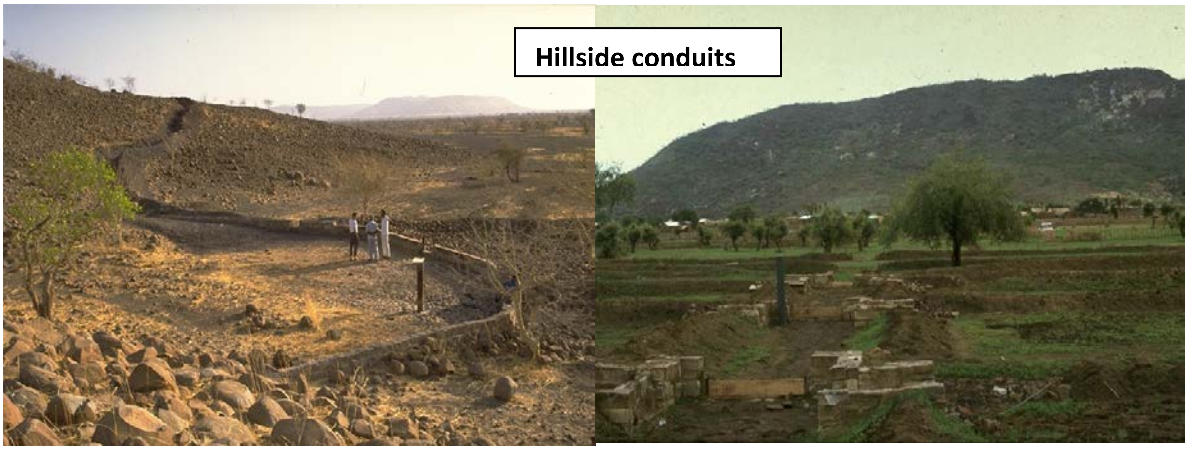
These techniques generally collect/direct large quantities of runoff from long slope catchments to the cultivated areas (***Example: Trapezoidal bunds or Hillside conduits***).

3.2 Techniques used in plain cultivated land with no adjacent hillsides

Since there is no external hillside that generates runoff, these techniques generally harvest runoff from internal catchment between the structures in a way to ensure good water distribution by facilitating either filtering or overflowing of excess runoff to adjacent downstream fields (***Example: Contour stone bunds***).







Hillside conduits

4 Flood water harvesting methods

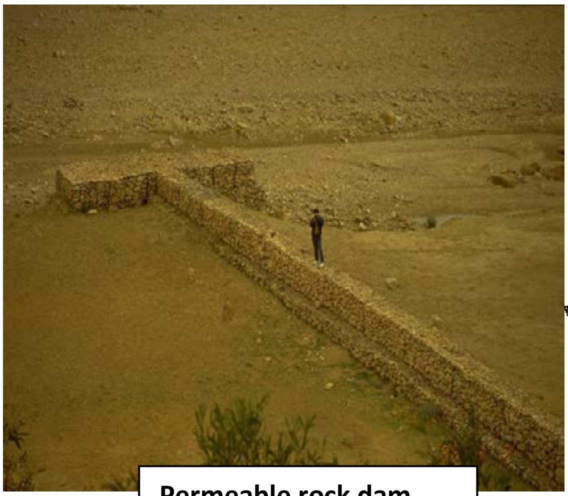
These systems collect not runoff but flood from seasonal streams with large catchment area upstream. They can best be classified based on how the flood is managed.

