Research article

Comparison of the Water Footprint of Cassava and Sugarcane in Northeast, Thailand

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Abstract The water footprint (WF) is an indicator of water use consists of the direct and indirect water use throughout the life cycle of crop produce and it varies on different climate and agricultural production system. This study aims to assess the water use of cassava and sugarcane cultivation in northeastern, Thailand using WF concept which is a tool for sustainable water analysis and management. The results of this study show the average the WF of cassava (345 m^3/ton) is more than that sugarcane (157 m^3/ton). At the provincial level, the WF of cassava is the most highest in Amnat Charoen (378 m^3/ton; green WF 44 m^3/ton, blue WF 233 m^3/ton and grey WF 101 m^3/ton), while Buri Ram has the lowest WF (313 m^3/ton; green WF 38 m^3/ton, blue WF 181 m^3/ton and grey WF 94 m^3/ton). For sugarcane, Amnat Charoen show the highest of WF of 167 m^3/ton, which consists of green WF 20 m^3/ton, blue WF 84 m^3/ton and grey WF 63 m^3/ton. Meanwhile, the lowest WF was 133 m^3/ton in Bueng Kan (green WF 16 m^3/ton, blue WF 64 m^3/ton and grey WF 54 m^3/ton). As a result, the different location, crop, agricultural production systems and yields have an effect on WF. Therefore, not only developing the efficiency water system to water resources sustainable but also increased crop productivity and soil fertility are certainly important for decrease the amount of water used in this region.

Keywords Water footprint, cassava, sugarcane, water resource, northeast Thailand

INTRODUCTION

Cassava and sugarcane is an annual crop in tropical region and can be cultivated in almost soil type and low organic matter such as in Northeastern region, Thailand generally is sandy soil, an average rainfall 30 years is 1,447.70 mm (Meteorological Department, 2009). Cassava and sugarcane is the main cash crop in northeast region which is a total cassava and sugarcane cultivation area of 4,578,385 and 3,260,700 ha and an average yield is 14,493,229 and 36,978,370 ton, respectively (office of agricultural economics, 2012). However, high production of cassava and sugarcane depends on not only their varieties, soil texture, fertility but also water supply still needs for increasing of the production in Thailand.

Meanwhile, northeast region has a low average rainfall and long dry season. Lack of water may effect to growth and yield in this region. Sometimes rainfall is insufficient for cultivation must be supplemental irrigation, surface water and groundwater for produce high crop yield. Therefore, a limited of water resource in Northeast region is should be seriously and carefully to water use and management.

A tool that has been used to estimate water requirement on crop production is the water footprint (WF). The concepts of the WF have been introduced by Hoekstra in 2002 which was an indicator of water used for produces the goods and service, by measured through over the full supply chain considering water use both direct and indirect including by source and polluted volumes in water. The WF consists of three component which are the green WF refer to the rainwater consumed, the blue WF refers to the volume of surface and groundwater consumed (evaporated) as a result of the production of a product and the grey WF refers to the volume of freshwater that is required to assimilate the load of pollutants based on existing ambient water quality standards (Hoektra et al., 2011). The WF concept is considered as an alternative toot to improve the water used plan and manage under the existence of a limited resource on the climate change (Hoekstra et al., 2009).

Therefore, the objective of this study was to assess WF of cassava and sugarcane cultivation in Northeast, Thailand with the findings can be used as a guideline for future water resource management for cassava cultivation in Northeast, Thailand.

METHODOLOGY

Table 1 Harvest Area, production and yield average on period 2003-2012 of cassava and sugarcane in Northeast, Thailand

