MENUJU PENGELOLAAN AIR BERKETAHANAN IKLIM

Perubahan Global dan Dampaknya: Menuju Pembangunan Berketahanan Iklim di Indonesia

FGB ITB Future Science and Technology Talk #8
26 Juli 2024

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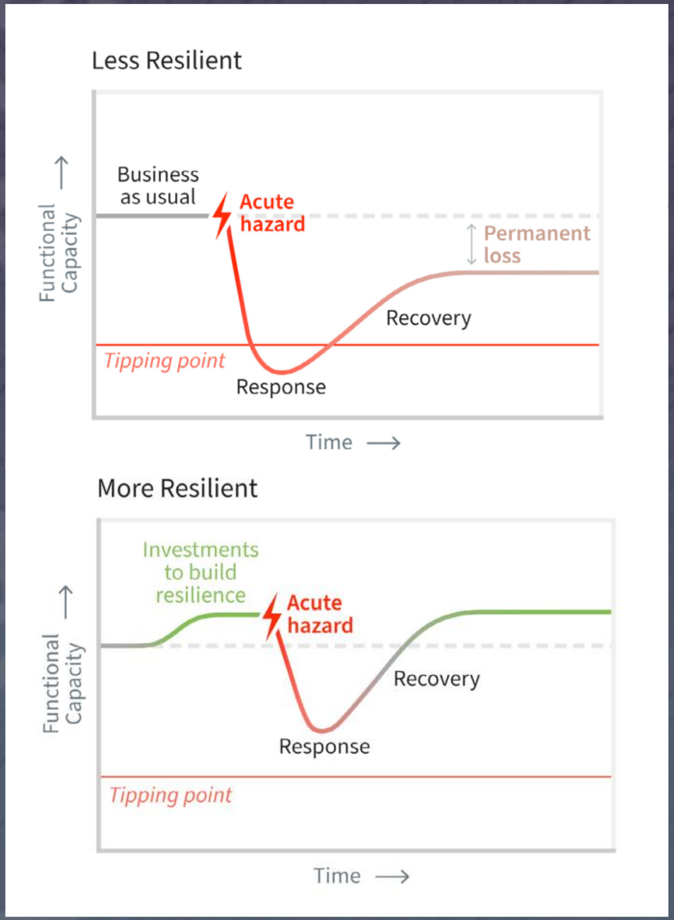
MENUJU PENGELOLAAN AIR BERKETAHANAN IKLIM

- PENGERTIAN
- DATA HISTORIS INDONESIA
- PROYEKSI KE DEPAN INDONESIA
- MEMBANGUN PENGELOLAAN AIR BERKETAHANAN IKLIM
- RESPON KE DEPAN?

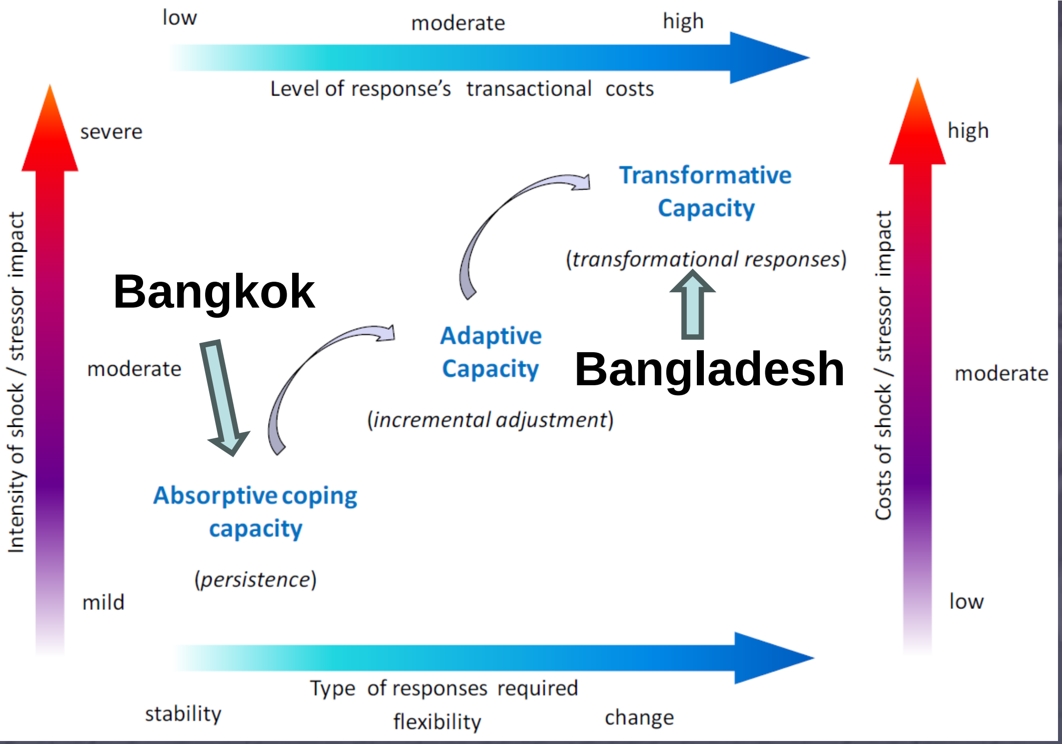
PENGERTIAN

KETAHANAN

Kapasitas sistem untuk menyerap gangguan, mempertahankan, mengatur ulang, dan meningkatkan berbagai fungsi dan umpan baliknya dari waktu ke waktu sesuai dengan arah pengembangannya ke depan.



(Gardiner, Ned, ed., Matt Hutchins et al. 2023)



(Béné et al. 2015)

