GBEP meeting, 25-29 May 2015

Implications of biofuels policy mandate in Thailand on water

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Biofuels Development Plan 2008 – 2022 in Thailand

Start E20

Start E85 + Flex-fuel vehicle (FFV)

Sell B3 nationwide and sell B5 as optional

	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22
Ethanol demand (M.litres/day)	1.24	1.34	2.11	3.0					6.2					**9.0**	9.0
Biodiesel demand (M.litres/day)	1.35	1.35	1.35	3.0					3.6					**5.97**	4.5

Alternative Energy Development Plan : AEDP (2012-2021)

25.0

Major feedstocks used for biofuels production

Bio-ethanol

Molasses

Cassava

Sugarcane

Biodiesel

Oil palm

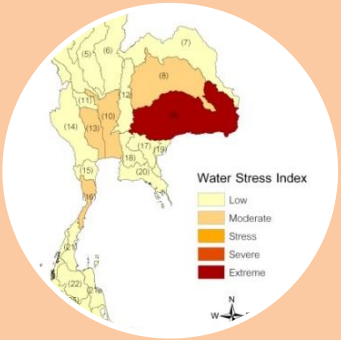
New alternative diesel

- ❑ Biodiesel from Jatropha, algae
- ❑ ED95, FAEE, Diesohol
- ❑ BHD, BTL

Water deprivation from feedstock expansion in Thailand

Water requirement for biofuel feedstock cultivation

- Crop water requirement (CWR)
- $ET_c = K_c \times ET_0$
- Effective rainfall



Potential impact on water use

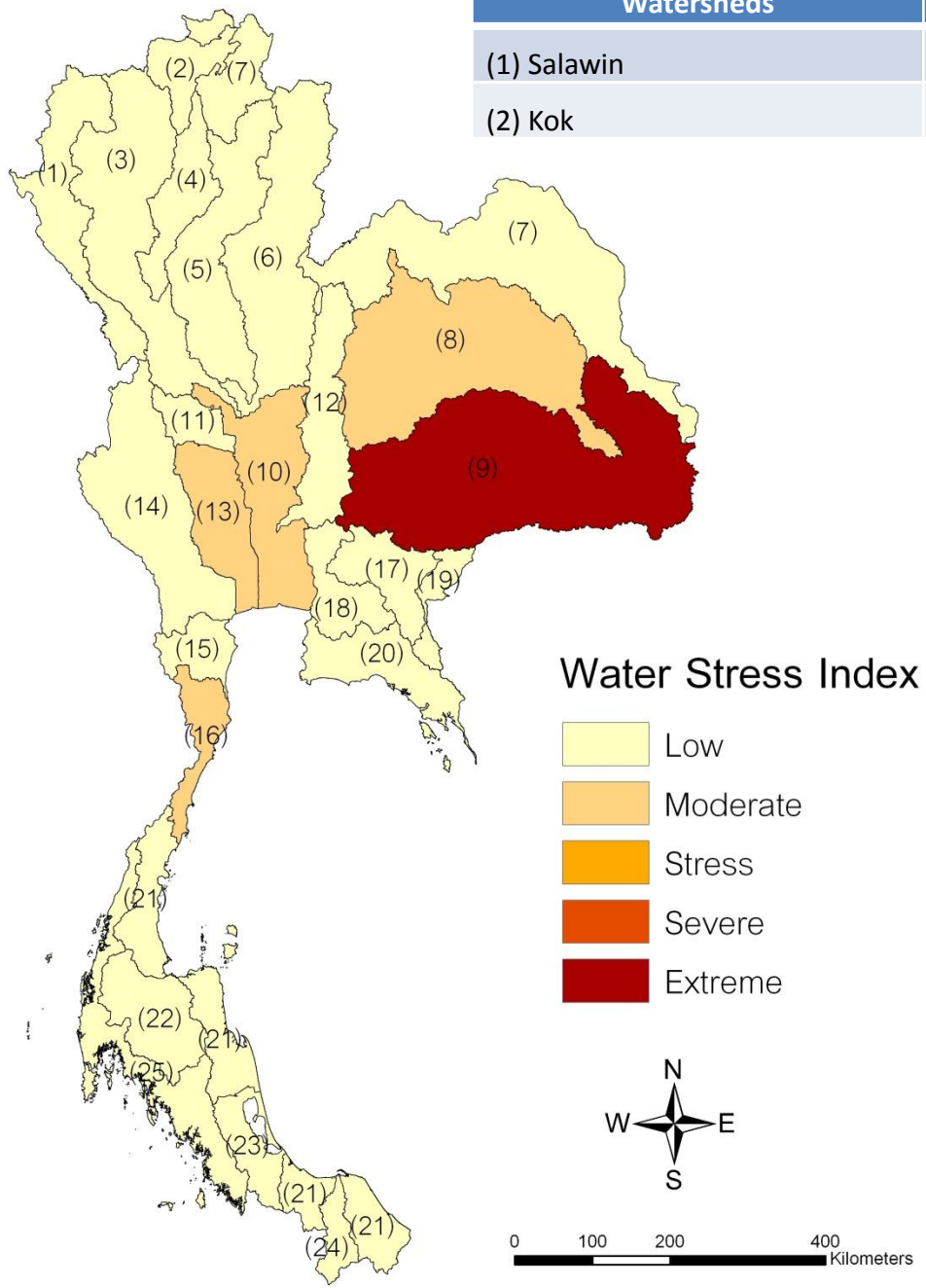
- Water stress index (WSI)