Province	Cassava			Sugarcane		
	Average harvested area (ha)	Average production (ton/year)	Average yield (ton/ha)	Average harvested area (ha)	Average production (ton/year)	Average yield (ton/ha)
Loei	26,518.7	531,095.5	20.0	13,249.2	803,122.7	60.6
Nong Bua Lum Phu	6,866.9	137,659.5	20.0	7,663.4	479,683.7	62.6
Udon Thani	26,855.2	551,312.0	20.5	64,239.0	3,900,521.0	60.7
Nong Khai	6,753.8	128,970.1	19.1	1,625.3	99,780.8	61.4
Bung Kan	4,113.4	84,256.0	20.5	241.6	18,000.0	74.5
Sakon Nakhon	11,731.9	217,621.2	18.5	4,015.1	240,684.7	59.9
Nakhon Phanom	3,017.7	56,545.6	18.7	1,200.8	73,203.3	61.0
Mukdahan	15,920.4	299,082.5	18.8	14,171.1	908,303.3	64.1
Yasothon	7,639.8	156,861.6	20.5	1,415.8	90,985.6	64.3
Amnat Charoen	5,265.0	99,356.4	18.9	1,042.3	66,145.6	63.5
Ubon Ratchathani	19,490.5	380,353.9	19.5	1,819.2	132,560.0	72.9
Sri Sa Ket	11,192.7	222,623.2	19.9	834.4	55,434.3	66.4
Surin	7,039.1	128,947.5	18.3	14,679.9	969,175.3	66.0
Burirum	31,498.8	636,715.3	20.2	18,148.9	1,150,709.0	63.4
Mahasarakham	17,461.9	333,141.4	19.1	7,777.4	495,478.0	63.7
Roi Et	14,925.4	285,697.3	19.1	4,215.6	281,601.1	66.8
Kalasin	43,352.4	918,329.2	21.2	41,621.9	2,714,353.7	65.2
Khon Kaen	35,243.1	690,881.6	19.6	75,477.1	5,076,625.0	67.3
Chaiyaphum	59,413.8	1,183,106.8	19.9	56,839.9	3,599,376.3	63.3
Nakhon Ratchasima	266,674.8	5,437,998.3	20.4	84,747.7	5,232,631.7	61.7
Total	**620,975.4**	**12,480,554.9**	**392.9**	**415,025.6**	**26,388,375.1**	**1,289.3**

Source: Office of Agricultural Economics (2012)

Study area and planting design: Data collections were the data of cassava and sugarcane cultivation areas in Northeast, Thailand during 2003-2012 cover 20 provinces collected from the Office of

Agricultural Economics (Table 1). The planting time of cassava is between April through May and harvesting time is between October through November (8 months), while planting time of sugarcane is October and harvesting time is December (14 months). Climate data of past 30 years from Thai Meteorological Department and soil type from Office of Soil Survey and Land Use Planning.

Calculation of water footprint of cassava and sugarcane: Water footprint calculated of cassava and sugarcane cultivation use the water footprint concept following the WF assessment manual of Hoekstra et al. (2011) as showed in equation (1)

$$WF = WFgreen + WFblue + WFgrey \tag{1}$$

Green and blue water footprint can be calculated by using crop water use (CWU, m^3/ha) divided by cassava and sugarcane yield (Y, ton/ha) as equation (2) and (3)

$$WFgreen = \frac{CWU}{Y} \tag{2}$$

$$WFblue = \frac{CWU}{Y} \tag{3}$$

Equation (2) and (3) CWU can be calculated by accumulation of daily evapotranspiration (ET, mm/day) using the CROPWAT model as equation (4)

$$CWU = 10 \times \sum_{d=1}^{lgp} ETgreen, blue \tag{4}$$

Where the factor 10 is applied to convert the unit from mm into m^3/ha and lgp denotes the length of growing period in days which is .244 days for cassava and 426 days for sugarcane.

In this study, evapotranspiration (ET) can be calculated by CROPWAT 8.0 model (FAO, 2009) as following equation (5) (Hoekstra et al., 2011) which required the spatial data (latitude, longitude of Meteorological stations and elevation), climate data of each province (maximum temperature (°C), minimum temperature (°C), humidity (%), wind speed (km/day), sunshine (hours) and rainfall amount of past 30 years (2003-2009)), crop parameters (crop name, planting date, harvest, crop coefficient (Kc), crop development state, the length of growth stage, rooting depth, critical depletion and crop height) and soil characteristic (soil series, soil texture, total available soil moisture and initial soil moisture depletion).

$$ET_{green,\ blue} = Ks \times Kc \times ET_0 \tag{5}$$

Where Kc is the crop coefficient, Ks a water stress coefficient, and ET_0 the reference evapotranspiration (mm/day).

The grey water footprint was calculated by multiplying the chemical application rate per hectare (Appl, kg/ha) with the leaching-run-off fraction (α) divided by the maximum acceptable concentration (Cmax, kg/m^3) minus the natural concentration for the pollutant considered (Cnat, kg/m^3) and then divided by the crop yield (ton/ha) (Charoensuk et. al., 2012) as equation (5)

$$WFgrey = \frac{(\alpha \times Appl)/(Cmax - Cnat)}{Y} \tag{5}$$

The leaching-runoff fraction (α) assumed 10% of the chemical application rate (Allen et al., 1998). In this study considered only the effect of nitrogen fertilizer used. The maximum acceptable concentration for nitrate (Cmax) reference from surface water and groundwater standard value is 5 mg/litter (Pollution Control Department Thailand, 2011) and the natural concentration for the pollutant considered (Cnat) is 0 mg/litter (Mokonnen and Hoektra, 2011).