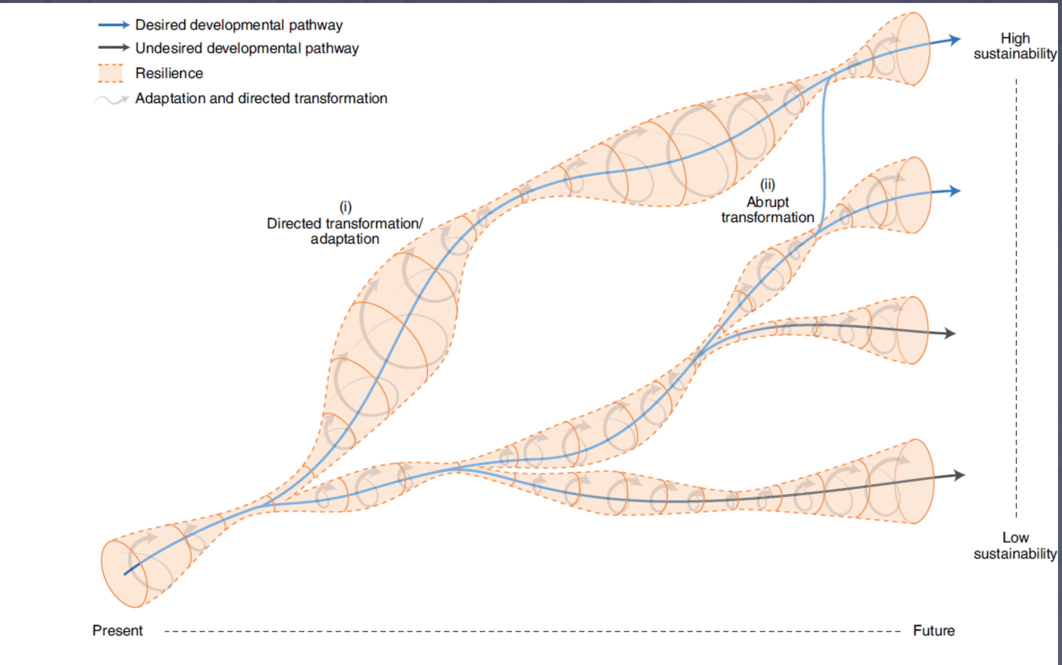


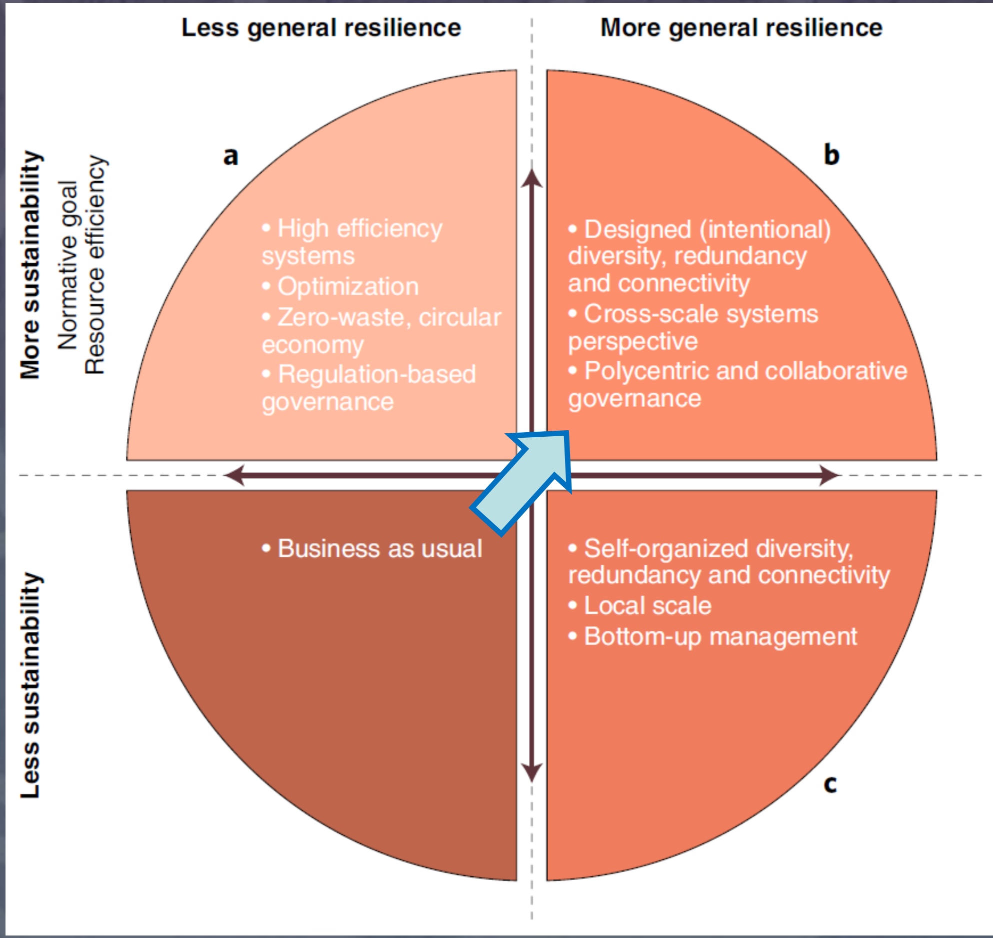
Fig. 2 | Interlinkages between sustainability, resilience and transformations. See text and Box 1 for further explanation.

(Elmqvist et al. 2019)

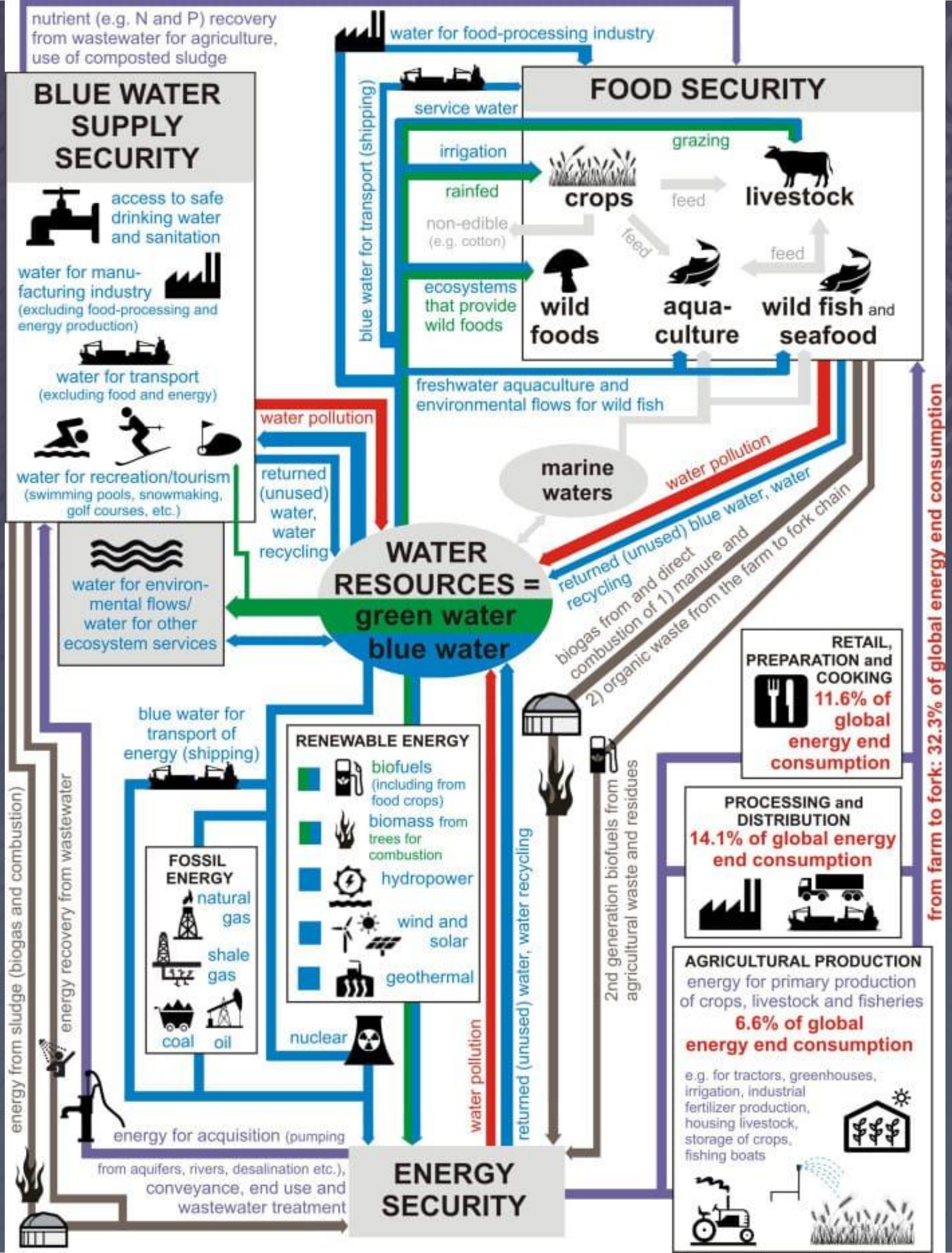
KETAHANAN SUMBER DAYA AIR

Holistik (sistem) : alami dan manusia plus umpan balik

PSDA :
- ❖ Konservasi
- ❖ Pendayagunaan
- ❖ Pengendalian Daya Rusak



(Elmqvist et al. 2019)

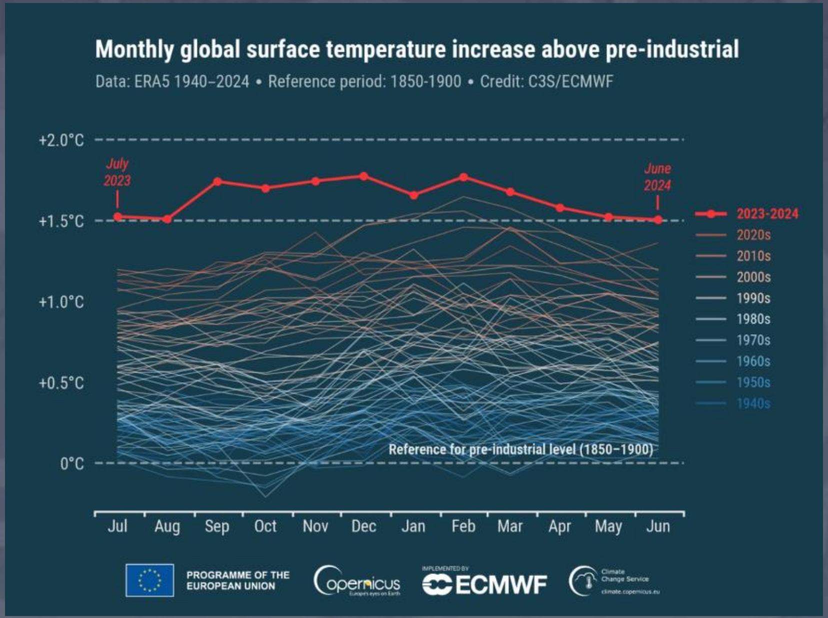


(Vanham 2015)

“GANGGUAN IKLIM”

