Indonesian Water Balance and Waterfootprint

YAB Labmath

LabMath-Indonesia, Bandung

19 May 2009, APN-Symposium Effects of CC on CoastalZoneManagement

Focus

Effects of Climate Change may have large impacts.

Modelling and simulation tools can help to mitigate

- **predict expected effects of CC,**
- **predict effects of proposed actions (management, policy)**

For Environmental water (agriculture)

Effects of CC and human activities

- **urbanization,**
- **deforestation,**
- **change of crop-growth**

have large influence on (ground) water.

- CLIMATE CHANGE
- **INDONESIAN WATER BALANCE**
- INDONESIAN WATER FOOTPRINT
  - Detailed Model
  - Tables

Indonesian Water Balance

Global Water Balance

Precipitation = Evapotranspiration
+ overland run-off
+ river discharge
+ ground water

Depend on:
- climate/weather
- land-use , crop
- human / industrial use

Aim:
DATA-ASSIMILATED HYDROLOGICAL MODEL (Spatial and Temporal)

For management/policy:
What is Effect of Changes (agricultural use, Climate Change)

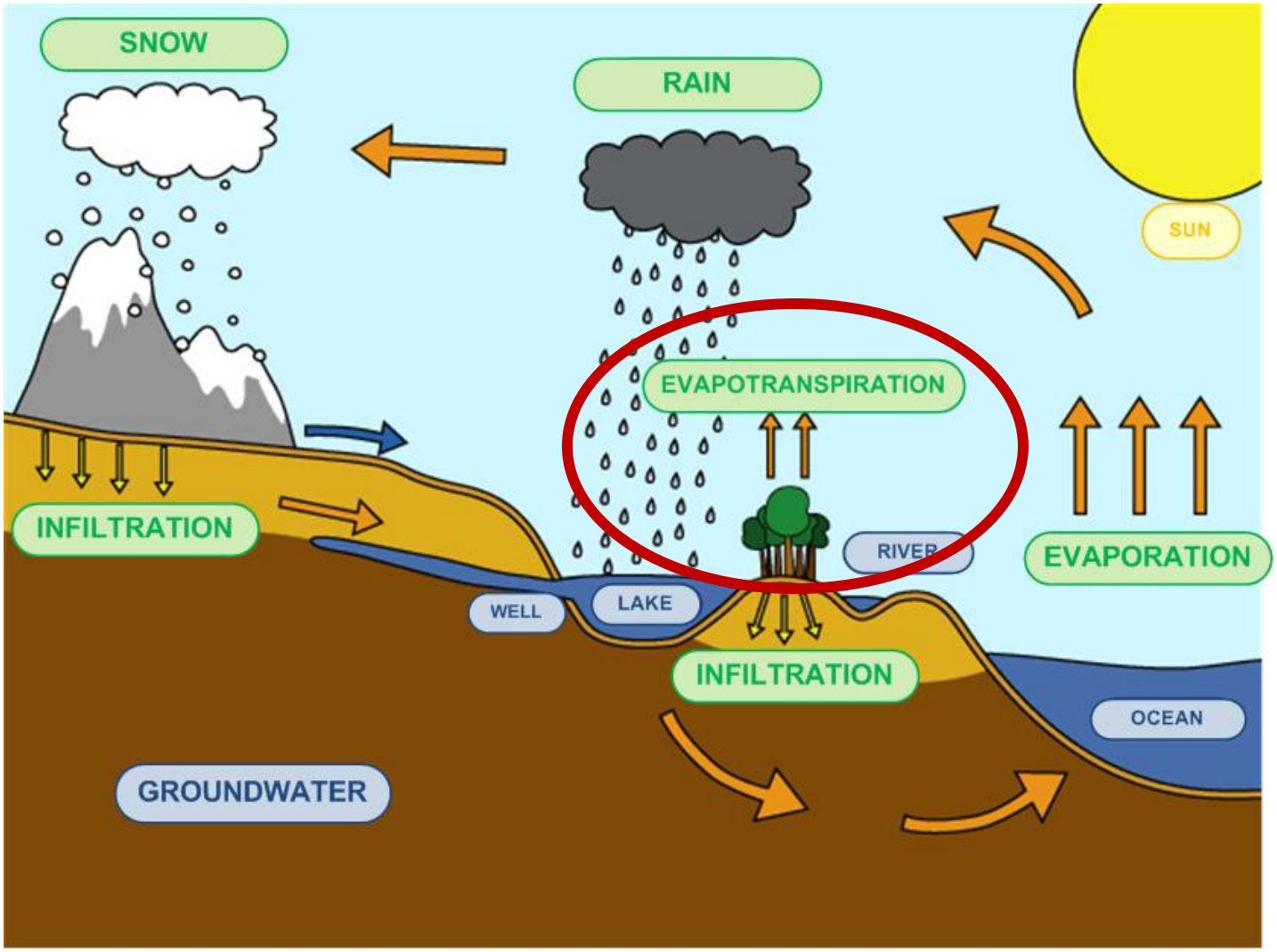
Effects of Climate Change on Environmental Water

