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Water management on farms assessed by new tool, Flanders

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Researchers have developed a new model that highlights how agricultural practices impact on water availability in the wider landscape. The model, AquaCrop-Hydro, could be used to inform agricultural management decisions and policy related to water and land use, to ensure best allocation of water resources. Such tools are not only useful currently, but will be especially important in future in areas where climate change impacts on water availability and affects crop productivity.

AquaCrop-Hydro builds on the crop simulation model AquaCrop, developed by the Food and Agriculture Organisation of the United Nations (FAO). This is integrated with a hydrological model[1] to offer insights into optimal water management on farms, taking into account the needs of stakeholders in the catchment as well as crop productivity. Resource efficiency will be key for climate mitigation and adaptation, and is one of the themes considered by the European Network for Rural Development, alongside water and soil management.

Crop simulation models can be used to investigate various processes that determine crop growth and yield, the researchers explain. Water use and its effect on productivity is one such variable that can be modelled. The way water is managed on a farm can affect whole catchments, and many different stakeholders, from households to ecosystems. A management strategy that optimises crop water in one farmer's field may therefore only be successful if it does not affect the neighbouring farms.

Hydrological models, meanwhile, simulate the movement of water in a catchment, accounting for crop transpiration (water uptake) as part of this, though existing models rarely consider how crop growth and management practices will affect crop transpiration and production. To achieve this requires a large amount of data, which can be difficult to gather, and complex computations, say the researchers.

Acknowledging that previously developed agro-hydrological models are often data demanding and resource intensive, the researchers suggest that their new model has various advantages over previous attempts. The model not only simulates crop production and water productivity at the field scale, but can also be used to see effects of management changes on hydrological processes at the catchment scale. It concentrates on data that are easy to obtain, easy to use, and is widely applicable to a variety of agricultural catchments and situations, say the researchers.

The crop modelling element, AquaCrop, is based on inputs detailing weather, crops, soil and groundwater properties, as well as management practices used (e.g. irrigation, mulching). It indicates the amount of crop produced per unit of water use, which varies depending on conditions (e.g. air temperature). The daily soil water balance (the amount of water contained in the soil) is calculated based on incoming and outgoing water flows, e.g. rainfall and surface run-off. Water dynamics within the soil are also considered, such as deep percolation to groundwater and capillary rise — whereby water rises from lower levels, potentially reaching crop roots.

In AquaCrop-Hydro, the catchment area is divided into land units with similar characteristics and use (e.g. type of crop cover). The soil water balance at catchment scale is derived by combining water use/flow simulations for land units over the whole area. The hydrological model is then used to simulate discharge into the outlet (water flow into a river or body of water). Averages of simulation results over longer periods are used to investigate trends over time.

1. Willems, P. (2014). Parsimonious rainfall–runoff model construction supported by time series processing and validation of hydrological extremes – Part 1: step-wise model-structure identification and calibration approach. *Journal of Hydrology*, 510: 578–590.

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The researchers note that AquaCrop was developed for land covered with herbaceous crops (e.g. wheat), but model settings for bare land plus other adjustable options can be used to simulate other land uses (e.g. urban, forest or grassland).

The researchers evaluated the model in Flanders, Belgium, in the Plankbeek stream catchment, where agriculture cover is 94%. Simulations were conducted from 2000 to 2014, using crop, soil and management inputs, plus daily weather and rainfall records. The most common crops planted were winter wheat, potato, maize and sugar beet.

AquaCrop-Hydro's simulations of discharge were compared with records of actual discharges to the stream from a monitoring station, and simulations of crop productivity with records of production on 70% of the area. Using statistical analysis, the researchers found that observations and simulated findings matched quite well, though not perfectly. For example, the model performed well for winter barley production, but poorly for winter wheat. The model found that about two-thirds of rainfall in the Plankbeek catchment was used by crops or evaporated, while 27% reached the groundwater or river. Surface run-off accounted for 7.5% and 0.2% was stored in the soil.

The total water volume simulated over 13 years was about 7% lower than suggested by observations, which the researchers attribute to errors at several stages. For example, the model was not completely accurate in predicting the amount of water reaching the river during peak-flow events (e.g during storms). Observations may also be subject to error, the researchers note. AquaCrop-Hydro performed best over longer time periods such as a month, compared to single days. More evaluation in different locations is necessary to improve the model, the researchers acknowledge.

The researchers emphasise one of the major strengths of the model is its low data requirements. The data required is easily obtainable, from field observations, agricultural statistics or other literature. Data on river flows for calibrating the hydrological element of the model is widely available from river-monitoring stations, they say, or can even be taken from a similar catchment nearby. The model also includes many default settings, for use where data are unavailable, while the number of available pre-defined settings, for example for crops such as maize and barley, is growing.

The researchers say that the model could be used to support decisions regarding water allocation in a catchment; for example, how much should be reserved for ecosystem services functions, domestic water use and hydropower, as well as agriculture. It can reveal trade-offs between practices such as irrigation and water availability in the wider landscape — especially important if the climate becomes drier, and where increasing levels of carbon dioxide or other factors affect crop growth. It may also highlight if increased cultivation of cover crops could be beneficial for the water balance, although it would not be able to indicate their optimal location, i.e. the model isn't designed to inform spatial planning of agriculture.

While the researchers acknowledge the model could be improved, they argue that it functions well and is, therefore, promising for the evaluation of agricultural water management and supporting sustainable practices.