Pesticide Risk Reduction Programme – Ethiopia

Surface water and groundwater scenario development
5-9 November 2012

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joint collaborative programme on pesticide registration and post-registration

MoA




Towards a sustainable use of pesticides in Africa

Summary sw and gw scenario development

- B2.1: Development of a scientific evaluation system for the registration of pesticides – Evaluation of dossiers of chemical pesticides

So:

- Registration procedure:
- Developing scientific methods to assess risks in Ethiopian context and for use pattern requested by registrant
- Nov '11 workshop: Environment – drinking water high priority
- Nov '12 workshop: Focus on risks for drinking water production from surface water and groundwater

Definition of protection goals: results

PG	1st	2nd	3rd	4th	5th
Ground water	-	2		3	1
Surface water	10	-	-	-	-
Aquatic ecosystem	-	2	2	-	1
Soil ecosystem	-	6	2	1	-
Terrestrial ecosystem	-	-	6	2	

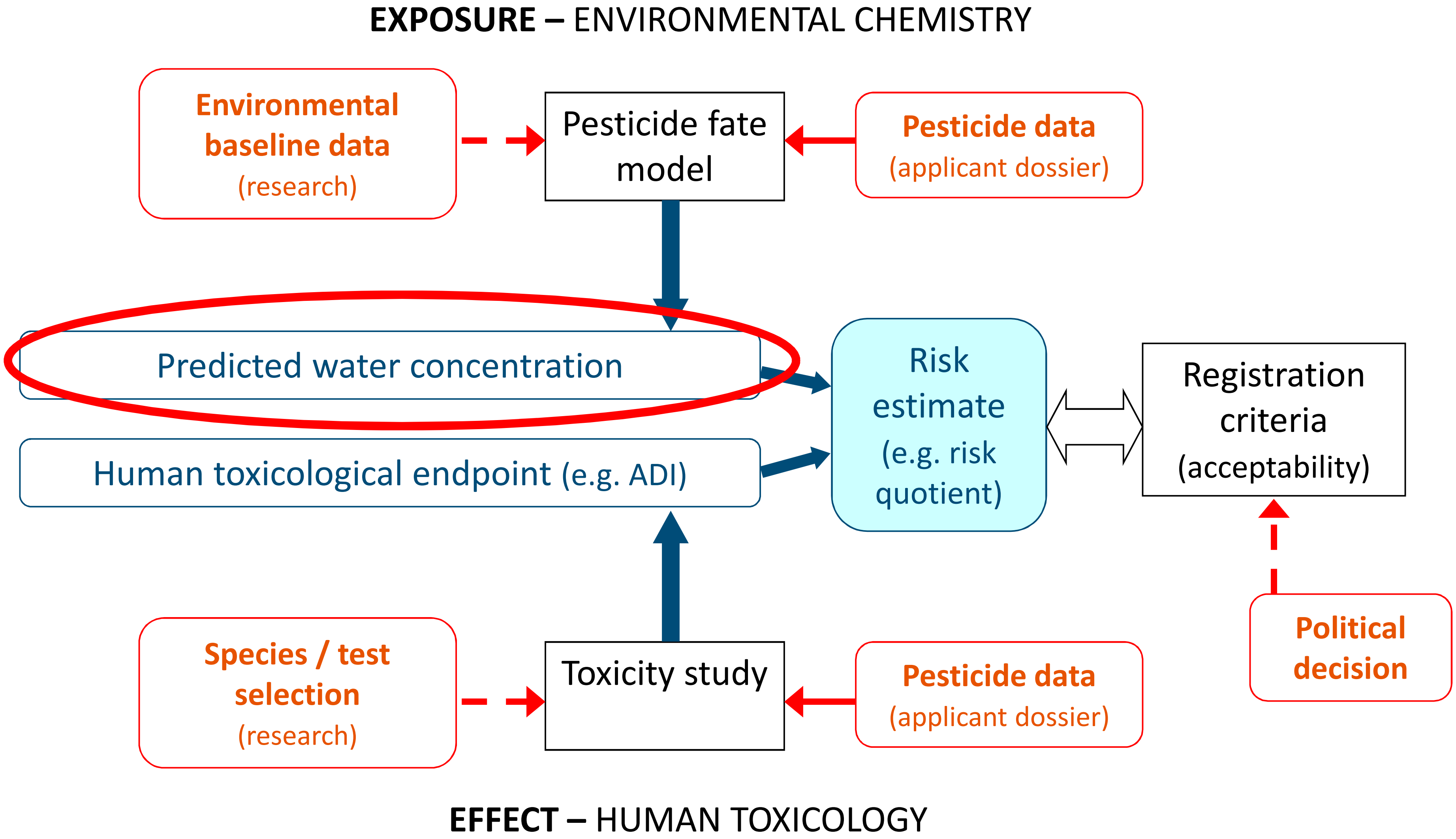
- First priority to protect is surface water, used for drinking water (Nov ‘11 workshop, important rural areas + main source for drinking water in Rift Valley)

- Second priority is groundwater: 90% rural areas and 40% major towns get drinking water from gw source (Nov’12 workshop, Water Works Design and Supervision Ethiopia)

Summary sw and gw scenario development

- Workshop 5-9 November 2012 development of scenarios to estimate concentrations in surface water and groundwater used for drinking water production.
- Present were:
  # Alemayehu Woldeamanual- APHRD- PRRP coordinator
  # Dr Dereje Gorfu –EIAR- crop characteristics
  # Mr Engida Zemedagegenhu- Water Works Design and Supervision Ethiopia- groundwater knowledge
- From Alterra: several gw and sw scenario development and model experts: Mechteld ter Horst, John Deneer, Jos Boesten and Paulien Adriaanse

Risk assessment drinking water



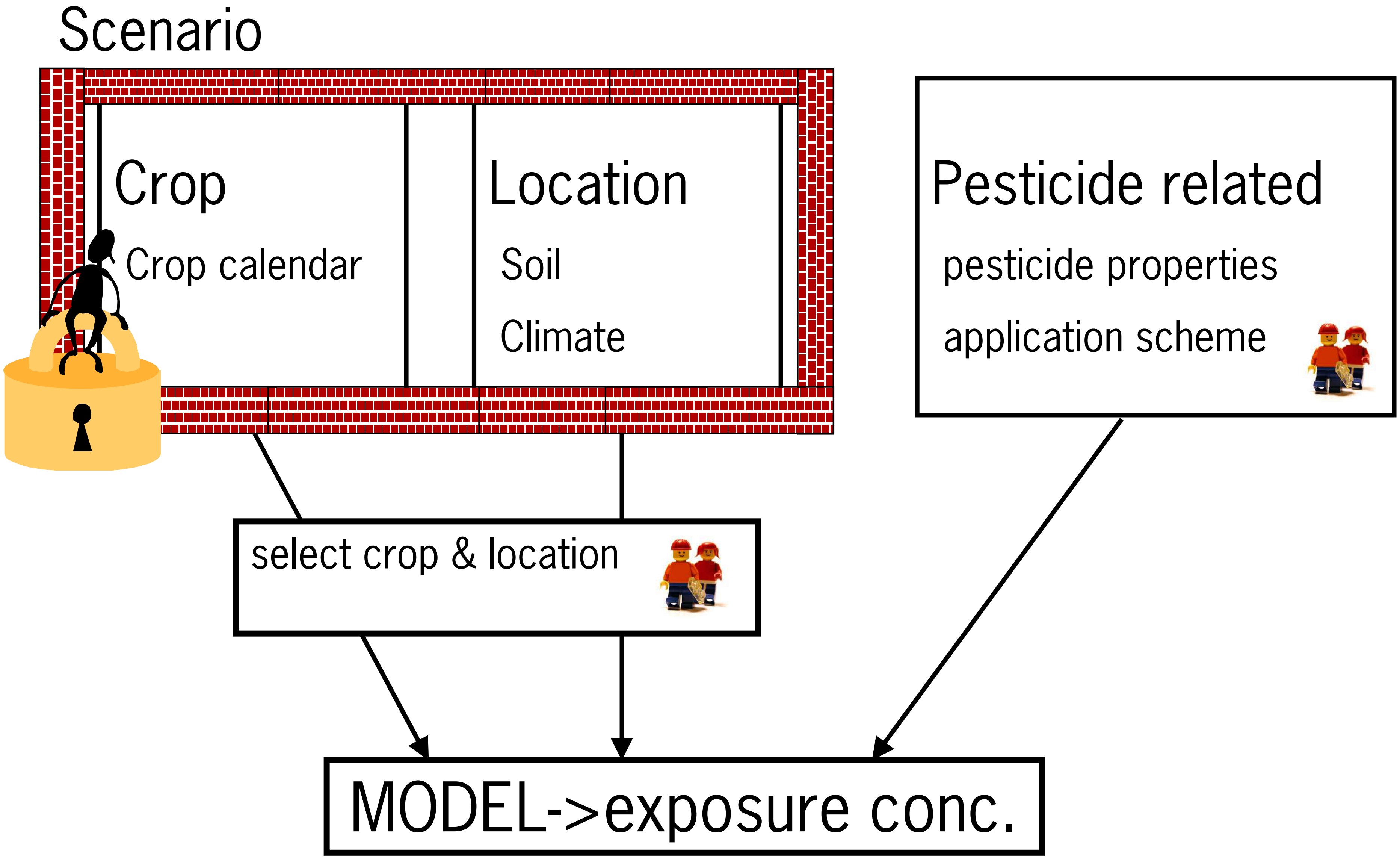
Summary sw and gw scenario development

- PEC: local relevant concentrations, so specific for Ethiopian conditions
- Concentrations according to GAP use (not point sources, industry)

- Concentration depends on
  # protection goal (what, where, how strict)
  # agro-environmental conditions, compound properties

- Fixed set of agro-environmental conditions is called scenario

2. Relation model, scenario, input data



Summary sw and gw scenario development

- Scenario should be based upon

  EU: ‘realistic worst case approach’

  (Directive 91/414/EC of EU)

  Ethiopia: phrase in Proclamation ??

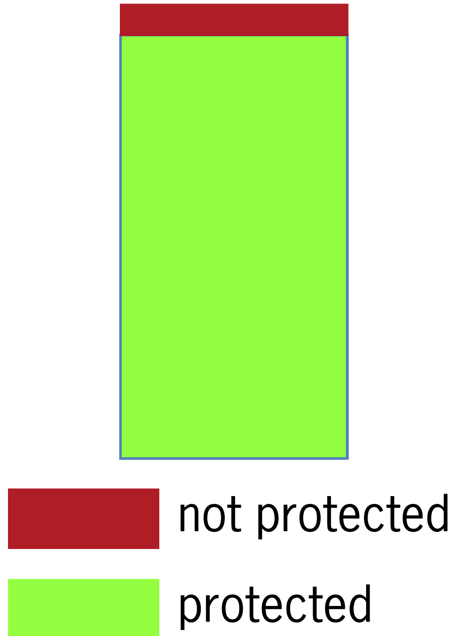
- Realistic worst-casedness or the vulnerability of the scenario is often translated as ‘90th-percentile occurrence in time and space’

Interludum: Vulnerability

Scenarios should be protective

x % of in reality existing situations (in time and space) in Ethiopia are protected

Situations in Ethiopia



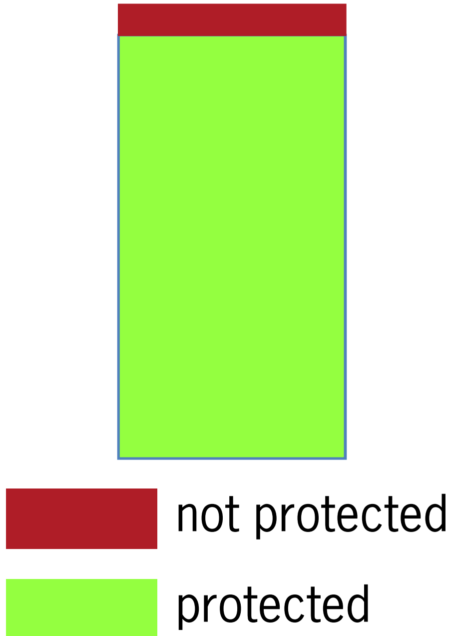
50% means half of all situations in Ethiopia are protected = average situation

90% means that 90% all situations in Ethiopia are protected = EU translation of “realistic worst case situation”

Interludum: Vulnerability

Scenarios should be protective, "realistic worst case"

Situations in Ethiopia



Proposal: 99th%-ile occurrence in time and space is protected, so 1% is not protected

More strict than in EU because human-toxicological standard is used in Ethiopia (exceedance means casualties)

Summary sw and gw scenario development

- Scenario development according to scheme developed by Alterra, based on experience in scenario development in EU since early ‘90 (soil, groundwater, surface water, greenhouses in NL and EU, groundwater and surface water in China)

- See next slides: in Nov ’12, we walked through procedure for surface water and groundwater, separately

- First define protection goals into detail, next develop scenarios, parameterise these and develop software

Definition of protection goals

1. Data gathering
2. Identification of scenario zones
3. Options for protection goals
4. Choice of protection goals per scenario zone
5. Definition of conceptual model for protection goals

Scenario selection and parameterization

6. Choice of models

Linear model, but loops occur !