Temp increase
Stronger winds
→ **ET** ↑

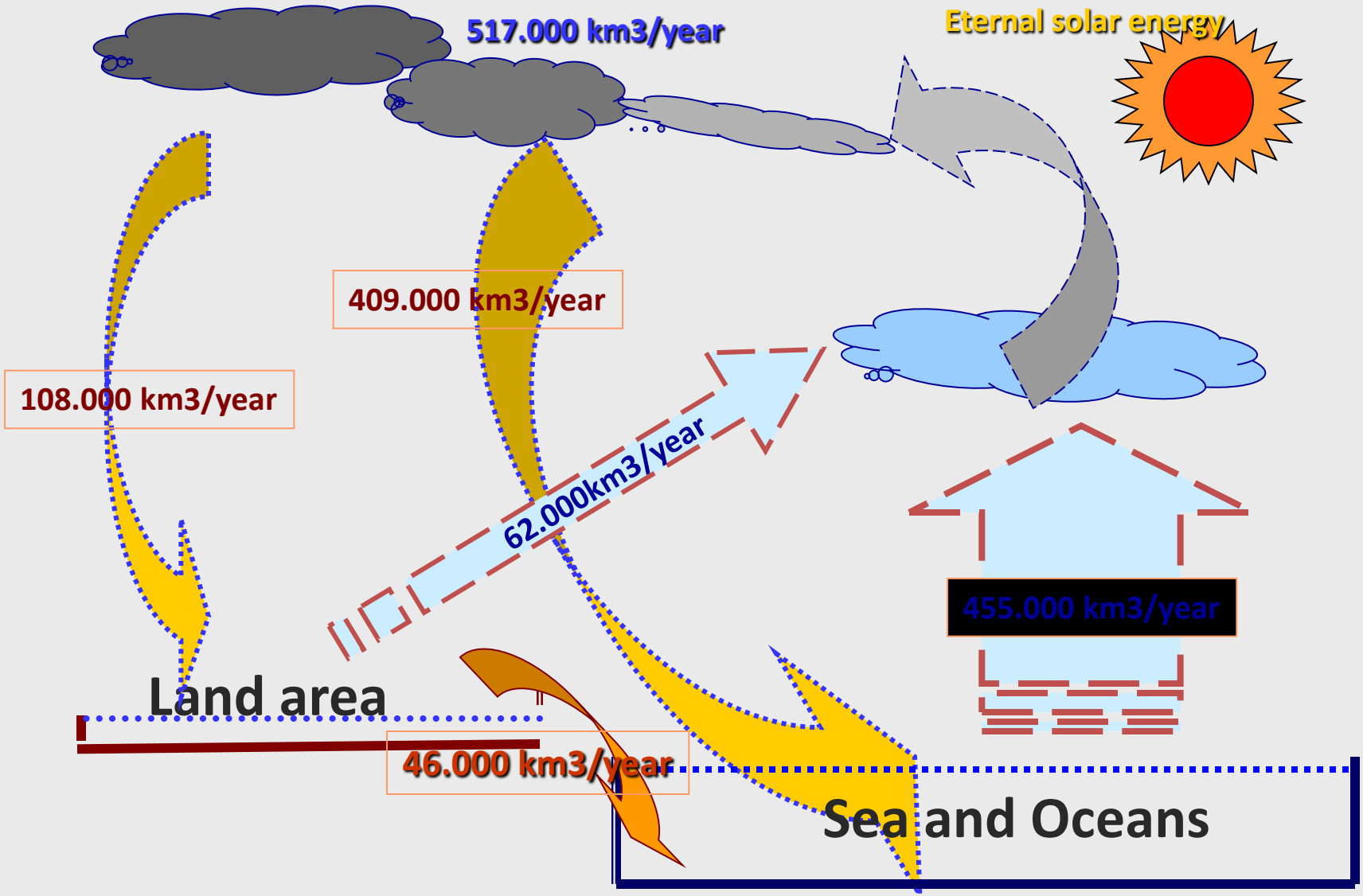
Intensified rain → **Run-off** ↑

→ **Ground water** ↓
Flooding ↑

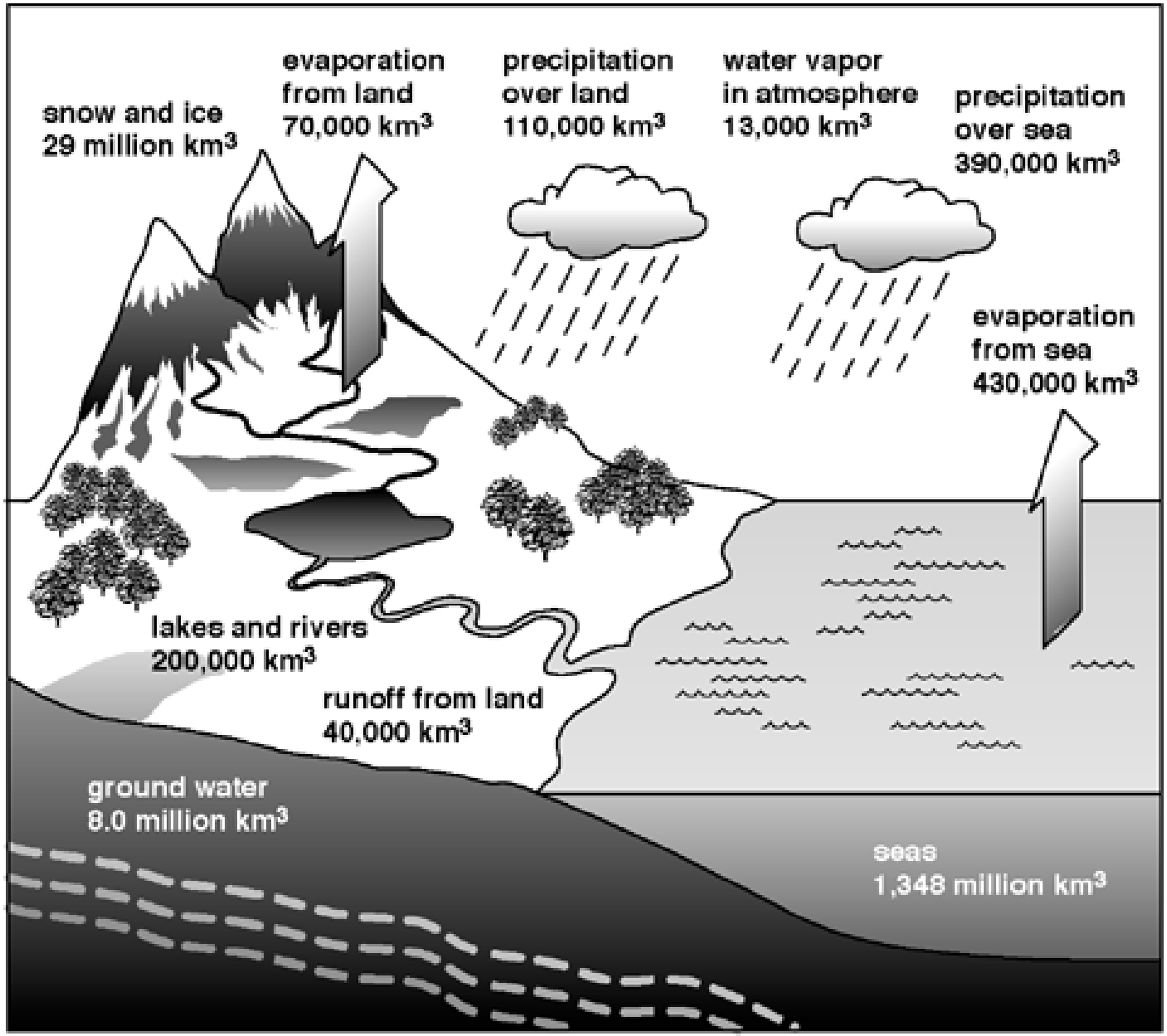
Water balance



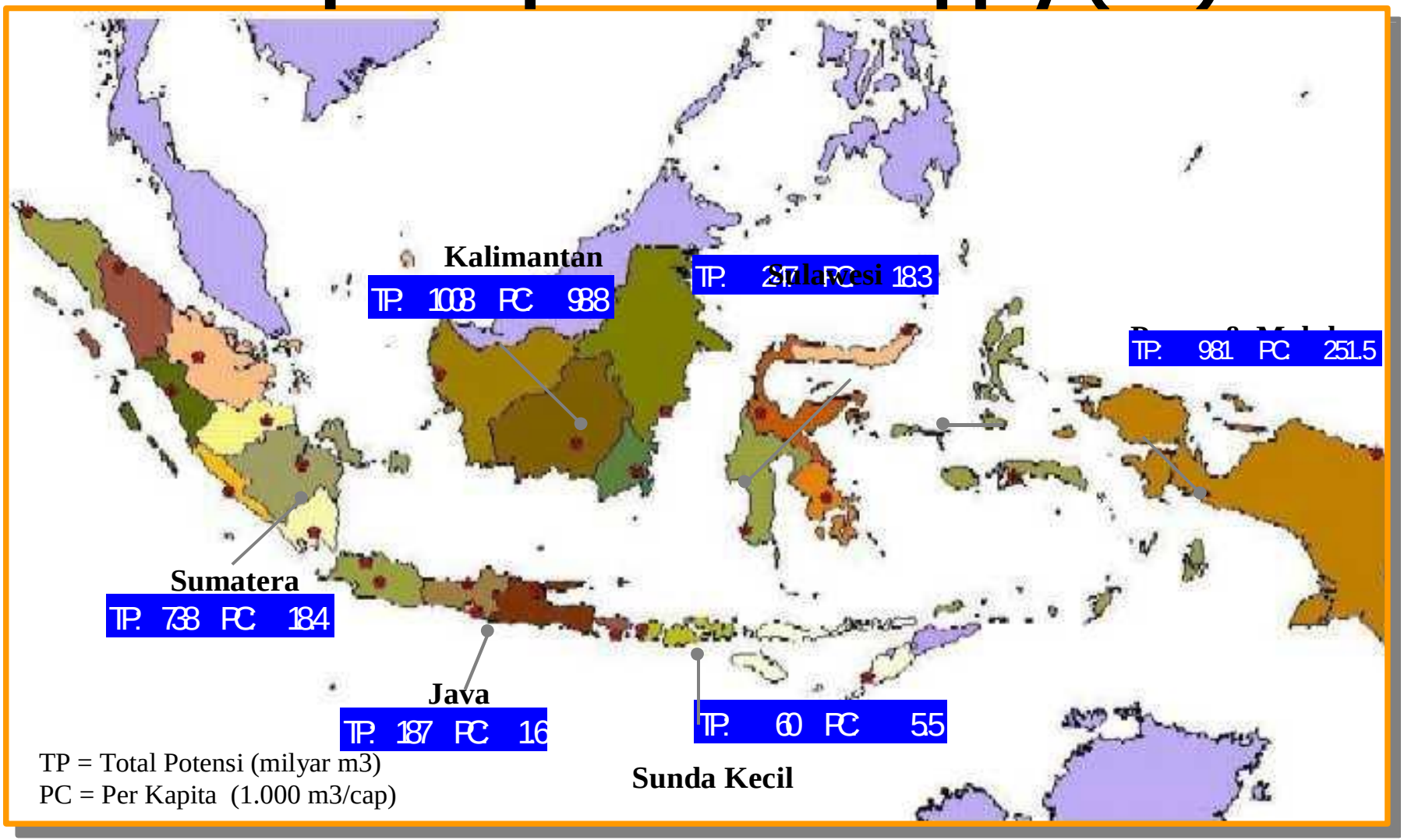
THE HYDROLOGICAL CYCLE



Data-based hydrological models

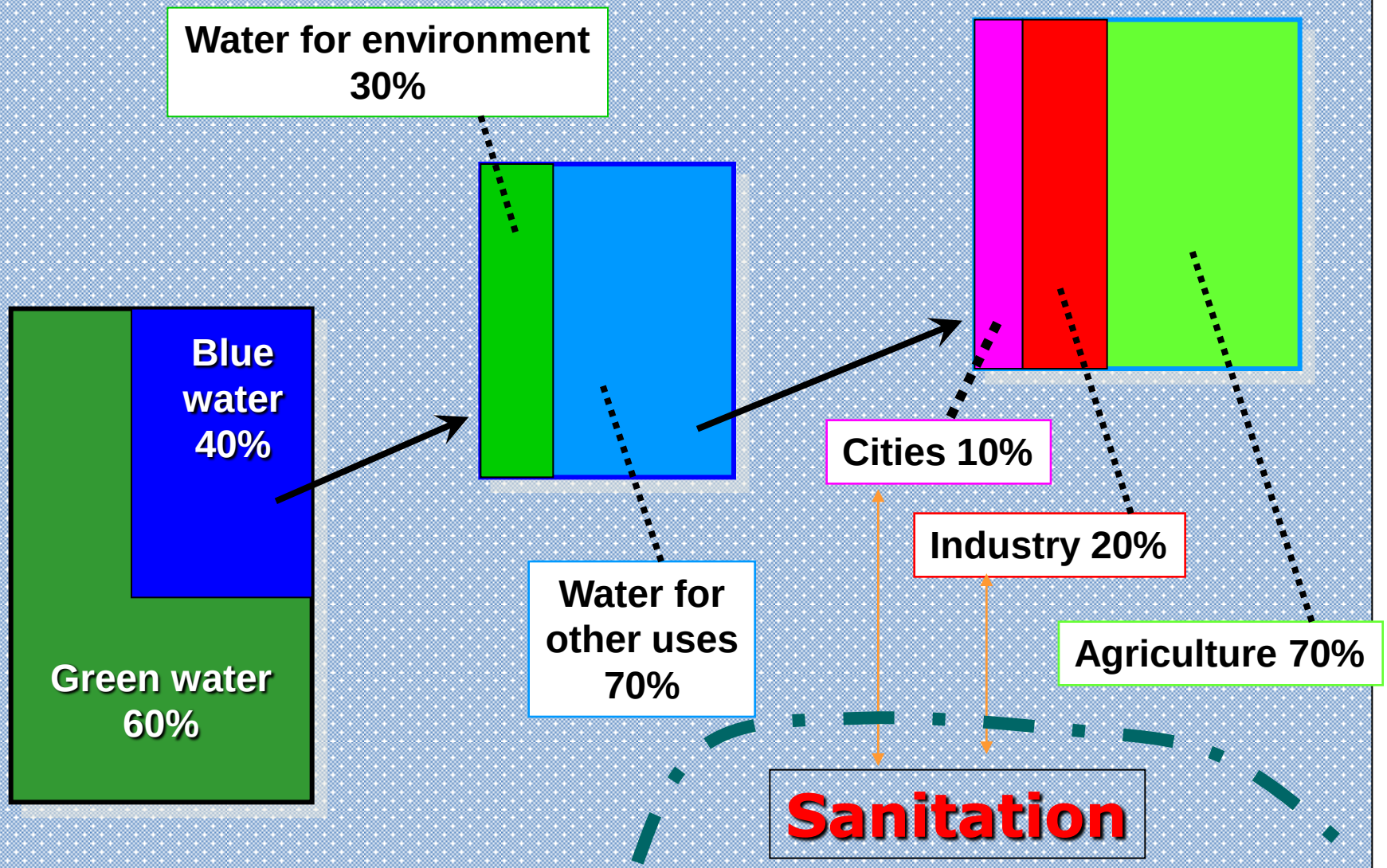


Potential water availability (TP) and per-capita water supply (PC)