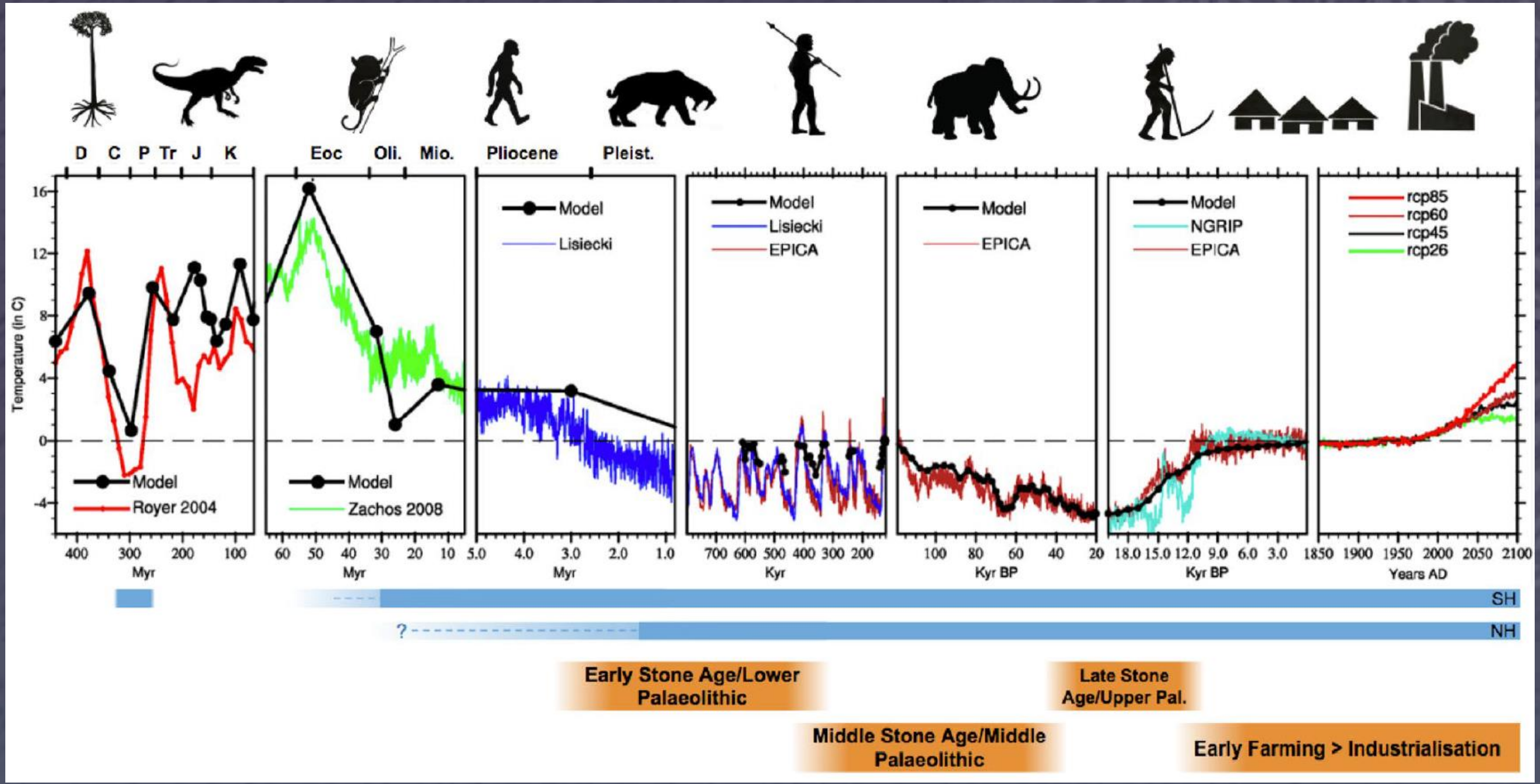
“Gangguan iklim” meliputi:
1. Variabilitas
2. Perubahan

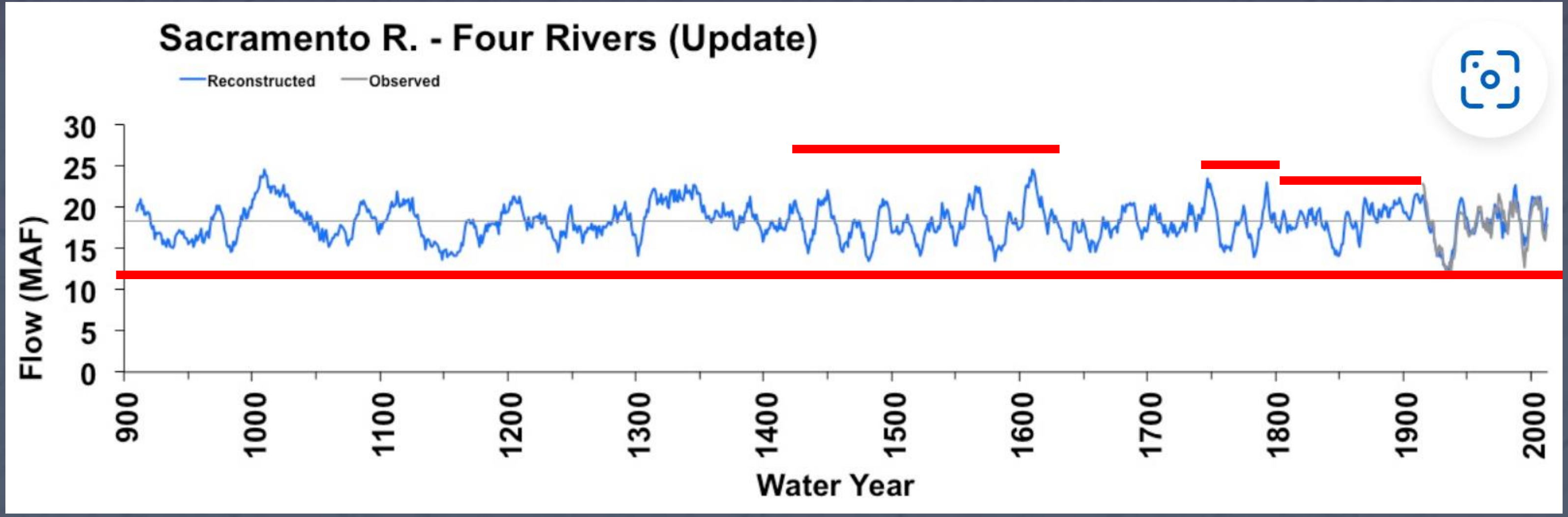
Berbagai skala spasial dan temporal, bahkan dalam skala umur desain infrastruktur air.



(https://climate.copernicus.eu/copernicus-june-2024-marks-12th-month-global-temperature-reaching-15degc-above-pre-industrial 2024)

(Haywood et al. 2019)

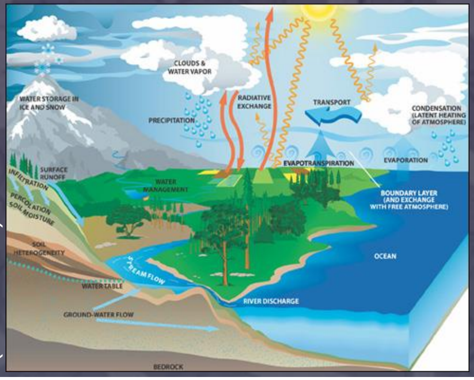




(https://www.treeflow.info/content/sacramento-river-four-rivers-index-ca-update, 2024)

DATA HISTORIS INDONESIA

KLIMATOLOGI DAN MUSIM HUJAN INDONESIA



(NASA 2011)

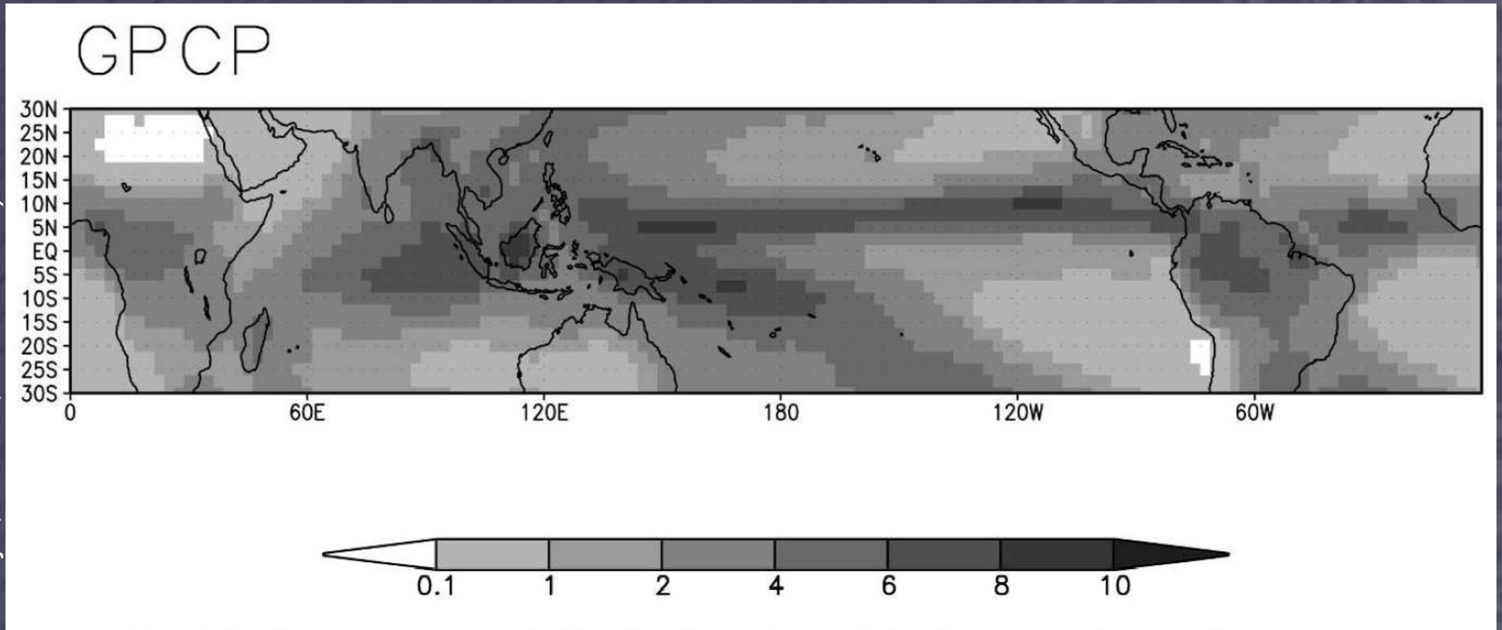
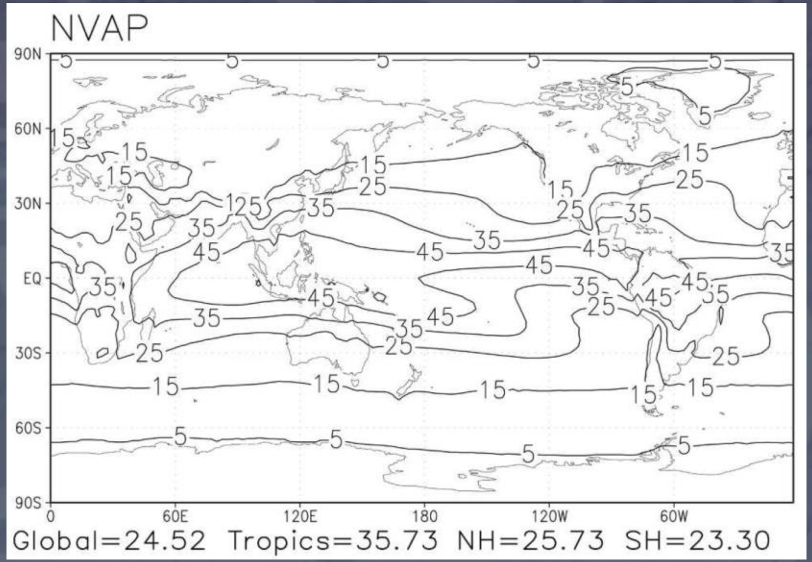