7. Definition of vulnerability drivers and development of scenario selection procedure

8. Application of scenario selection procedure

Nov’12

9. Parameterization of scenarios in the models

10. Design and construction of software tool

Definition of protection goals

How to define protection goals into detail ?

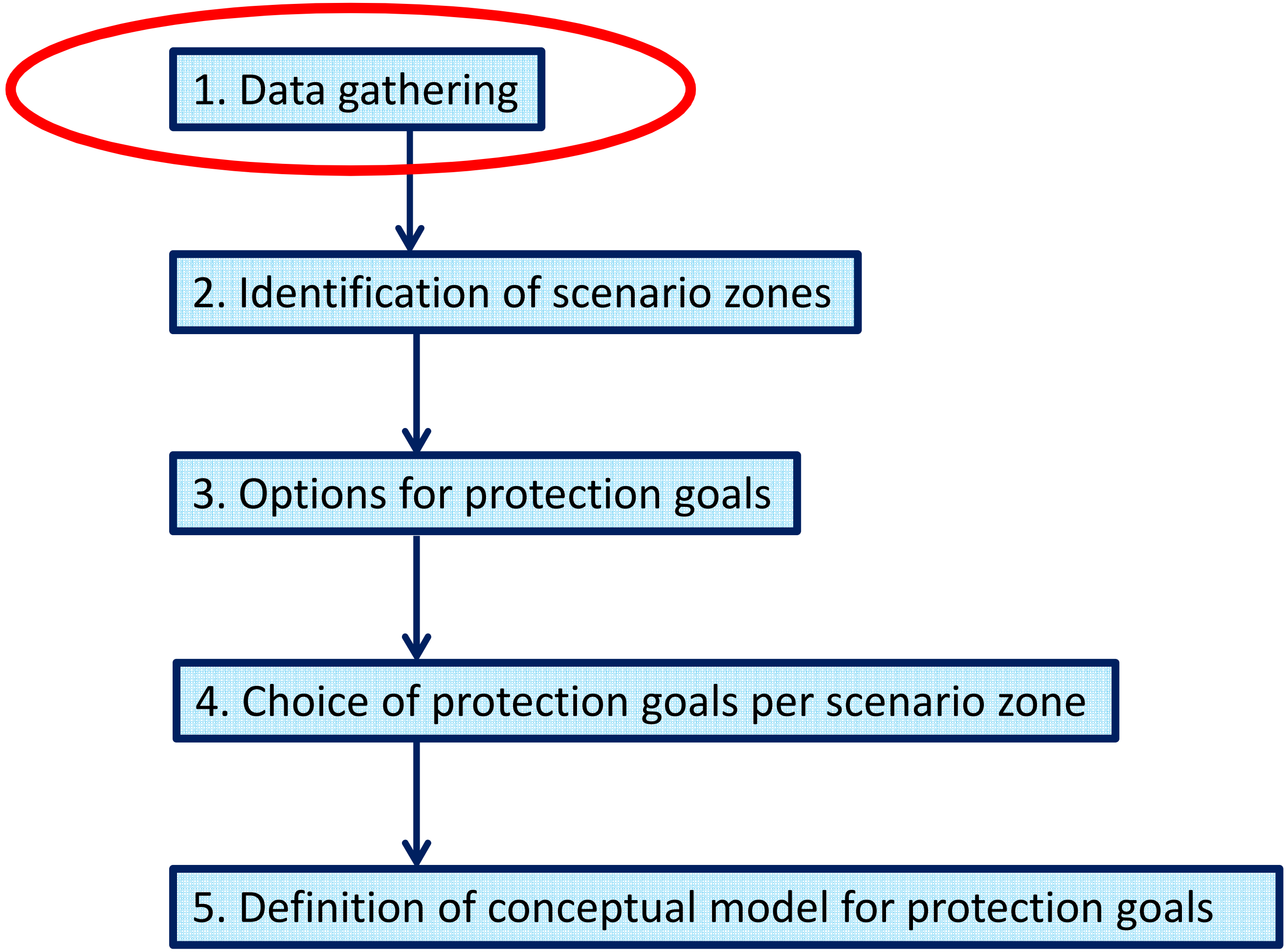
Answer questions:

- What do you want to protect ?
- Where ?
- When and how strict ?

Why is definition of protection goals important?

- If protection goals have been defined into detail
- we know which exposure concentrations we need to assess, so
- we can design scenarios, so
- we can perform standardized, cheap, reproducible risk assessments for registration

Definition of protection goals



Summary sw and gw scenario development

1. Data gathering

- Inventory of agro-environmental characteristics and existing environmental standards in Ethiopia (CR1, Nov ‘11) + workshop Nov ’11

- More details on meteorology (precipitation, yearly totals, daily totals, evaporation, 30 years, model-based, so no data gaps, 80*80 km^2), soils (oc, 5*5 km^2, ISRIC, HWSD)
- More details on groundwater (Mr Engida)
- More details on crops and pesticide use (Dr Dereje)
- More details on pesticide use, registration (Alemayehu)

Definition of protection goals

1. Data gathering
2. Identification of scenario zones
3. Options for protection goals
4. Choice of protection goals per scenario zone
5. Definition of conceptual model for protection goals

Summary sw and gw scenario development

2. Identification of scenario zones

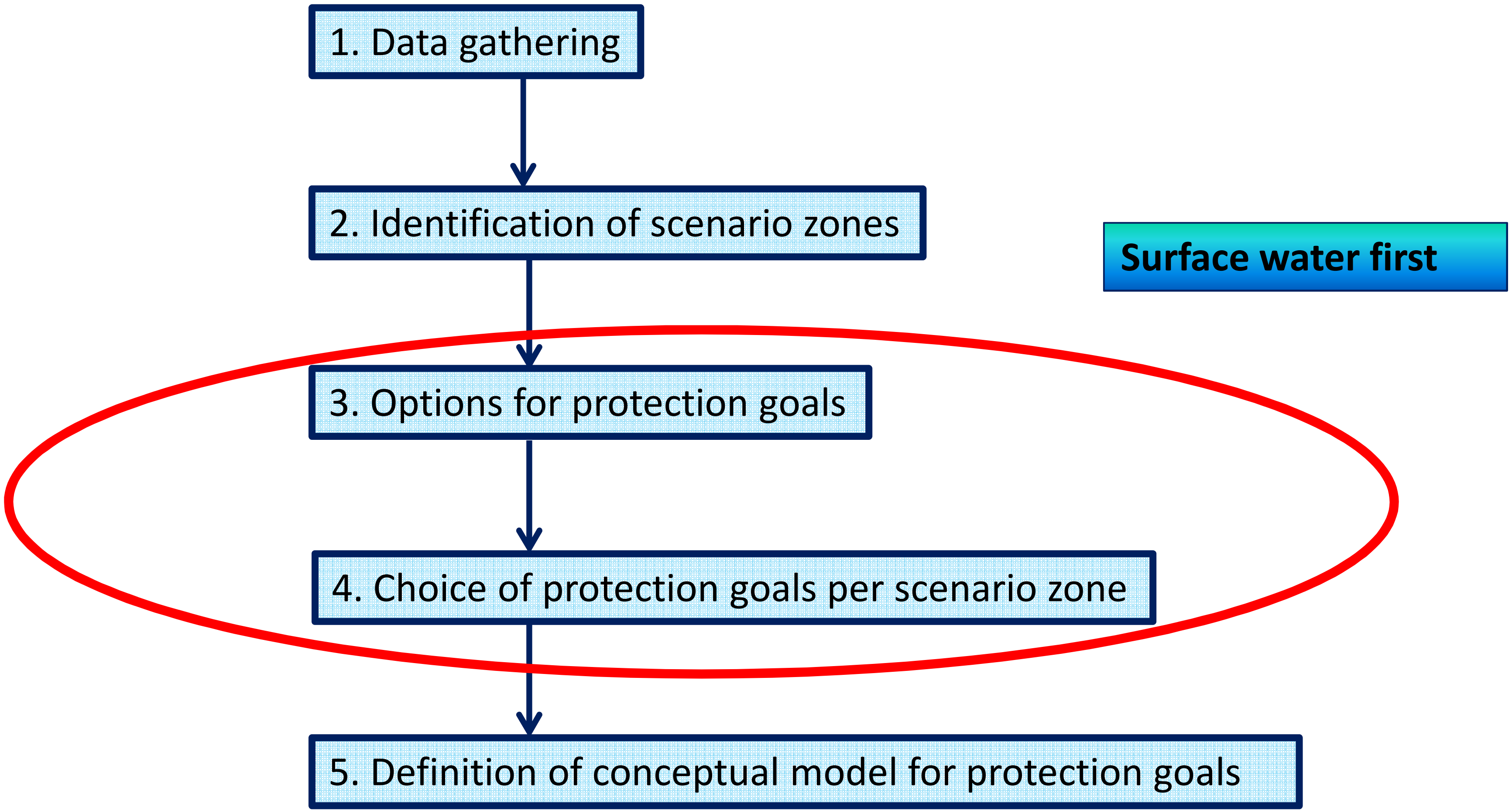
- Two zones identified:
  < 1500 m and > 1500 m,
  same for sw and gw scenarios,
  similar to zones used for Efficacy assessments in Ethiopia

- Correspond to distinction between Kolla and Woina Dega traditional agro-ecological zones

- Use of more than 1 zone gives flexibility in registration procedure, but may be difficult to uphold
- Important for scenario selection procedure (%-ile selection)

- To be approved by political level, i.e. Pesticide Advisory Board ?