Peter E. Hehanussa

Water use[s] by the ecosystem



"Agriculture beyond Food"

Application for research cluster:

Modelling Indonesian Water Flow

PI's: **H. Partiwan (IPB) & M. Booij (UT)**

Projects:

1. Modelling the total water balance in Indonesia
   (H. Partiwan& M. Booij)
2. Modelling and measuring the evapotranspiration
   (Satyanto Krido Saptomo & B. van Groesen)
3. Remote sensing techniques to support quantitative water cycle monitoring for agricultural water management
   (M. Ardiansyah & C. Mannaerts)

Stake holders: **KLH – RISTEK – Deptan - BMKG**

Relevance to understand Environmental water

Indonesian Peatland (60% of world):

Quote from PanEco &YEL

" Palm oil expansion is a social & ecological disaster "

WISE USE of Tropical Peatland:

" The MRP and its associated fires are the largest landscape disaster in recent times anywhere in the world."

Ground water

Effects of CC and human activities (urbanization, deforestation, change of crop-growth) have large influence on (ground) water.

Math/physical modelling will give insight in effects, and tools for management/policy.
(Remember Jamaluddin Jompa: " we need scientific 'proof' to convince people/governments")

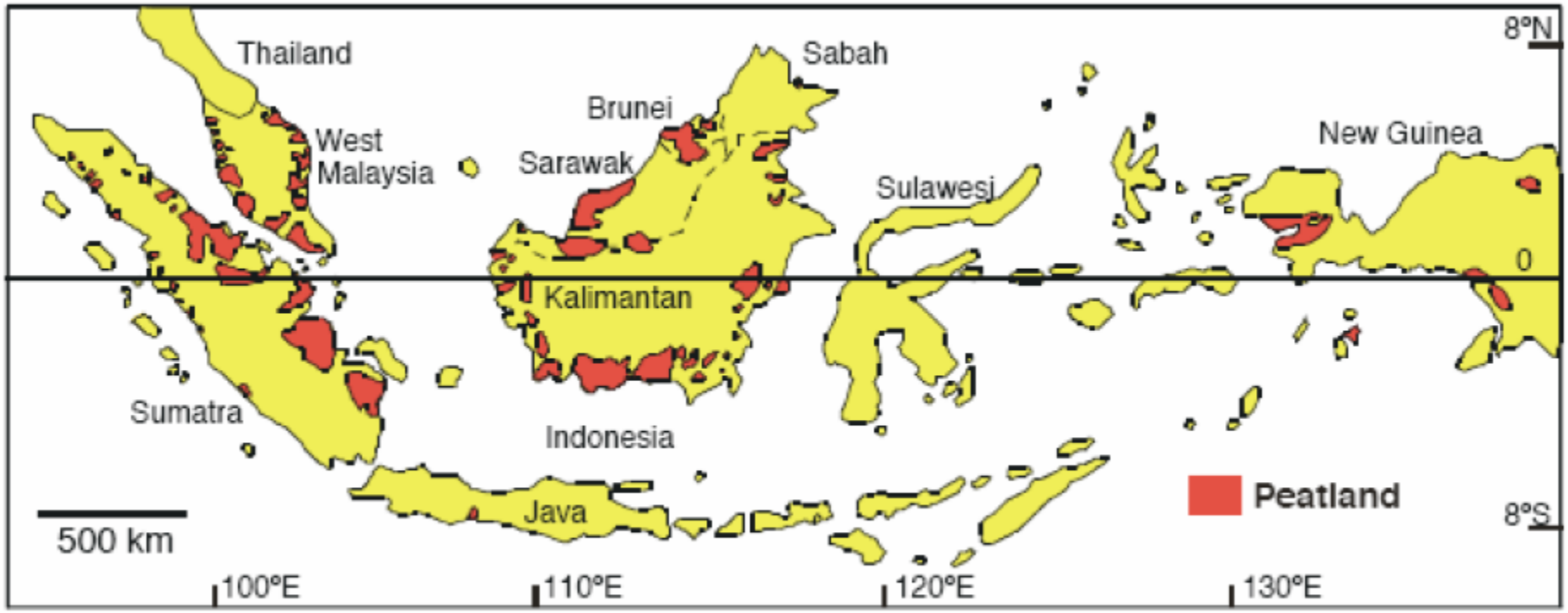


Figure 2.2: Geographical distribution of peatland in Malaysia and Indonesia

- CLIMATE CHANGE
- INDONESIAN WATER BALANCE
- **INDONESIAN WATER FOOTPRINT**
  - Detailed Model
  - Tables

INDONESIAN WATER FOOTPRINT of agricultural products, LMI'08

Study executed at LabMath-Indonesia

- Gullit Widarta, LabMath-Indonesia
- Rik Bulsink, UTwente
- Mees Beeker, UTwente

Co-supervision

- Prof. Arjen Hoekstra, UTwente
- Dr. Martijn Booij, UTwente

Reports:

- F. Bulsink: The water footprint of Indonesian provinces, July 2008
- P.M. Beeker: External water footprint of Indonesian provinces, July 2008

Acknowledgement

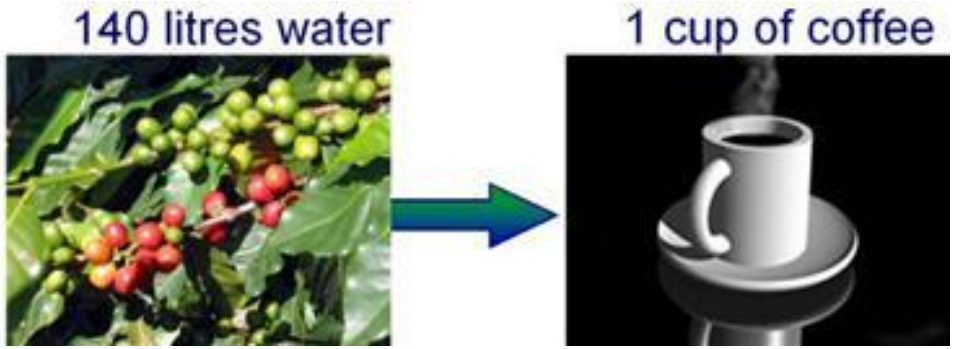
- Prof. Peter Hehanussa (LIPI)
- Prof. Bustana Arifin

INDONESIAN WATER FOOTPRINT of agricultural products

www.waterfootprint.org

Main References

- [A] :
  - J.A. Allen, 1998, Virtual Water: A strategic resource, global solutions to regional deficits, *Groundwater* 36(4): 545-546.
- [H-C] :
  - A.Y. Hoekstra & A.K. Chapagain, 2008, *Globalization of Water*, Blackwell.
  - A.K. Chapagain & A.Y. Hoekstra, 2004, *Water footprints of nations*, Value of Water Research Report Series no. 13, UNESCO-IHE, Delft.



??? Litres of water → 1 kg of RICE

Indonesian Water Footprint: Concepts

Virtual Water Content [A]

The volume of water that is actually used to *produce* a commodity.

Water Footprint [H-C]

Virtual Water *consumed* by the inhabitants of a region.

Water types

Green: *rainwater* available for crop growth.

Blue : *groundwater and surface water* through irrigation

Gray : water needed to dilute toxic remainders from fertilizer (nitrate)

[H-C]

Country	Water Footprint (m^3/y/ capita)	% External component
China	700	7%
Japan	1150	65%
Indonesia	1317	10%
USA	2500	19%

Indonesian Water Footprint: Model

Water Footprint

Follows from *VWC* and consumption & in-export data.

Virtual Water Content

Water use for Crop growth: $VWC = {}^{CropWaterUse}/_{Yield}$ [m3 /kg]

Crop Water Use:

- for Evapotranspiration (*ET*) = *E*vaporation + *T*ranspiration

  water vapour from ground surface — water vapour from crop

- for dilution of toxic remainders from fertilizer ('*gray*').