$$WSI = \frac{1}{1 + e^{(-6.4)(WTA^*)}\left(\frac{1}{0.01} - 1\right)}$$

- Water deprivation

Water deprivation ($m^3 H_2O_{eq}$ $unit^{-1}$) = Water deficit (m^3 $unit^{-1}$) × WSI

Allen, 1998; RID, 2011 Pfister et al., 2009; Ridoutt B. and Pfister S., 2010; Gheewala et al. (2013)



Watersheds	WSI
(1) Salawin	0.017
(2) Kok	0.018
(3) Ping	0.023
(4) Wang	0.021
(5) Yom	0.044
(6) Nan	0.015
(7) Khong	0.014
(8) Chi	0.471
(9) Mun	0.927
(10) Chao Phraya	0.339
(11) Sakae Krang	0.031
(12) Pasak	0.050
(13) Thachin	0.287
(14) Mae Klong	0.018
(15) Petchaburi	0.022
(16) West Coast Gulf	0.158
(17) Prachin Buri	0.016
(18) Bang Pakong	0.026
(19) Thole Sap	0.019
(20) East-Coast Gulf	0.015
(21) Peninsula-East coast	0.067
(22) Tapi	0.060
(23) Thale sap Songkhla	0.014
(24) Pattani	0.025
(25) Peninsula-West coast	0.012

Gheewala et al. (2014), Water 6(6): 1698-1718

WATER DEPRIVATION FROM FEEDSTOCK EXPANSION FOR BIOETHANOL

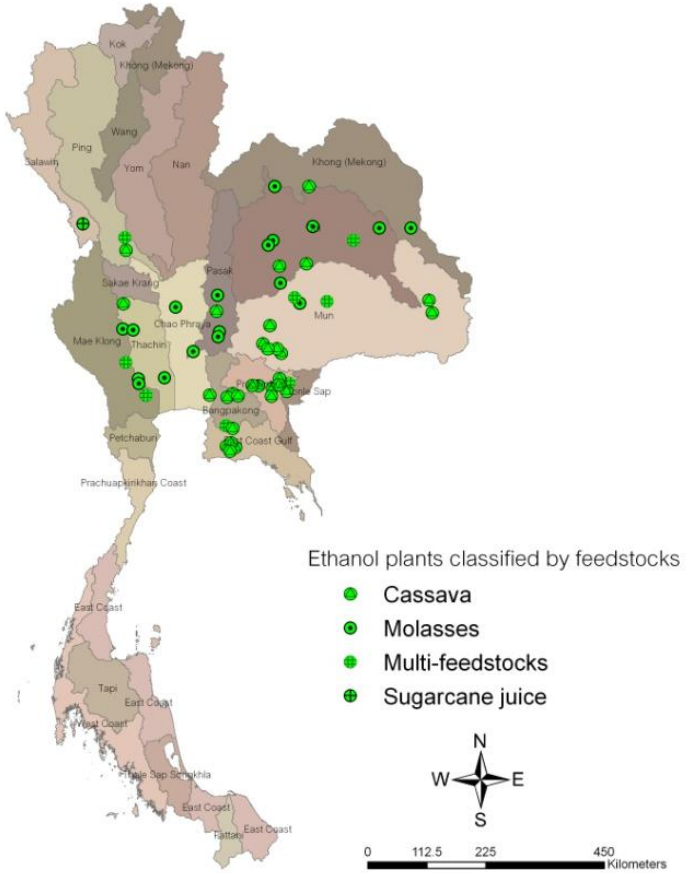
Water deprivation from feedstock expansion in Thailand: Bioethanol

Objective

- Apply the WF and WSI approaches to help policy makers to understand the impacts of bioethanol production on water use and stress;

