Managing the Water Balance
How Farmers Determine *Green* and *Blue* Water Flows in the Save Basin in Zimbabwe

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Abstract: Water security is a principal concern for the 21st century. Productivity of rain-fed farming in Sub-Saharan Africa (SSA) is far below its potential, yet rain fed agriculture will remain the dominant system for decades to come (FAO, 2003).

In semi-arid and sub-humid regions in SSA, rain-fed agriculture uses only 15 to 30% of the rainwater for crop production. High losses are due to runoff, low infiltration during high-intensity rains, poor crop rooting conditions, past and present soil erosion, and evaporation losses from soil and canopy, in particular during pre-planting and early crop stages. In addition, runoff can cause damaging flash floods, erosion and water turbidity, and without storage downstream, substantial water is lost from the catchment.

Proposal

Worldwide, agriculture is seen as the largest water consumer. However, the role of farmers in rain fed agriculture as contributors to the water resource balance should be recognized. Farmers need to be rewarded financially or given appropriate incentives for effective management interventions to permit further investment in improved soil and water management practices. This proposal is based on the observations that:

- Soil properties and farmers' soil management practices are decisive in the partitioning of precipitation into *green* water[1] and *blue* water[2] flows.
- *Green* water management[3] interventions improve (i) rain water use efficiency and hence yield potential, and (ii) at the same time, improves *blue* water resources, by reduced run-off, thereby causing a reduction in flash floods, erosion and water turbidity, and an increase in groundwater recharge and more stable river base flow.

Issues addressed:

The seasonal dynamics of green and blue water flows in rain fed agriculture are insufficiently known for most soil and (agro-)climatic regions. Quantitative spatial information is lacking on runoff, evaporation, deep percolation, groundwater recharge, both under current and improved soil management. How can the green and blue water information needs of farmers, catchment managers and policy-makers be met to support their decisions on investment in improved soil management at both field and basin level? What scope is there, in quantitative terms, to reduce runoff and to increase green water when through optimizing green water management under specific soil and climatic conditions?

Objectives

The purpose of the Save basin pilot study is to quantify water balance effects for site specific conditions and for current and potential land use practices, which includes improved soil management aiming at optimizing green water (crop/bio-mass transpiration).

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[1] *Green water*, originally defined as evapotranspiration, is the water vapour flow to the atmosphere (Falckenmark 1995, and Falckenmark and Rockstrom 2004). Redefined as a concrete resource, *green water* is the water held in the soil and available to plants for transpiration. Water held in the soil that evaporates at the soil surface is recognized separately, as it can be influenced by soil management (Savenije 1999, Ringersma *etal*. 2003).

[2] *Blue water* is water which can be collected, pumped and transported; it includes run-off, groundwater, and river and lake water.

[3] *Green water* management includes all techniques and approaches to reduce runoff, increase water infiltration and reduce soil evaporation.

Method

Green and blue water dynamics were analyzed by modeling water balances for local soil and (agro-)climate conditions, and for maize, the dominant cereal crop in Zimbabwe. Three databases were used to analyze green and blue water flows under three soil management scenarios for using as a case study, the Save River Basin in Zimbabwe. Resource data were taken from the regional soils and terrain "SOTERSAF" database of Southern Africa (FAO and ISRIC, 2003), a climatic database (FAO, 1992), and a global database of soil and water conservation technologies (WOCAT, 2004). The three water balance scenarios chosen for effective rain water infiltration are: (A) Optimal soil water management, no runoff, hence 100% infiltration, (B) 20% runoff, 80% infiltration, (C) 40% runoff, 60% infiltration. Soil management scenarios were defined using field cases comprehensively documented in the WOCAT database (WOCAT, 2004) and Ringersma et al. (2003). Green water-optimizing techniques include minimum tillage, mulching, tied ridging, terracing, and modifying dates of sowing. The input maps were generated by overlaying a soil map (moisture retention properties and soil depth) and climate data. Maize yields of a climatically adapted variety and components of the water balance were calculated using a simulation model (Boogaard et al. 1998). The model output was evaluated with yield data of local maize varieties at different altitudes and rainfall conditions (Seed Manual, 2003).