Model (simplified) [A]

$$CWU \approx \underbrace{K \times ET_0}_{} + \underbrace{\text{'gray'}}_{}$$

Aver: 80 % + 15 % + 5 %

- ET_0 = *CWU* for 'normalised' crop (physical model, only dependent on meteorological data)
- *K* : factor dependent on CROP

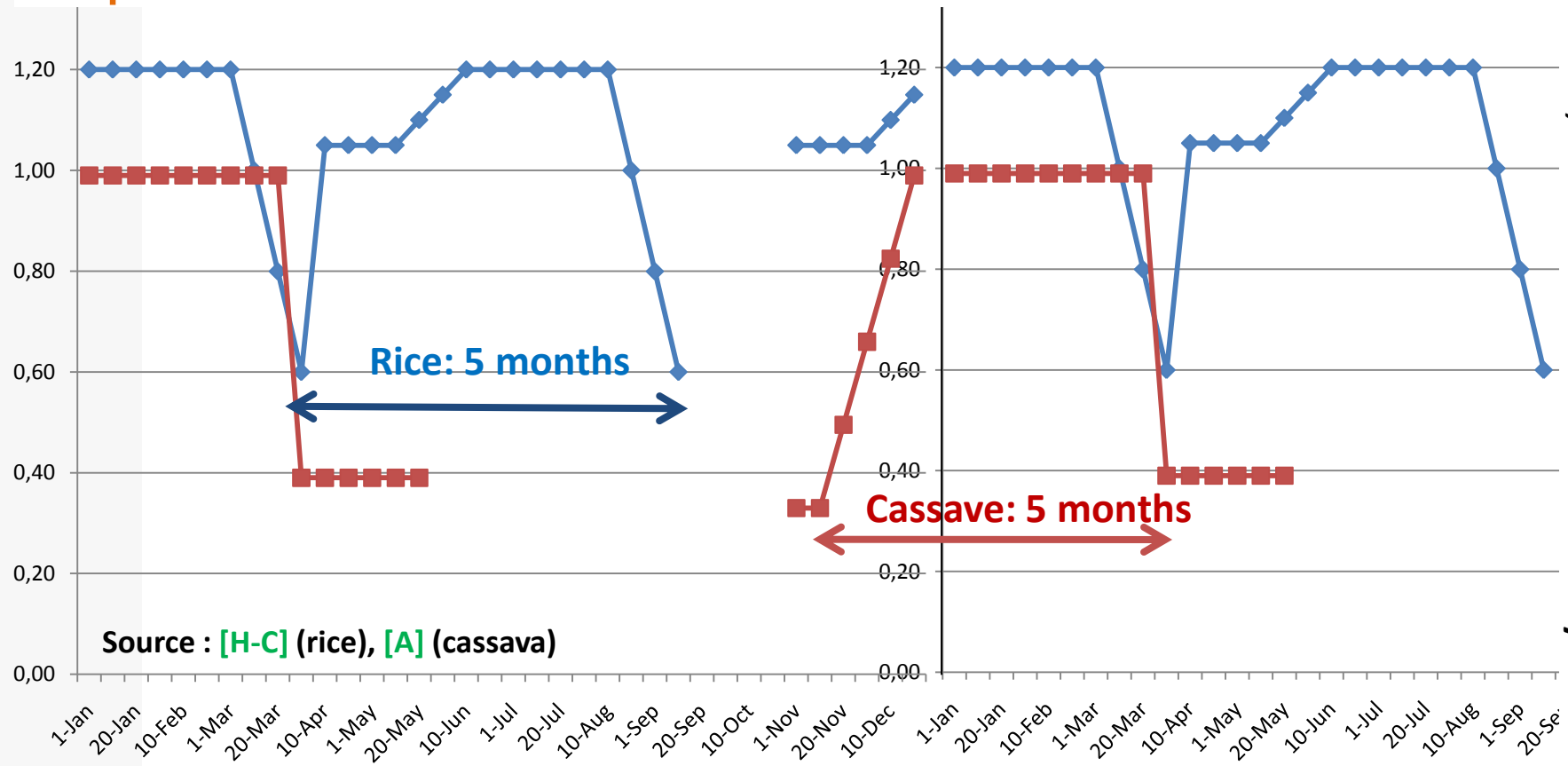
Indonesian Water Footprint: Model

Model

$$CWU \approx K \times ET_0 + \text{'gray'}$$

- ET_0 = *CWU* for 'normalised' crop (physical model, only dependent on meteorological data)
- K : factor dependent on CROP

Crop coefficients *K* for Jawa



NOTE: LMI'08 uses growth period and K_c-values that are specific for Indonesia, different than those in the study of H-C.

INDONESIAN WATER FOOTPRINT of agricultural products, LMI'08

Justification - specification

- DATA:
  - Meteorological: FAO & BMG
  - Crop parameters: FAO, [A], [H-C], yield data: DepTan; in this study specific for Indonesia
  - International transport of crops: BPS; NO data for inter-province tranport (modelled by production/consumption)
- PERIOD: 2001 – 2004
- Selection of CROPS [ONLY *agricultural* products in WFp]
  - Restricted to 10 crops: Rice, maize, cassava, soybeans, fruit, groundnut, coconut, oil palm, bananas, coffee, cocoa beans
  - Selection motivated by major coverage:
    - 77% of the total production,
    - 86% of total water use and of total agricultural land use
- Model for human consumption FAO

INDONESIAN WATER FOOTPRINT of agricultural products, LMI'08

Study executed at LabMath-Indonesia

WARNING

The presented results are 'as good as possible'.

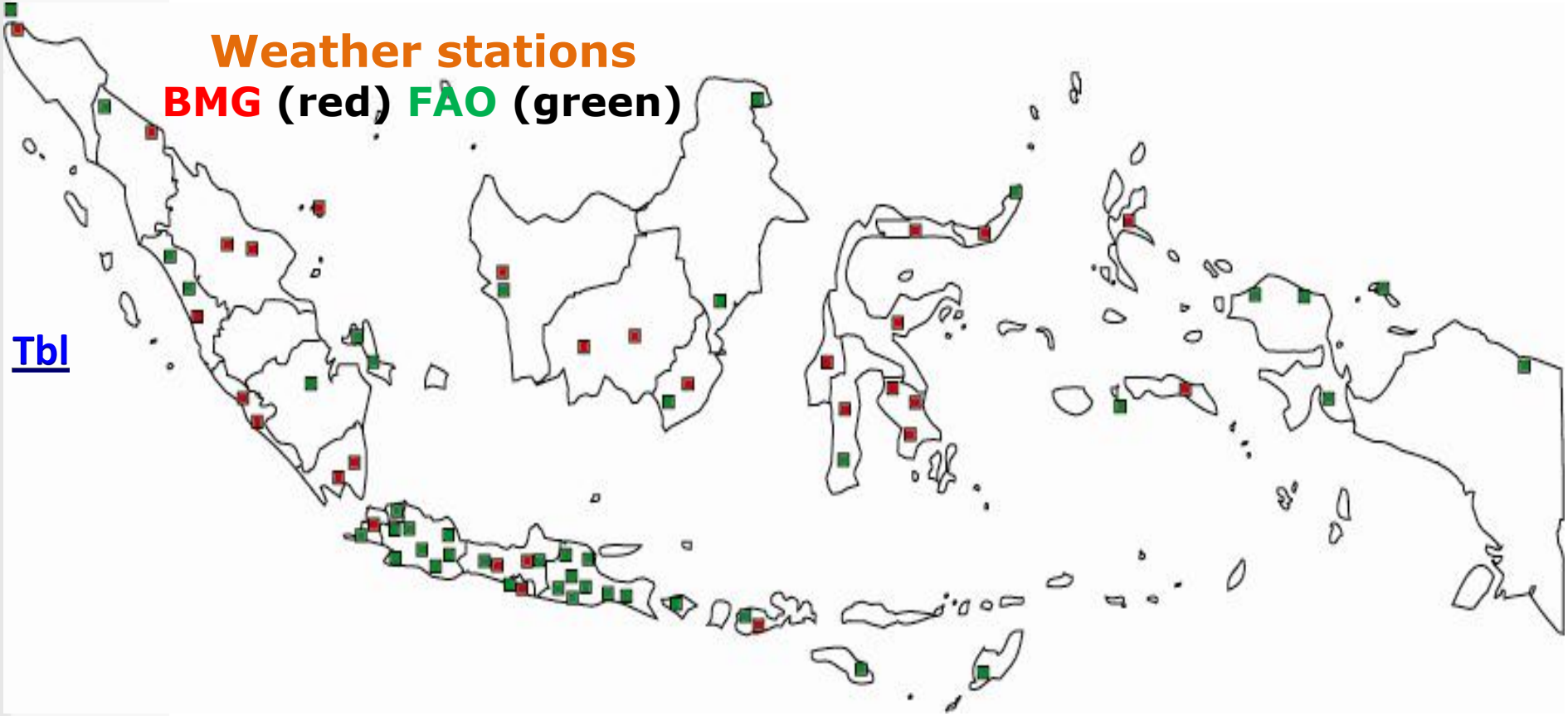
Main reason for insecurities and deviations:

- Global: Poor quality of weather data (measurements); modelling of areal rain from isolated measurement points
- Local: Data about inter-island trade of products (and hence virtual water) are unkown; hence external component rather insecure.

Yet,

- The main (global, averaged) results obtained agree quite well with the literature, despite differences in some modelling parameters.