Definition of protection goals



Protection goals: surface water

- We need set priorities, so limit number of protection goals for which we can work out the scenarios

- Proposal: take 2 most vulnerable goals, i.e. where we expect the highest concentrations

Proposal

1. River type: stream/small river near villages,
   entire Ethiopia (most vulnerable + widespread)
2. Pond/lake type: temporary pond, (cattle drinking)
   Rift Valley, east Ethiopia (also vulnerable)
3. (Rift Valley lakes: used when groundwater unsuitable for drinking water, less vulnerable because of size)

Definition of protection goals

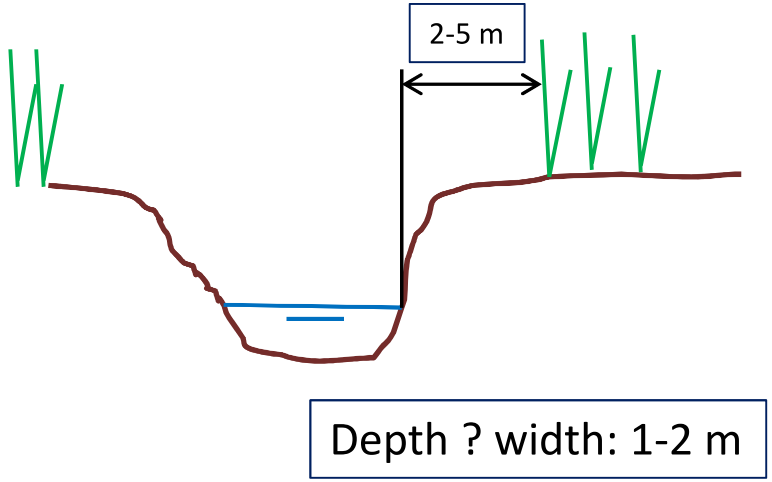
1. Data gathering
2. Identification of scenario zones
3. Options for protection goals
4. Choice of protection goals per scenario zone
5. Definition of conceptual model for protection goals

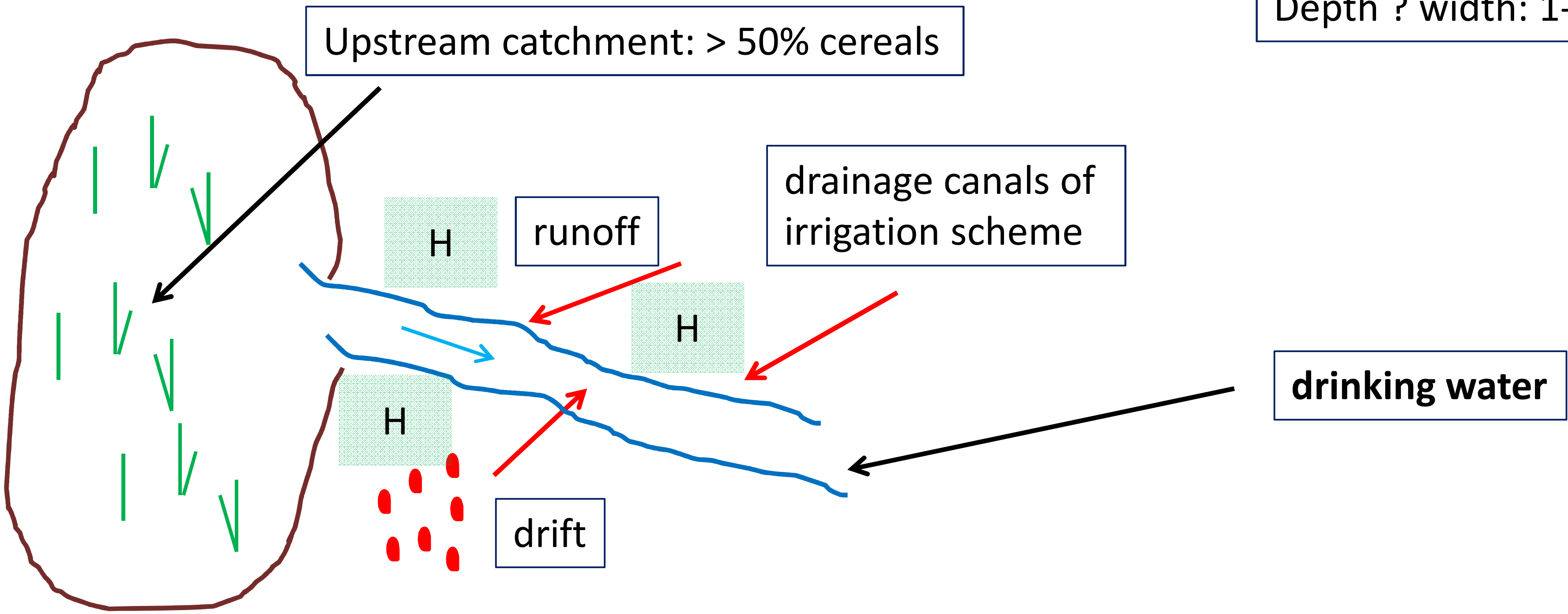
Surface water first

Protection goals #1: surface water

Stream/small rivers

- Drinking water (villages) until depleted (just before Kiremt, horticulture still done)
- Drinking water for cattle
- Irrigation of horticulture (H)



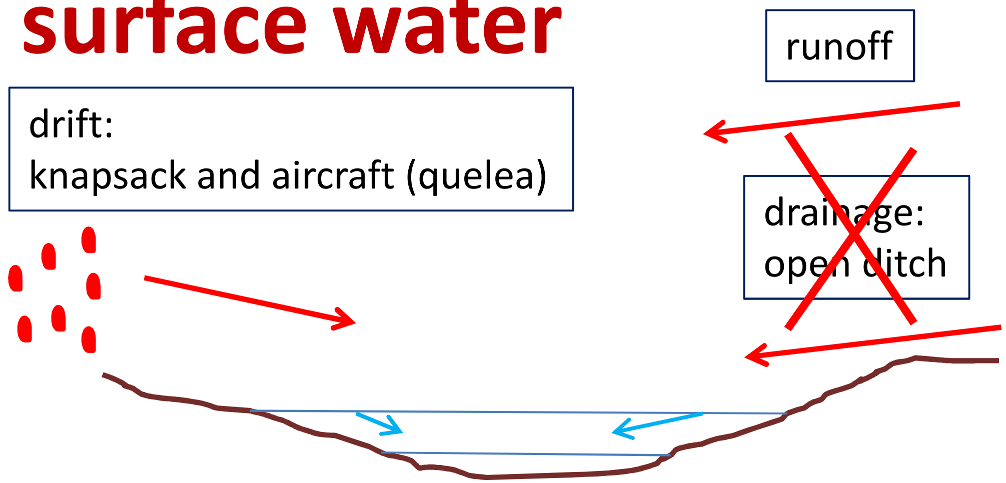


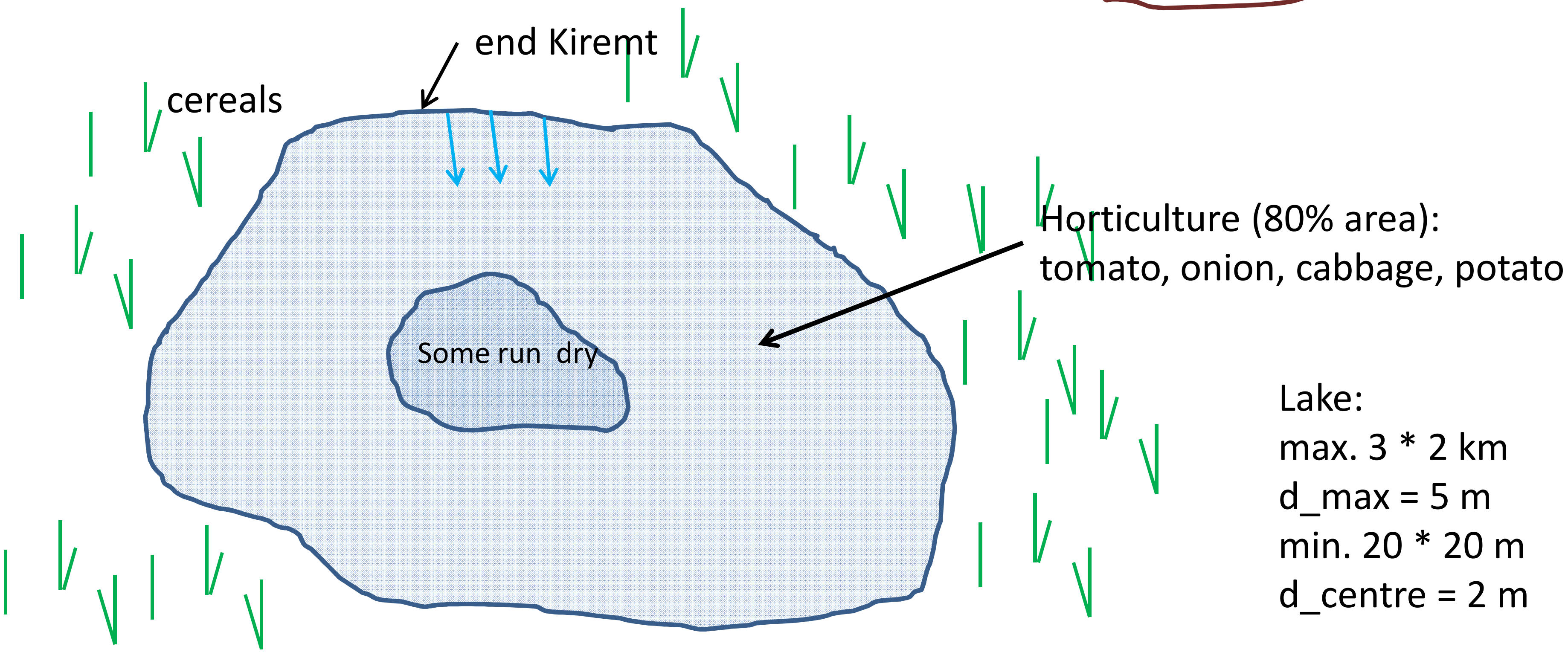
Protection goals #2: surface water

Temporary lakes/ponds/swamp
Koka area,
southern areas: sand filters->men drinking

- Drinking water for cattle (until dry)
- Horticulture (irrigation with pumps)

- Start after Kiremt rains until dried up
- E.g. Koka area (swamp),
  in Rift Valley



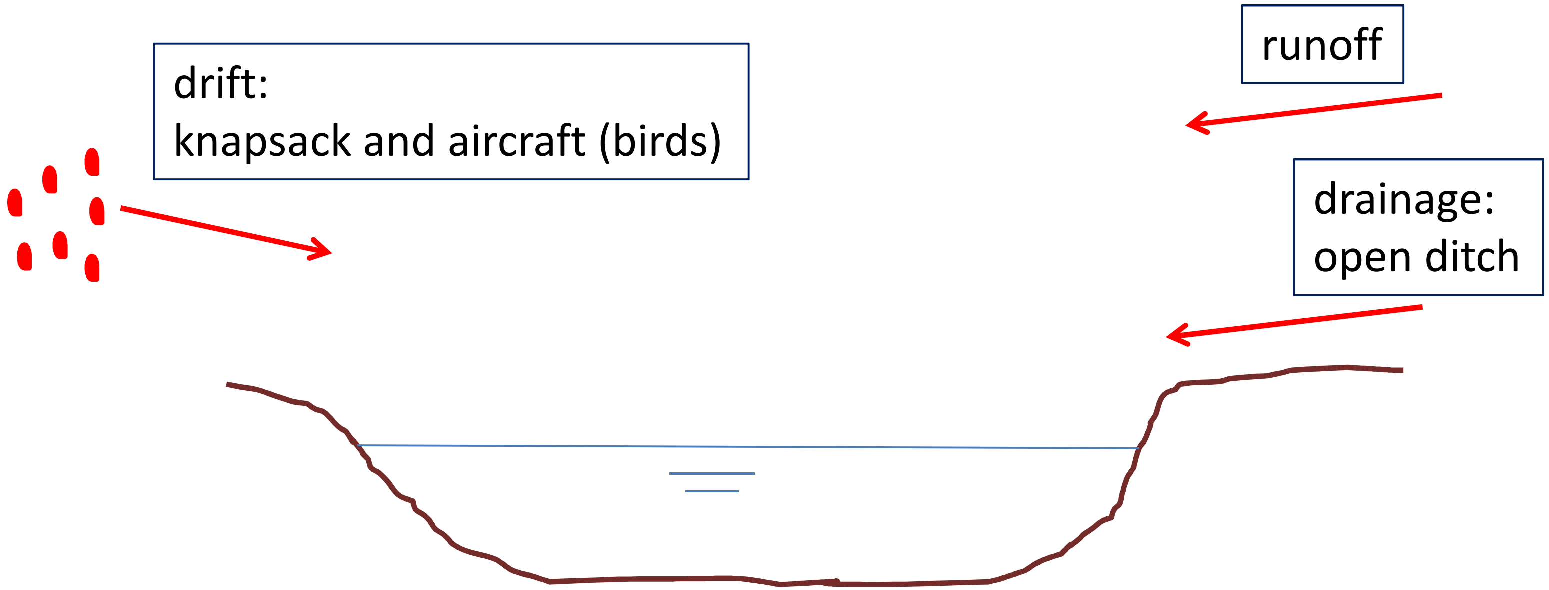


Lake:
max. 3 * 2 km
d_max = 5 m
min. 20 * 20 m
d_centre = 2 m

Protection goals #3: surface water

Rift Valley lakes

- Drinking water for man and cattle
- E.g. lake Ziway, lake Nagano, select smallest lake