FIG. 14. The mean annual distribution of precipitation over the tropical ocean.

(Sudradjat, Ferraro, Fiorino 2005)



(Sudradjat, Ferraro, Fiorino 2005)

Sumber uap air lokal hanya ~<10%

(Dirmeyer dan Brubaker 2007)

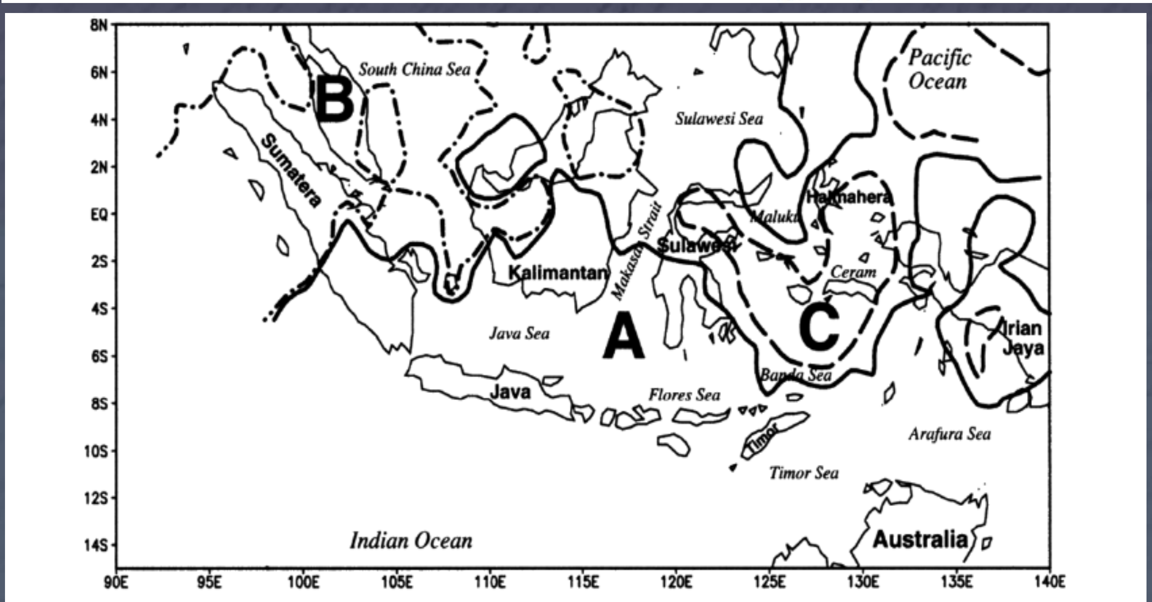
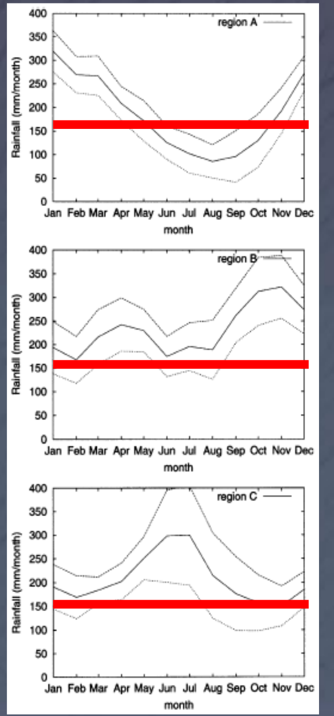


Figure 2. The three climate regions according to the mean annual patters using the DCM. Indonesia is divided into Region A in solid line, Region B in short dashed line and Region C in long dashed line

Int. J. Climatol. 23: 1435–1452 (2003)



(Aldrian dan Susanto 2003)

DATA HISTORIS CURAH HUJAN CILIWUNG HULU

Stationaritas berubah oleh berbagai hal :

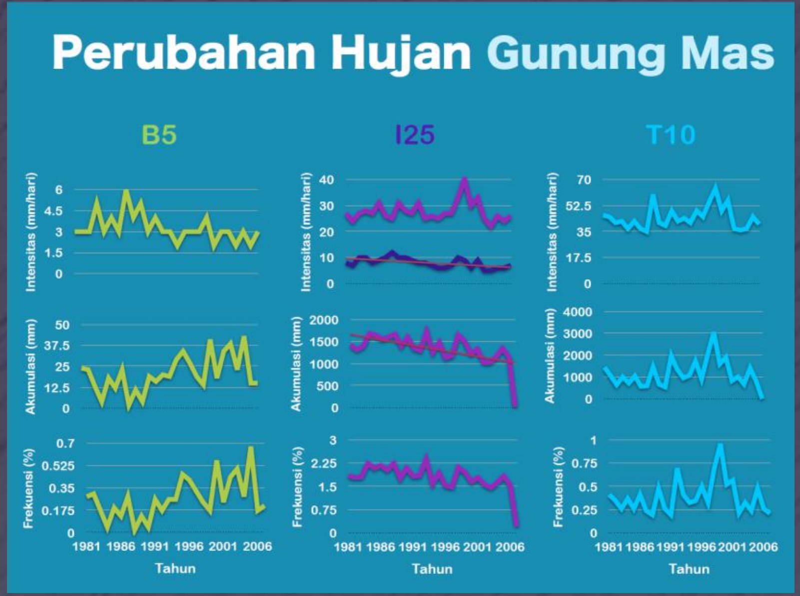
- ❖ perubahan sistem konvektif hujan (*Clausius-Clapeyron*, *vertical lapse rate*, *condensation buoyancy)* (*instantaneous*-1 jam dan 100 m-1 km)
- ❖ perubahan "*atmospheric rivers*" lokal, regional, dan global (sirkulasi atmosfir, *monsoon*, ENSO, IOD, dlsb.)
- ❖ Perubahan tata guna dan tutupan lahan

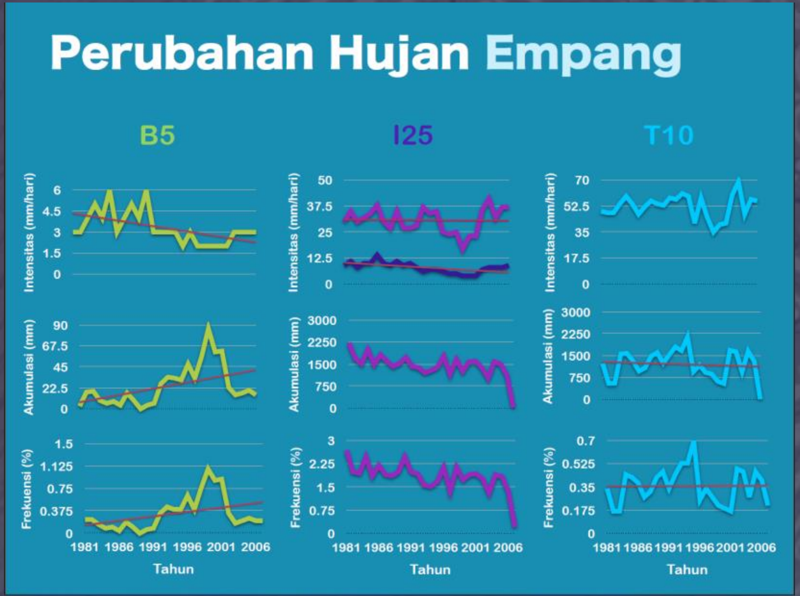
[Perubahan intensitas, durasi hujan dan antar hujan, frekuensi, kumulasi, pdf, luas wilayah]

