How much water does rice use?

by Bas Bouman

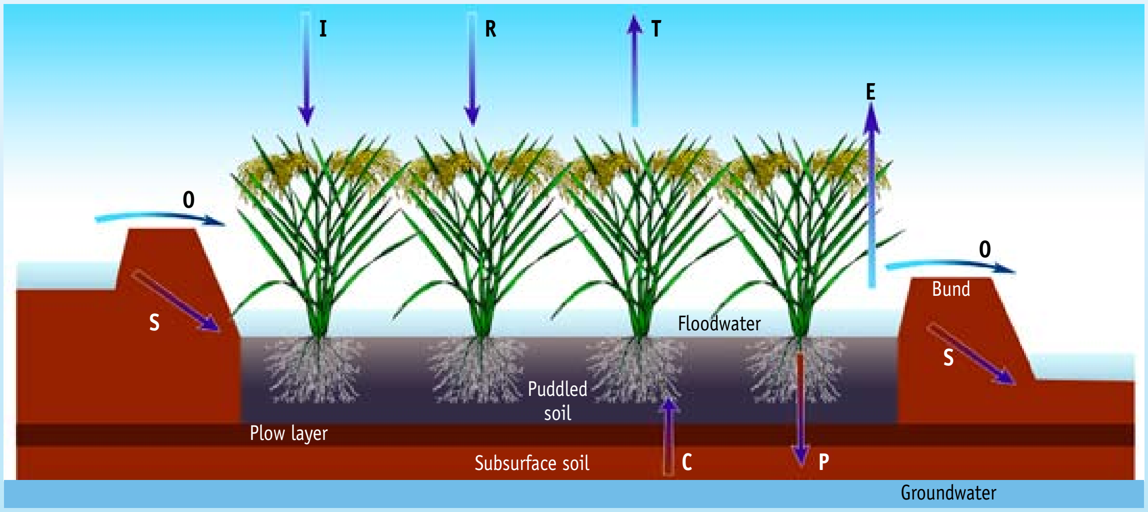
Rice Today examines this often-asked (and often poorly answered) question

Many people ask the question, "How much water does it take to produce 1 kg of rice?" The answer to this question lies in the definition of "water use" and of "rice." We can identify three types of water "use"—through transpiration, evaporation, and a combination of seepage and percolation—at, respectively, three scales of rice—the plant, the crop, and the field.

The ***rice plant*** "uses" water through the process of transpiration, which cools the plant and drives the upward sap flow—which carries essential nutrients—from roots to leaves. This is a "real" water use, since once the plant has taken up water and released it to the atmosphere through transpiration, that amount of water is no longer available for reuse by that same plant in the same growth cycle. Transpired water enters the global water cycle and will eventually return to the earth as rain or snow.

The ***rice crop*** comprises the plants and underlying soil. Besides transpiration from the plants, water leaves the crop from the soil underneath through evaporation. Like transpiration, evaporated water is "lost" and cannot be used again by that same crop in the same growth cycle. This combined water use by a rice crop is called "evapotranspiration."

In ***rice fields***, water is often ponded to ensure there is plenty for the crop to take up. Besides evapotranspiration, outflows of water from a field occur through seepage and percolation: sideward and downward water flows through the soil and bunds out of the field. For an individual farmer, these are real losses as well, and she considers the total combined outflows by evapotranspiration, seepage, and percolation as water use by her rice field (see figure). The farmer needs to ensure sufficient irrigation (to complement rainwater if rainfall is insufficient) to match all these outflows. At a larger spatial scale, however, seepage and percolation



WATER BALANCE of a puddled rice field: C = capillary rise; E = evaporation; I = irrigation; O = over-bund flow; P = percolation; R = rainfall; S = seepage; T = transpiration.

flows from one field enter the groundwater or creeks and drains, from where other farmers may reuse the water to irrigate other fields. This is in contrast to the water losses by evapotranspiration, which cannot be recaptured.

Rice plant water use (by transpiration)

Pot experiments and greenhouse studies carried out at the International Rice Research Institute (IRRI) have shown that rice plants growing under a range of water applications transpired 500–1,000 liters of water to produce 1 kg of rough (unmilled) rice.[1] This is at the high end of comparable cereals such as wheat and barley.

