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Sustainability of agricultural water use worldwide: the concept of Water Debt

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Water is a renewable but limited resource. Most human use of freshwater resources is for agriculture, and global water demand for agriculture is increasing because of the growth in food demand, driven by increasing population and changing diets. Water Footprint measures the pressure exerted by agriculture on freshwater sources by quantifying the amount of water used for crop production. An important development of the water footprint indicator, necessary to assess the impact of agricultural production on water resources across products and regions, is to relate the water footprint to locally available water resources. Different indices have been introduced in the literature to compare water use to availability, however these indicators generally consider all crops together, not allowing the identification of critical crops, and most indicators do not separate the use of surface water from groundwater.

In this study, we explore the sustainability of water use for the production of 9 major crops, globally at a 5'x5' spatial resolution. We split the crop water footprint into green and blue water footprint, making also distinction between surface and ground water footprint. In order to quantify the extent to which water use is sustainable, we introduced the concept of Water Debt. The term, borrowed from the carbon footprint literature and inspired by early considerations about sustainability is used to indicate the payback time required by the hydrological cycle to replenish the water resources (i.e. soil moisture, surface water bodies, and aquifers) used for annual crop production. We mapped, for each crop, the number of years required to replenish the water withdrawn from the three different sources. Each map identifies the hotspots for each water source, highlighting regions and crops that threaten most the water resource. We found that the water debt with soil moisture is heterogeneous in space but always lower than 1 year indicating a non-surprising sustainability of rain-fed agriculture. The highest values, i.e. 6 months, are found in the US core agricultural area, in Northern India and Eastern China. Rice and sugar cane make the largest contribution to global soil moisture depletion. Water debt in surface water is particularly high in areas of intense wheat and cotton production; major hotspots are located along the Nile River and near the Aral Lake. The water debt in groundwater is much larger in the High Plain aquifer and Indo-Gangetic plain. On global average, seed cotton has the highest water debt in surface water (i.e. 6.5 years) while rice has the highest debt in groundwater (i.e. 4.2 years).