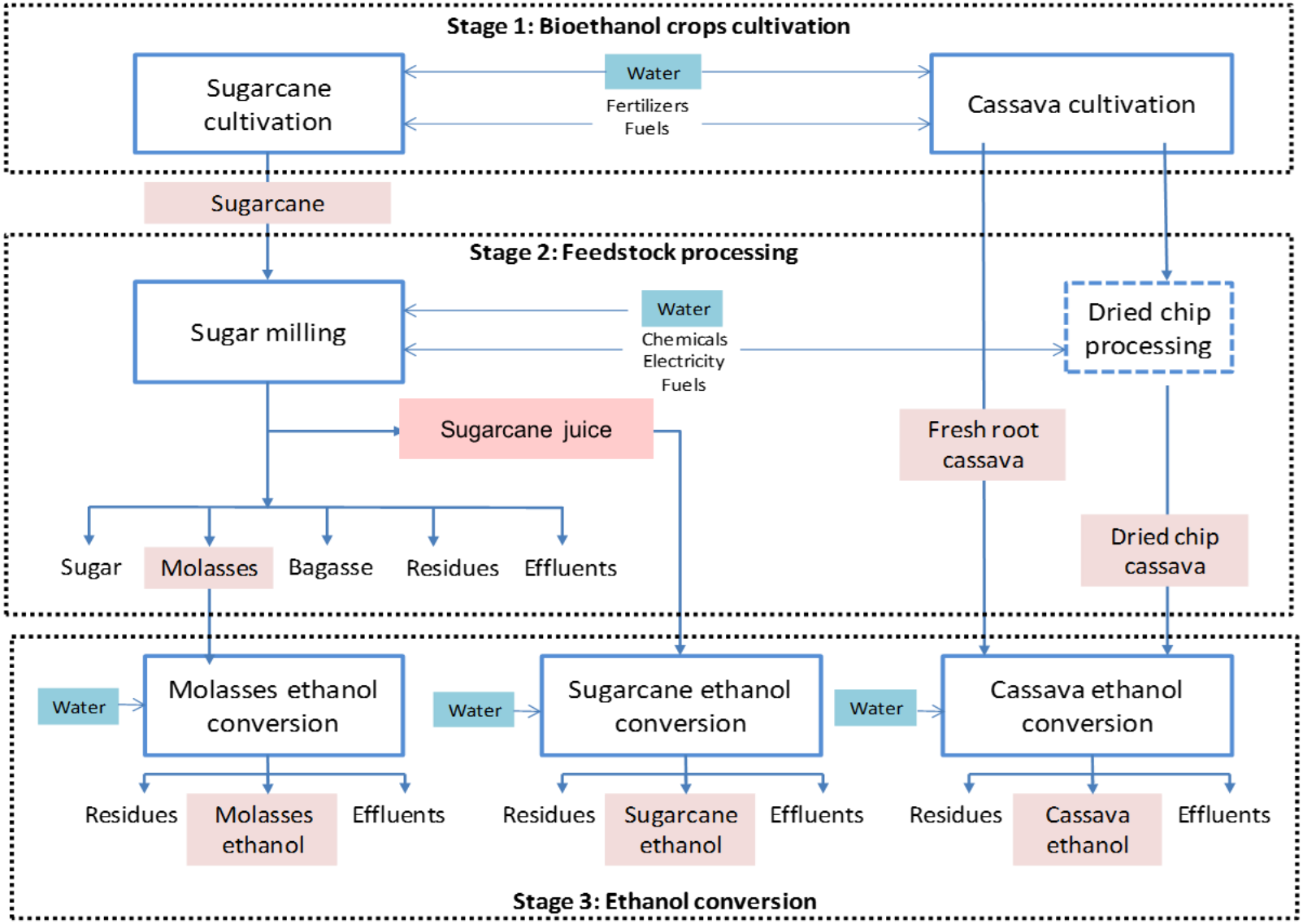
Scope of the assessment

- Feedstock: cassava, sugarcane and molasses.
- 48 registered bioethanol plants located nationwide area evaluated;
- Relevant to 26 provinces and 13 watersheds;
- Impact is evaluated by the characterization factor so called *"water deprivation potential"*



Gheewala et al. (2013), Bioresource Technology 150: 457–465

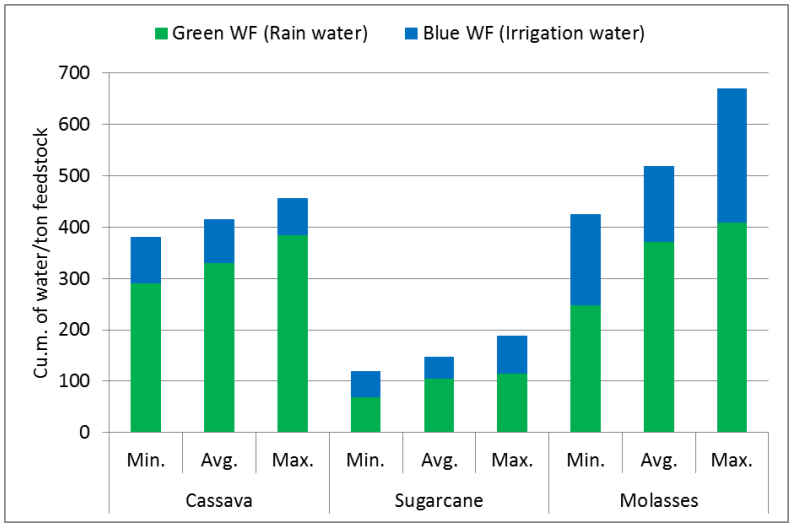
Bioethanol production systems in Thailand