Protection goals sw in scenario zones

most vulnerable

#1 Small river:
occurs only in scen zone >1500 m

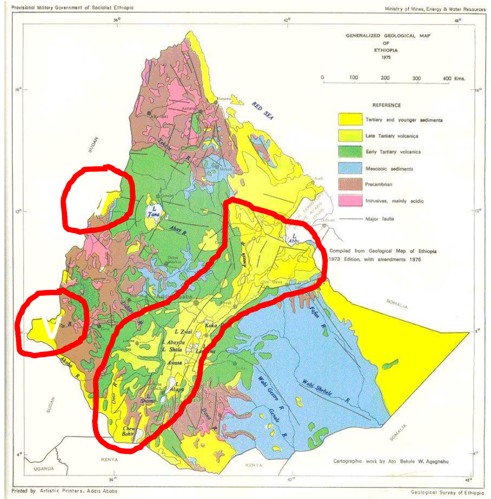
#2 Temporary pond occurs both in
scen zone > 1500 m (but <2000 m) and
scen zone < 1500 m (but >500 mm rain)

Definition of protection goals

1. Data gathering
2. Identification of scenario zones
3. Options for protection goals
4. Choice of protection goals per scenario zone
5. Definition of conceptual model for protection goals

Now groundwater

Protection goals gw in scenario zones



#1 Alluvial aquifers along small rivers
#2 Volcanic aquifers of shallow wells

#1 and #2 may be close to each other

#3 Alluvial aquifers at RV margins and lowlands
(map circles around yellow locations, overlain with scenario zones)

#4 Fractured basement rocks of shallow wells

Definition of protection goals

1. Data gathering

2. Identification of scenario zones

3. Options for protection goals

4. Choice of protection goals per scenario zone

5. Definition of conceptual model for protection goals

Now groundwater

Protection goals#1: groundwater

Alluvial aquifers along small rivers (diverging rivers, highlands)

Hand dug wells, min 3 m deep, average 15 m deep

Top layer is clay, thickness varies

Water infiltrates from soils above with mainly cereal production

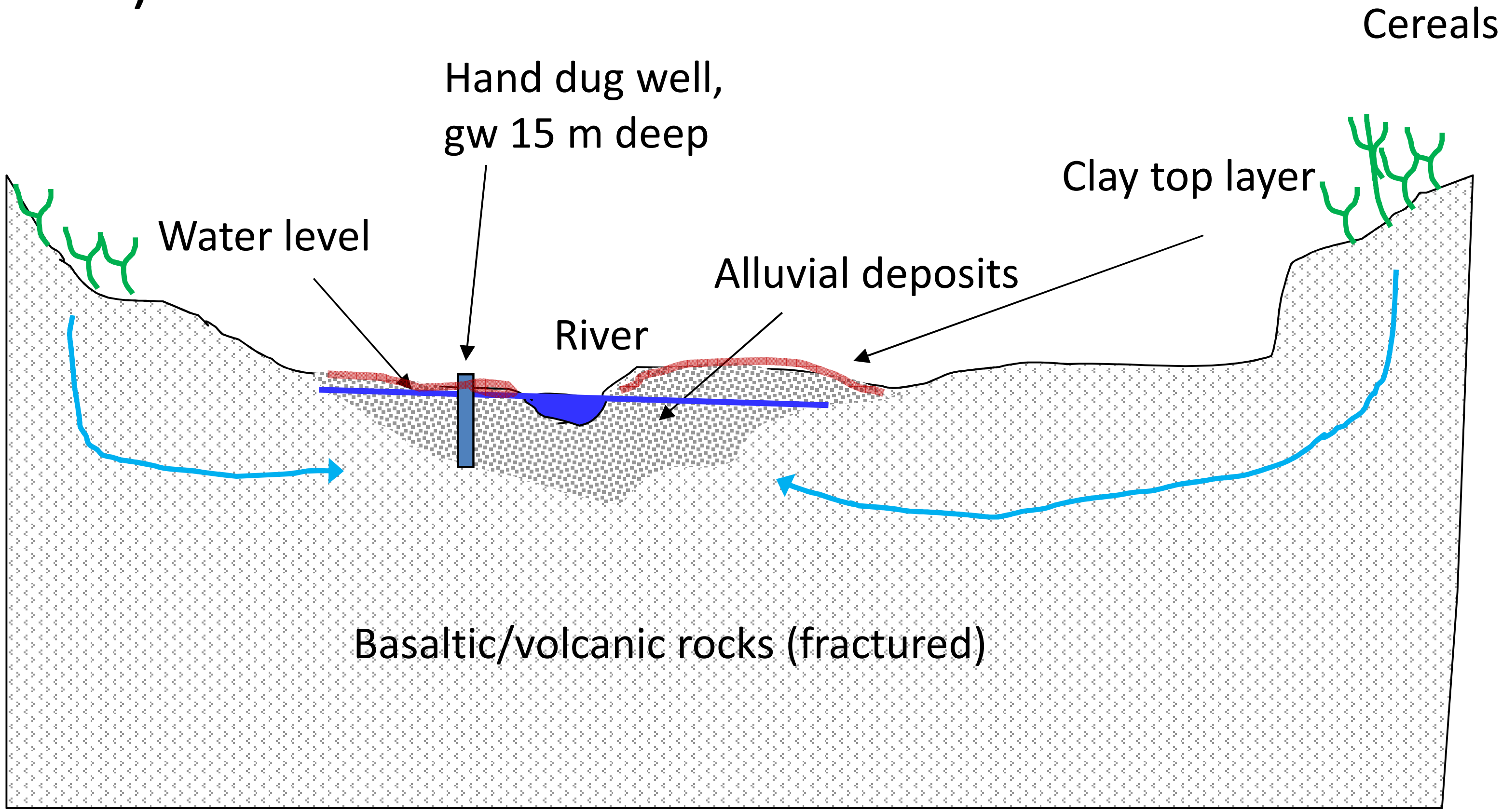
Gentle slopes

General there is water in well, esp. if rain is high and geological formation favourable

Close to gw #2 (some km)

Protection goals#1: groundwater

Alluvial aquifers along small rivers (diverging rivers, highlands)



Protection goals#2: groundwater

Volcanic aquifers of shallow wells

Drilled wells, min depth 50 m, up to 100 m deep

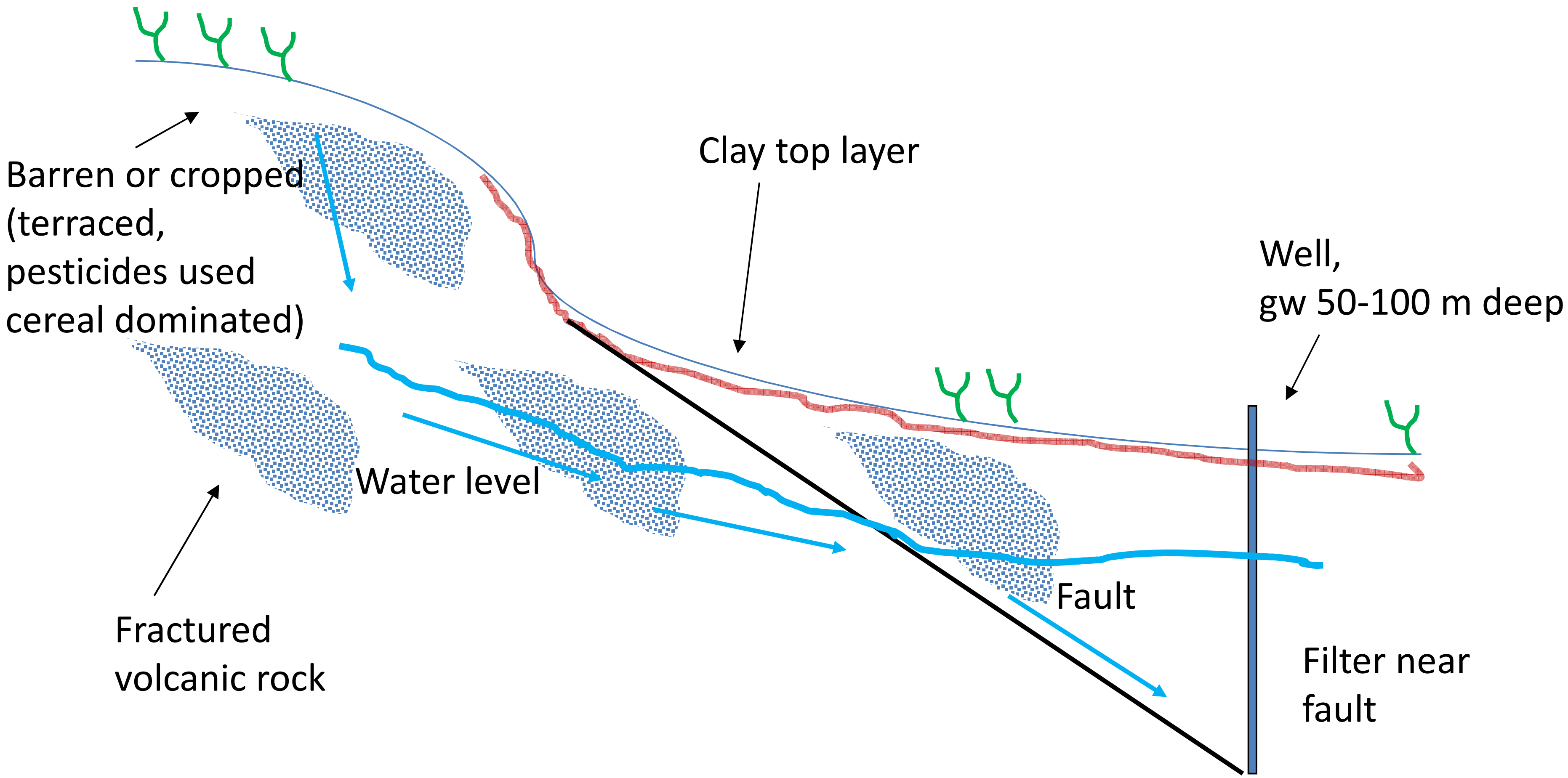
Clay layer on top

Water from above fractured volcanic rocks, either barren (bushes), or cultivated: then often terraced (otherwise erosion) with pesticide use. Cereals dominate, some pulses (faba bean)
Can be flat land, steep slopes, but gw is deep or population is high (therefore deeper)

