[K2.05]

Managing land and water resources sustainably worldwide and in sub-Saharan Africa

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Background:

Increased future demands for food, fibre and fuels from biomass can only be met if the available land and water resources on a global scale are used and managed as efficiently as possible. In the past, the global agricultural production could be increased mainly through yield increases due to intensification and technological change, expansion of arable land into currently non-agricultural areas and to a smaller extent also through increases in the cropping intensity.

Globally, cropland is expected to increase by 120 Mha until 2030 and an additional expansion in world's cropland by 142-454 Mha for bioenergy production is expected in 2050 (Beringer *et al.*, 2011). As agriculture already account for about 70% of the freshwater withdrawals in the world and additional water demand potentially arise from land expansion and intensification it is questionable whether there will be sufficient freshwater to satisfy the growing needs of agricultural and non-agricultural sectors. Worldwide productivity increases of at least 1% p.a. in a business-as-usual scenario with cropland expansion, population increase and shifts in diets and income and up to 1.4-1.8% p.a. with additional pressures on land and water resources are required until 2055 to fulfill global food and bioenergy demand (Lotze-Campen *et al.*, 2009).

Sub-Saharan Africa is a hotspot of food-insecurity. About 20 out of 33 countries in sub-Saharan Africa are facing long-lasting severe food insecurity today. Population pressure is projected to increase and will exacerbate the alimentary shortage. In sub-Saharan Africa and Middle East and North Africa the cumulative pressures of reduced trade, additional bioenergy demand, avoided deforestation, and climate change on land and water resources until 2055 require an even stronger productivity increase to fulfill the regional food and bioenergy demand: 2.4% p.a. in sub-Saharan Africa and 4.9% p.a. in Middle East and North Africa (Lotze-Campen *et al.*, 2009).

Methods:

In the view of this situation this study quantifies the potential of intensifying agricultural production sustainably by (i) increasing the water use efficiency and (ii) optimize the crop's growing conditions to avoid temperature and water stress.

Methods for increasing water use efficiency include low-tech solutions such as the collection of rainwater during wet periods and its later use during dry-spells and the increase of productive plant transpiration by avoidance of unproductive soil evaporation (Rost *et al.*, 2009). Moreover, adapting the sowing date to a shifted start of the wet season will ensure optimal growing conditions and low risk of drought at important crop growth stages and, therefore, allow for better use of rainwater and potentially increased crop yields. Switching to more suitable crops with a shorter growing period, heat tolerance or drought resistance might also lower the negative impact of climate change. Also multiple cropping systems provide more harvest security for farmers and allow for crop intensification.

Accordingly, we perform several simulations to quantify the potential increase in crop production in sub-Saharan Africa and worldwide through different water and land management strategies under present climate conditions. Details on the scenarios and their implementation in the global dynamic vegetation and water balance model LPJmL (Bondeau *et al.*, 2007) can be found in Rost *et al.* (2009) and in Waha et al. (2013):

- The baseline run, in which crops on areas equipped for irrigation were assumed to be irrigated, thus representing irrigation as the only water management.
- Vapor shift: Simulations representing strategies to achieve a vapor shift from evaporation to transpiration by reducing soil evaporation during the growing periods.
- Rainwater harvesting: Simulations representing rainwater harvesting strategies that store (sub-)surface runoff from cropland over a year for potential use via micro-irrigation

during periods of crop water limitation.

- Dynamic sowing dates: Simulations with sowing dates adapted to changing climatic conditions instead of a constant sowing date.
- Highest-yielding cropping system: Simulations with the highest-yielding crop or if possible with the highest-yielding multiple cropping systems grown on available rainfed area.

Results:

Applying these management strategies globally would increase global crop production by more than 50% under present climatic conditions if both vapor shift and water harvesting techniques were combined at a level of 85% each (i.e. the theoretical potential). However, it is very unlikely that this theoretical potential can be accomplished at large scale (Rost *et al.*, 2009). More moderate scenarios suggest an increase by 6% to 19% for water management strategies and 0.7% to 3.8% for sowing date and cropping system adaptation (Waha *et al.*, 2011).

There is a huge potential to increase crop production already in rainfed agriculture by applying low-tech water and land management strategies. However it remains unclear if farmers will be able to apply the most beneficial management techniques because of several limitations. Introducing an unknown crop, cropping system or water management strategy may also require some adjustments to current technology and management. In the most ambitious water management strategy considered here global production increases on current cropland of 0.6-0.8% p.a. can be achieved but will not be sufficient compared to required productivity changes of 1.4-1.8% p.a. Thus, the remaining productivity increases need to be achieved through e.g. investments in research and development in the agricultural sector in order to improve water use efficiencies, the use of fertilizer and seeds.

Key references:

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Keywords: cropping system, optimal rainwater usage, low-tech management option