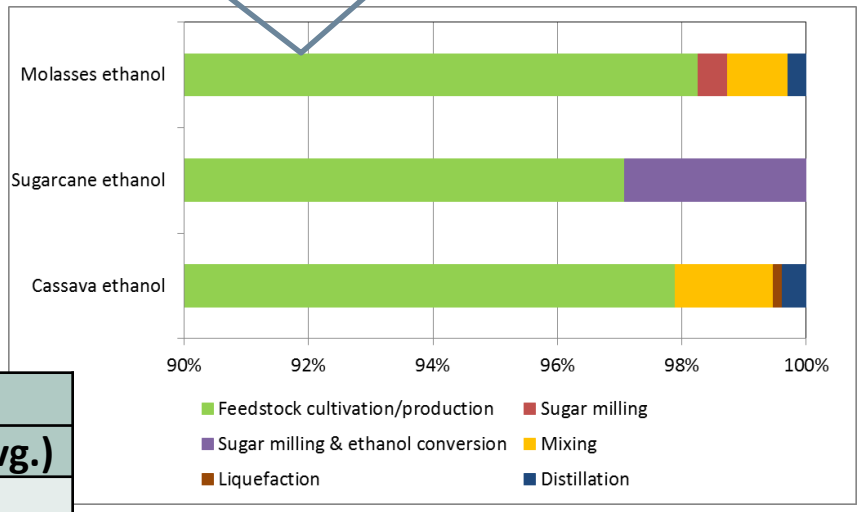
Gheewala et al. (2013), Bioresource Technology 150: 457–465

Water Footprint of Bioethanol production

Comparative WF of the bioethanol feedstocks



Feedstock cultivation contributes around 97-98% of total blue water footprint of bioethanol



Comparative WF of bioethanol

Bioethanol products	WF (L water/L bioethanol)	
	Total WF	Blue WF (Avg.)
Cassava ethanol	2,372 – 2,579	528
Sugarcane ethanol	1,396 – 2,196	490
Molasses ethanol	1,976 – 3,105	699

Gheewala et al. (2013), Bioresource Technology 150: 457–465

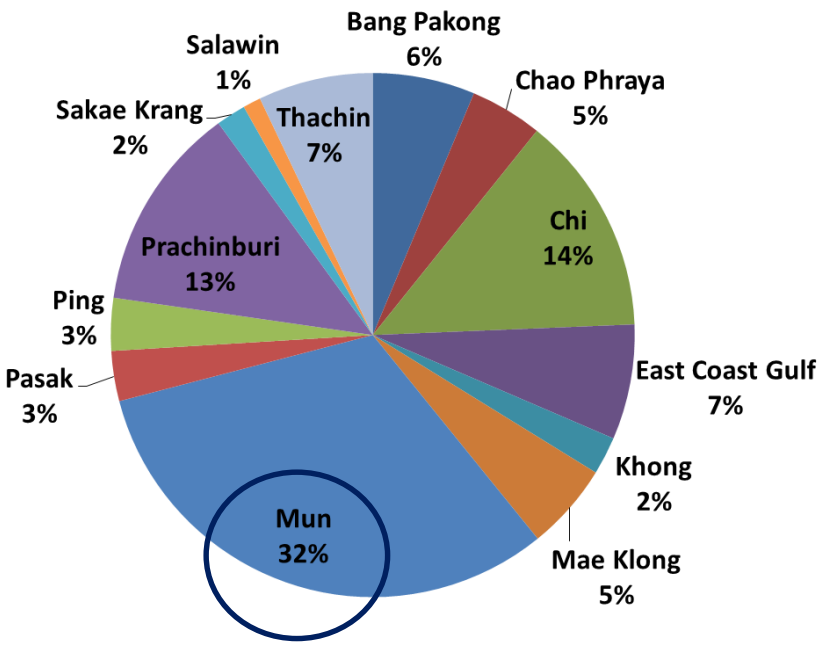
Implications of the bioethanol policy mandate on water use and stress

- Scenario 1: Policy mandate scenario
- Scenario 2: Full production capacity scenario

		Water requirements (Million m^3/year)					
		Dry season		Wet season		Total	
		Green water	Blue water	Green water	Blue water	Green water	Blue water
Scenario 1	Cassava ethanol plants	754	933	3,974	25	4,728	958
	Sugarcane ethanol plants	8	17	75	1	83	18
	Molasses ethanol plants	102	295	1,039	159	1,141	454
	Multi-feedstocks plants	74	146	534	49	608	195
	Total	**938**	**1,391**	**5,622**	**234**	**6,560**	**1,625**
Scenario 2	Cassava ethanol plants	1,047	1,296	5,520	34	6,567	1,331
	Sugarcane ethanol plants	11	23	104	2	115	25
	Molasses ethanol plants	141	410	1,444	220	1,585	630
	Multi-feedstocks plants	103	203	741	68	844	270
	Total	**1,303**	**1,932**	**7,809**	**324**	**9,112**	**2,256**

