A global spatial framework for agricultural productivity

Burgeoning populations, changing diets and an upcoming bio-based economy have led to concerns that the world's food production system will be unable to cope by 2050 (Ray et al., 2013). Questions arise as to where we can produce crops most efficiently, in sufficient quantities and how we should go about doing this without jeopardising our biodiversity and the limited resource base that we have.

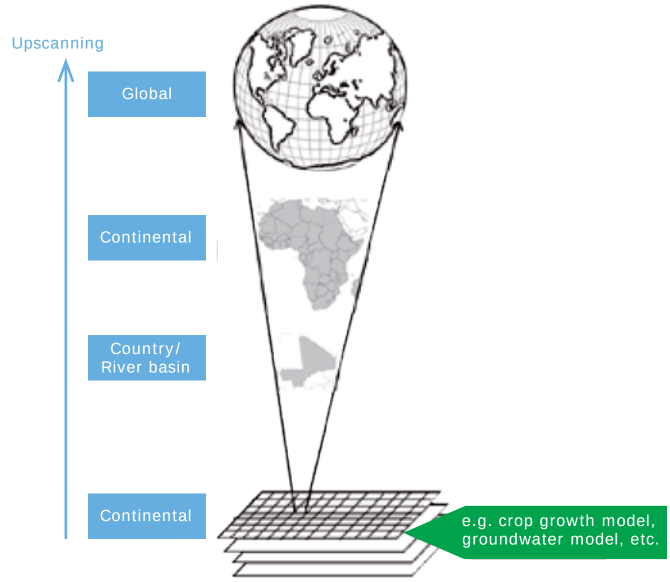
Researchers at Wageningen UR have been using their knowledge to find innovative ways of addressing these issues. They initiated a project to contribute to building the knowledge base by providing spatial insight into local and global crop production conditions to be able to explore options for sustainable crop intensification. A comprehensive tool, the spatial **F**ramework for global **R**esource **A**vailability and **M**odelling of input use **E**fficiency in crop production (FRAME), was developed to look at the agro-ecological options to increase crop production with the greatest input efficiencies, and illustrate this in a spatially explicit way to reveal local development options.

Using the databases: how they work

A large number of global spatial databases (weather, soil, land cover/use, agricultural management and socio-economic data) with different resolutions are combined with crop simulation models and empirical calculation rules in a coherent framework (Figure 1). Special expertise is used to link data to estimate crop yield potentials, required input use and to assess yield risks (e.g., due to weather variability). FRAME is being used in a number of different agro-ecological studies ranging from quick-scans of crop suitability for a given location to calculating crop water use in relation to regional irrigation water availability. Crop productivity is calculated based on knowledge of the locally available resources and water and nutrient input use efficiencies. By aggregating local results (mostly at a resolution of approximately 9x9 km near the equator, but recently also databases with 1 km^2 resolution are being used), national, regional and global consequences can be made visible in maps (e.g., Figure 2). In FRAME, the knowledge of local conditions is made explicit, and it allows for a further accumulation of knowledge as more information per grid cell becomes available. Methods for downscaling and upscaling have also been developed to allow for analysis at different scales.

An example: Intensification options for maize production in Africa

FRAME has been used to explore options for sustainable intensification of maize production in Africa. Firstly, rainfed potential maize yields were calculated and compared with actual yields. The difference between the two yields obtained is referred to as the ‘yield gap’ (potential minus actual). Additional information on, for example, fertiliser use, suggests that for maize to reach its full potential, it would require more inputs, like fertilisers. Secondly, the minimum amount of required nitrogen (N) fertiliser application was calculated based on local weather and soil conditions, crop characteristics, management and yield level. Finally, the efficiency of applying extra N fertiliser to produce more grain dry matter (DM) was determined. Figure 2 illustrates the spatial differences in fertiliser use efficiency of maize harvested areas in Africa. This information can help in, for example, land use planning (in terms of, e.g., where to grow maize with the highest fertiliser efficiency), in exploring options to improve fertiliser efficiency and in estimating the total amount of extra N fertiliser required for a targeted maize production at the national level.



Different databases with information at grid cell level on weather, soils land use and socio-economic characteristics. These data are used in models (e.g. for crop growth and groundwater flows) and calculated results form new layers of grid cell information.

Figure 1 A spatial Framework for global Resource Availability and Modelling of input use Efficiency in crop production (from Conijn et al., 2011)

Conclusion

FRAME is being used to assess some of the most important aspects of sustainable production – production potentials, yield gaps and efficient resource/input use. Information about the spatial and temporal variation in crop production and input requirements allows for better targeting of

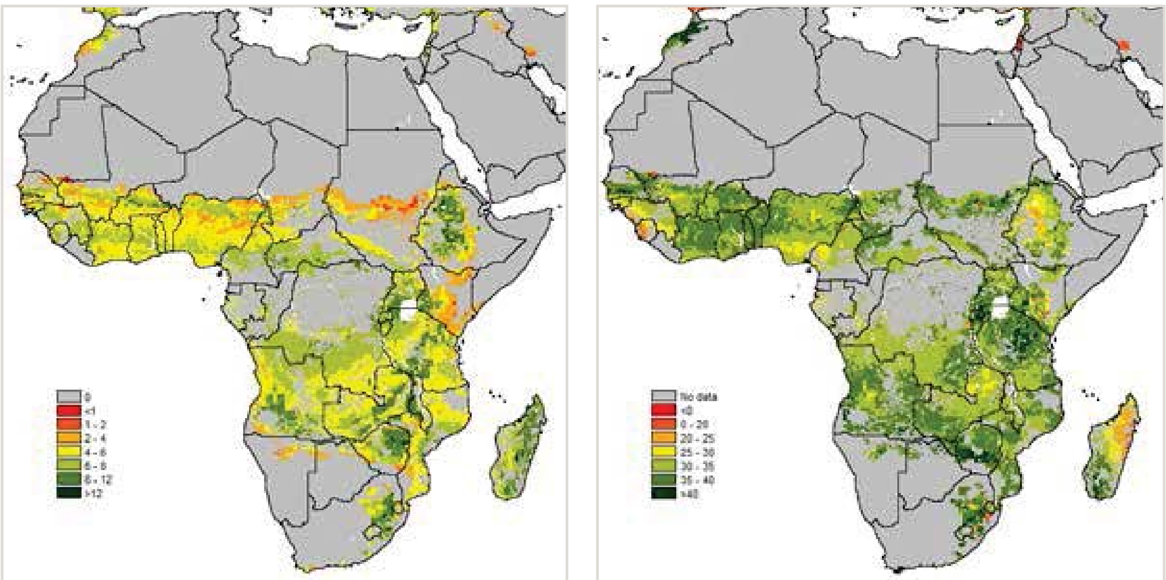


Figure 2 Left: Calculated grain yield of rainfed maize harvested areas in Africa (t DM ha_{-1} per harvest). Right: Amount of extra grain yield produced per amount of extra fertiliser N applied (kg grain DM/kg fertiliser N) for rainfed maize harvested areas in Africa (based on Conijn et al., 2013)

interventions aimed at improving local food security (*more with less*) and is supportive in developing risk mitigating tools such as crop insurance. FRAME has been used in a number of other projects such as for the European Union's Seventh Framework Programme for Research (FP7; Conijn et al., 2011), World Food Programme (WFP; Meijerink et al., 2012), International Fund for Agricultural Development (IFAD; Conijn et al., 2011), 'The Sustainability Consortium' (TSC; Haverkort et al., 2013; Evert et al., 2013) and to support the Dutch government to develop policies on sustainable agriculture (Hengsdijk et al., 2014).

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