Water supply and demand for rain-fed agriculture in Africa

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Water scarcity for rain-fed cultivation

- Water is becoming the scarcest resources in meeting the need for increasing global food production
- Need to improve water efficiency of crops
- Scope to do this through
  - Selective breeding
  - Better use of available water to increase yield /mm
    - Additional fertiliser etc inputs
    - Water harvesting
      - Increases Yield per Hectare cultivated and per mm of water used
      - But reduces cultivated area
      - Essential for cultivation where rainfall is low
      - Most benefit where runoff coefficients is high, giving
        - » Increased water gathering potential
        - » Nutrient addition through deposition of eroded sediment
      - Other negative effects
        - » Risk of increased local salinisation
        - » Greater upstream use of runoff takes away from downstream users

Water use efficiency for Millet yield

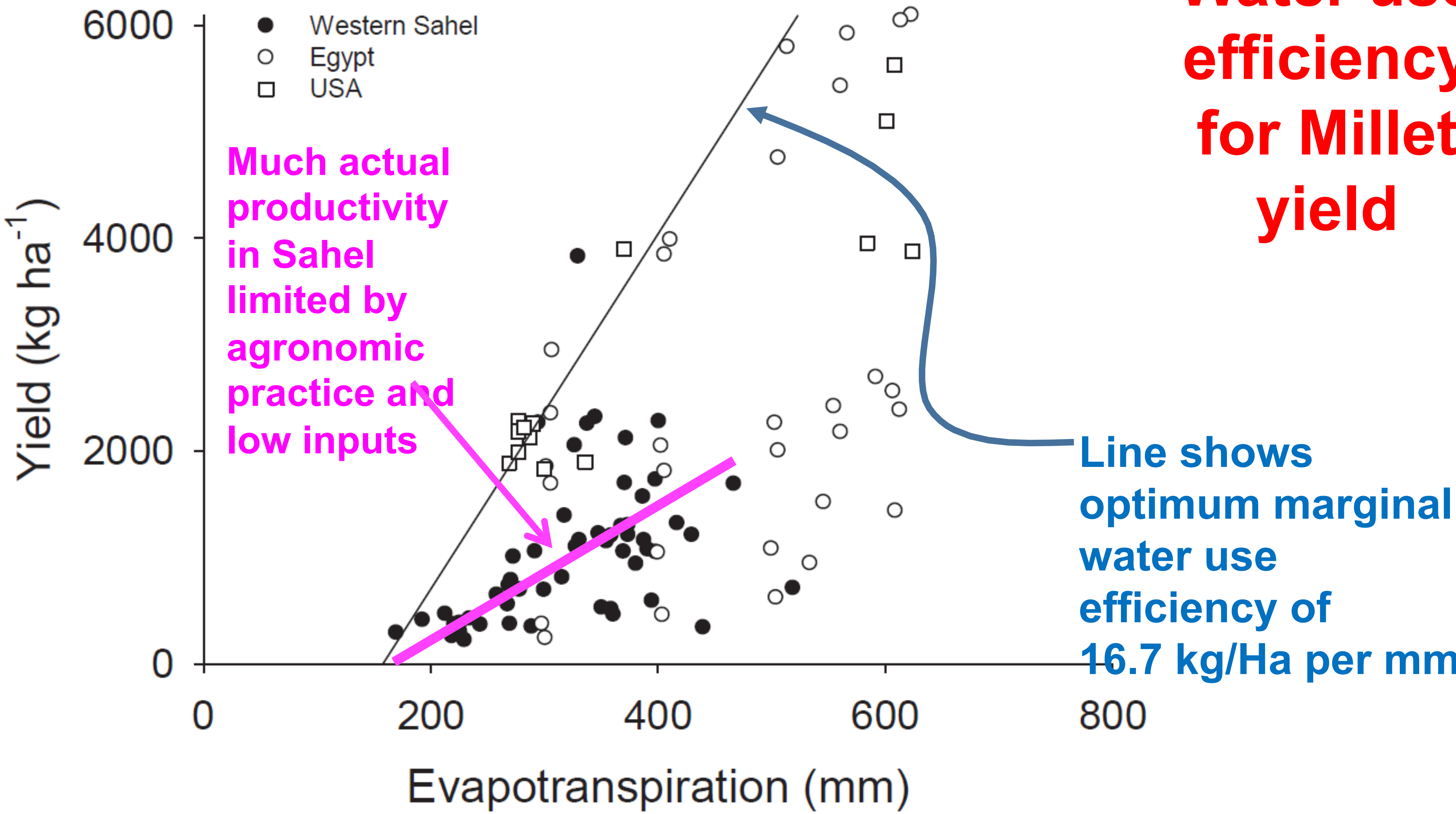
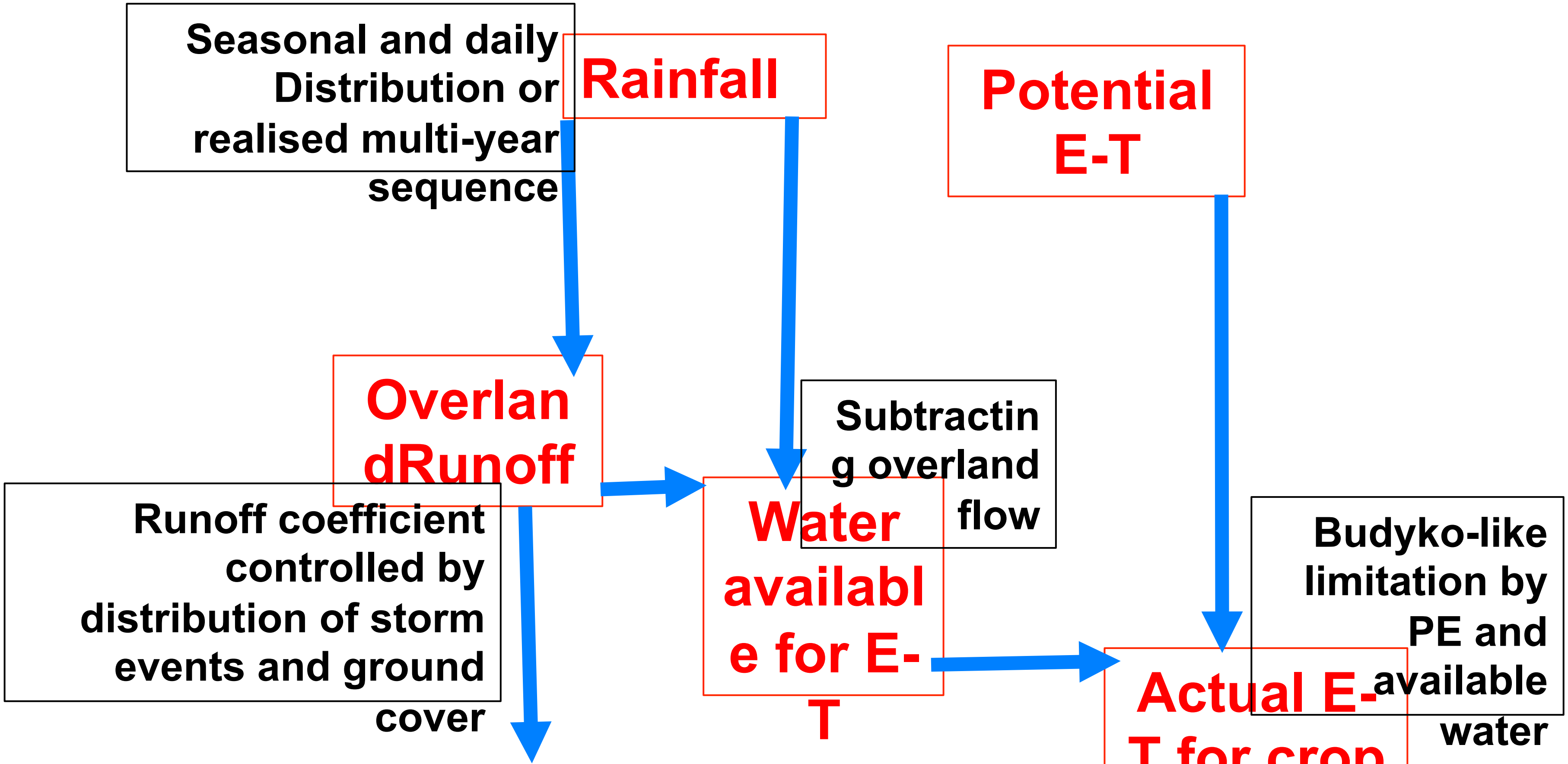