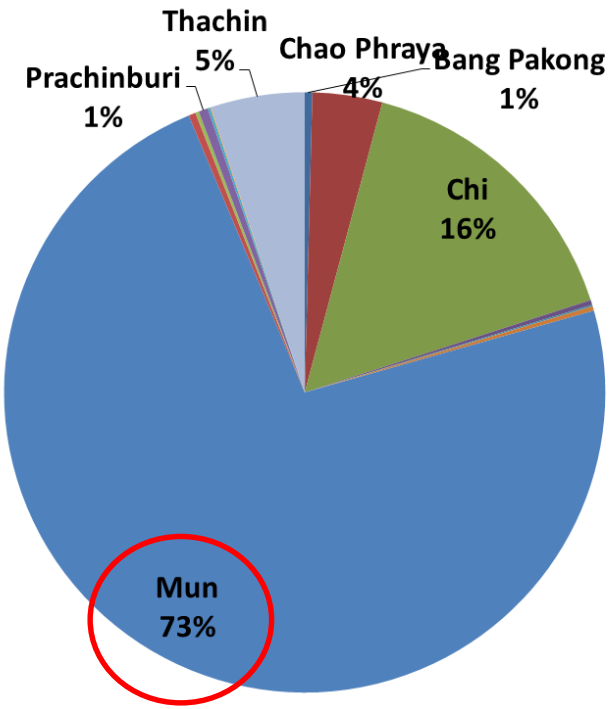
Gheewala et al. (2013), Bioresource Technology 150: 457–465

Implications of the bioethanol policy mandate on water use and stress



Share of blue water requirements for bioethanol production in 2021 classified by watersheds

Share of water deprivation potentials from bioethanol production in 2021 classified by watersheds



Gheewala et al. (2013), Bioresource Technology 150: 457–465

Recommendations to enhance water efficiency of bioethanol production in Thailand

- **Crop evapotranspiration (ET) reduction**
  - Development of crop varieties (drought-tolerant, high-yield, short growth period), improvement of agricultural practices using GAP in farming,
- **Promotion of sugarcane ethanol** (as nowadays there is only one ethanol plant using sugarcane juice in operation)
- **Enhancing water use efficiency in feedstock processing and ethanol conversion (water reuse and recycling program)**
  - New technologies development such as dry cleaning of sugar cane to eliminate sugarcane washing, treatment of vinasse by biodigestion technique to reduce the organic load and recirculating into the process
- **Promotion of bioethanol feedstock cultivation in the low water stress areas**

Gheewala et al. (2013), Bioresource Technology 150: 457–465

WATER DEPRIVATION FROM FEEDSTOCK EXPANSION FOR BIODIESEL

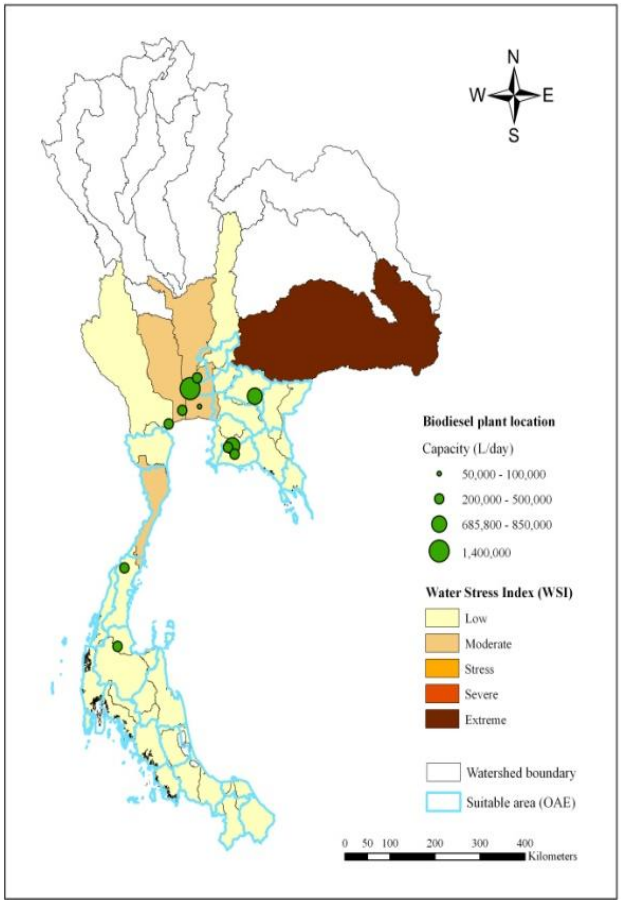
Water deprivation from feedstock expansion in Thailand: Biodiesel