Close to gw#1 (some km)

Protection goals#2: groundwater

Volcanic aquifers of shallow wells



Protection goals#3: groundwater

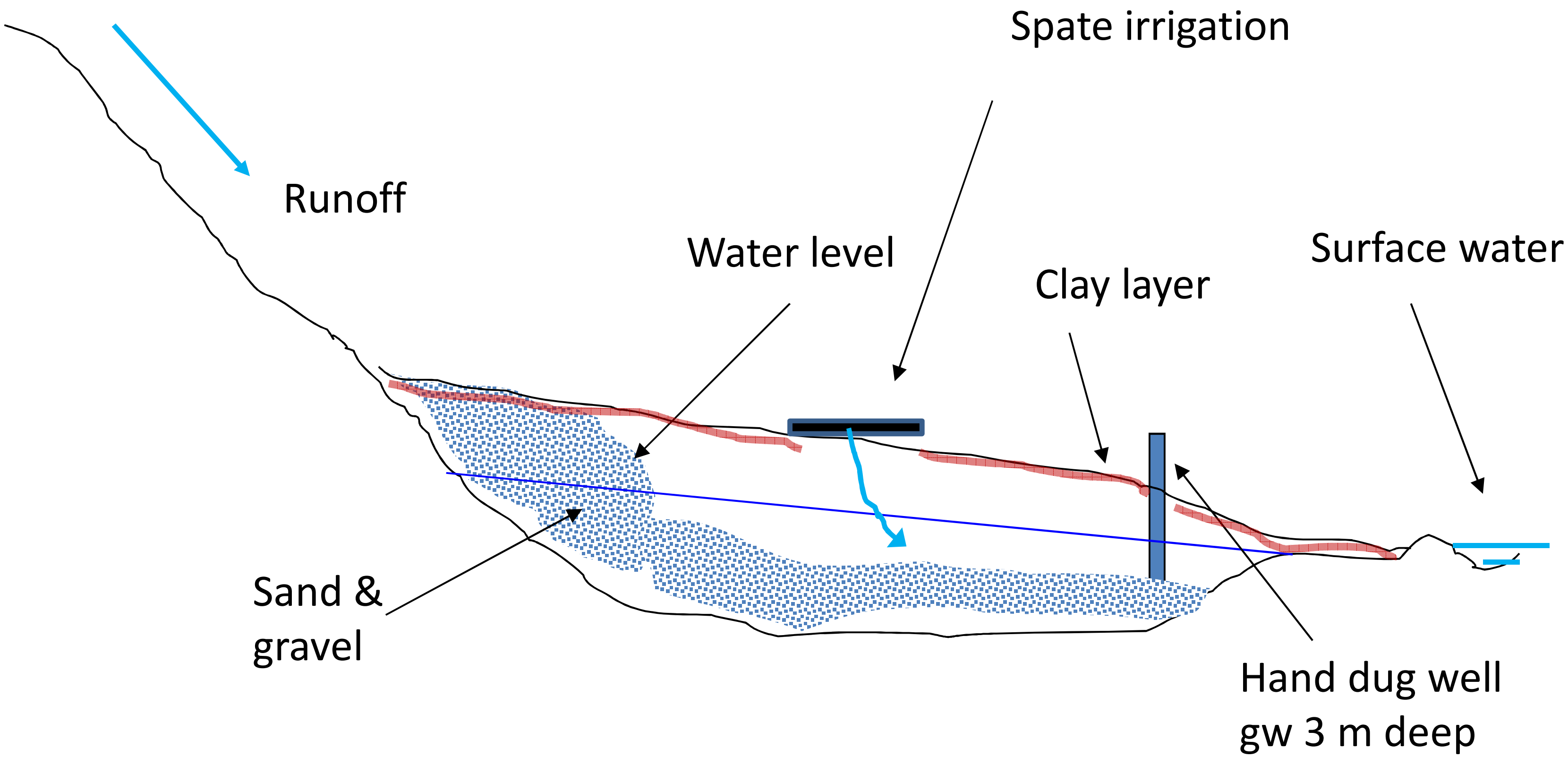
Alluvial aquifers at the Rift Valley margins or lowlands

Most vulnerable are shallow wells (3 m, hand drilled), then near surface water. (Otherwise depth from artesian to 230 m)
Top layer of clay.

Water comes from runoff/percolation from hills/mountains, runoff from volcanic rocks, irrigation return water (spate irrigation)

Protection goals#3: groundwater

Alluvial aquifers at the Rift Valley margins or lowlands



Protection goals#4: groundwater

Fractured basement rocks of shallow wells

Drilled wells, min 10-12 m deep, max 50 m deep,
Fed by runoff from massive basement rocks

If fractured zone thick: water all year round, if thin, dry from Dec to June. Fractured zone often near small rivers

More arid zones, sorghum, limited teff, so limited pesticide use, so not so vulnerable

Protection goals gw in scenario zones

most vulnerable

#1 Alluvial aquifers along small rivers:
occurs only in scen zone >1500 m

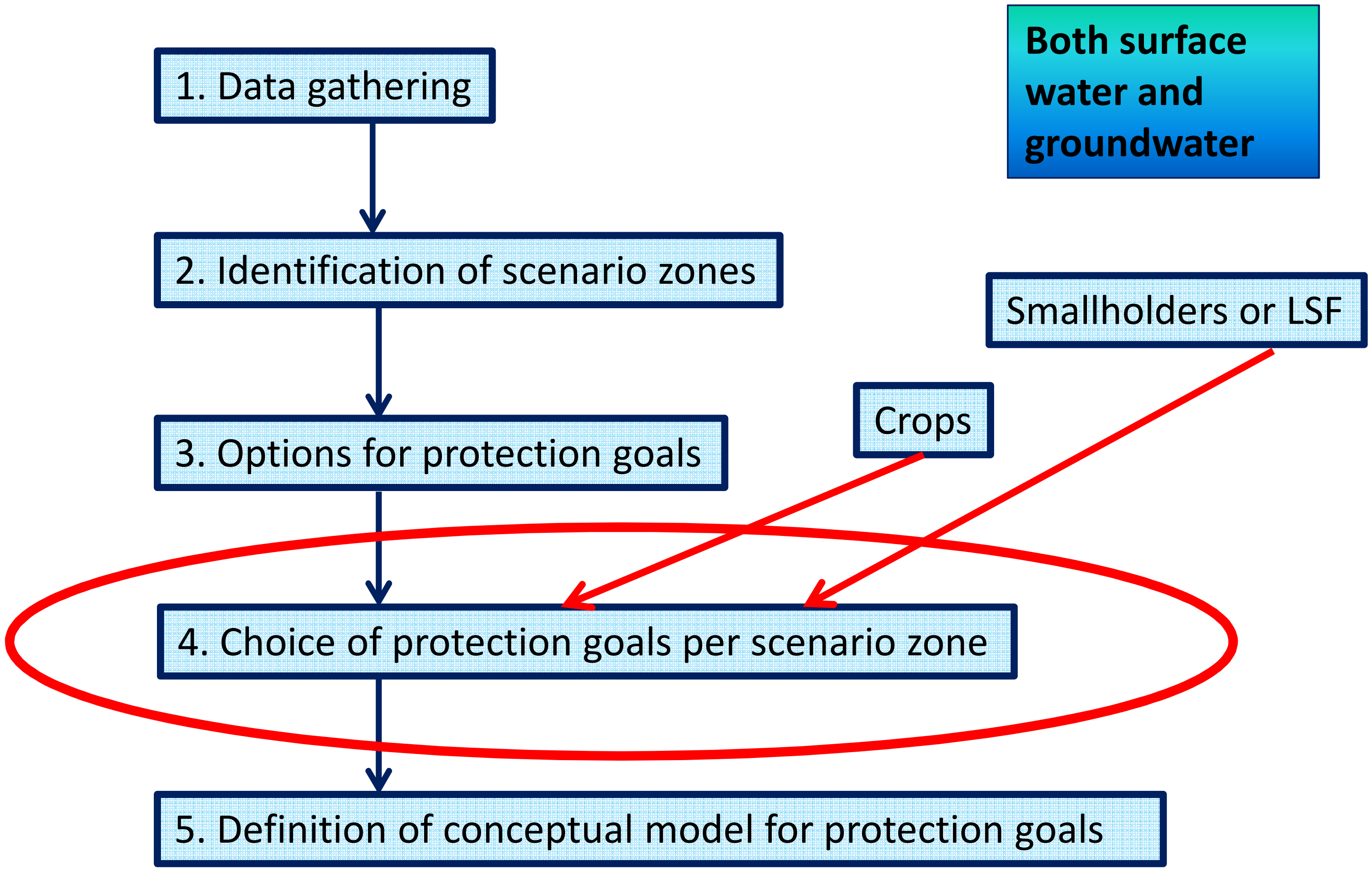
#2 Volcanic aquifers of shallow wells:
occurs only in scen zone >1500 m

#1 and #2 may be close to each other

#3 Alluvial aquifers at RV margins and lowlands (map circles around yellow locations, overlain with scenario zones):
occurs mostly in scenario zone <1500 m,
may be in scenario zone >1500 m (but then < 2000 m),

#4 Fractured basement rocks of shallow wells
not considered, less vulnerable

Definition of protection goals



Types of farming in scenario zones

Smallholders
- these are evenly distributed across scenario zone >1500 m,
- these are evenly distributed in zone 1000-1500 m in scenario zone < 1500 m

Large Scale Farms (LSFs)
- these occur in both scenario zones, irrigated, along major rivers (4, 5 up to max 10 km away)
(dominant < 1500 m because big rivers, flat, fertile alluvial, less >1500 m, may be irrigated, mostly rain fed, mostly cereals)

Crops in types of farming and scenario zones

Large Scale Farms, LSFs:

zone > 1500 m:
wheat, barley, maize
Also pulses (faba bean, field pea, French bean, chickpea), coffee, citrus, vegetables (on, tom, pepp, cabb)

zone < 1500 m:
sorghum, sesame, French bean (Faseolis vulgaris)
sugarcane, cotton, maize
Also citrus, sweet potato (for planting mat.), vegetables (tom, on, pepp, cabb)

Vegetables are: onions, tomato, pepper, cabbage, French beans

Crops in types of farming and scenario zones

Smallholders:

Zone > 1500 m:

Teff, maize, wheat, barley, vegetables (all),

Also potato, pulse (faba bean, field pea, French bean, chickpea, lentils), pome/stone fruit,

Zone < 1500 m (1000-1500 m):