Results

Results for various water infiltration scenarios were presented on green and blue water maps. These maps are shown in Fig 1 with the projected effects of the different management scenarios on crop yield and simulated flows of water: green water (crop transpiration), lost water (soil evaporation) and blue water (groundwater recharge).

The following results can be observed for the two major agro-climatic zones of the Save Basin (average percentages):

- *Dry hot lowlands*
  Soil evaporation in this semi-arid region may account for up to 50% of the total water balance. From scenario C to A, unproductive runoff decreases from 100 mm to zero, reducing the risk of flash floods and water erosion, *green* water increased from 20 to 100 mm with a projected increase in crop yields of up to 40%, while groundwater recharge increased from zero to 75 mm, amounting to 750 m^3 ha yr^{-1}.
- *Moist warm-temperate highlands*
  Using scenario C to A, runoff decreased from 300 mm to zero, *green* water increased from 175 mm to 350 mm, with a projected maize yield increase of up to 60%, while groundwater recharge increased from 50 to 320 mm, which translates to 2700m^3 ha yr^{-1}.

Conclusions

- The Save case shows the relevance of quantifying the potential benefits of various soil management practices optimizing green water in rain fed agriculture for local soil conditions and agro-climatic zone.
- *Green* and *blue* water information and maps for current and improved *green* water management are valuable to support farmers, water basin managers and policy makers in their decisions to invest in improved soil and water management.
- Farmers are key stakeholders in partitioning of the *green* and *blue* water flows at farm and basin level.
- The results of the Save pilot study concur with the recommendations of the InterAcademy Panel (IAC report, 2004): "potential of rain fed agriculture needs to be recognized and assigned priority", reduce land degradation" and "explore higher-scale integrated basin strategies".