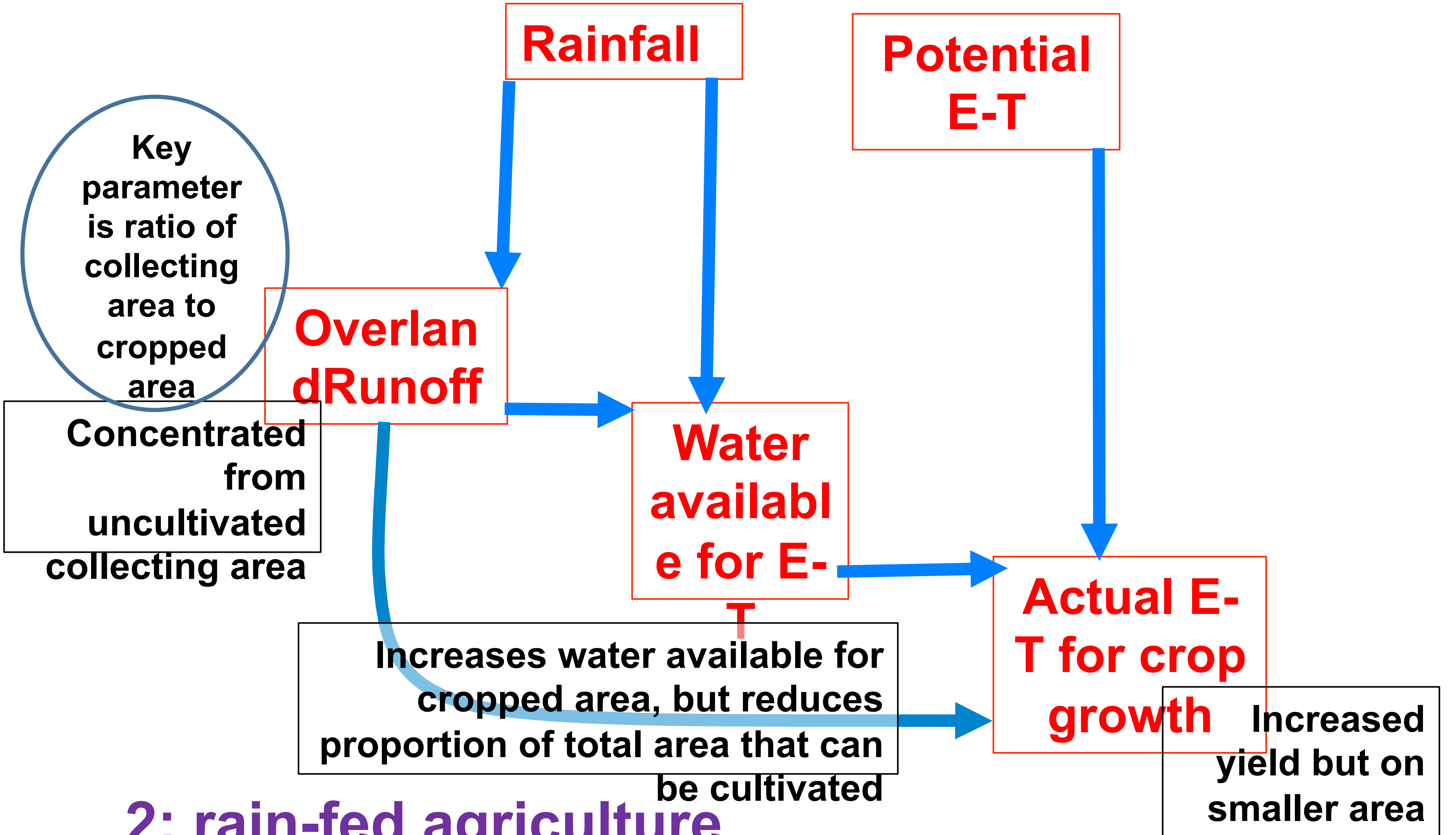
Figure 11 from Sadras, Grassini & Steduto, 2011: Status of water use efficiency of main crops. In: The state of world's land and water resources for food and agriculture (SOLAW). FAO, Rome and Earthscan, London

Hydrology of water harvesting



1: rain-fed agriculture with no water conservation

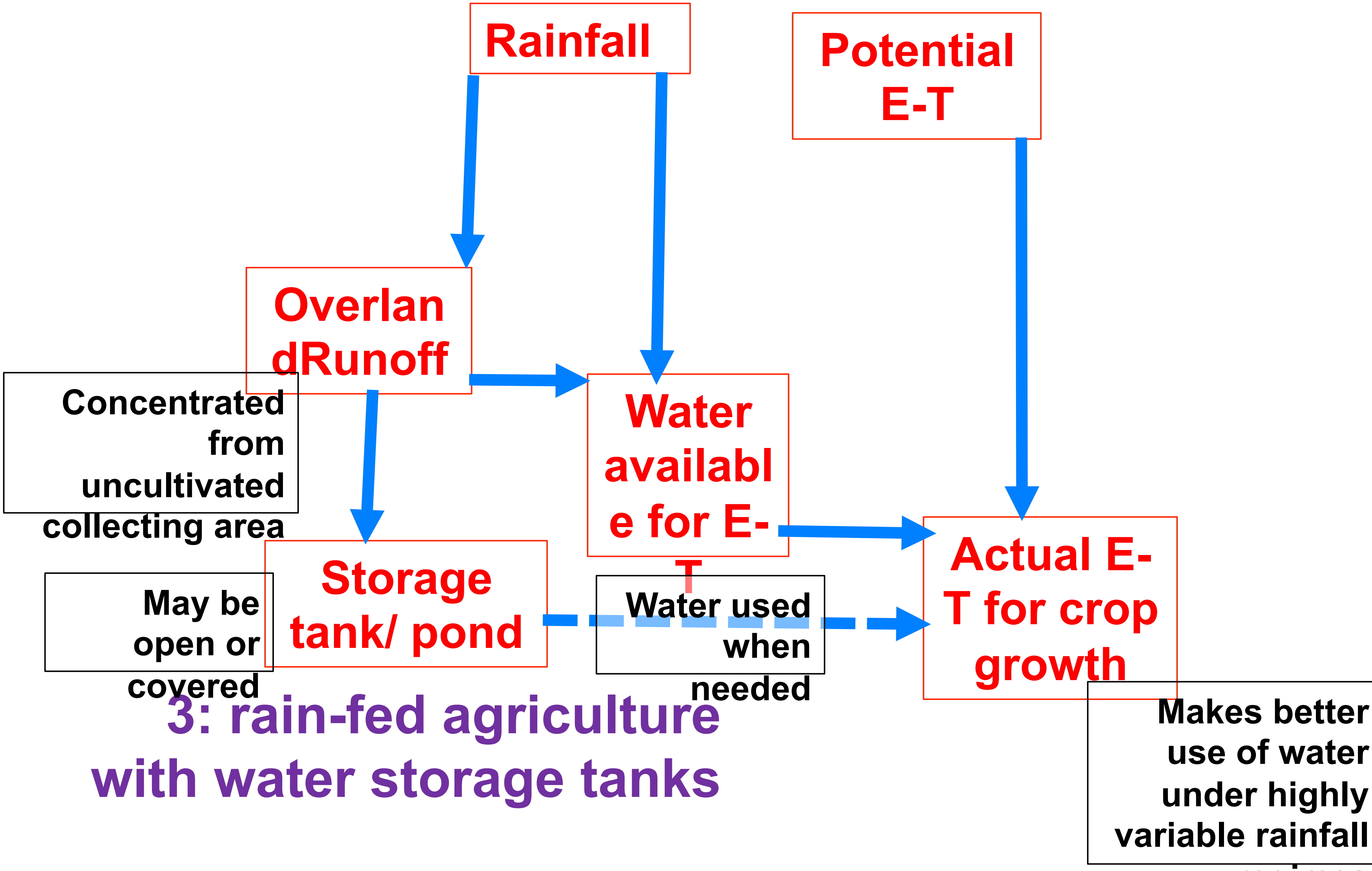
Hydrology of water harvesting



2: rain-fed agriculture with rainwater harvesting

Problems during unexpected dry periods

Hydrology of water harvesting



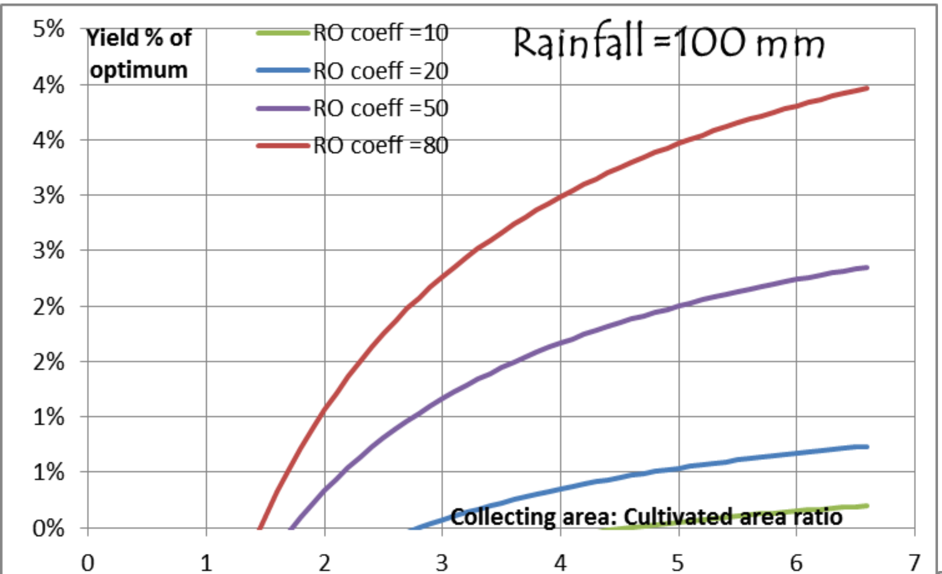
3: rain-fed agriculture with water storage tanks