INDONESIAN WATER FOOTPRINT



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INDONESIAN WATER FOOTPRINT

Calculated Evapotranspiration

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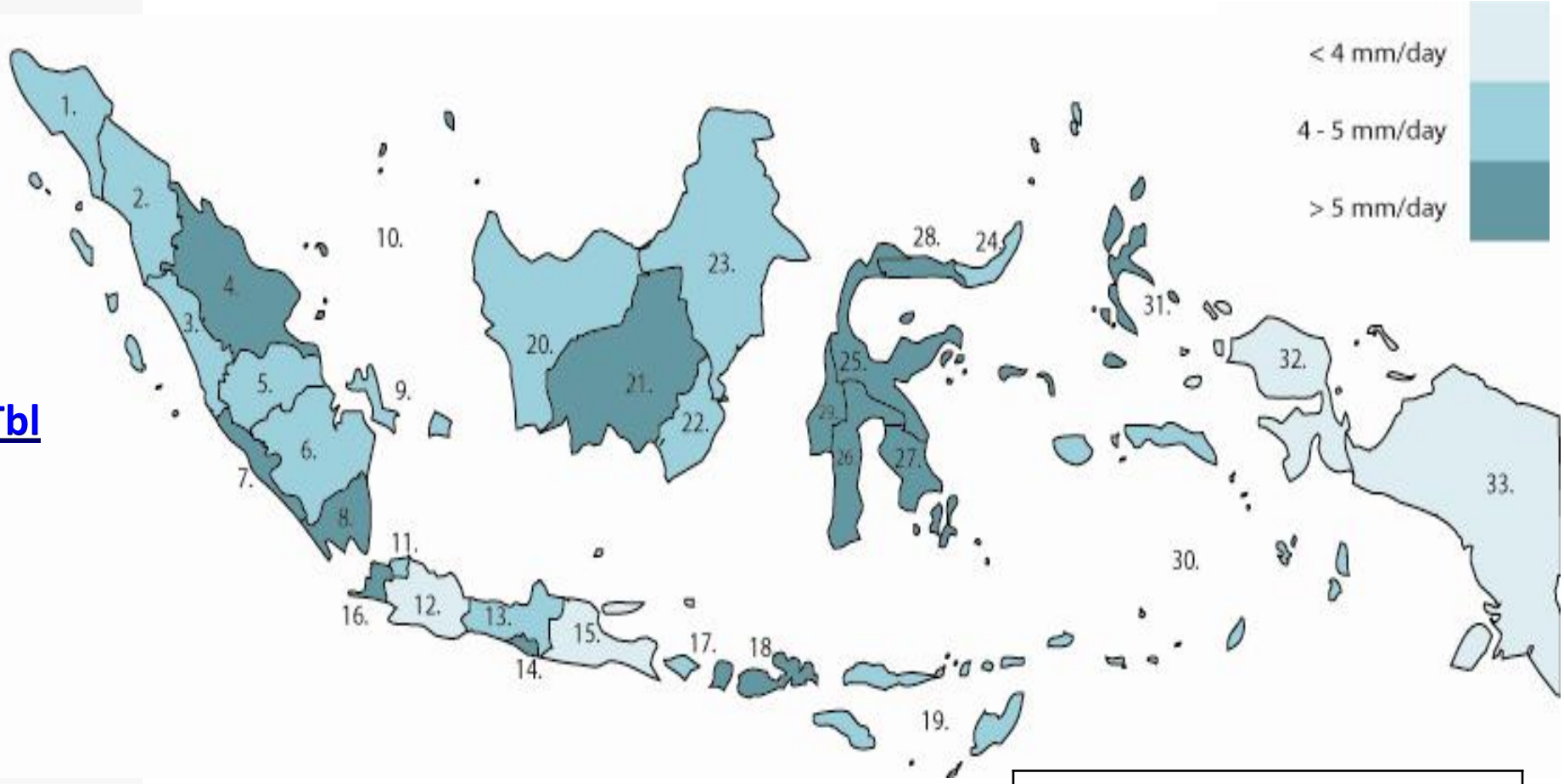
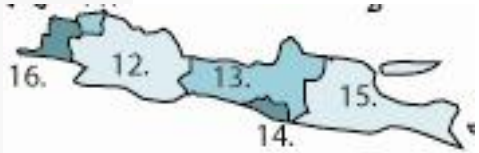
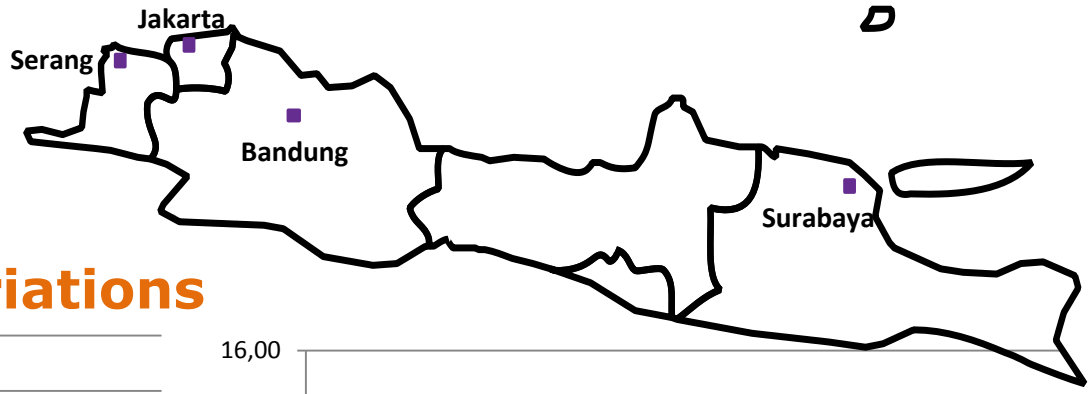


Based on data of *FAO and BMG '06.*
Note: Using only BMG data gives very different results.

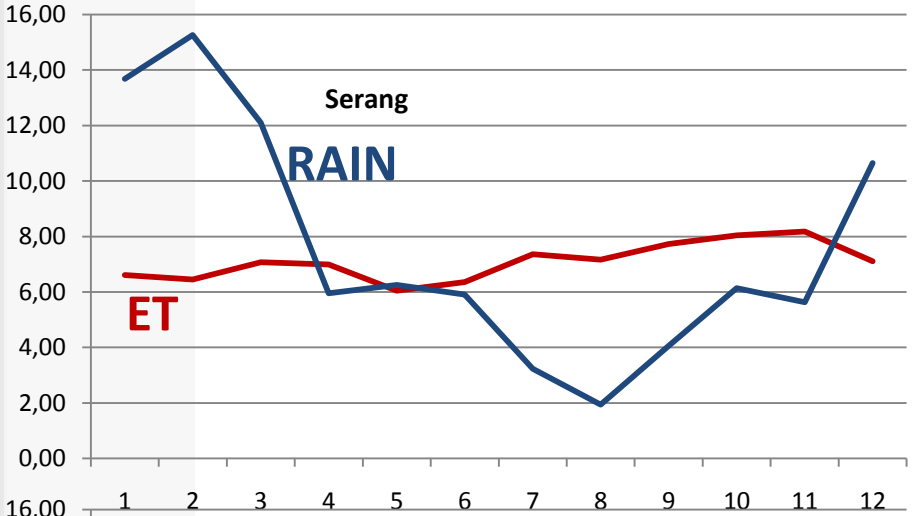
AVERAGED OVER INDONESIA		
	LMI '08 (2000-04)	H-C (97-01)
ET		3.23