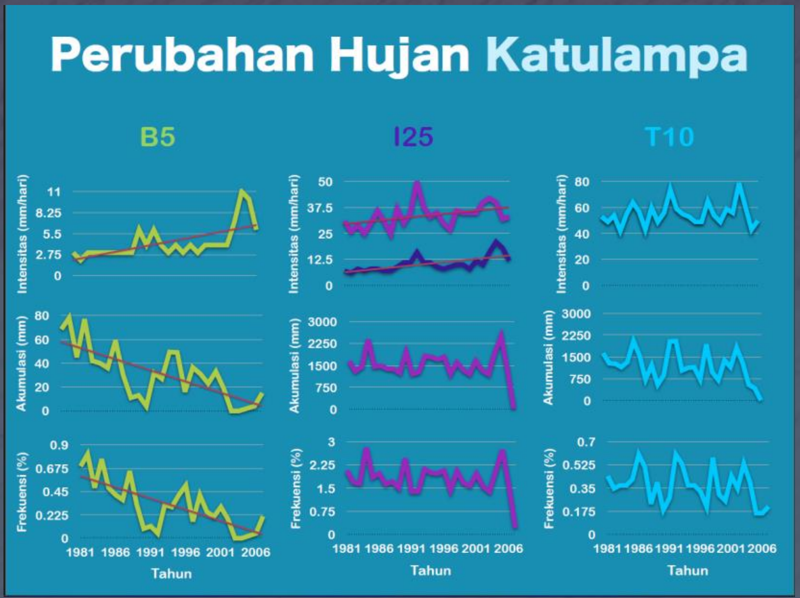
Misal:

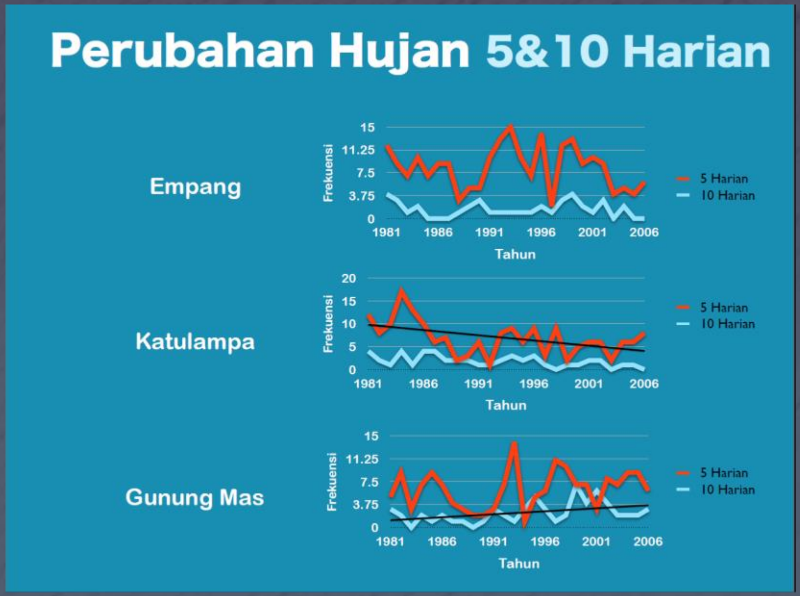
Untuk DAS Citarum Hulu : (Wulandari dan Sudradjat 2013)

(Wulandari dan Arief Sudradjat 2013)



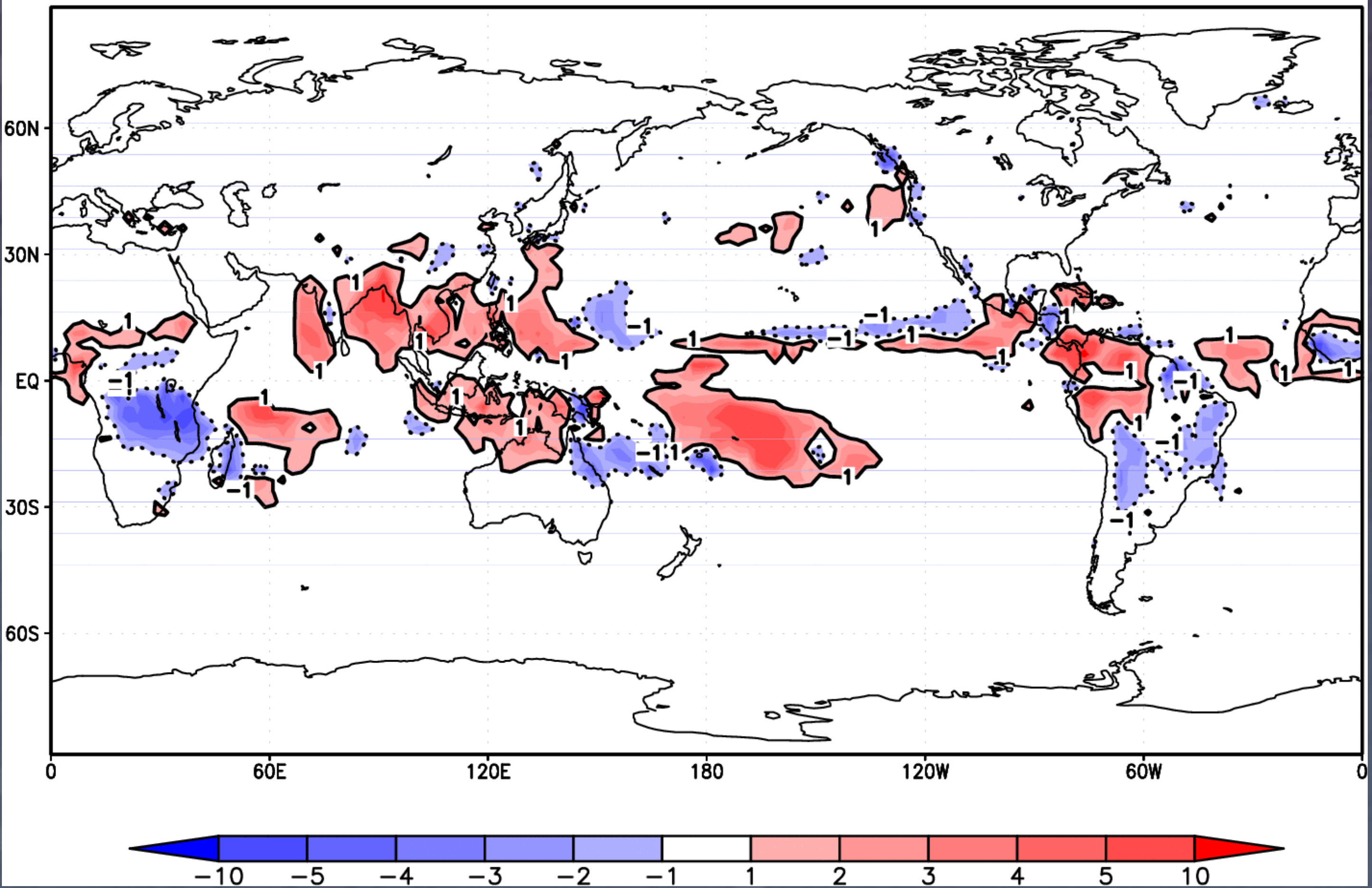




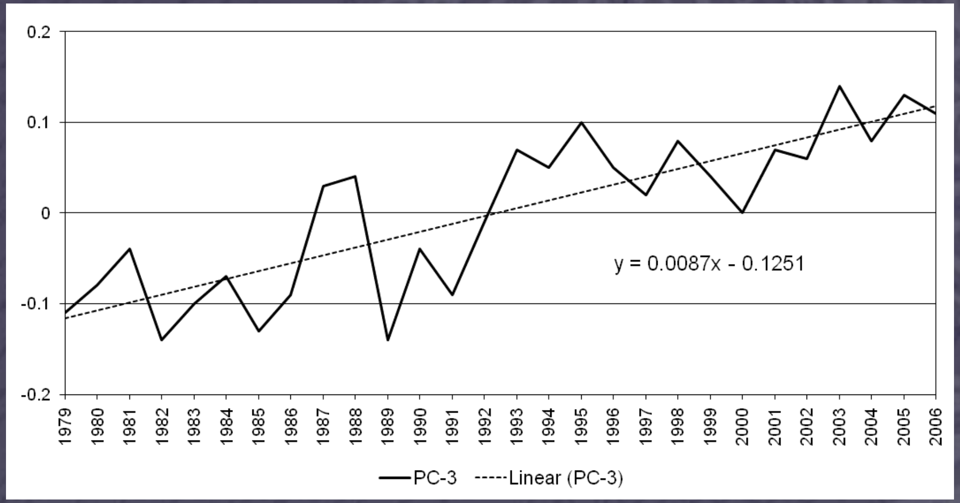


Data harian (bukan data jam-jaman). Walaupun ada berbagai perubahan interdekadal, tidak terdeteksi pola yang seragam.