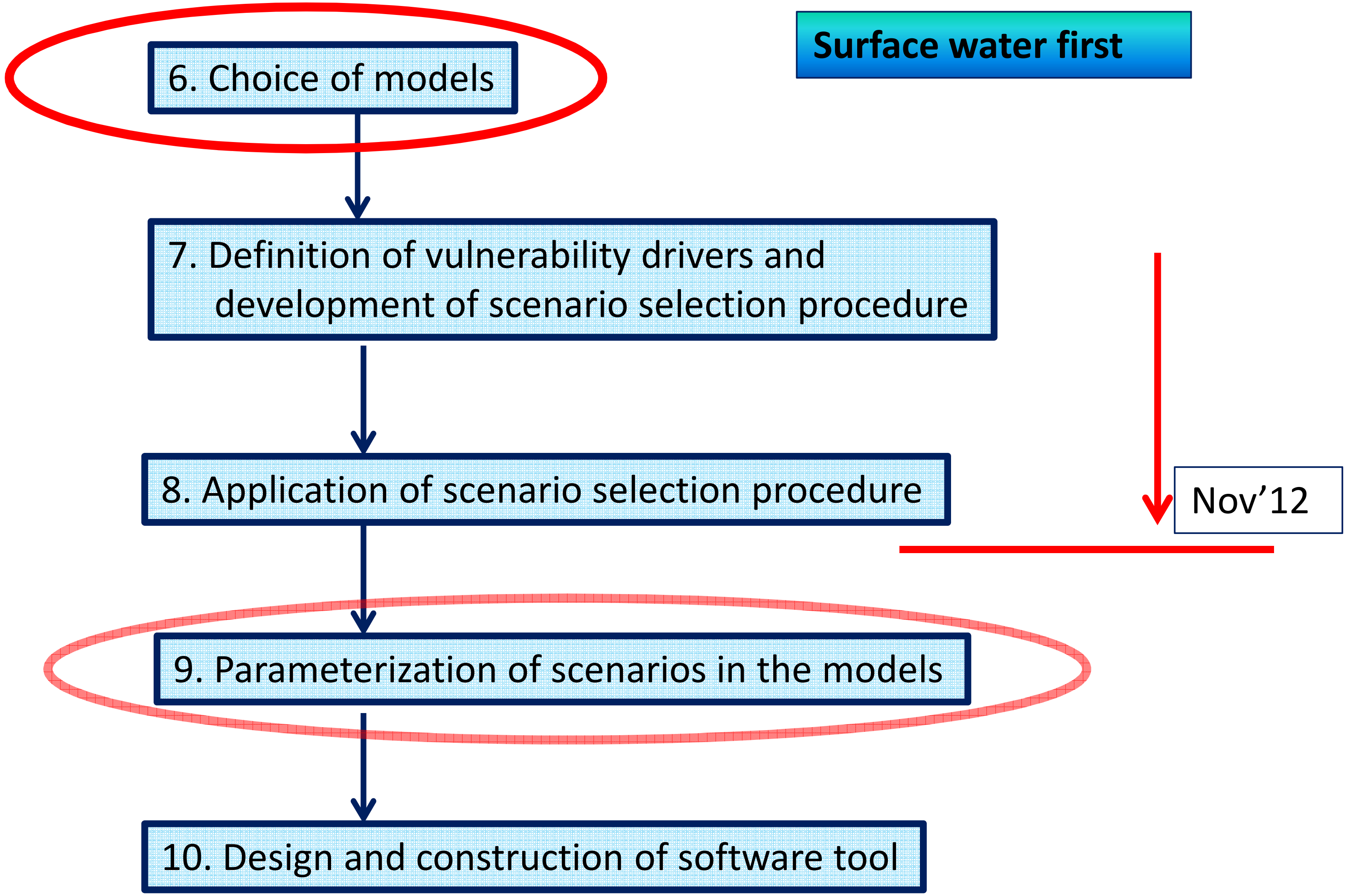
Teff, maize, wheat, barley, vegetables (all),

Also potato, sweet potato, banana (few pesticides), mango

Coffee (no pesticides, so not needed)

Vegetables are: onions, tomato, pepper, cabbage, French beans

Scenario selection and parameterization

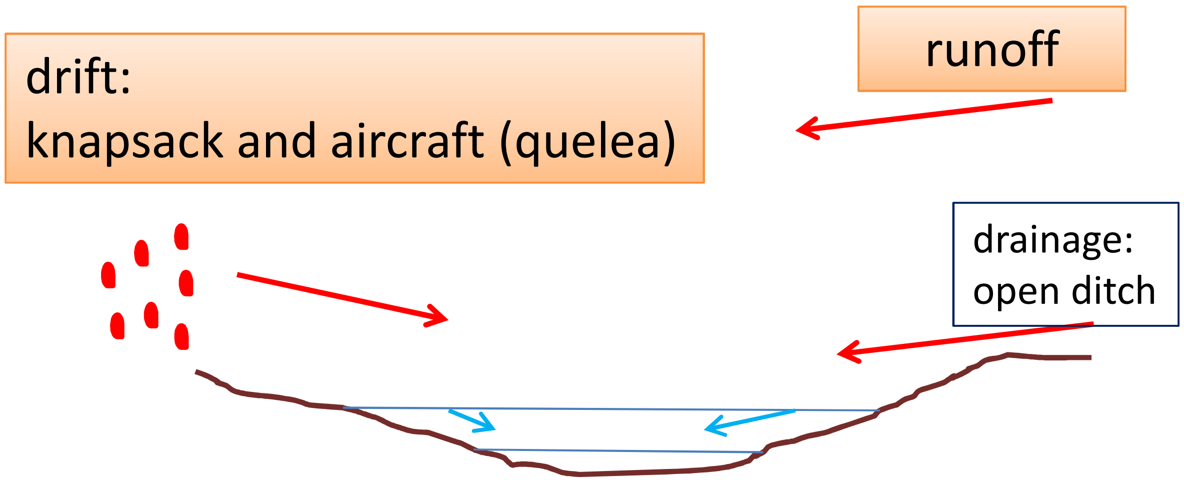


Selected models for surface water

6. Choice of models

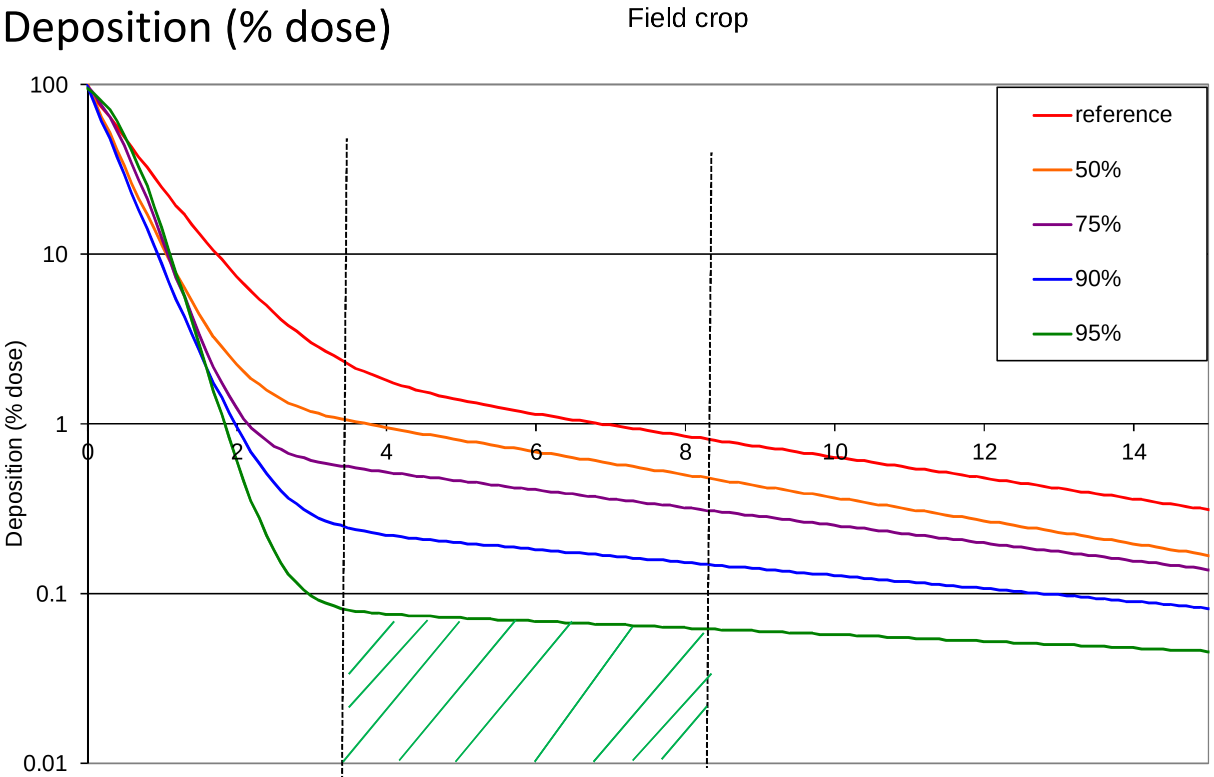
Entry routes

Most important entry routes of pesticides in to the surface water

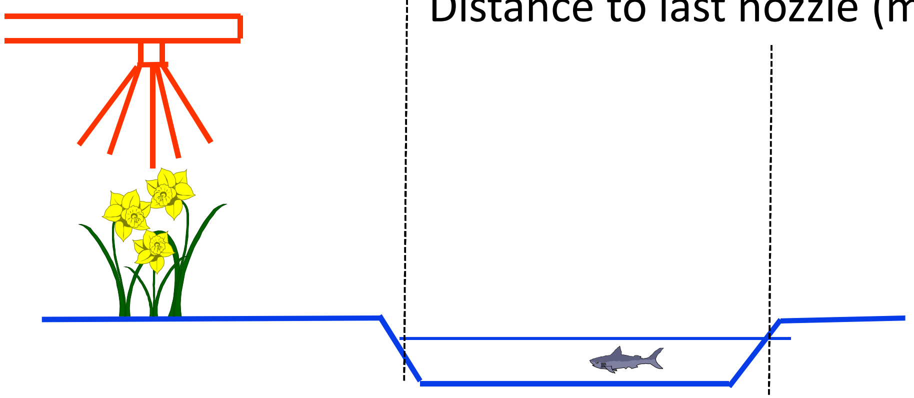


Selected models for surface water: Drift

Deposition (% dose)



Distance to last nozzle (m)



6. Choice of models

Different types of nozzles (% drift reducing)

Drift curve is function of

- Application technique
- Nozzle type
- Pressure

Knapsack sprayer: IDEFICS model-based available

EU or NL data for tractor mounted: model-based and measured available

Selected models for surface water: Runoff

6. Choice of models

Proposed model:

- PRZM (Pesticide Root Zone Model) model (Carsel et al., 1998)
  - Simulates pesticide runoff from agricultural fields
  - Used in USA and EU

Agricultural runoff can carry sediment, nutrients and pesticides to surface waters.
USDA Soil Conservation Service

N.B. PRZM calculates
sheet runoff flow, not via gullies !