4.1 Techniques that spread the flood in valley bottoms

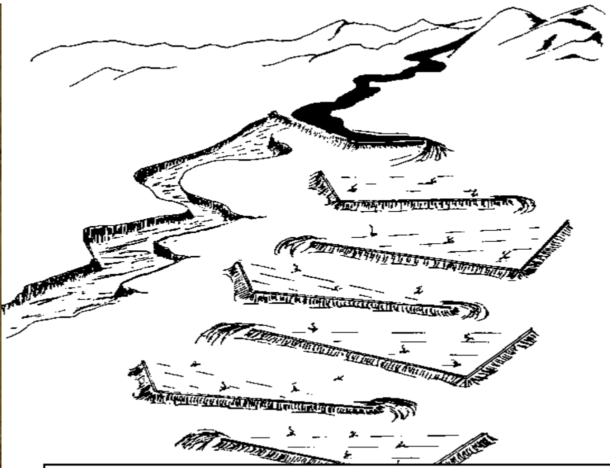
These structures are typically long and low walls constructed across a valley for dual purpose. On the one hand, water and eroded sediments are deposited behind the structures creating favourable conditions for plant growth. On the other, gully development is also healed and the entire valley stabilized (***Example: Permeable rock dams/Check dams***).

4.2 Techniques that divert flood from seasonal streams and spread it onto a floodplain

These systems generally constitute of a flood diversion structure constructed across a seasonal water course associated with conveyance canals and water spreading bunds (***Example: Flood diversion systems with spreading bunds***).



Permeable rock dam



Flood diversion structure with spreading bunds

5 Atmospheric water harvesting methods

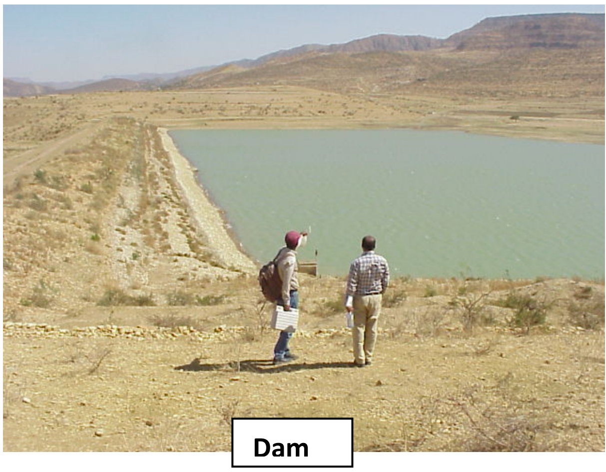
Although limited in areal extent, harvesting of dew from clouds is very important in suitable areas, where nothing could otherwise grow.

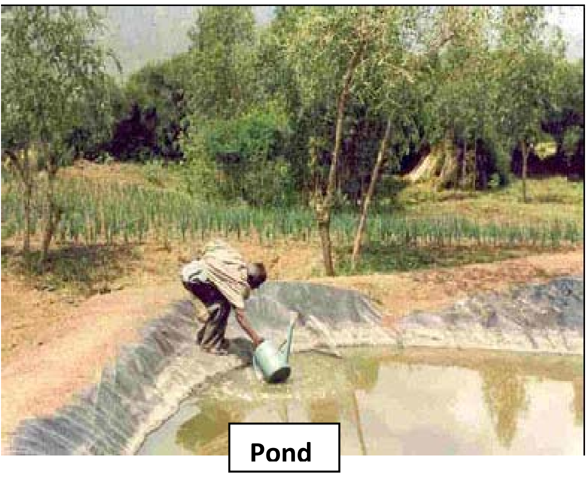
B WHT that store runoff/flood in storage mediums

As indicated earlier, these systems can either be macrocatchment or flood water harvesting methods based on the water source. However, the most important factor to categorize them separately is the way the runoff/flood is managed. Unlike the first group of WHT that encourage storage of water in the soil profile, these systems store the water in storage structures and make it available for longer period. They also minimize the risk of crop failure better than the first group especially during dry spells which is very common in drylands. The best way to sub-categorize these systems is based on where the water is stored.

6.1 Techniques that store water above ground (*Example: Dams, ponds, roof water harvesting tanks*)

6.2 Techniques that store water below ground (*Example: Cisterns, sub-surface dams*)


Dam


Pond


Roof water harvesting tank


Cistern