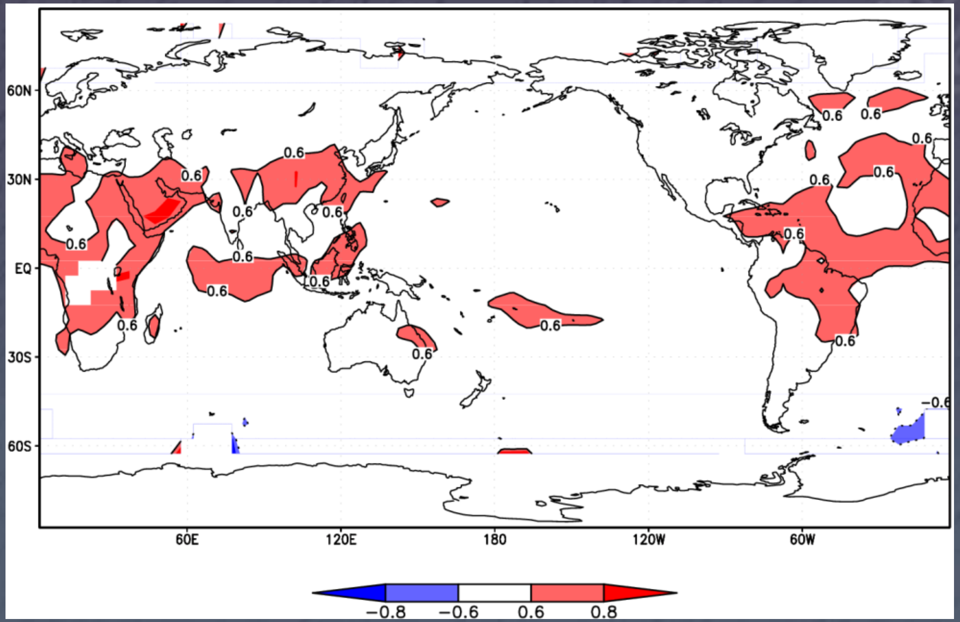
DATA HISTORIS CURAH HUJAN MONSOON WILAYAH TROPIS



(Sudradjat 2010)

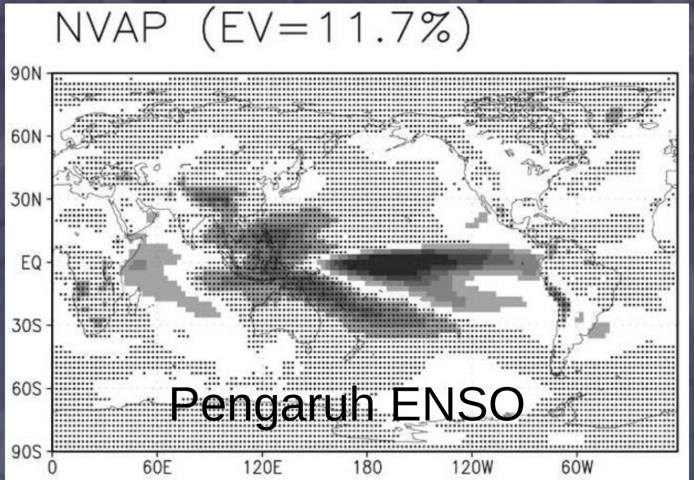


(Sudradjat 2010)

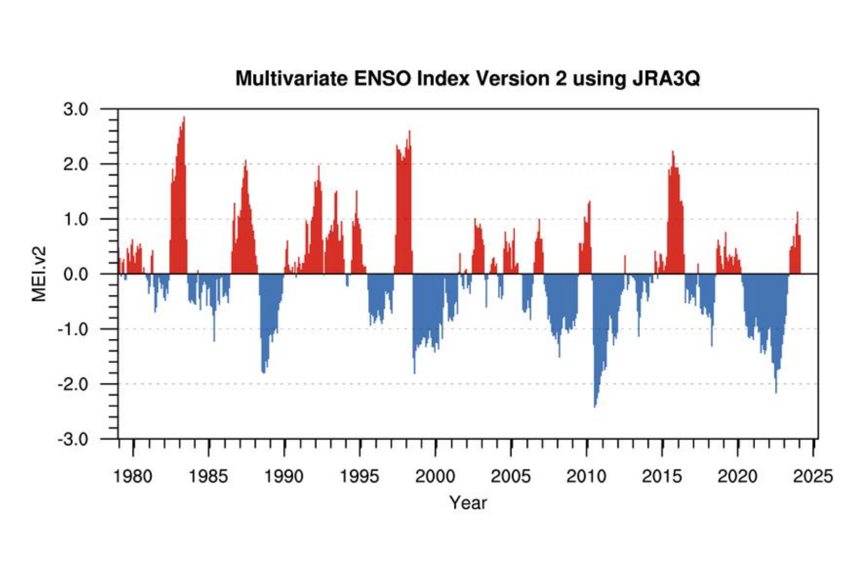


ENSO mempengaruhi variabilitas rerata hujan tahunan (EOF1 dan EOF2; 41.84% EV). Perubahan interdekadal hanya 0,8% (7,47% EV). (Sudradjat 2010). (pdf dan ekstrimitas berubah?).

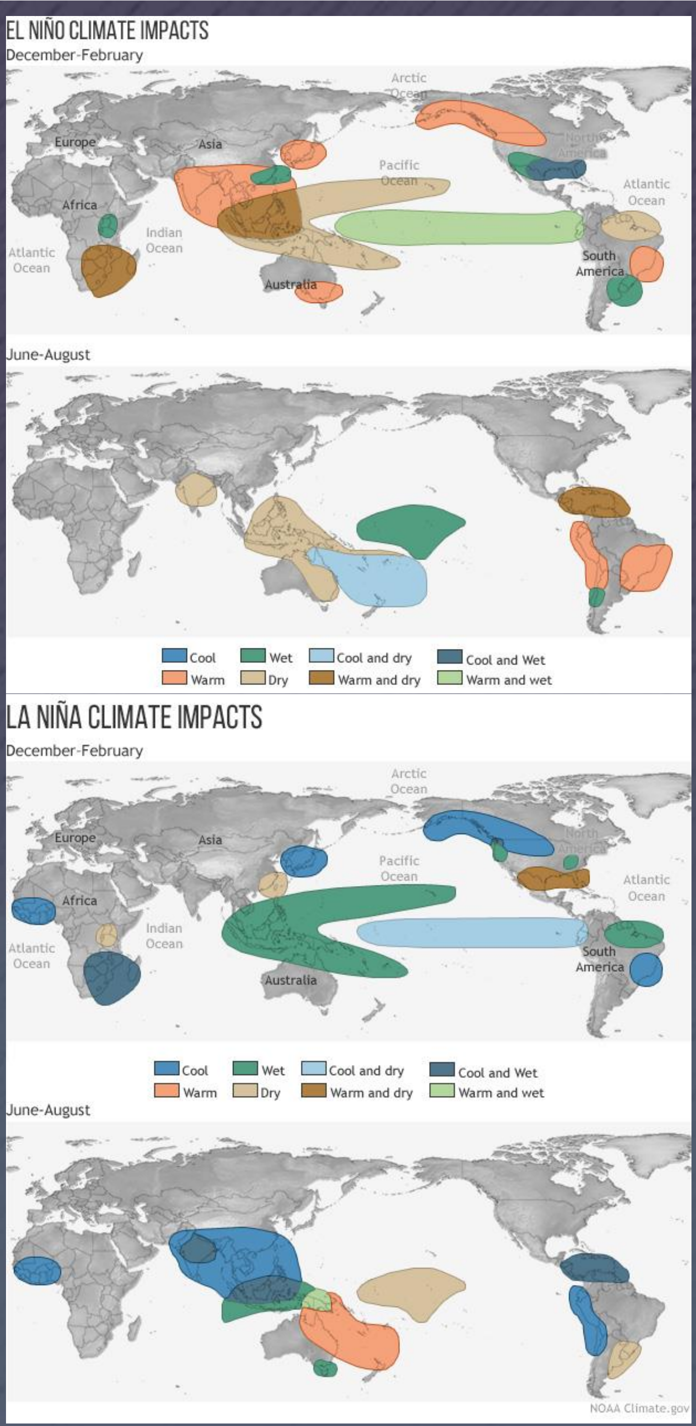
VARIABILITAS HUJAN OLEH ENSO DAN IOD



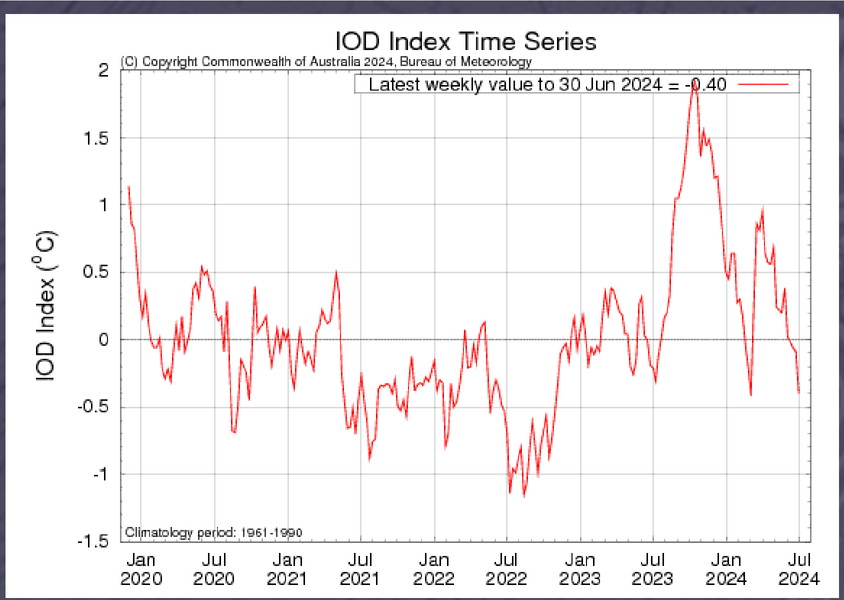
(Sudradjat, Ferraro, Fiorino 2005)