Rice crop water use (by evapotranspiration)

The estimated water use by evapotranspiration of all rice fields in the world is some 859 cubic kilometers per year.[2] With a global rough rice production of around 600 million tons, it takes an average of 1,432 liters of evapotranspired water to produce 1 kg of rough rice. This is roughly the same as the world-average water use of wheat, but higher than that of maize and barley (see Table 1).

Table 1. World-average water use by evapotranspiration of major nonrice grain crops (liters of water per kg of grain).

Source	Wheat	Maize	Barley
Falkenmark and Rockström, 2004[3]	1,480	1,150	1,000
Chapagain and Hoekstra, 2004[4]	1,300	900	–

The variability in water use by evapotranspiration by rice crops is large. Table 2 summarizes experimental data from well-managed lowland field experiments with rice.

Table 2. Liters of evapotranspired water needed to produce 1 kg of rough rice.

Source	Minimum	Medium	Maximum
Zwart and Bastiaansen, 2004[5]	625	909	1,667

By comparison with total global water use, Table 3 puts the world rice water use by evapotranspiration into perspective. Producing the world's rice accounts for 12–13% of the amount of evapotranspired water used to produce all of the world's food (food crops and grass and fodder for livestock).

Table 3. Total global water use (cubic kilometers of water per year).

Source	Chapagain and Hoekstra, 2004[4]	Falkenmark and Rockström, 2004[3]
Total	7,450	8,160
Food	6,390	7,200
Industry	716	780
Domestic	344	180

Rice field water use (to account for evapotranspiration plus seepage and percolation)

On average, about 2,500 liters of water need to be supplied (by rainfall and/or irrigation) to a rice field to produce 1 kg of rough rice. These 2,500 liters account for all the outflows of evapotranspiration, seepage, and percolation. This average number is derived from a large number of experimental data at the individual field level across Asia. Variability is large, ranging from around 800 liters to more than 5,000 liters. This variability is caused by crop management (such as variety planted, fertilization regime used, and pest and disease controls adopted), weather, and soil properties. At the field level, water inputs to rice fields are 2–3 times those of other major cereals.

Although rice's water productivity in terms of evapotranspiration is similar to that of comparable cereals such as wheat, rice requires more water at the field level than other grain crops because of high outflows—in the forms of seepage and percolation—from the field. However, because these outflows can often be captured and reused downstream, rice's water-use efficiency at the level of irrigation systems (which comprise many fields) may be higher than that at the field level. Nevertheless, around one-quarter to one-third of the world's developed freshwater resources are used to irrigate rice (which, it must be remembered, is the staple food for almost half the world's population).

Rice production must be viewed in the light of the emerging water crisis, as climate-change-induced shifts in rainfall patterns combine with the diversion of irrigation water for urban and industrial uses. As agricultural water scarcity increases, there is a growing need for water-saving technologies such as aerobic rice (varieties that grow well in unflooded fields; see *High and dry* on pages 28-33 of *Rice Today* Vol. 6, No. 4) and more efficient irrigation regimes such as alternate wetting and drying (see *The big squeeze* on pages 26-31 of *Rice Today* Vol. 7, No. 2).

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1 Haefele SM, Siopongco JDLC, Boling AA, Bouman BAM, Tuong TP. 2008. Transpiration efficiency of rice (*Oryza sativa* L.). Field Crops Research. (In press.)
2 Mom R. 2007. A high spatial resolution analysis of the water footprint of global rice consumption. Master thesis, University of Twente, Enschede, Netherlands.
3 Falkenmark M, Rockström J. 2004. Balancing water for humans and nature: the new approach in ecohydrology. Earthscan, London, UK. 247 p.
4 Chapagain AK, Hoekstra AY. 2004. Water footprint of nations. Value of water research report series No. 16. Delft (Netherlands): UNESCO-IHE. 76 p
5 Zwart SJ, Bastiaansen WGM. 2004. Review of measured crop water productivity values for irrigated wheat, rice, cotton and maize. Agric. Water Management 69:115-133.