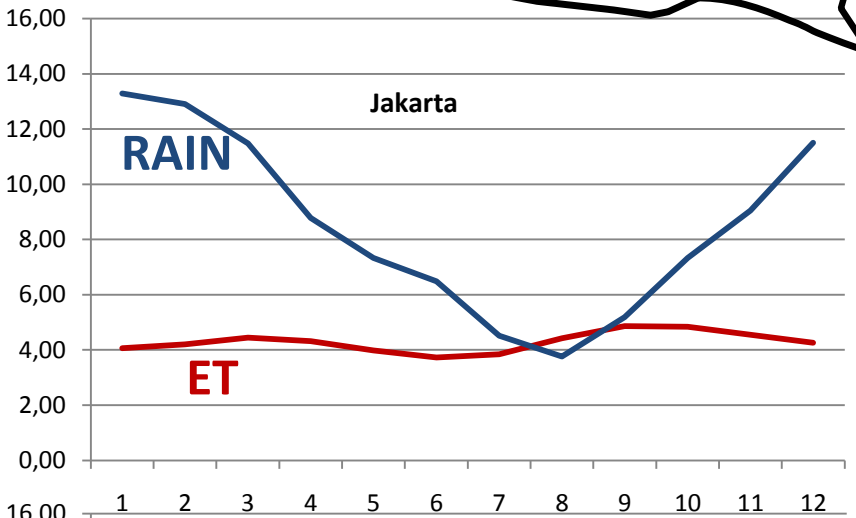
INDONESIAN WATER FOOTPRINT

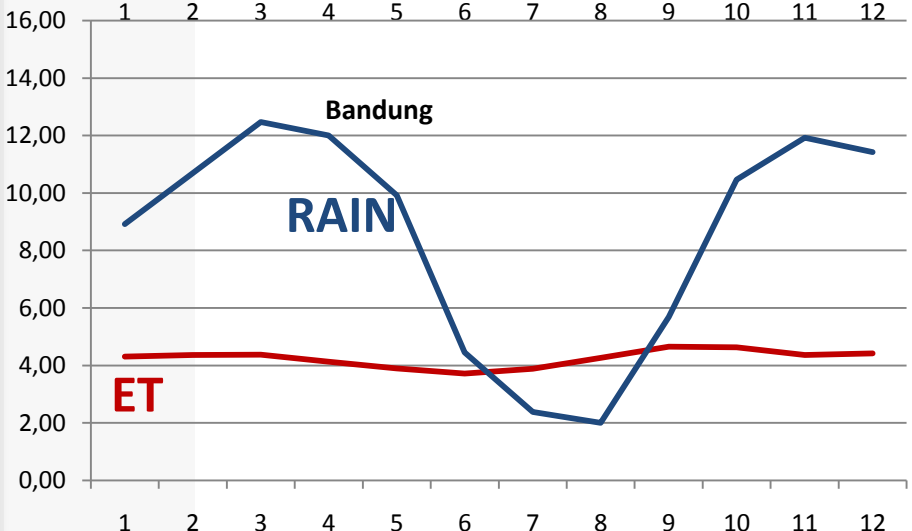


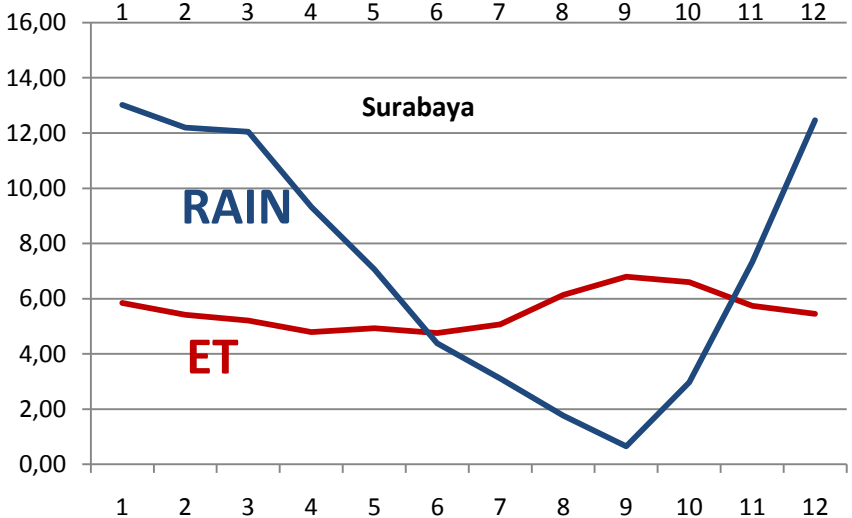


Evapotranspiration:
Spatial and temporal variations

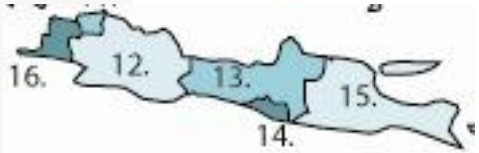


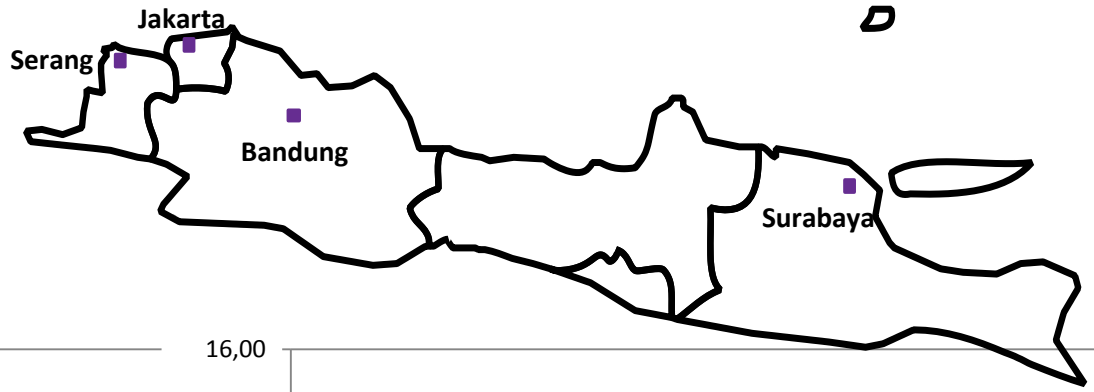




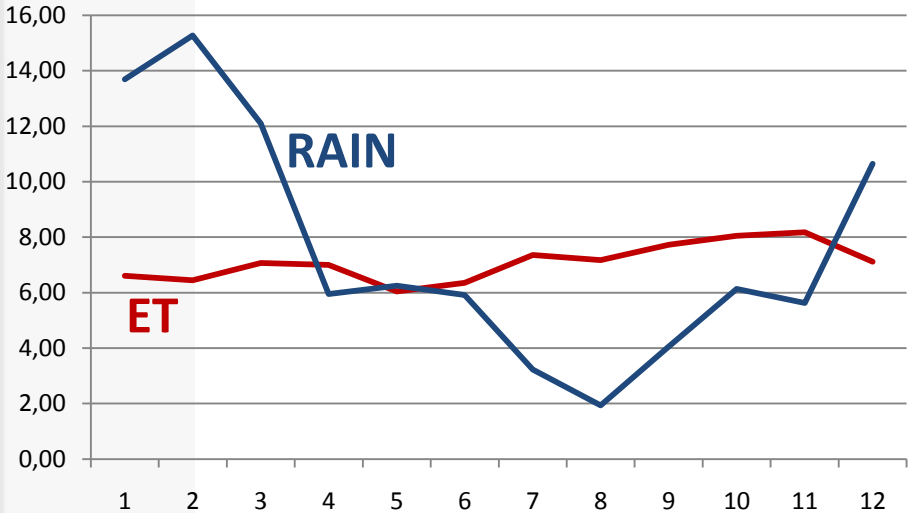


INDONESIAN WATER FOOTPRINT

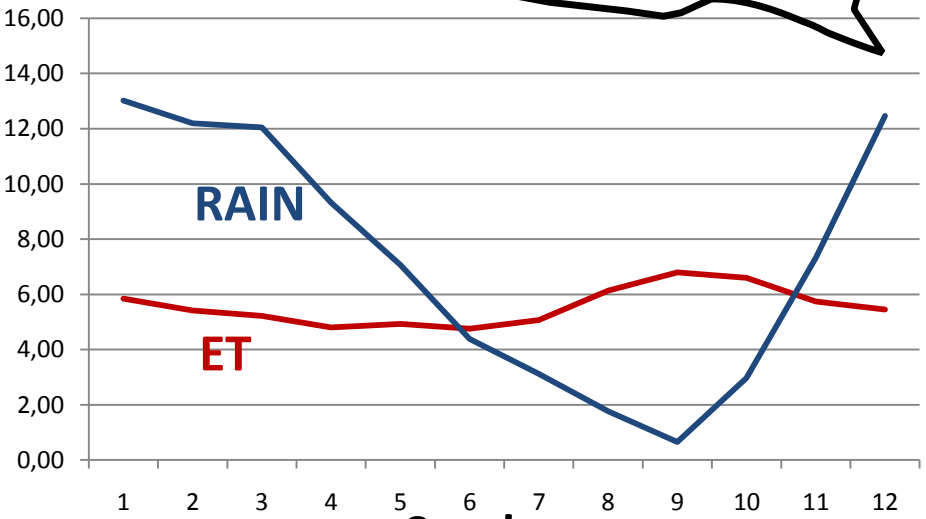




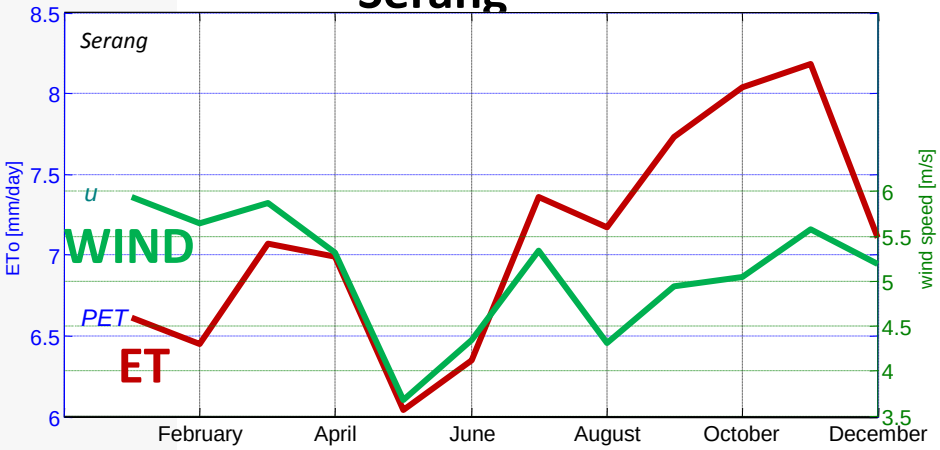
Evapotranspiration:
Effect of Wind

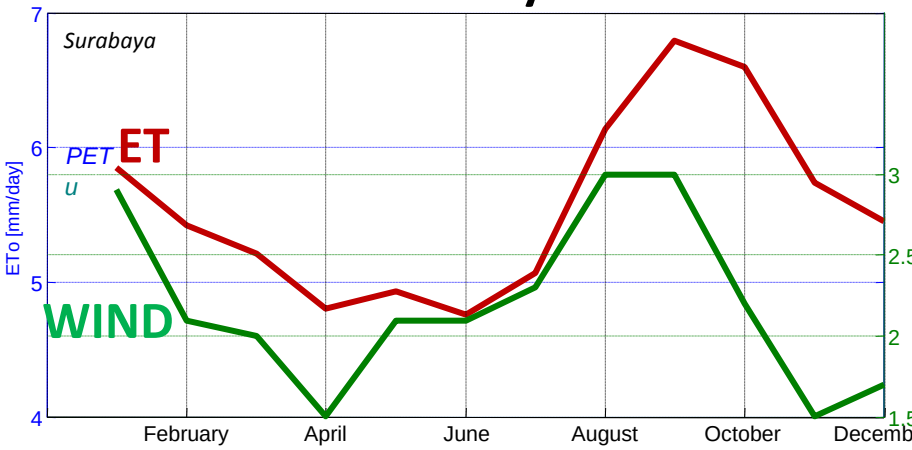


Serang



Surabaya

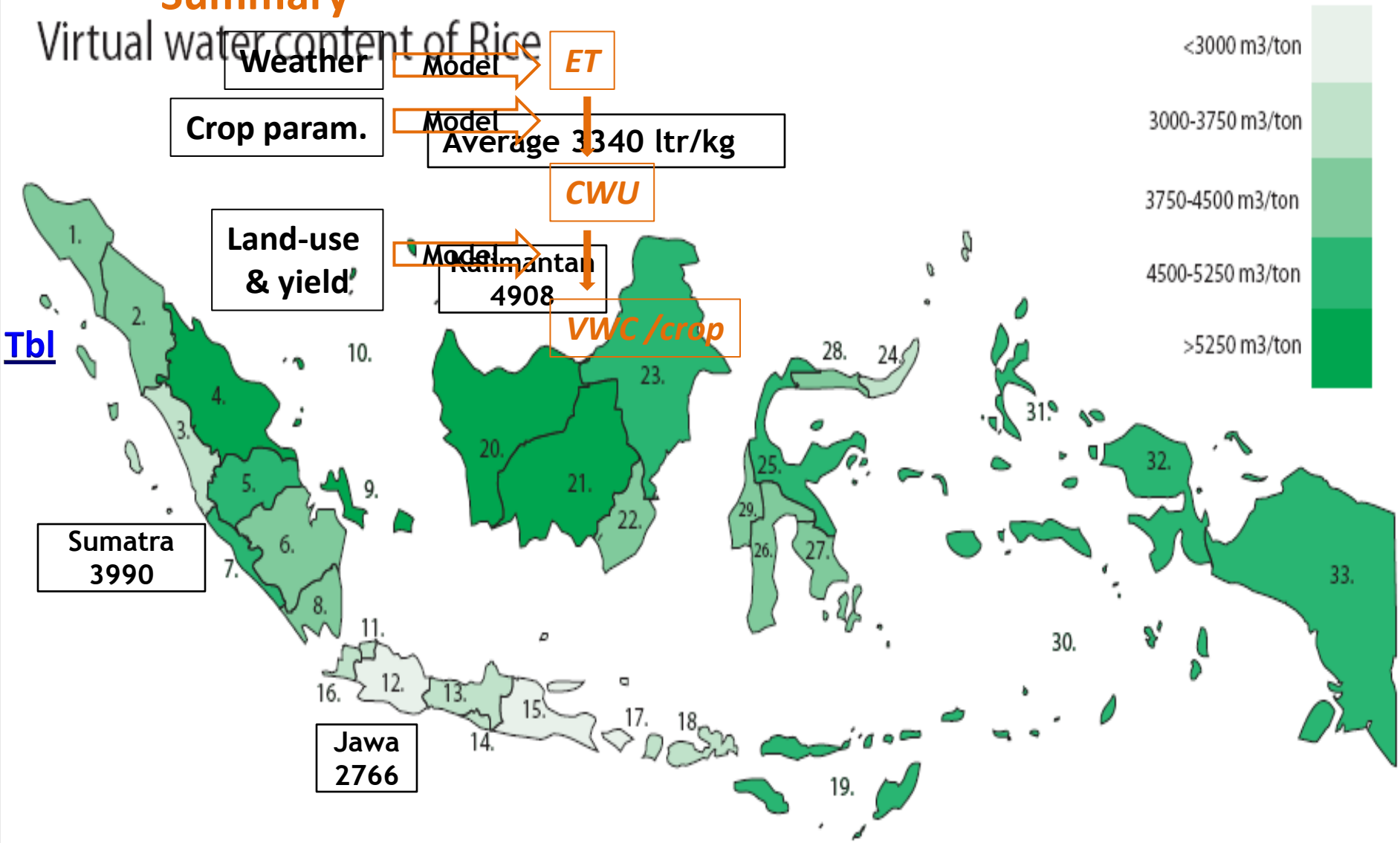




INDONESIAN WATER FOOTPRINT

Virtual Water Content of rice

Summary



INDONESIAN WATER FOOTPRINT

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Virtual Water Content

AVERAGED OVER INDONESIA		
CROP	*VWC* (m^3/ton)	
	LMI'08	H-C
Coffee	22910	17665
Cocoa	9406	9959
Rice	3340	2150