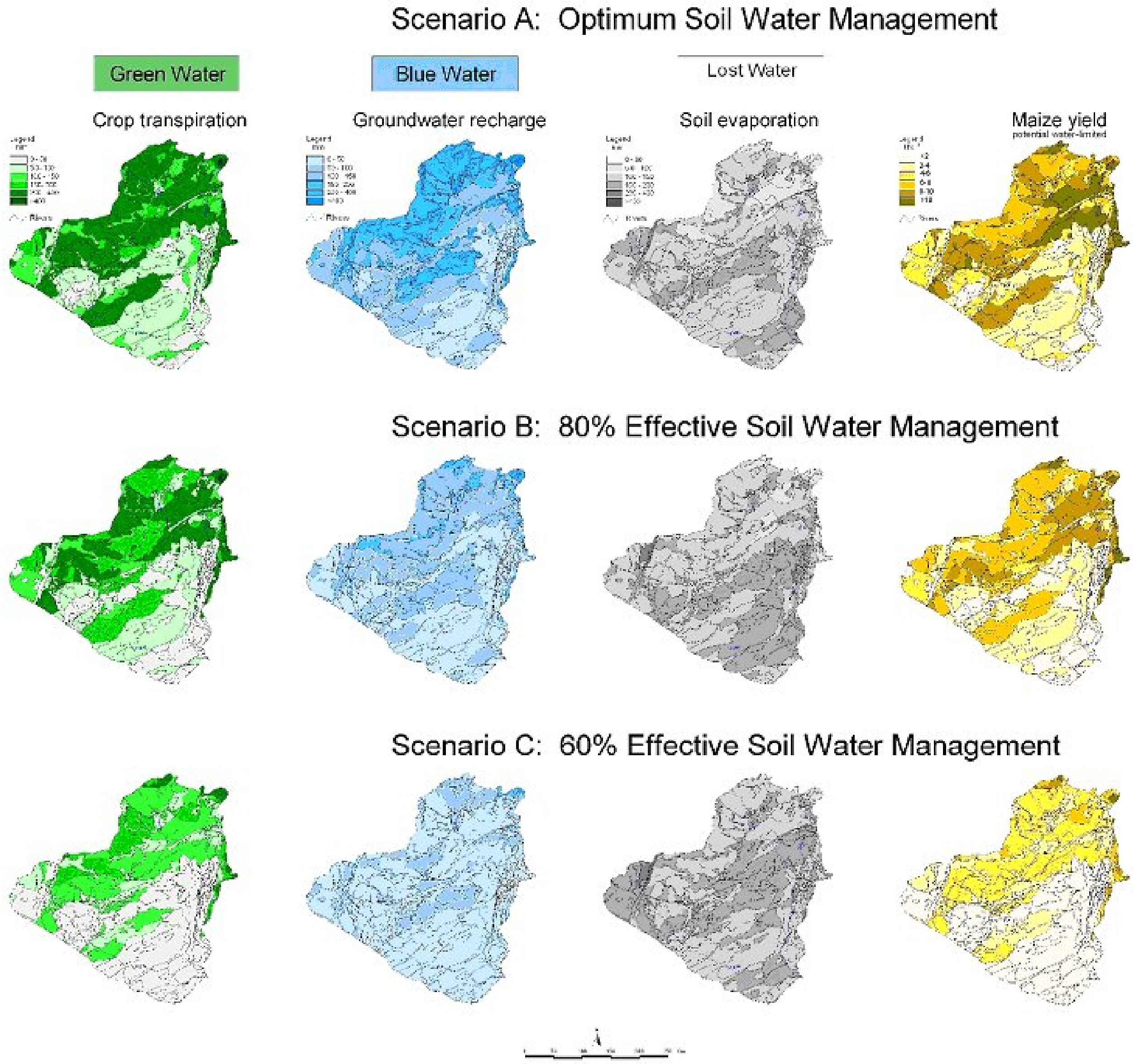

Figure 1 – Green and Blue Water maps for three soil & water management scenarios (effectiveness of run-off control) in the Save Basin, Zimbabwe

Discussion

The on-site effects are the focus of the the Save pilot. Nevertheless modelling of the effects of reduced run-off (by improved soil and water conservation techniques) on the water balance components (crop transpiration, soil evaporation and deep percolation) may enhance the understanding of the processes for the whole watershed, which includes downstream effects. The need of validation of model simulation results by groundtruthing, should be stressed, using available indicators such as ground water level and river discharges.

Erosion does not always have exclusively negative consequences, as it may cause beneficial sedimentation downstream (without erosion no Holland!). Nevertheless, inappropriate human choices of land use and soil management may result in enhanced run-off, with damaging effects both on-site and downstream. It just depends on local conditions which of these is the more important. In recent years several serious events were reported of mud streams, land slides etc. due to chances in land use and inappropriate soil and water management (e.g. the very recent catastrophe in the Philippines).

The Save pilot study is specifically targeted to give answers to practical questions of improved land use and soil and water management at the field level and its potential effects at a larger scale. The study is a 'broad brush' approach, which will need to be followed by detailed hydrological basin analysis.

Although agricultural land use may be a minor portion of the basin, thereby reducing the effects of improved soil and water conservation, modelling can also be targeted on the quantification of effects of improved forest and rangeland management.

Suggested follow-up

1. Water security and rain fed agriculture are linked and will require large investments to reverse current negative trends affecting rural and urban poor.
2. Cost/Benefit analyses are needed to compare investment in effective green water management, which enhances soil capacity to store and filter water, with current solution of constructing costly water storage devices down streams to capture run-off and control flash floods.
3. Essential for implementation of improved *green* water management at a large scale is the recognition of the farmers' status of delivering blue water services and subsequently the rewarding for these public services by downstream users.
4. *Green water credits* are a proposed mechanism (Dent, 2004) for transfer of cash to rural people in return for improved soil & water management activities that are at present unrecognised and un-rewarded: a pro-poor investment in people and in the environment.

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www.isric.org for more information on green water

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