Selected models for surface water: Runoff

Proposal for Ethiopia

9. Parameterization of scenarios in the models

- Take the R4 (worst case EU) standard PRZM input
  - Parameterising soil for PRZM is too ambitious in PRRP
- Use Ethiopian weather (daily rainfall and evapotranspiration)
- Use Ethiopian crops

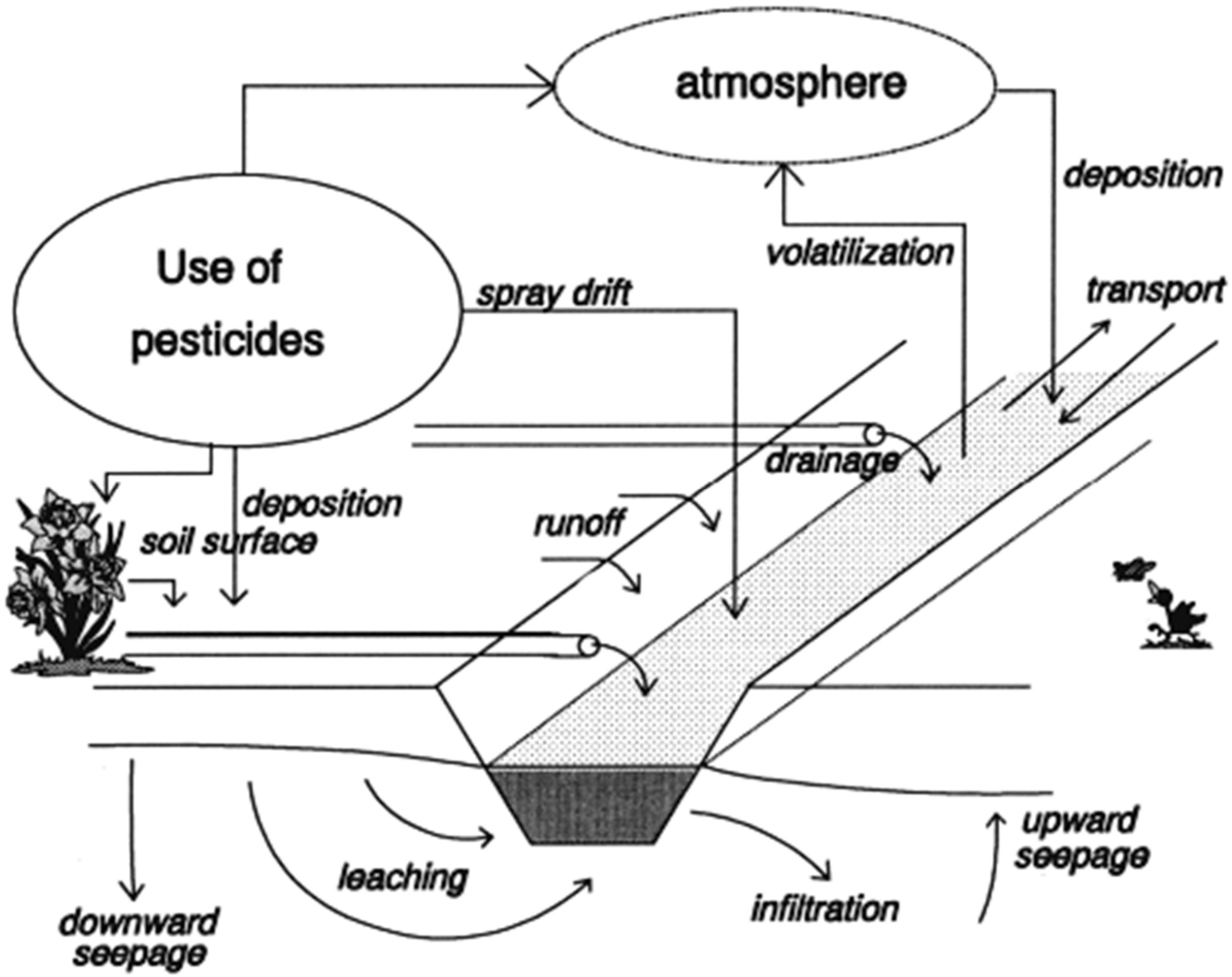
Selected models for surface water: Fate in SW

- Selected model: TOXSWA

- Developed by ERA team of Alterra
- Used in NL and EU pesticide registration
- Ditch, stream and pond scenarios parameterised for TOXSWA in EU

6. Choice of models

Selected models for surface water: Fate in SW



TOXSWA

6. Choice of models

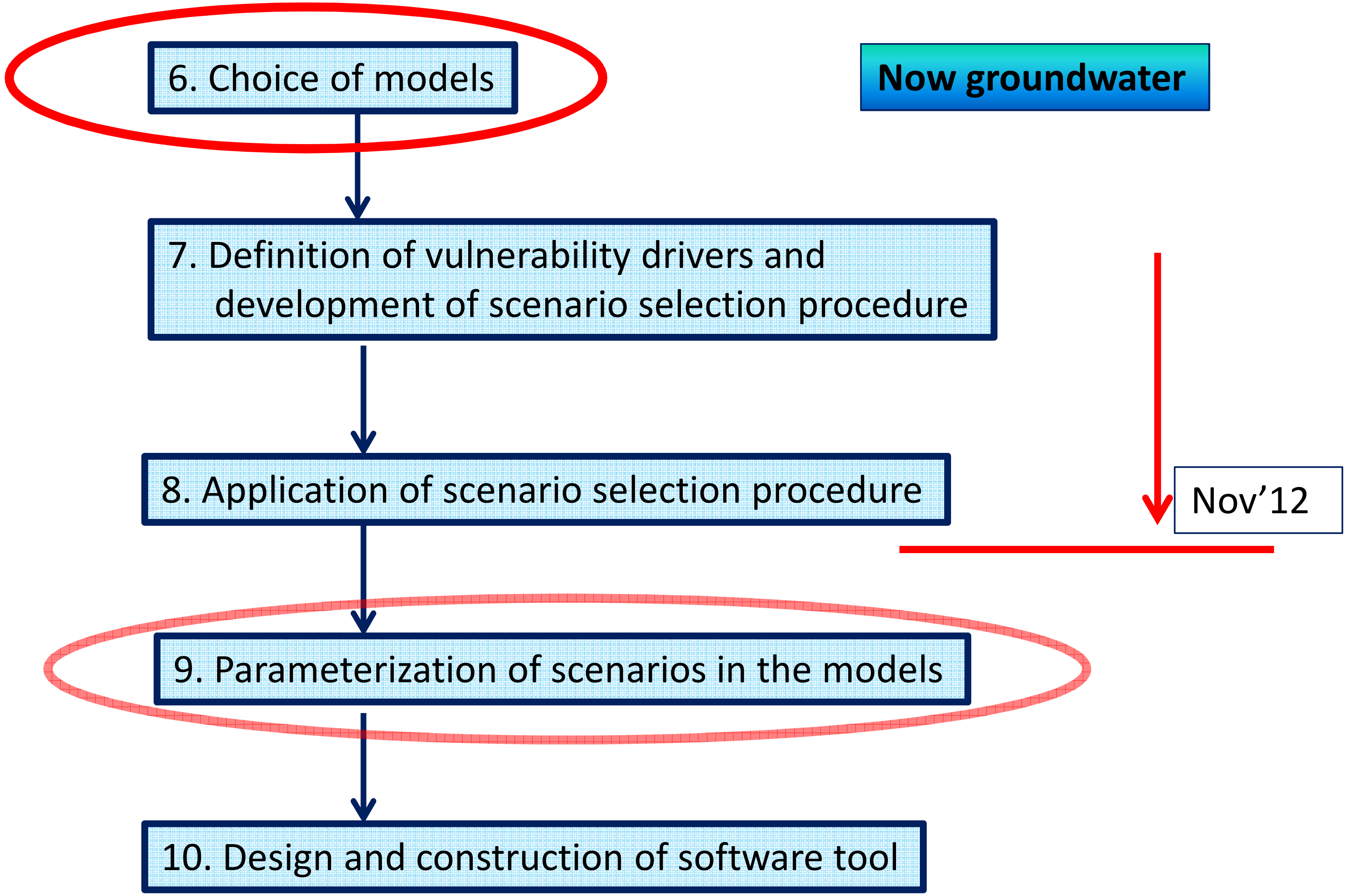
Selected models for surface water: Fate in SW

9. Parameterization of scenarios in the models

Proposal for Ethiopia

- Temporary lakes
  - EU FOCUS pond properties (sediment, sus.sol, macrophytes)
  - Ethiopian lake dimensions
    - E.g. minimal dimension of lake were people and/or cattle still drink water
  - EU FOCUS pond properties (sediment, sus.sol, macrophytes)
  - Ethiopian contributing area and crops

Scenario selection and parameterization



Groundwater protection goal

6. Choice of models

The EuroPEARL meta-model

$$Ln\ (C_L) = \alpha_0 + \alpha_1 * X_1 + \alpha_2 * X_2$$

C_L : the concentration (µg/L) in leaching water at 1 m depth, given a net soil deposition of 1 kg/ha

α_0 , α_1 , α_2 : regression parameters that depend on

- temperature and annual rainfall
- not compound specific, but specific to a region

X_1, X_2 depend on

- soil properties (organic matter and water content)
- compound properties (K_{om}, DT_{50} degradation)

TIKTAK ET AL.: MAPPING GROUND WATER VULNERABILITY TO PESTICIDES

J. ENVIRON. QUAL., VOL. 35, JULY–AUGUST 2006

Groundwater protection goal

6. Choice of models

Parameters $\boldsymbol{\alpha_0}$ **,** $\boldsymbol{\alpha_1}$ **,** $\boldsymbol{\alpha_2}$ determined by regression of output of EuroPEARL (spatially distributed model, used in NL and EU) and the metamodel output:

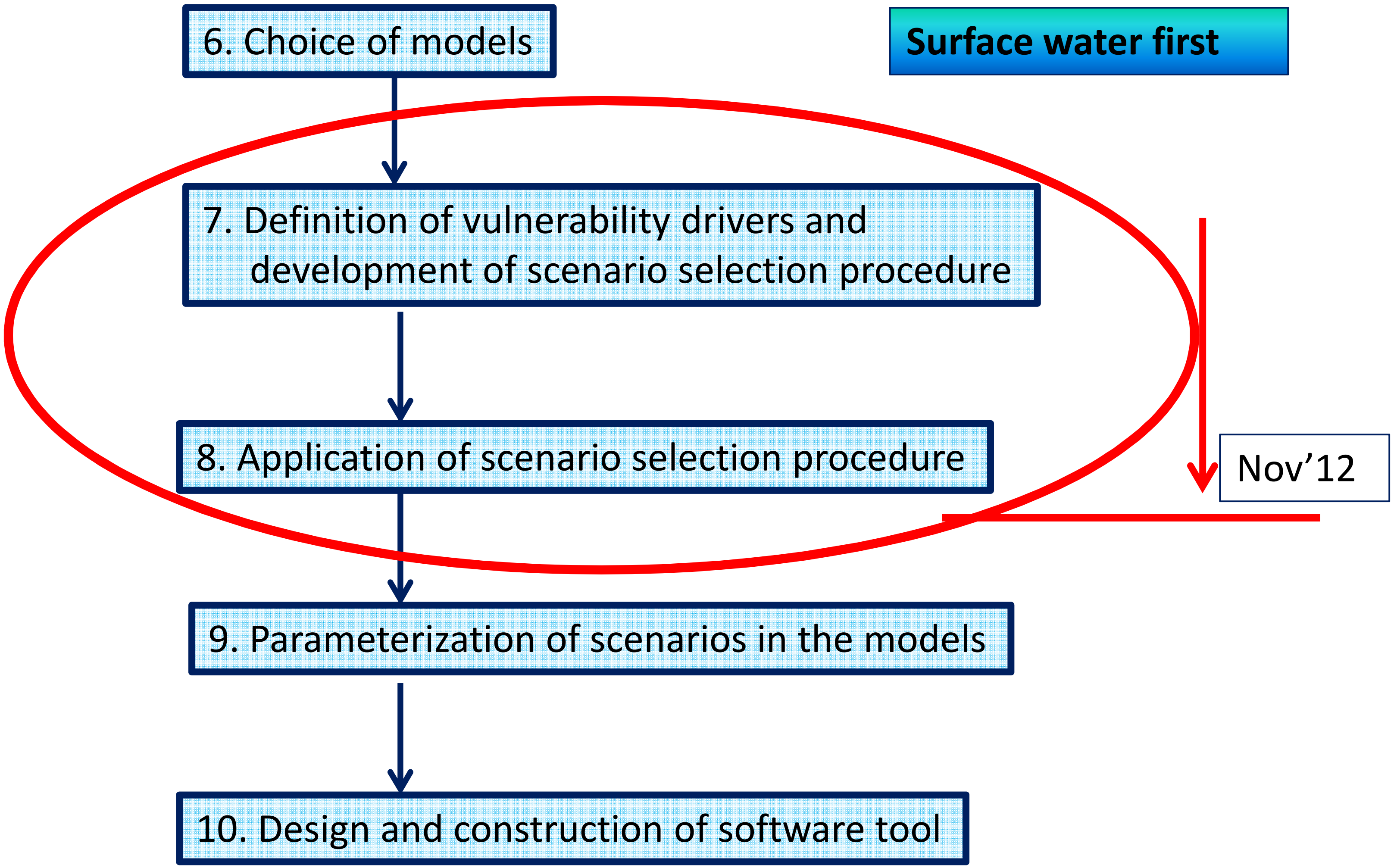
- $\boldsymbol{\alpha_0}$ **,** $\boldsymbol{\alpha_1}$ **,** $\boldsymbol{\alpha_2}$ taken for climate zone warm, wet (up to >800 mm rain, >12.5 C)-> most representative for Ethiopia