RESULTS AND DISCUSSION

Water Footprint of Cassava

The calculation of water footprint (WF) of cassava cultivation for 20 provinces in Northeastern Thailand showed that the average total WF was 345 m^3/ton consist of green, blue and grey WF were 40 m^3/ton, 208 m^3/ton and 97 m^3/ton, respectively (Table 2). At the provincial level, Amnat Charorn (378 m^3/ton) has higher WF than Mukdahan (375 m^3/ton), Ubon Ratchathani (375 m^3/ton), Roi Et (370 m^3/ton), SriSa Ket (369 m^3/ton), Mahasarakham (361 m^3/ton), Surin (356 m^3/ton), Nong Khai (350 m^3/ton), Yasothon (347 m^3/ton), Khon Kaen (346 m^3/ton), Sakon Nakhon (346 m^3/ton), Chaiyaphum (336 m^3/ton), Nong Bue Lum Phu (334 m^3/ton), Nakhon Phanom (334 m^3/ton), Loei (327 m^3/ton), Udon Thani (326 m^3/ton), Bung Kan (322 m^3/ton), Nakhon Ratchasima (320 m^3/ton), Kalasin (318 m^3/ton) and Burirum (313 m^3/ton) which is the lowest one.

As the result show blue WF higher than grey WF and green WF in all provinces. The highest blue WF was found in Ubon Ratchathani (235 m^3/ton), while the lowest one was 181 m^3/ton in Burirum. Grey WF, Surin is the province where the grey WF is the highest (104 m^3/ton), while Kalasin has the lowest grey WF (90 m^3/ton). Meanwhile, green WF which is the lowest WF of cassava cultivation was found Amnat Charoen has the highest green WF (44 m^3/ton) and lowest green WF was 37 m^3/ton in Kalasin. These results are consistent with Kongboon and Sampattagul (2012) which reported that the blue WF of cassava in Northern Thailand is higher than green are 232 and 129 m^3/ton, respectively.

Water Footprint of Sugarcane

As show in Table 2, sugarcane consists of green, blue and grey WF. The average total WF was 157 m^3/ton consist of green, blue and grey WF were 19 m^3/ton, 76 m^3/ton and 62 m^3/ton, respectively. At the provincial level, the WF increases in the following order: Amnat Charorn and Sakon Nakhon (167 m^3/ton), Yasothon and Udon Thani (165 m^3/ton), Mukdahan (164 m^3/ton), Nong Khai (163 m^3/ton), Nong Bue Lum Phu (161 m^3/ton), Loei, SriSa Ket and Mahasarakham (160 m^3/ton), Nakhon Phanom (159 m^3/ton), Roi Et (158 m^3/ton), Kalasin and Chaiyaphum (156 m^3/ton), Nakhon Ratchasima (155 m^3/ton), Burirum and Khon Kaen (149 m^3/ton), Surin (146 m^3/ton), Ubon Ratchathani (145 m^3/ton) and Bung Kan (133 m^3/ton).

Besides, the result show that blue WF of sugarcane cultivation was higher than gray WF and green WF in all provinces. The highest blue WF, grey WF and green WF were found in Amnat Charorn (84 m^3/ton), Loei and Udon Thani (66 m^3/ton) and Amnat Charorn, Yasothon, Loei and Sakon Nakhon (20 m^3/ton), respectively. Whiles, the lowest blue WF, grey WF and green WF was found in Bung kan with 64, 54 and 20 m^3/ton, respectively. During 2003-2012, northeast region was low the harvested yield and also the low rainfall amount makes the rainwater is not enough for water consumption. So, the irrigated water was the main water used for sugarcane cultivation and blue WF was higher than green WF and grey WF. But this study was not similarly with Kongboon and Sampattagul (2012) who study WF of sugarcane in northern, Thailand which reported that green WF of sugarcane was higher than blue WF and grey WF.

The WF of crops varies across of difference crop species, crop yields and region. The WF of cassava is larger than sugarcane by 2.2 times. So, in this region sugarcane is better than cassava which is can save more water use for sugarcane production. When compared the WF of cassava and sugarcane in northeast was lower than Thailand and global (Table 3). The green WF, which is the rainwater that evaporated during crop growth for Thailand is substantially lesser than the global average. However, in northeast region not only rainwater but also irrigated water is the main water used. This is mainly due to the differences in crop yield. The difference of topography, soil characteristic, yield, crop coefficient, cultivation period and area, evapotranspiration, and water balance are influential to the total WF (Sukumalchart et al., 2011).