Groundnut	2968	2231
Coconut	2854	2071
Maize	2396	1285
Soybeans	1878	2030
Banana	849	1074
Oil Palm	848	635
Cassava	497	460

Tbl

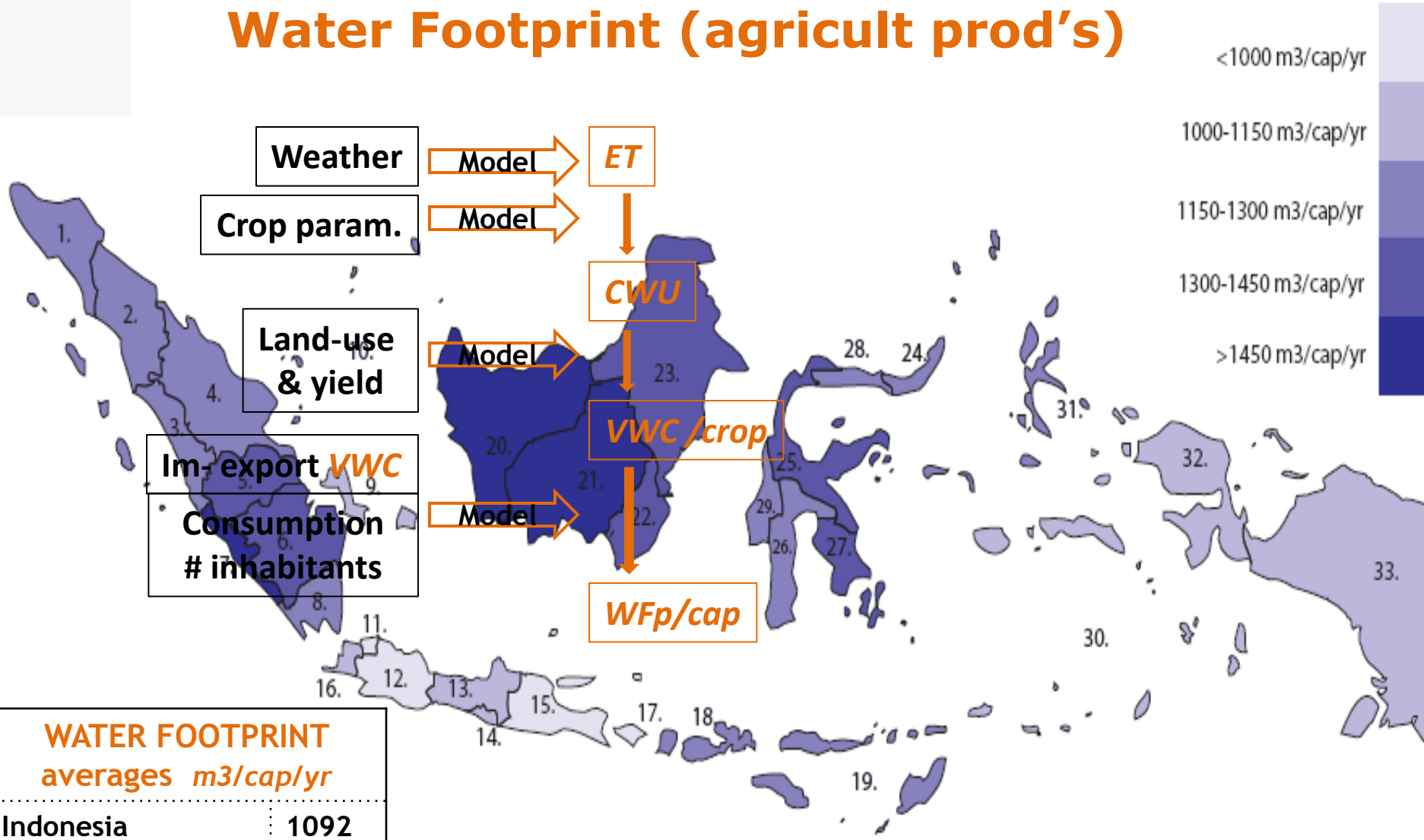
Differences between LMI'08 and H-C:

- ET calculation based on climate data:
  - H-C use climate data (Mitchell, 2003),
  - LMI uses CLIMWAT (FAO, 2008c) and BMG-data
- LMI uses **different monthly values** for ET for each province, H-C use one set of monthly ET.
- **LMI includes gray component**, H-C do not.
- **LMI values are specific for Indonesia** , H-C values are general for tropical zones.
- **LMI data from 2000-'04;**
  H-C data from 1997-2001 (economical crisis)

AVERAGED OVER INDONESIA		
	LMI '08 (2000-04)	H-C (97-01)
ET		3.23

INDONESIAN WATER FOOTPRINT

Water Footprint (agricult prod's)



WATER FOOTPRINT averages *m3/cap/yr*	
Indonesia	1092
Kalimantan Tengah	1760
Jakarta	841