Consequences of extrapolating the EuroPEARL metamodel to Ethiopia

- Ethiopia → more wet and higher temperature
- Meta model → increasing q results in increasing concentration

Defensible because conservative

Scenario selection and parameterization



Summary sw and gw scenario development

7. Definition of vulnerability drivers and
development of scenario selection procedure

- Simple back-of-envelope calculations demonstrated that runoff is main driver for concentration in surface water (dimensions water body and spray drift are less important)

- Main vulnerability driver is runoff, translated as number of days with daily rainfall above 20 mm

- Determine probability of P_{day}>20 mm in time and space

- Repeat procedure for selected protection goals, i.e.
  # small streams >1500 m
  # temporary pond 1500-2000 m
  # temporary pond < 1500 m but > 500 mm

Summary sw and gw scenario development

7. Definition of vulnerability drivers and
development of scenario selection procedure

- Procedure (small streams):
  # use grids (80*80 km^2) and select grids > 1500 m
  # each grid, each year: Number of d with P_{day}>20 mm
  -> 33 values (33 yrs)-> rank per grid and select 99th%ile
  = nr 33 for each grid (now *temporal* %-ile)

  # plot this single value per grid on the map
  # rank all grids (>1500 m) and select 3 grids with
  highest %-ile (96.5, 98.2 and 100%) (now *spatial* %-ile)
  # next, select most suitable grid for protection goal:

  here: small streams in agricultural areas

Summary sw and gw scenario development

Three candidate locations for surface water protection goal #1:
small streams in areas > 1500 m

Summary sw and gw scenario development

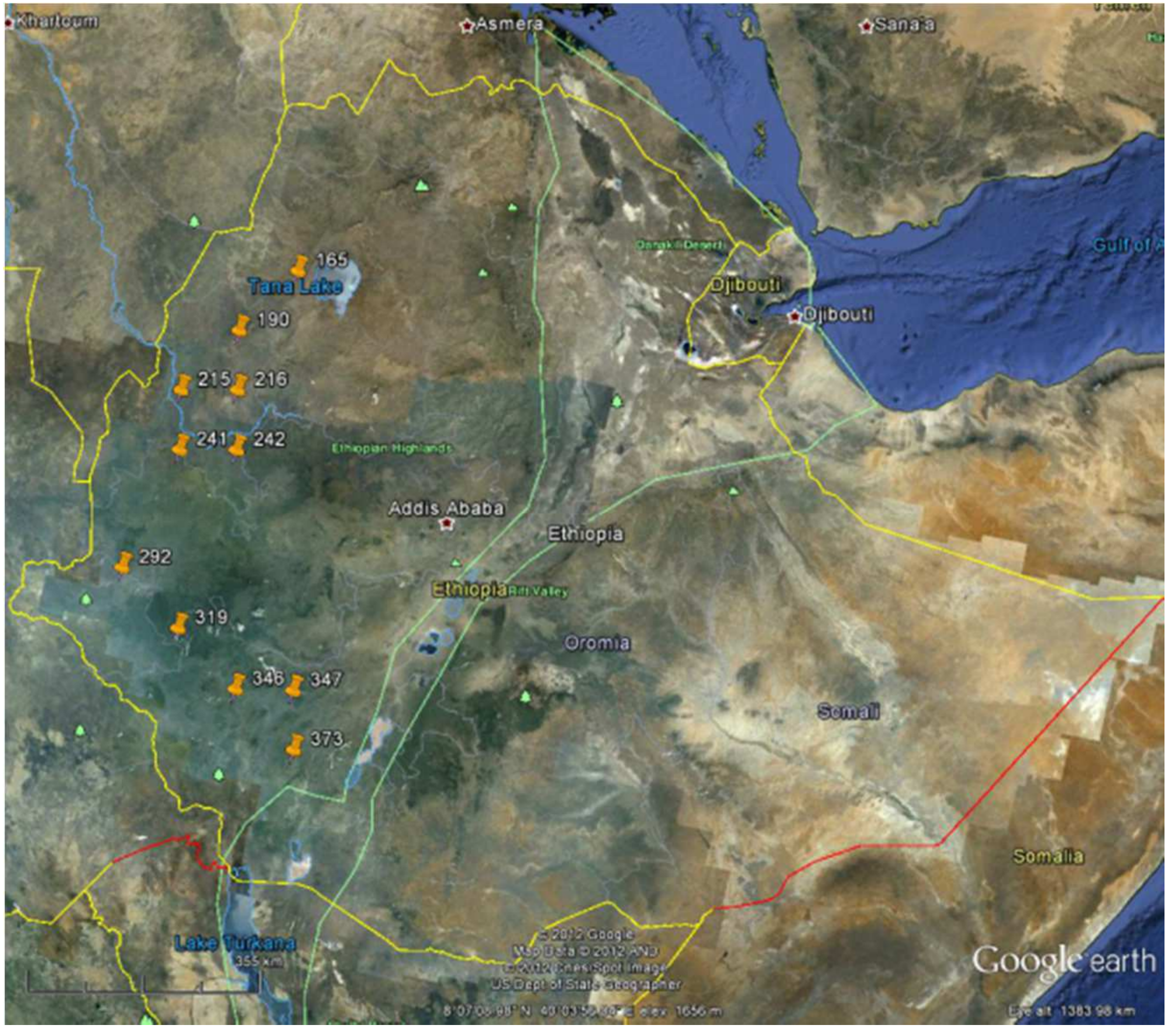
Temporary ponds:

Criteria:

streams >10 km apart

flat area

cultivated area



Top eleven candidate locations for surface water protection goal #2a: temporary ponds in areas < 1500 m and with more than 500 mm rain

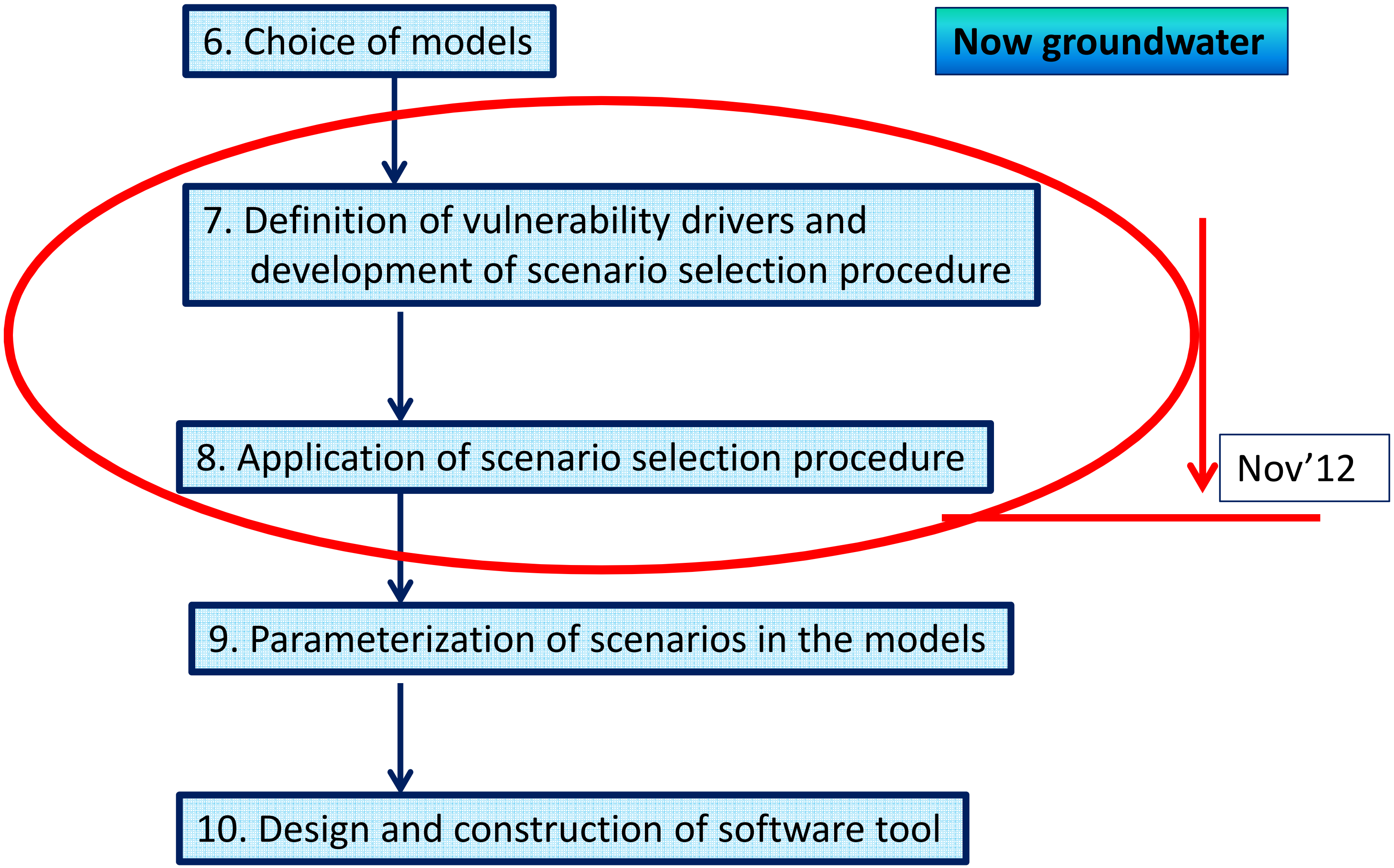
Summary sw and gw scenario development

Temporary ponds:

Criteria:
streams >10 km apart
flat area
cultivated area

Top twelve candidate locations for surface water protection goal #2b: temporary ponds in areas between 1500-2000 m

Scenario selection and parameterization



Summary sw and gw scenario development

7. Definition of vulnerability drivers and development of scenario selection procedure

- Scenario selection procedure possible with aid of simple analytical model (metaPEARL) run for spatial distributed data (percolation, oc- 5*5 km)
- Thus leaching calculated for selected grids (e.g. 1500 m)

- Done for 49 compounds (leaching is f(properties), K_{om} = 10, 20, 30, 60, 120, 240, 480 L/kg and DT_{50} = 10, 20, 30, 60, 120, 240, 480 d)
- 98-100%ile selected for each compound, -> 49 compounds overlain-> common grids qualify as candidate locations

Summary sw and gw scenario development

Six candidate locations for groundwater protection goals #1 and 2:
alluvial aquifers along small rivers and volcanic aquifers on shallow wells > 1500 m

Summary sw and gw scenario development

Six candidate locations for groundwater protection goal #3a:
alluvial aquifers in the Rift Valley margins and lowlands < 1500 m

Summary sw and gw scenario development

Three candidate locations for groundwater protection goal #3b:
alluvial aquifers in the Rift Valley margins between 1500-2000 m

Summary sw and gw scenario development

Next steps:

8. Application of scenario selection procedure

- First select scenario locations

9. Parameterization of scenarios in the models

- Next, start parameterisation:
  # crop development data
  # confirm layout small streams and temporary ponds
  # obtain horticultural irrigation data

10. Design and construction of software tool

- Adapt PRIMET tool for sw and gw concentrations

Summary sw and gw scenario development