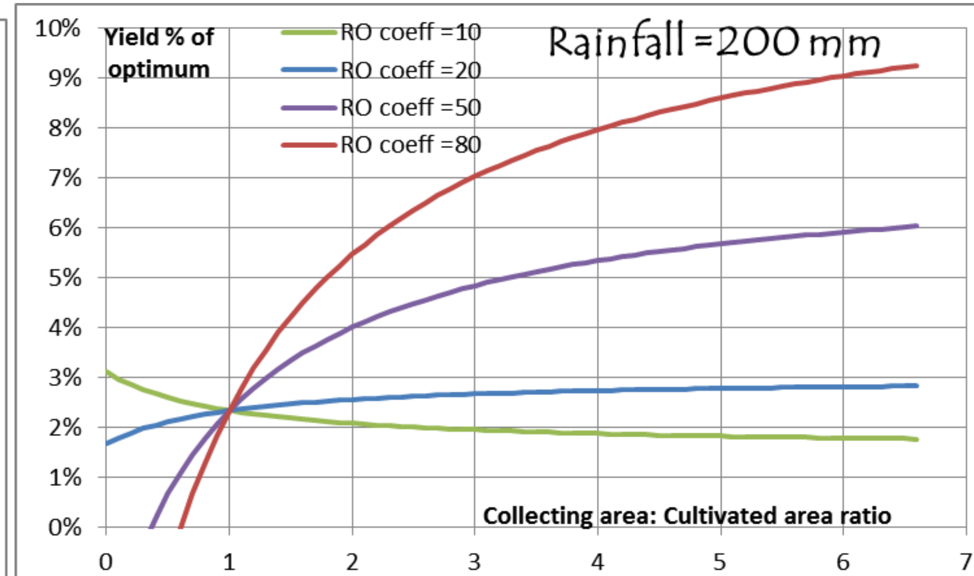
Effective average yield with water Harvesting (with Pet = 1500mm)

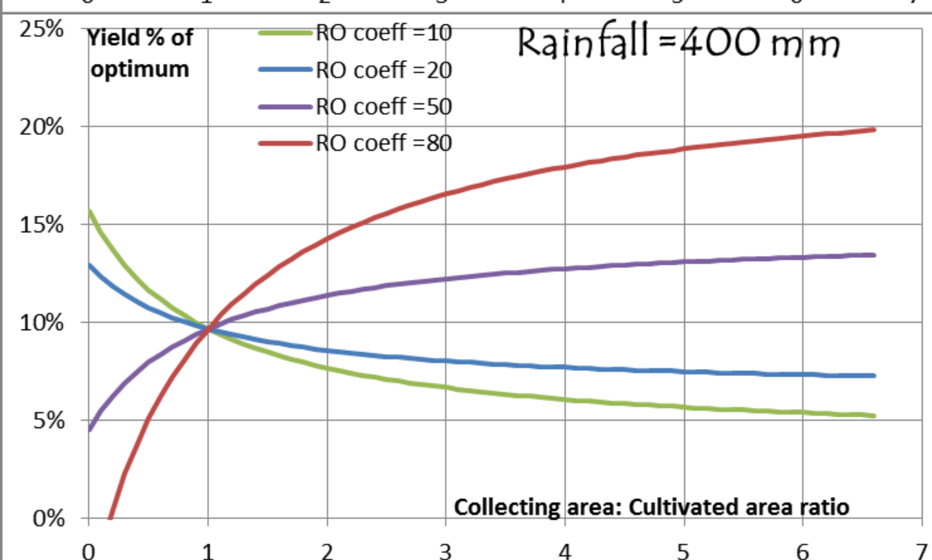
(assuming that water collecting area is unproductive)

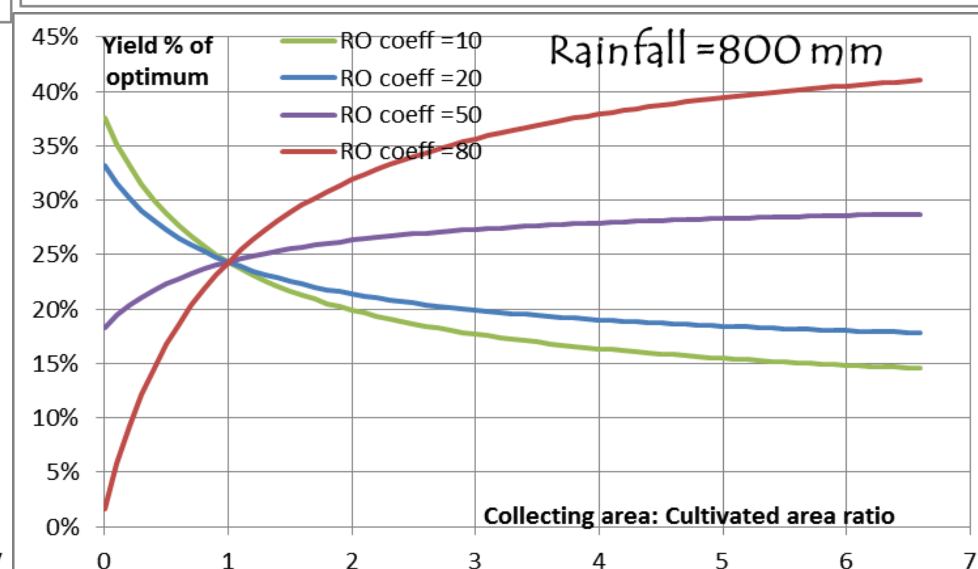
In very dry areas, there is no crop without water harvesting.