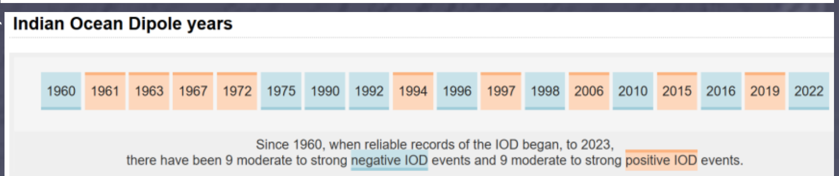
(https://psl.noaa.gov/enso/mei/ 2024)



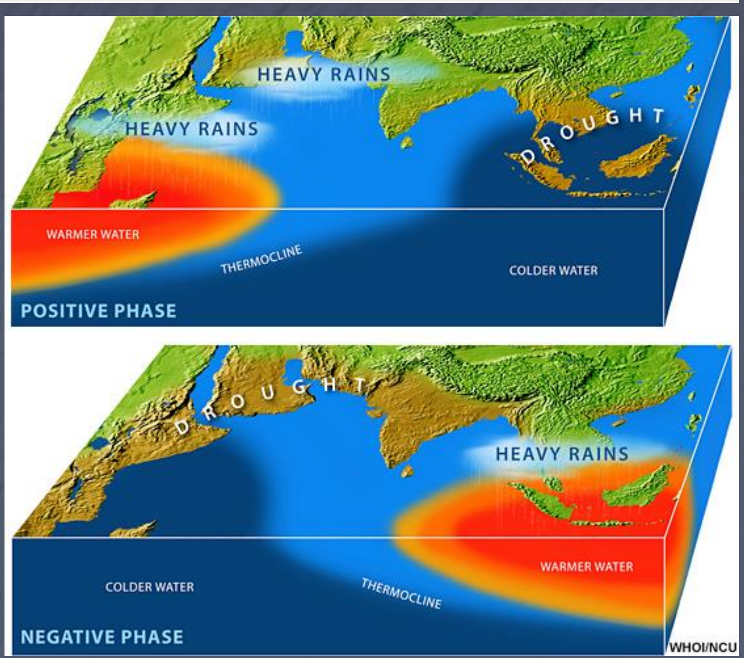
(https://psl.noaa.gov/enso/mei/img/meiv2.timeseries.png 2024)



(https://psl.noaa.gov/enso/mei/ 2024)



(http://www.bom.gov.au/climate/iod/ 2024)



(https://www.chanthaburi.buu.ac.th/~wirote/met/tropical/textbook_2nd_edition/media/graphics/indian_ocean_dipole_whoi.jpg 2024)

DATA HISTORIS DEBIT SUNGAI CITARUM HULU

Stationaritas berubah oleh berbagai hal :

- ❖ perubahan iklim-hujan
- ❖ Sistem air tanah dan air permukaan
- ❖ Aktivitas manusia (langsung dan tidak langsung)

Misal:

Untuk DAS Citarum Hulu :

a. Perubahan interdekadal tidak terdeteksi
b. ENSO pernah hampir diam (1920-1960)
c. ENSO mempengaruhi debit aliran sungai
d. Koefisien limpasan DAS meningkat signifikan (~20%)
e. Sensitivitas terhadap variabilitas hujan (dan ekstrimitas) debit aliran sungai meningkat (lebih akibat d-c)

(Sudradjat, Muhamad, Nurohman 2020)

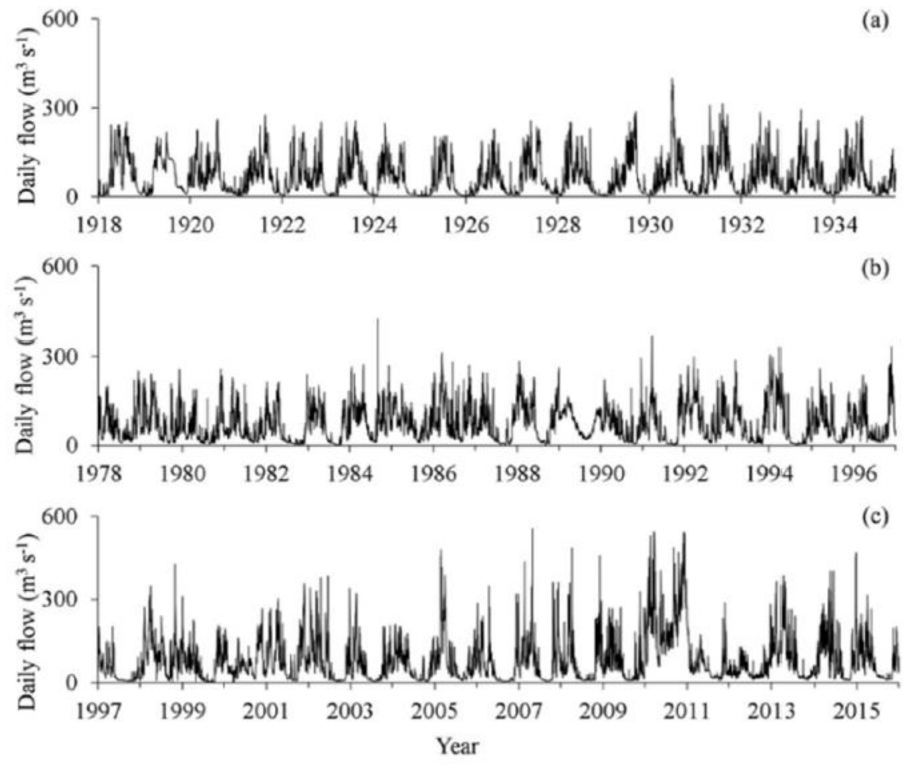
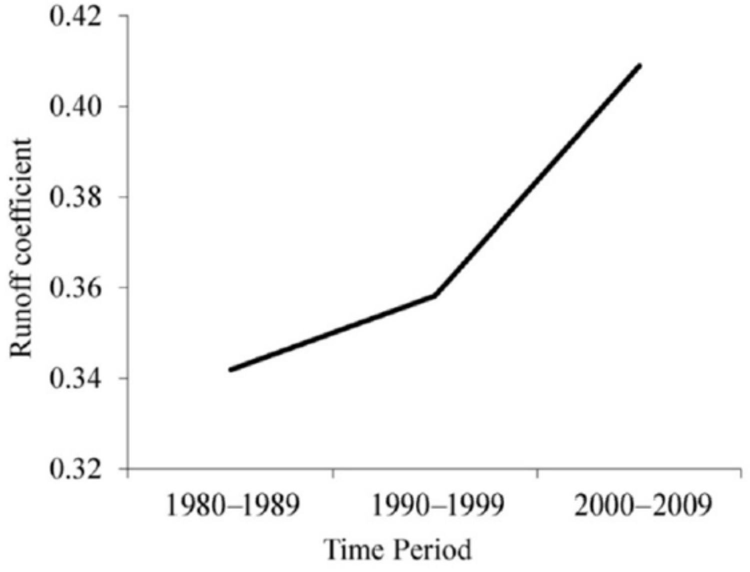


Figure 5. Recorded daily flows during (a) the low anthropogenic activities and (b) first-halves and (c) second-halves of high anthropogenic activities periods.