Objective

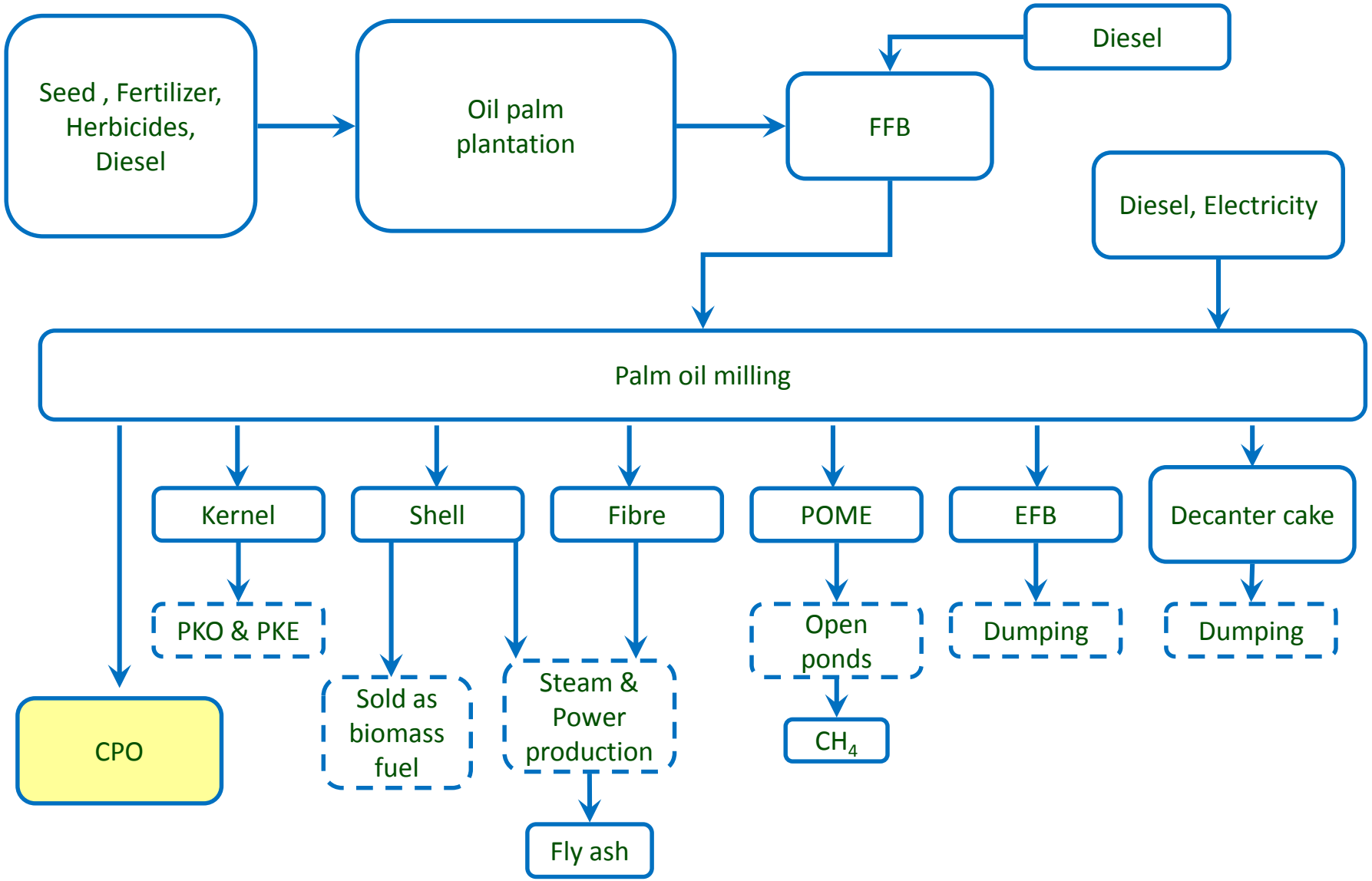
- Apply the WF and WSI approaches to help policy makers to understand the impacts of biodiesel production on water use and stress;

Scope of the assessment

- Feedstock: oil palm
- The suitable areas by the MOAC: 3 regions falling under 13 watersheds;
- Two boundaries: administrative and hydrological;
- Impact is evaluated by the characterization factor so called *"water deprivation potential"*