It is always a good strategy to increase the runoff coefficient from collecting







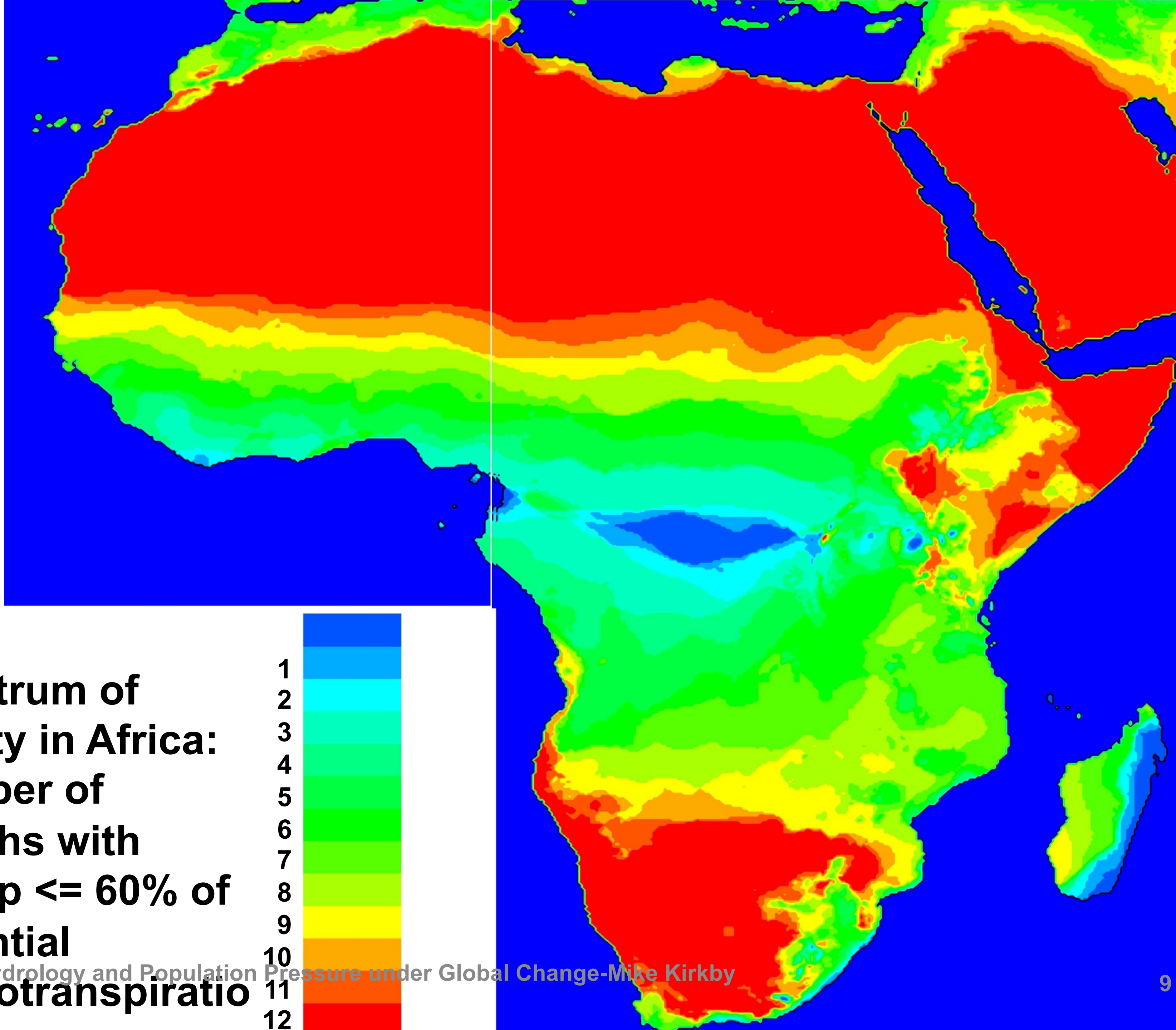


Objectives as part of WAHARA* project

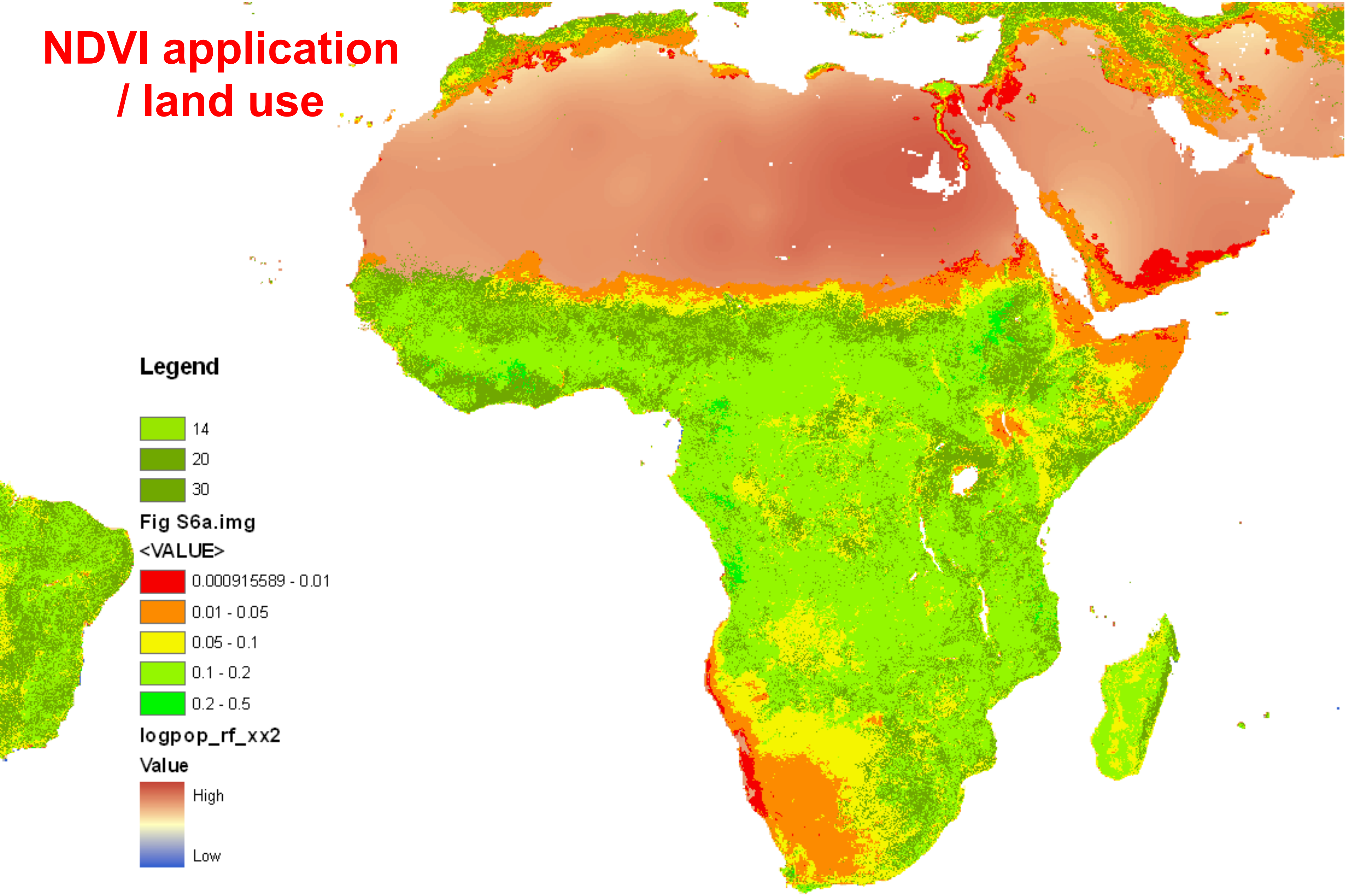
- **Make use of available climate and other data to put particular areas into their broad regional context using a water balance model**
  - Shortfall of reliable rainfall for rainfed crop production
  - Required ratio of water harvesting area to crop harvesting areas
- **Provide initial advise to researchers and stakeholders on options for improving water use and sustainability of crop production**
  - Localising the model, with additional information provided at local level, to suggest a range of possibly suitable alternative water harvesting methodologies

WAHARA (WAter HARvesting in Africa) is an ongoing FP7 project, working with partners in Burkina-Faso, Ethiopia, Tunisia and Zambia to share good WH practice, mainly in the context of rain-fed agriculture.

Spectrum of Aridity in Africa: Number of months with Precip <= 60% of Potential Evapotranspiratio

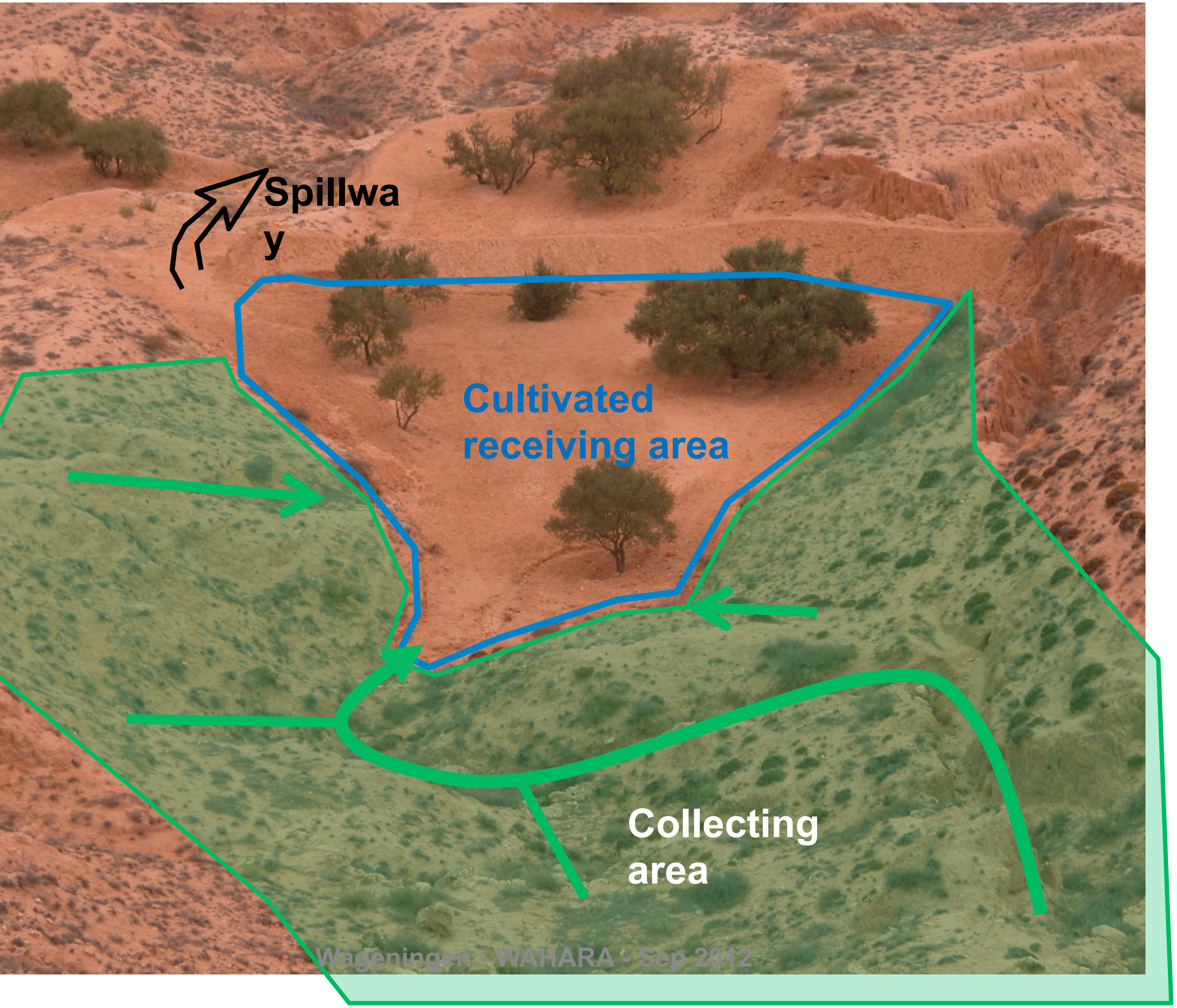


NDVI application / land use



Principles of Surface water harvesting

(at scales from a few square metres up to many square kilometres)



A_R = Cultivated Area
A_C = Collecting Area

Collecting area is defined to include that part of the cultivated area from which runoff is retained.

$\Psi = A_C/A_R$

For in-field water conservation,
$\Psi \leq 1$

With external collecting area (as shown),
$\Psi > 1$

Classification of water harvesting methods for rain-fed agriculture

- Soil conservation measures to reduce runoff, ψ=1.0
  - Water retention in the soil
  - Stone Lines, terraces and water retention pits
- Micro catchments for immediate water use
  - Collecting areas around each small group of plants: ψ=2-5
  - Partial diversion of stream water during flow events: ψ>10
    - May enable transfer of water from wetter adjacent uplands
  - Small hillside catchments supplying a cultivated area: ψ=5-10
  - Overspill from cropped areas cascades downslope
- Retention in open ponds or covered tanks
  - Supplied by a collecting area or stream diversion during flow events
  - Potential to delay water use until next period of crop stress
  - Covered tanks reduce evaporation loss during storage and disease vectors
  - Deliberate recharge of shallow groundwater
- Water harvesting may also be required for
  - Drinking Water and domestic needs
  - Watering livestock

