LETTER

Reply to Jongschaap et al.: The water footprint of *Jatropha curcas* under poor growing conditions

The water footprint (WF) of a product refers to freshwater consumed during production (1). We calculated bioenergy WFs assuming crop water requirements are met (2); Jongschaap et al. (3) correctly point out that this is not always true, giving an example for jatropha grown under poor, rain-fed conditions in South Africa.

Yields are generally expressed in ton/ha, but, when water is scarcer than land, it is more relevant to look at water yield, or the inverse WF (m^3/ton). The crop WF refers to evapotranspiration (ET) over the growing period divided by yield (Y). Under water-constrained circumstances, ET is relatively low, but Y is low accordingly. Worldwide, approximately half of jatropha is irrigated to boost yields (4). With better conditions, Y increases, but ET increases, too. Low water use does not go together with high oil yields (5).

Current agricultural practice strives for high yields under optimal circumstances (often requiring irrigation). Our estimates, based on good conditions, show that jatropha is a relatively inefficient biofuel crop (2). This comparison is fair because most current plantations aim at high yields under good conditions (4).

When jatropha is grown under water-stressed conditions, this can result in lower WFs per unit of oil than under good conditions. In the South African example (3), ET is 4,052 m^3/ha per year, oil yield 0.45 ton/ha per year and, given a higher heating value (HHV) of 37.7 MJ/kg, energy yield is 17 GJ/ha per year. This implies a WF of 238 m^3/GJ, less than WFs for plantations with good conditions and higher yields (2). This finding is highly relevant. Growing jatropha under good conditions can be contested for two reasons: (*i*) it competes with cultivating food crops also growing under good conditions and (*ii*) it gives a relatively low energy yield per unit of water (2). Growing jatropha under water-stressed, rain-fed conditions means that, without additional claims on scarce freshwater, marginal land that cannot be used for other crops is made productive. Competition remaining, however, is extensive livestock farming.

Jongschaap et al. (3) argue that WFs of jatropha oil are even lower if remaining press cake after oil extraction is included for heating. Assuming an HHV of 17.5 MJ/kg for press cake, in their South Africa case 1 ha provides 17 GJ/yr of oil and 14.6 GJ of press cake heat. With ET 4,052 m^3/ha per year, this gives a WF of 128 m^3/GJ of total energy. This form of computing, however, is incorrect, because one cannot compare a high-value energy form like oil with a low-value form like heat. Proper accounting allocates jatropha's water use over its final products according to relative product values (1). Because the value of 1 GJ of jatropha oil ($0.01 US/MJ) is ≈50 times the press-cake value ($0.0002 US/MJ), press cake energy is a by-product. Water is mainly for oil, resulting in 238 m^3/GJ of oil.

We conclude that it is essential to differentiate between rain-fed jatropha cultivation under highly water-stressed conditions and jatropha cultivation with irrigation or under rainfall conditions that are sufficient to grow other crops.

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