INDONESIAN WATER FOOTPRINT

WATER FOOTPRINT details/discussion

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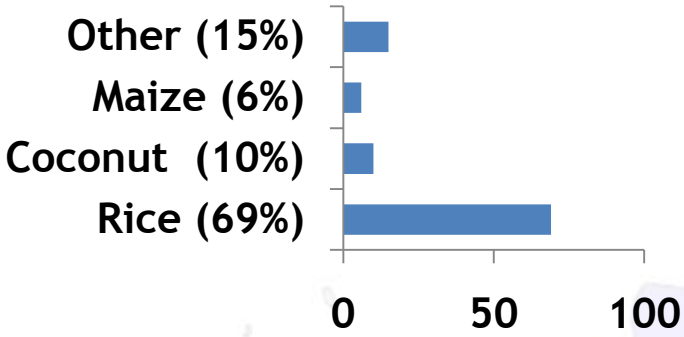
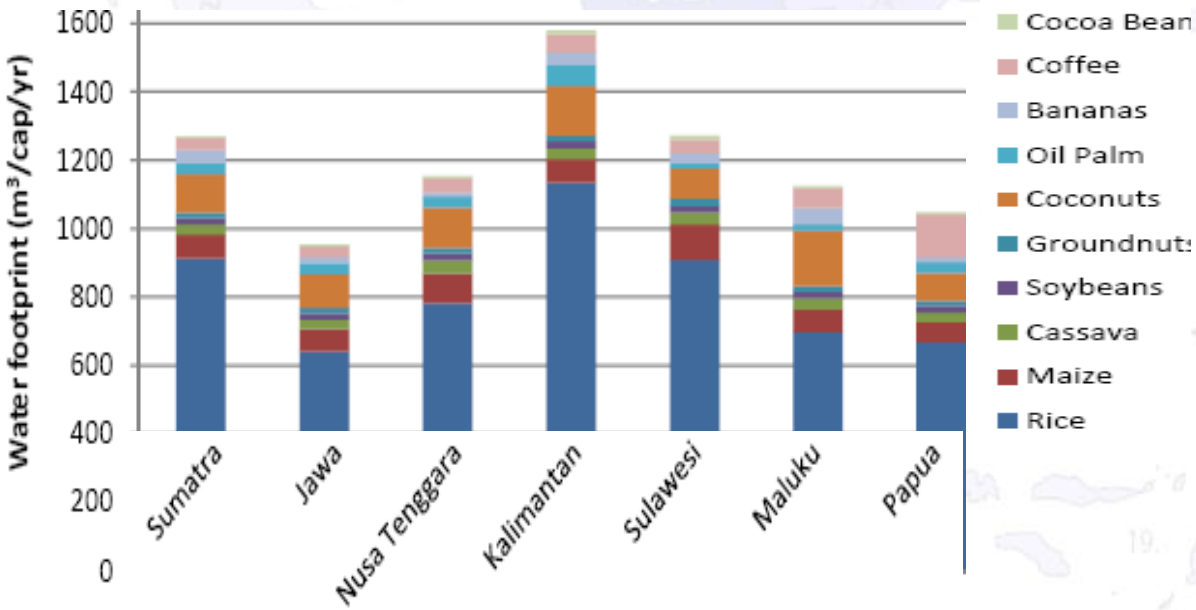
Av Crop contribution



Crop contribution per island-group



WATER FOOTPRINT averages *m3/cap/yr*	
Indonesia	1092
Kalimantan Tengah	1760
Jakarta	841

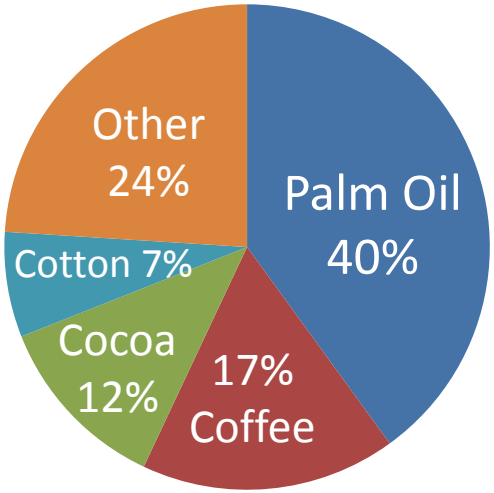
WATER FOOTPRINT Comparison *m³/cap/yr*	LMI '08 (2000-04)	H-C (97-01)
Water Footp	1092 (a)	1317
Internal Agri	1063	1153
External Agri	28	127

INDONESIAN WATER FOOTPRINT

Virtual Water Flows

International

Main Sumatra export: palm & coconut oil and coffee.



International water export (million m^3)	
Sumatra	29069
Jawa	933
Nusa Tenggara	1132
Kalimantan	5664
Sulawesi	5541
Maluku	541
Papua	653
Total	*43534*

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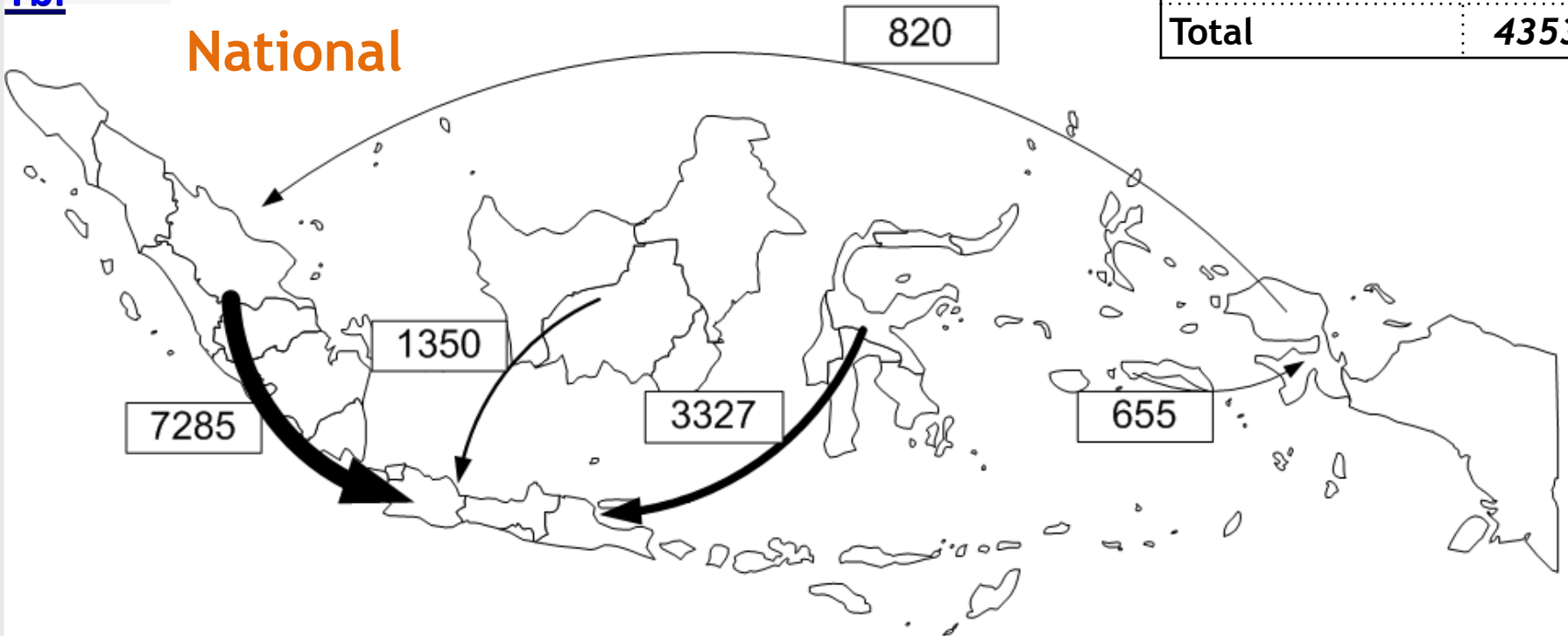
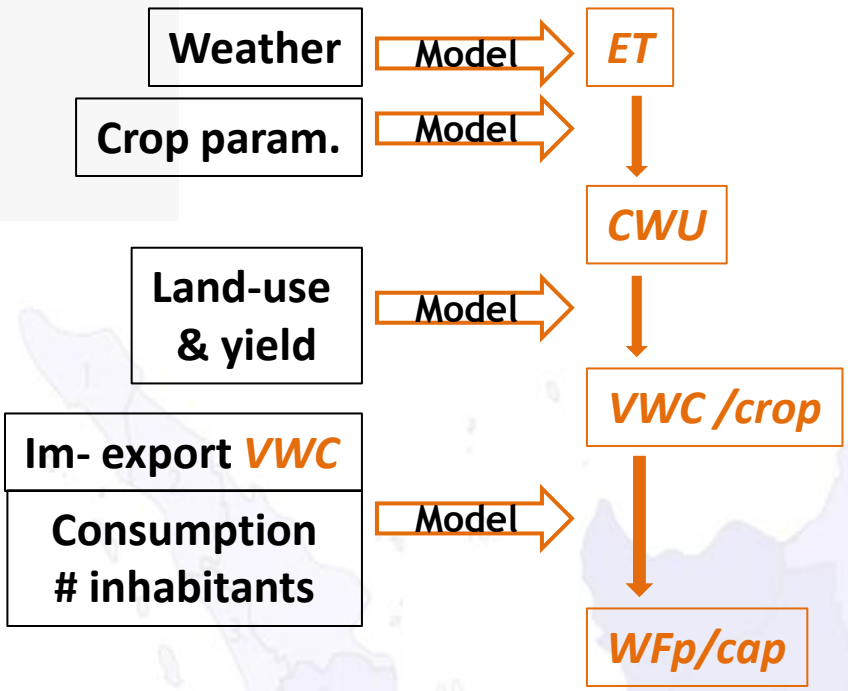
National



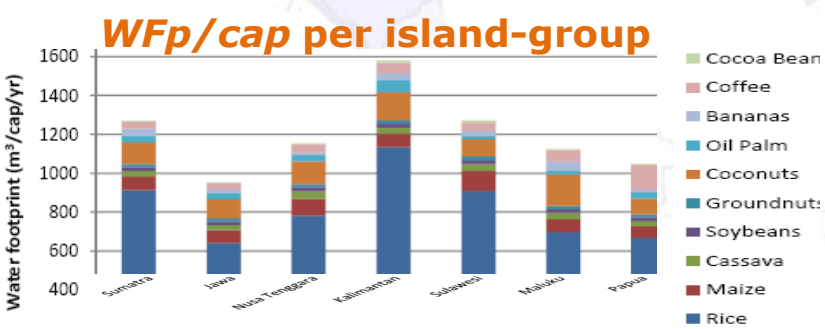
INDONESIAN WATER FOOTPRINT

Summary



Main results

- *WFp* for agri products is almost the same as *HC*-result.
- *WFp /cap* is for 70% determined by rice consumption (150kg/yr).
- *VWC* of the same crop can differ factor 2 over the provinces.
- *WFp /cap* in Jakarta is only half of that in Kalimantan caused by difference in *VWC* of crops from Kal and from Jawa.



	VWC Rice m3/ton	WFp m3/cap/yr
Indonesia (average)	3340	1092
Kalimantan Tengah	4908	1760
Jakarta	2766	841