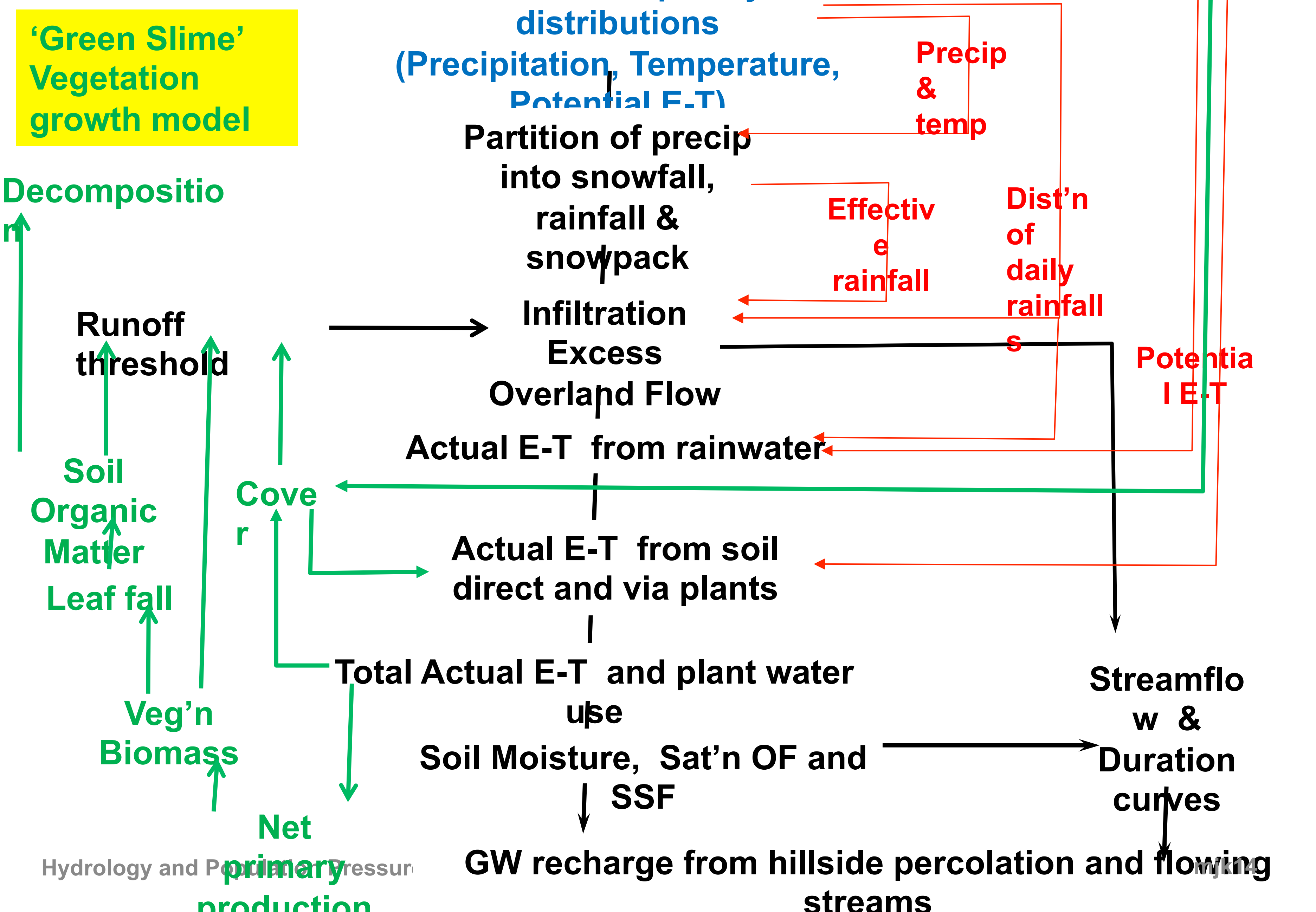

In situ water conservatio n
Ψ <= 1

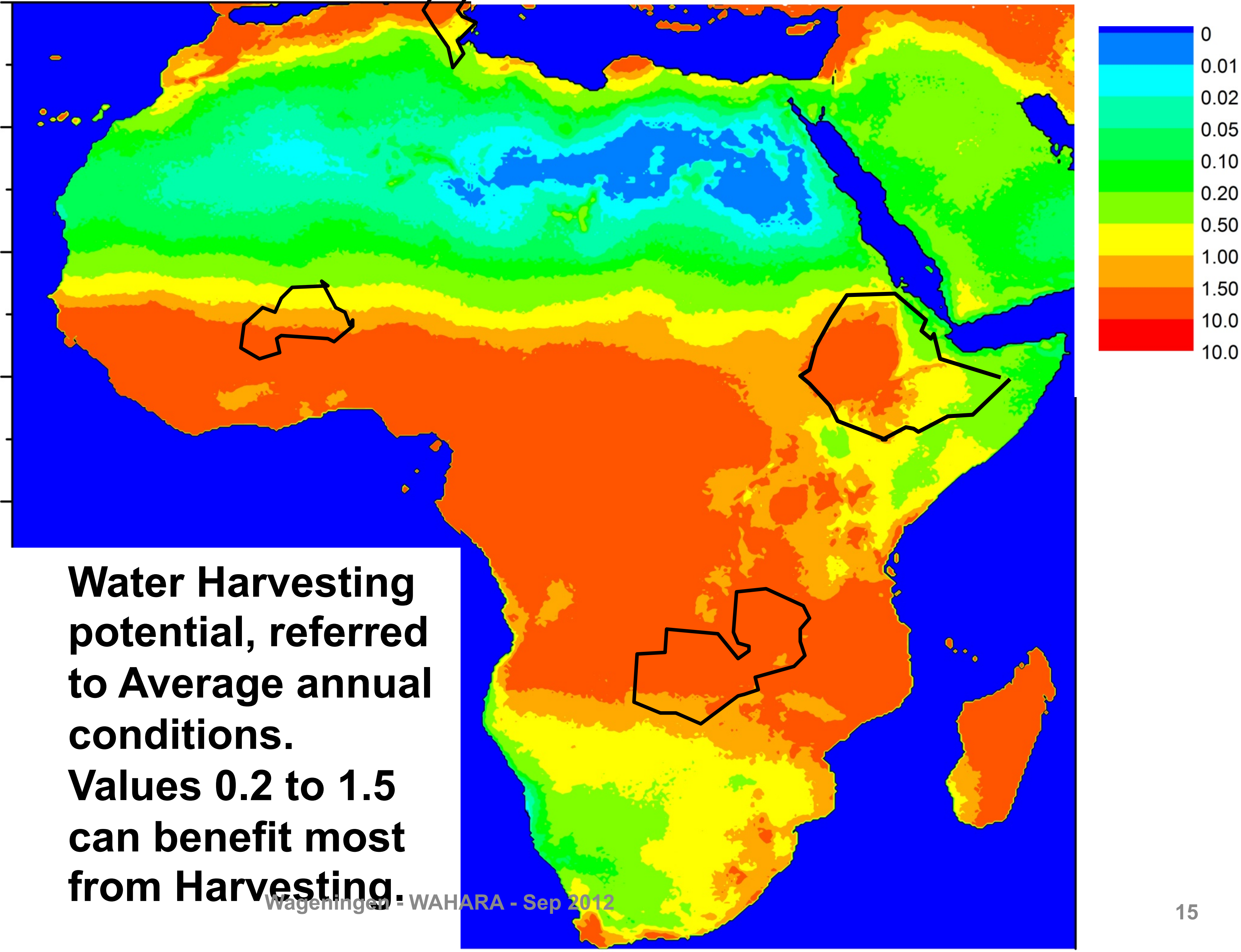

Half Moon micro-catchments
Ψ = 2- 5


Open storage

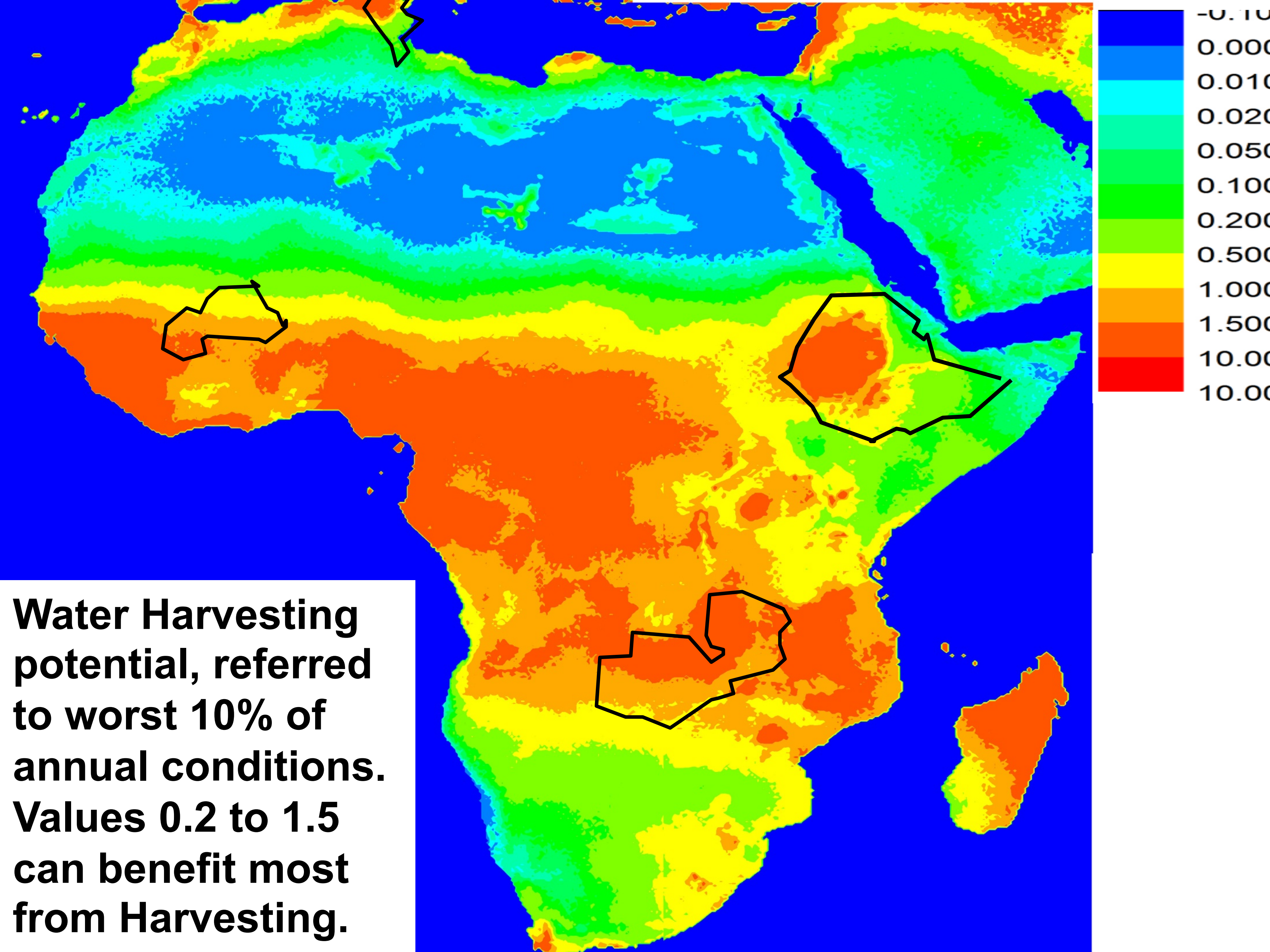

Covered underground storage tank for
mjk13

Model Scheme

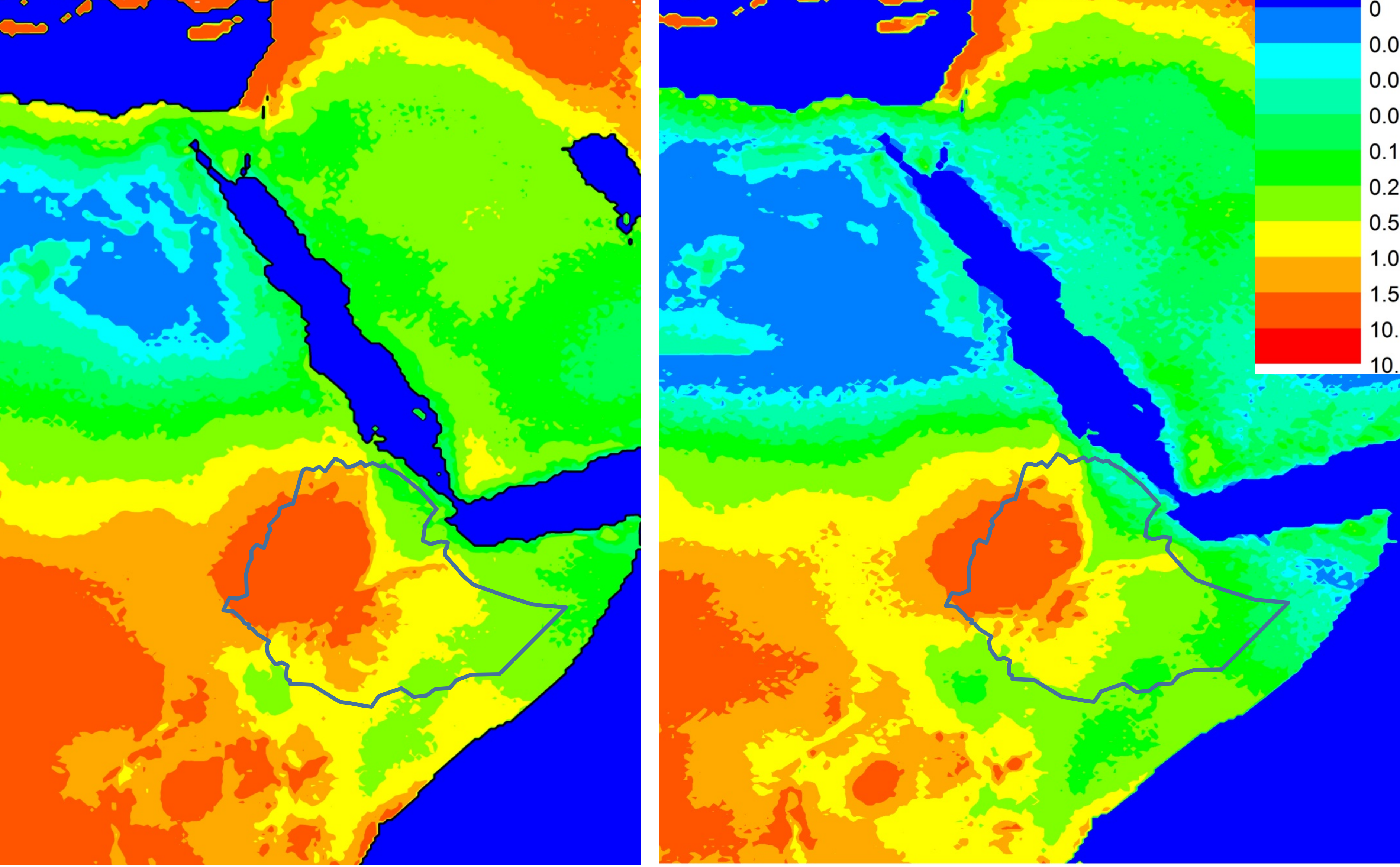