Table 2 The water footprint of cassava and sugarcane in Northeast, Thailand

Province	WF of cassava (m^3/ton/year)				WF of sugarcane (m^3/ton/year)			
	green	blue	grey	total	green	blue	grey	total
Loei	39	192	95	327	20	74	66	160
Nong Bua Lum Phu	39	201	95	334	19	78	64	161
Udon Thani	38	195	93	326	19	80	66	165
Nong Khai	41	209	99	350	19	78	65	163
Bung Kan	38	191	93	322	16	64	54	133
Sakon Nakhon	42	201	102	346	20	80	67	167
Nakhon Phanom	40	192	101	334	19	75	66	159
Mukdahan	43	231	101	375	19	83	62	164
Yasothon	41	214	93	347	20	83	62	165
Amnat Charoen	44	233	101	378	20	84	63	167
Ubon Ratchathani	43	235	97	375	17	73	55	145
Sri Sa Ket	42	231	96	369	19	80	60	160
Surin	43	209	104	356	18	68	61	146
Burirum	38	181	94	313	18	68	63	149
Mahasarakham	42	219	100	361	19	79	63	160
Roi Et	43	227	99	370	19	79	60	158
Kalasin	37	192	90	318	18	76	61	156
Khon Kaen	40	209	97	346	17	72	59	149
Chaiyaphum	39	201	95	336	18	74	63	156
Nakhon Ratchasima	37	189	93	320	18	72	65	155
Average	40	208	97	345	19	76	62	157

Table 3 A comparisons WF of cassava and sugarcane between Northeast, Thailand and Global scale

Scale	Cassava WF (m^3/ton)				Sugarcane WF (m^3/ton)			
	Green	Blue	Grey	Total	Green	Blue	Grey	Total
Global*	550	0	13	564	139	57	13	210
Thailand*	192	232	85	509	90	87	25	202
Northeast	40	208	97	345	19	76	62	157

** Source: Mekonnen and Hoekstra, 2011*

CONCLUSION

The water footprint of cassava and sugarcane in Northeast, Thailand for 20 provinces during 2003-2012 based on the crop yield over the full life span were 345 m^3/ton and 157 m^3/ton, respectively consists of three components: for cassava cultivation; green WF 40 m^3/ton, blue WF 208 m^3/ton and grey WF 97 m^3/ton. While, sugarcane cultivation; green WF 19 m^3/ton, blue WF 76 m^3/ton and grey WF 62 m^3/ton. In this region, blue WF higher than grey and green in both crops due to northeast region is relatively arid and low rainfall amount which affected to low crop yield. The usage of water in both from irrigation and surface water is necessary. The results from this study can be applied to water resource management guidelines for cassava and sugarcane cultivation which related to increase the crop yield in Northeast region.

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REFERENCES

Allen, R.F., Pereira L.S. and Raca, D.S. 1998. Crop evapotranspiration for commuting crop requirements. United Nation Food and Agriculture organization, Irrigation and Drainage Paper's Rome Italy. 333.

Center for Agricultural Information, Office of Agricultural Economics, Ministry of Agriculture and Cooperatives. 2012. Agricultural statistics of Thailand 2012. Source: www.oae.go.th/download/download_journal/yearbook55.pdf

Chapagain, A.K., Hoekstra, A.Y., Savenije, H.H.G. and Gautam, R. 2006. The water footprint of cotton consumption: an assessment of the impact of worldwide consumption of cotton products on the water resources in the cotton producing countries. Ecological Economics, 60, 186-203.

Charoensuk, L., Kongboon, R. and Sampattakul, S. 2012. Analysis water footprint of Oil Palm for biodiesel in Thailand. Conference and Presentation of Innovative Engineering and Management Sustainable Industry, 1, 17-18. October 2012 At Exhibition Centre BITEC Bangna, Bangkok, 1-10.

FAO. 2009. CROPWAT 8.0 Model. Food and Agriculture Organization, Rome, Italy.

Hoekstra, A.Y., Chapagain, A.K., Aldaya, M.M. and Mekonnen, M.M. 2011. The water footprint assessment manual, Setting the global standard. Waterfootprint Network, The Netherlands.

Kongboon, R. and Sampattagul, S. 2012. The water footprint of sugarcane and cassava in northern Thailand. Procedia - Social and Behavioral Sciences, 40, 451-460.

Khongboon R. and Sampattagul, S. 2012. Water footprint of bioethanol production from sugarcane in Thailand. Journal of Environment and Earth Science, 2 (11), 61-68.

Mekonnen, M.M. and Hoektra, A.Y. 2011. The green, blue and grey water footprint of crop and derived crop product. Hydrology and Earth System Sciences, 15, 1577-1600.

Meteorological Department. 2009. Climate data 1980-2009.

Sukumalchart, T., Pornprommin, A. and Lipiwattanakarn, S. 2011. Monthly water footprint of maize in major cultivated areas of Thailand, Proceedings of the first EIT International Conference on Water Resources Engineering "Water Resources Management under Risk of Natural Hazard and Data Uncertainty", Phetchaburi, Thailand.