Biodiesel production systems in Thailand

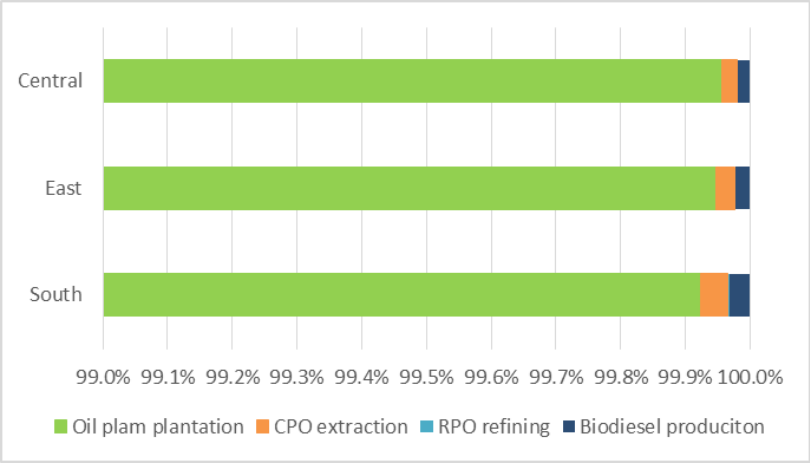


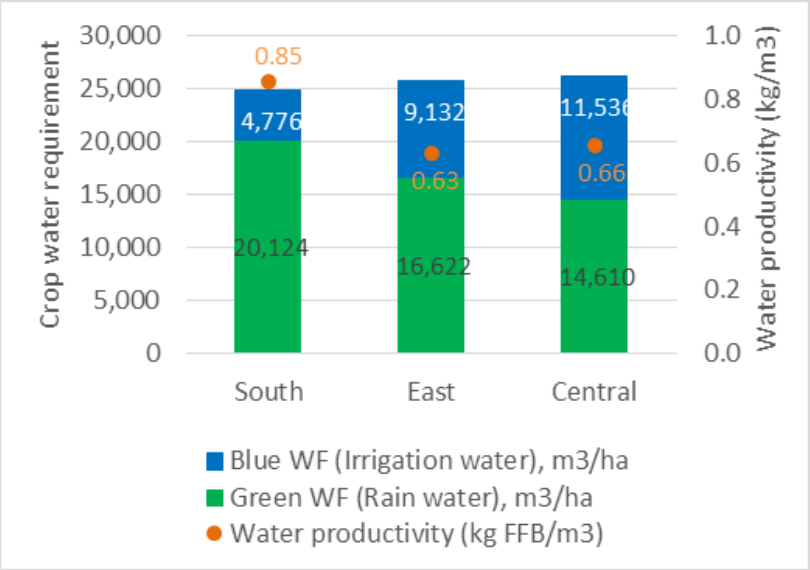
Silalertruksa T, Gheewala SH (2012), Energy 43(1): 306-314

Water Footprint of biodiesel production

Cultivation: approximately 13,000 m^3/ha/year (138 oil palm trees/ha)

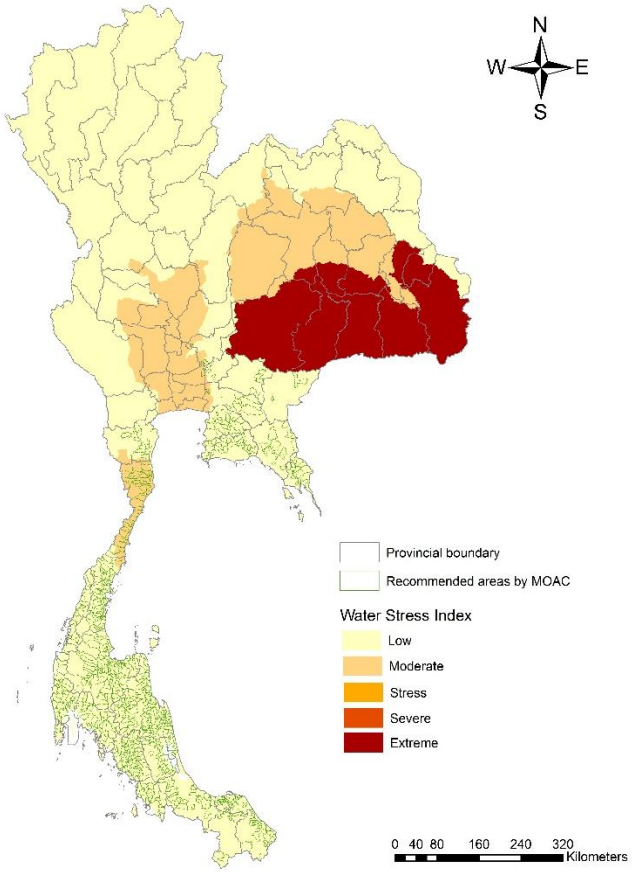
- Feedstock cultivation contributes more than 99% of total freshwater for producing biodiesel
- The highest water demand: Central region
- The lowest water productivity: Southern region
- Water use efficiency is significantly affected by crop productivity for oil palm aged between 5 to 10 years





Implications of the biodiesel policy mandate on water use and stress: oil palm expansion

- To mitigate the potential impact on freshwater resources, the suitable areas (by MOAC) located in Mun, Chao Phraya, West Coast Gulf are excluded.
- New oil palm plantation can either be expanded in a single region (Scenario 1) or spread over the three regions (Scenario 2).
  - Scenario 1: the expansion takes place in Eastern, Central, or Southern areas.
  - Scenario 2: the expansion is distributed proportionally, 79% in the South, 18% in the East and 3% in the Central region.