Water Harvesting potential, referred to Average annual conditions. Values 0.2 to 1.5 can benefit most from Harvesting.



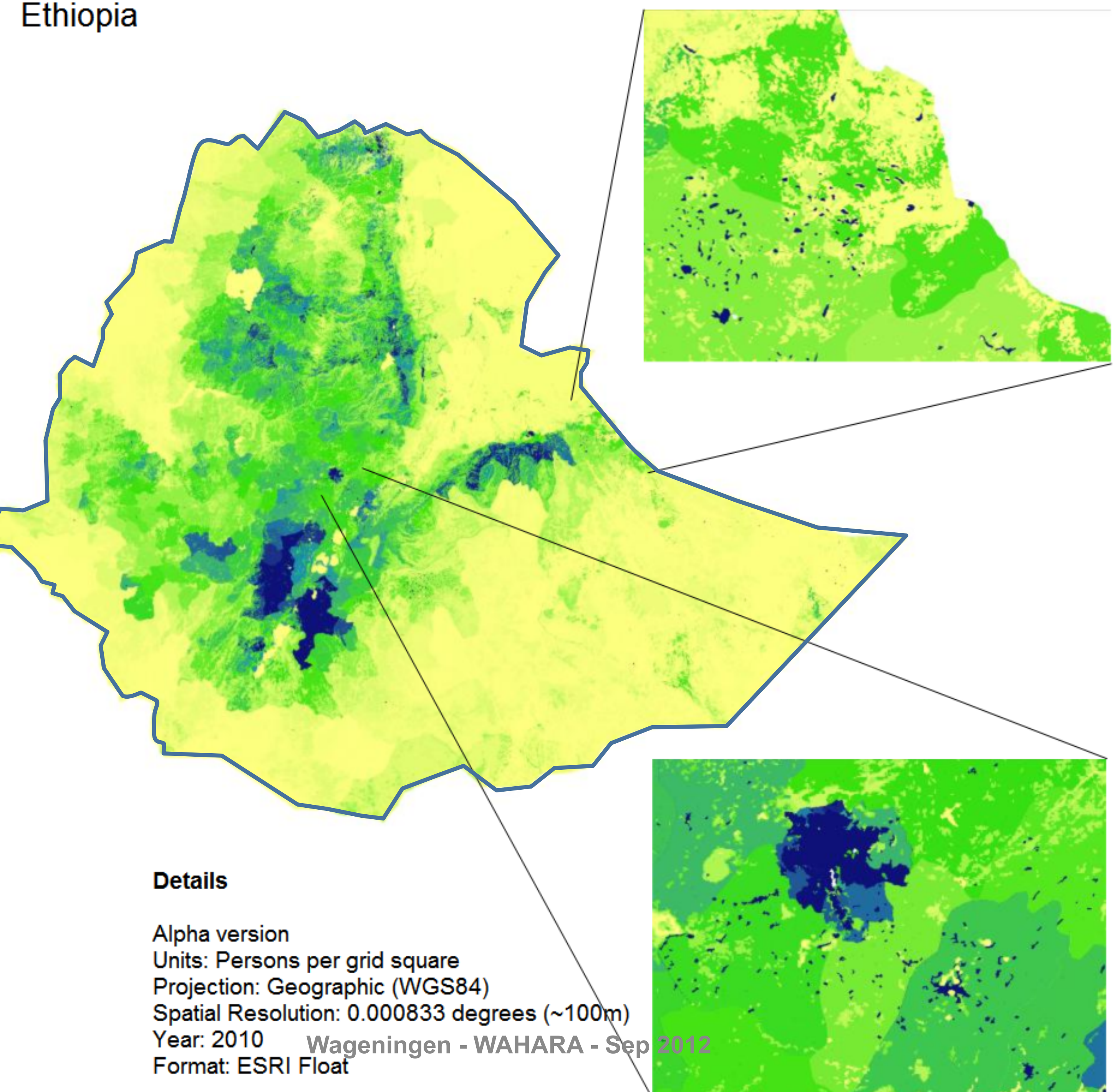
Water Harvesting potential, referred to worst 10% of annual conditions. Values 0.2 to 1.5 can benefit most from Harvesting.



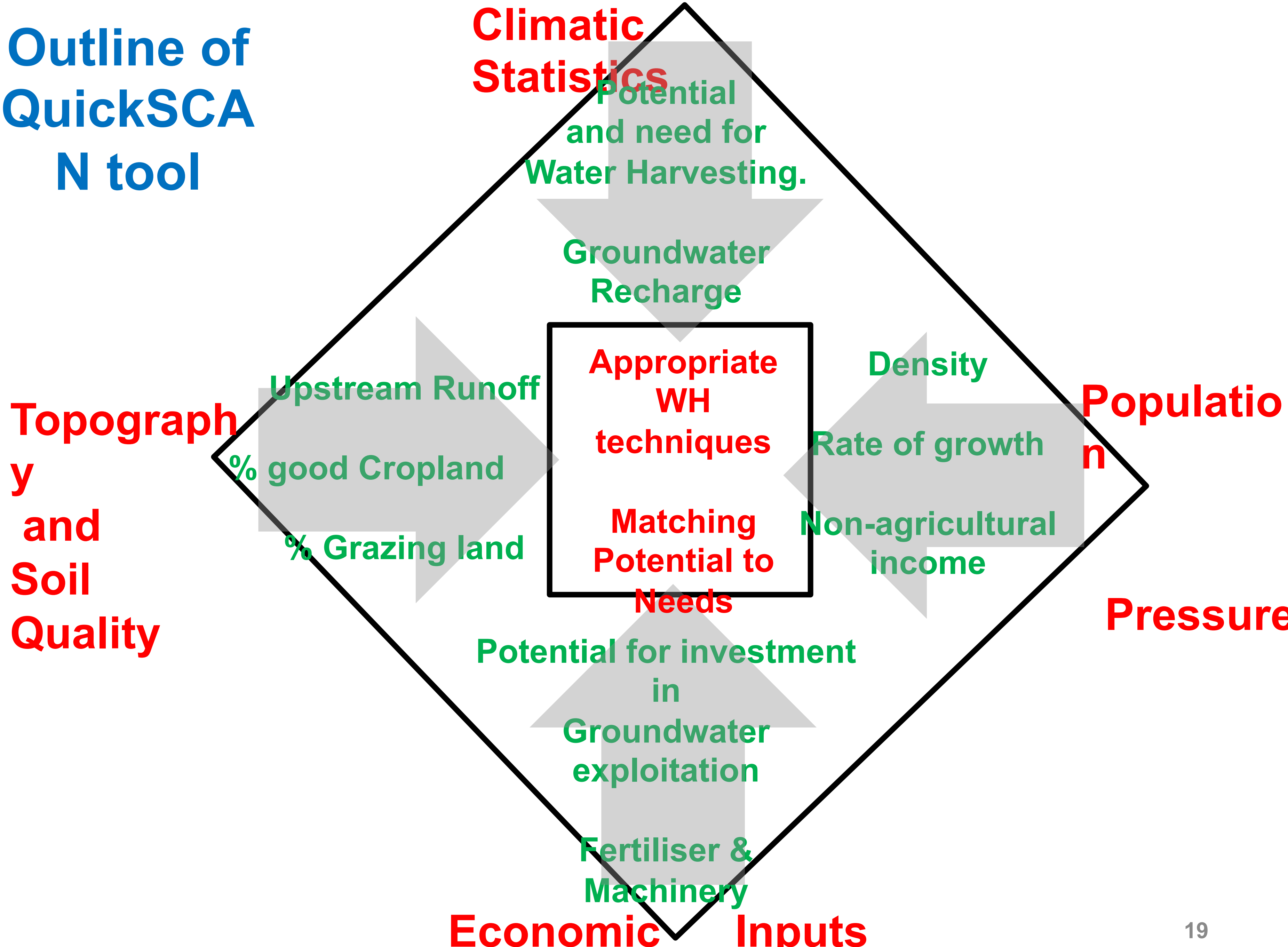
Water Harvesting Potential for NE Africa
Average (Left) and Worst 10% of Years (Right)

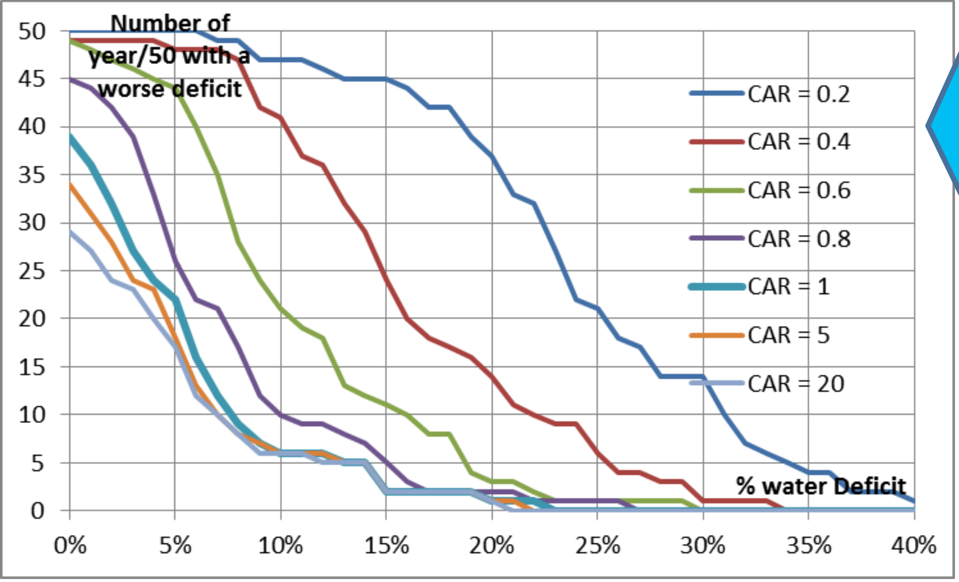
Population Density map for Ethiopia

Source Afri_Pop for 2010



Outline of QuickSCAN tool





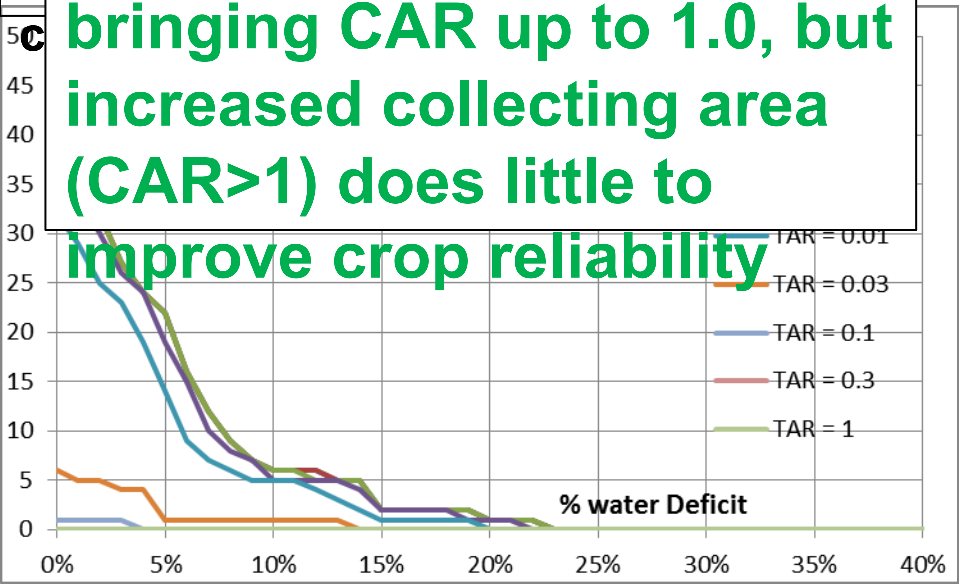
Direct water harvesting: CAR = Ratio of collecting area to cropped area : 0=No runoff retention: 1 = All runoff retention: >1 implies additional runoff collection

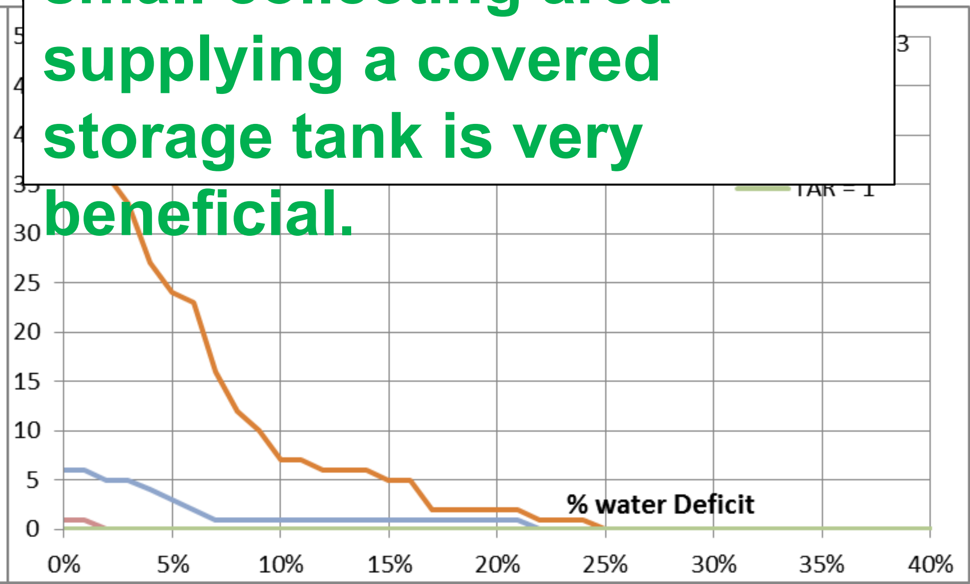
Analysis of reliability of crop production with water

However, an open tank/ pond needs a much larger collecting area to be effective

In this climate, there are very great benefits from conserving water in situ, bringing CAR up to 1.0, but increased collecting area (CAR>1) does little to improve crop reliability

Combined with in-situ water conservation, even a small collecting area supplying a covered storage tank is very beneficial.