Implications of the biodiesel policy mandate on water use and stress: oil palm expansion

The total additional freshwater withdrawal of oil palm expansion in the Eastern and Central regions of Scenario 1 is higher than that of Scenario 2.

Scenario 1	Crop water requirement (million m³)					
	South (100% plantation)		East (100% plantation)		Central (100% plantation)	
Year	Rainwater	Blue water	Rainwater	Blue water	Rainwater	Blue water
2013	465.8	104.6	383.6	206.2	338.9	260.0
2014	684.2	153.6	563.6	303.0	497.8	382.0
2015	842.5	189.1	693.9	373.1	612.9	470.3
2016	959.6	215.4	790.4	424.9	698.1	535.7
2017	1,035.6	232.5	853.0	458.6	753.4	578.1
2018	1,122.8	264.2	927.0	507.6	815.4	641.0
2019	1,192.0	285.4	985.0	543.1	865.1	686.3
2020	1,252.8	303.2	1,035.8	573.5	908.9	725.1
2021	1,310.7	319.2	1,084.0	601.8	950.6	760.9
Total	8,866	2,067	7,316	3,992	6,441	5,039
	10,933		11,308		11,481	

Scenario 2	Crop water requirement (million m³)						
	South (79% plantation)		East (18% plantation)		Central (3% plantation)		**Total**
Year	Rainwater	Blue water	Rainwater	Blue water	Rainwater	Blue water	
2013	366.2	82.2	70.4	37.8	10.3	7.9	575
2014	537.9	120.8	103.4	55.6	15.1	11.6	844
2015	662.4	148.7	127.3	68.4	18.6	14.3	1,039
2016	754.4	169.4	145.0	78.0	21.2	16.3	1,184
2017	814.2	182.8	156.5	84.1	22.9	17.5	1,277
2018	882.7	207.7	170.1	93.1	24.8	19.5	1,397
2019	937.1	224.4	180.7	99.6	26.3	20.8	1,488
2020	985.0	238.4	190.0	105.2	27.6	22.0	1,567
2021	1,030.4	251.0	198.9	110.4	28.9	23.1	1,642
Rainwater	6,970		1,342		196		8,508
Water deficit		1,625		732		153	2,511
Total	11,019						

Implications of the biodiesel policy mandate on water use and stress: oil palm expansion

Year	Scenario 1 Water deprivation (million $m^3H_2O_{eq}$)		
	South (100%)	East (100%)	Central (100%)
2013	4.5	3.9	5.6
2014	6.6	5.8	8.2
2015	8.1	7.1	10.1
2016	9.3	8.1	11.5
2017	10.0	8.7	12.4
2018	11.4	9.6	13.8
2019	12.3	10.3	14.8
2020	13.0	10.9	15.6
2021	13.7	11.4	16.4
Total	88.9	75.8	108.4

Year	Scenario 2 Water deprivation (million $m^3H_2O_{eq}$)			
	South (79%)	East (18%)	Central (3%)	Total
2013	3.5	0.7	0.2	4.4
2014	5.2	1.1	0.2	6.5
2015	6.4	1.3	0.3	8.0
2016	7.3	1.5	0.3	9.1
2017	7.9	1.6	0.4	9.8
2018	8.9	1.8	0.4	11.1
2019	9.6	1.9	0.4	12.0
2020	10.2	2.0	0.5	12.7
2021	10.8	2.1	0.5	13.4
			Total	87.1

Cases	Proportional areas			Water deficit (million m^3)	Water deprivation (million $m^3H_2O_{eq}$ ha^{-1})
	South	East	Central		
1	18%	79%	3%	3,679	79.2
2	8%	90%	2%	3,859	77.5
3	4%	95%	1%	3,925	76.7
4	0.5%	99%	0.5%	3,987	76.1
5	0.09%	99.9%	0.01%	3,990	76.0

Recommendations to enhance water efficiency of biodiesel production in Thailand

- The efficiency of water used in plantation depends on how well farmers meet the GAP standard to retain the peak crop productivity during that age.
- Development of oil palm varieties, with high oil yields, tolerance of drought , can help to reduce water used by the crop.

- The areas for oil palm cultivation are recommended based on low potential of water stress and small amount of additional freshwater withdrawal.
  - Central region potentially faces more water stress than cultivating oil palm in other regions.
  - The most advantageous option is expansion in the Eastern region (East Coast Gulf and Trat province).

Summary of results – biofuels

- Feedstock cultivation is the most water intensive process for producing biofuels.
- Agricultural practices and development of crop varieties significantly influence to reduce water used in the cultivation process.
- Water deprivation can help to indicate areas having potential for inducing water stress in watershed leading to people in these areas being less vulnerable to water stress.
- Additional freshwater withdrawal will lead to higher water deprivation especially in watersheds having extreme and moderate water stress.

THANK YOU

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