Conclusions

- Where rainfall is insufficient for good yields, water harvesting can generally increase yields, and use water more efficiently, even allowing for leaving collecting areas bare.
- Where rainfall shortfall is modest, the greatest returns are through retaining and conserving runoff water
- Measures to increase overland flow runoff coefficients on collecting areas are beneficial.
- Storage tanks/ponds provide greater increases in yield for a given collecting area than direct diversion of runoff, and

Thank you

Model
Scheme

Partition of Precipitation

Hydrological processes

Climate frequency distributions
(Precipitation, Temperature, Potential E-T)

Precip & temp

Runoff threshold estimated, month by month, from cover, biomass

Partition of precip into snowfall, rainfall &

Infiltration-Excess Overland flow
stimated as excess
f daily rainfalls
ver runoff
threshold, summed over Gamma distribution of rains

Saturation-excess and subsurface flow use a simplified TOPmodel

Rainfall component of actual E-T

Groundwater recharge estimated as fraction of deep-percolating water and of streamflow

Ac
dire

l Actual E-T ... nt use

Soil Moisture, Sat'n OF & SSF

GW recharge from hillsid...
streams

Soil component of Actual E-T calculated from unsatisfied demand that can be met from soil water

Model
Schem

'Green Slim
Vegetation
growth m

Decomposition rate an increasing function of temperature except when suppressed

Hydrological
processes

To allow for standing dead, cover converges towards a function of

Decompositio
n

Runoff
threshold

Soil
Organic
Matter

Leaf fall

Cove
r

Veg'n
Biomass

Net
primary
production

ration

e
rainfall

of
daily

ation
Excess
Overland Flow

Actual E-T from

Actual E
direct

Soil

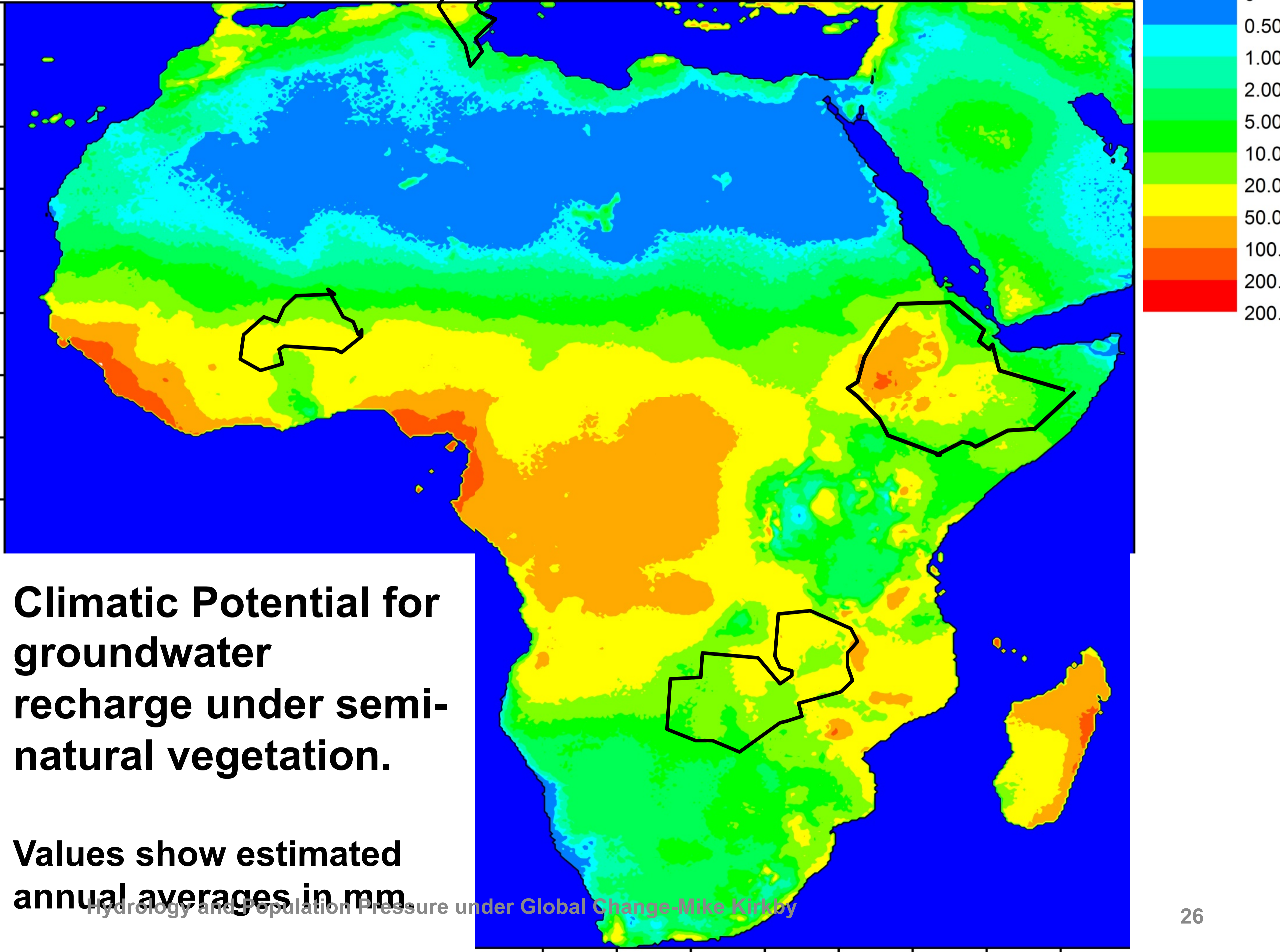
GW recharge fr

Gross productivity estimated as Actual E-T x WUE. Respiration loss as f (Temp ºC). Added to

Leaf Fall (etc) a function of biomass (a smaller proportion for larger structures). Loss transferred to

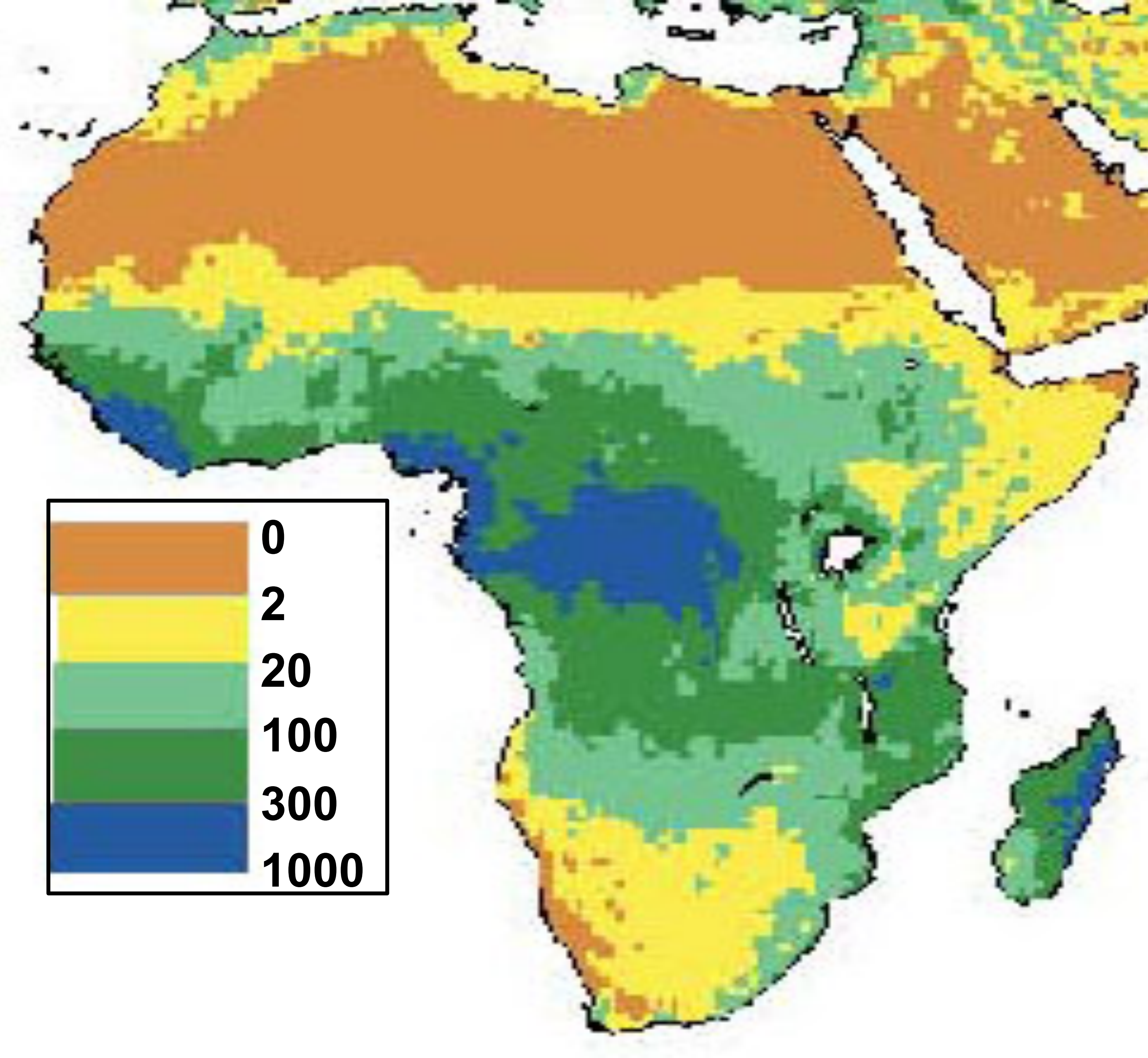
Model behaviour

- The model essentially budgets 1st Water and then Carbon
- Parameterisation aims for global rather than local values.
- Model hydrological response dominated by two parameters, which represent
  1. Rooting depth, R, from which plants can recover soil water
  2. Drainage depth, m, which determines rate at which soil drains through lateral subsurface flow (m as in TOPmodel)
- Extreme cases
  - R>>m: All water goes to evapo-transpiration
  - R<<m: All water goes to drainage
- Fitting to flow data, best fits generally lies between these extremes, so that both drainage and E-T interact (often with seasonal dominance of one or the other)
- Initial runs suggest that reasonable areal



Climatic Potential for groundwater recharge under semi-natural vegetation.

Values show estimated annual averages in mm.



Estimated ground water recharge (mm/ year) for Africa, from Doll & Fielder 2008, based on Water-GAP WGHM model