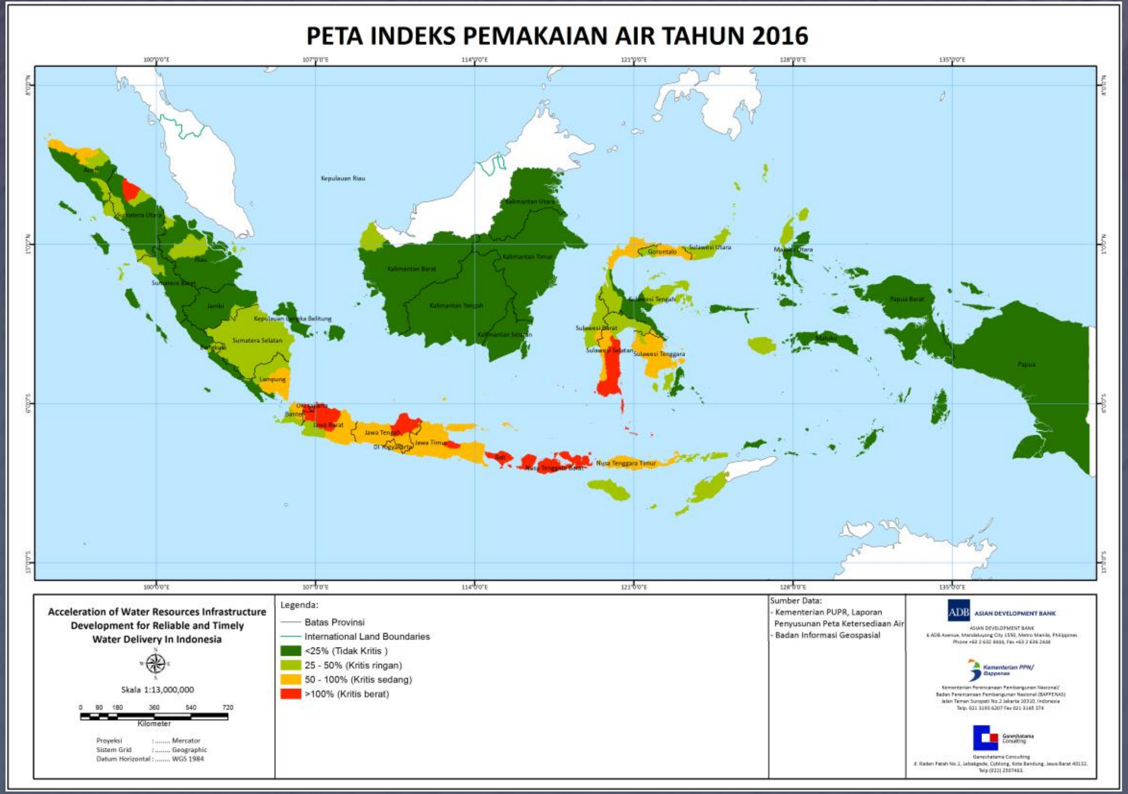
(Sudradjat, Muhamad, Nurohman 2020)



DAYA DUKUNG DAN DAYA TAMPUNG SUMBER DAYA AIR

Penduduk 2016 :
- Indonesia : **258.705.000**
- Jawa Utara : **115.715.113 (44,73%)**
- Jawa Selatan : **30.803.802 (11,91%)**

- ❖ ENSO dan IOD mempengaruhi variabilitas konsentrasi pencemar di badan air permukaan, misal Chl-a, melalui variabilitas debit dan washing-off. (IKA?).
- ❖ Daya tampung dan daya dukung air ke depan bukan hanya dipengaruhi oleh variabilitas dan perubahan iklim saja.



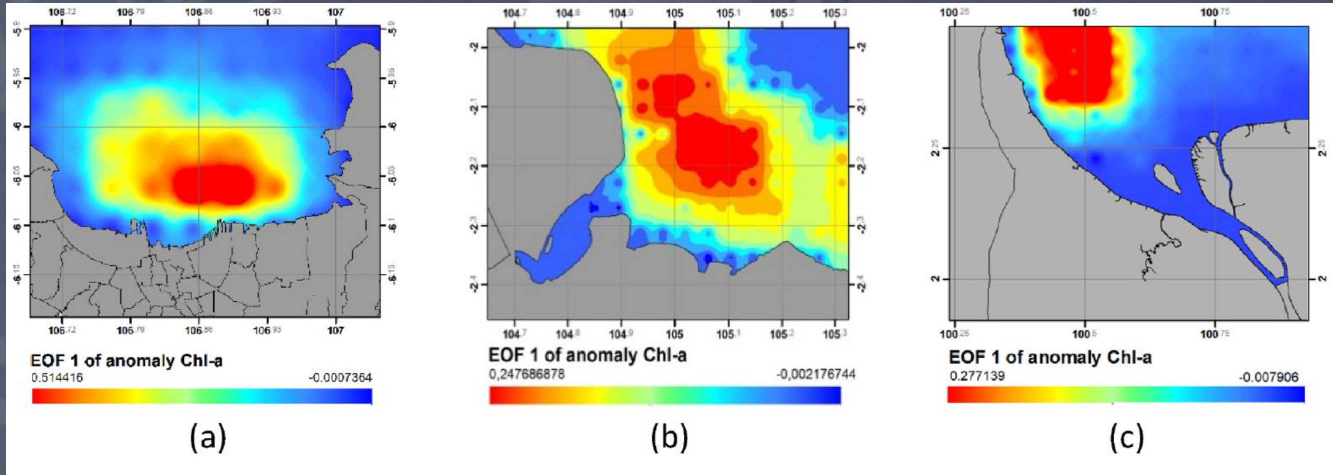
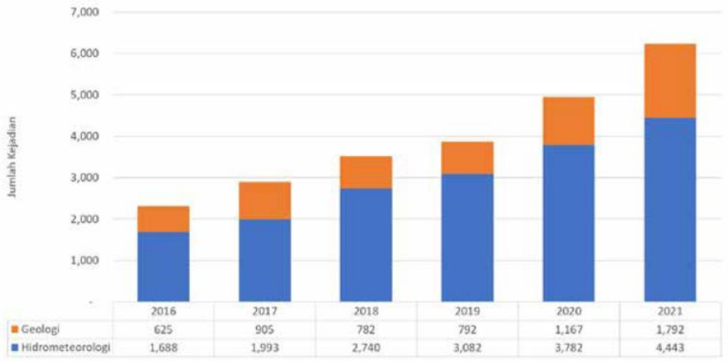


Fig. 9. The first EOFs of Chl-a anomalies in Jakarta Bay (a), Musi Estuary (b), and Rokan Estuary (c).

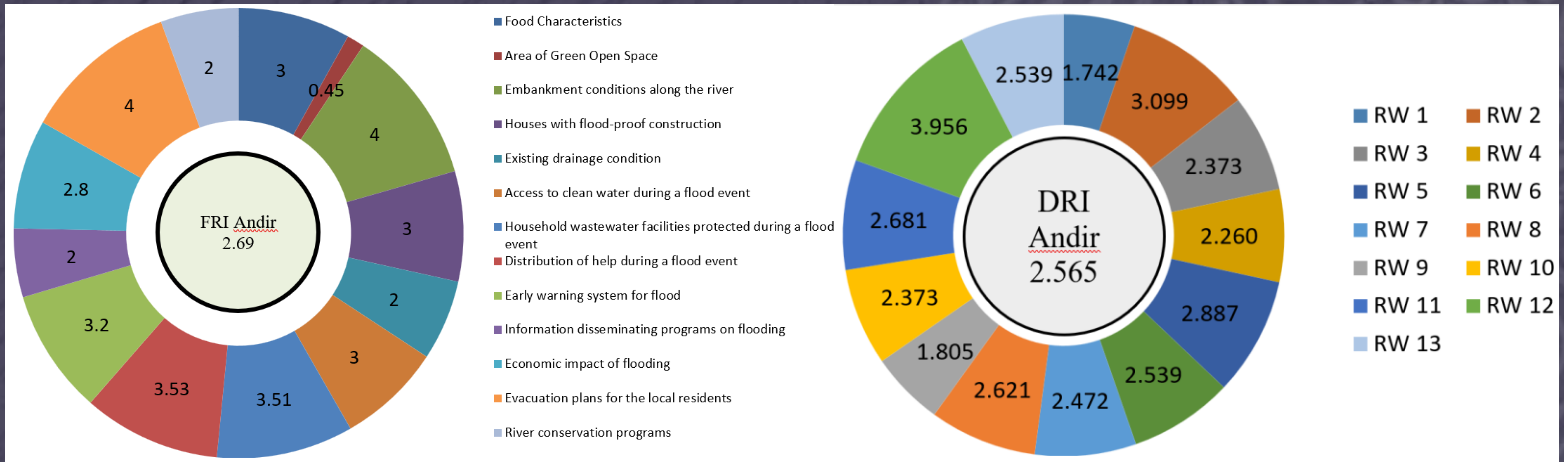
(Sudradjat, Muntalif, Marasabessy, Mulyadi, Firdaus 2024)

KEBENCANAAN, RISIKO DAN RESILIENSI

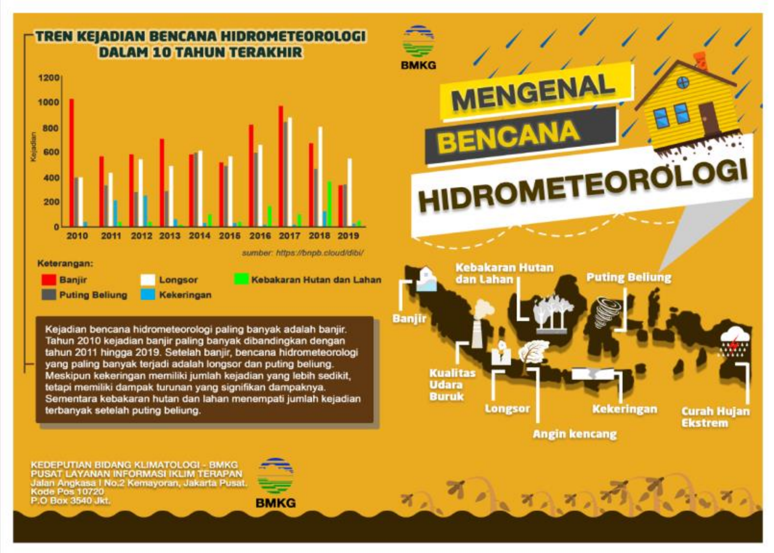


Gambar 12. Grafik Jumlah Kejadian Bencana 2015 - 2021 (diolah dari BNPB, 2021)

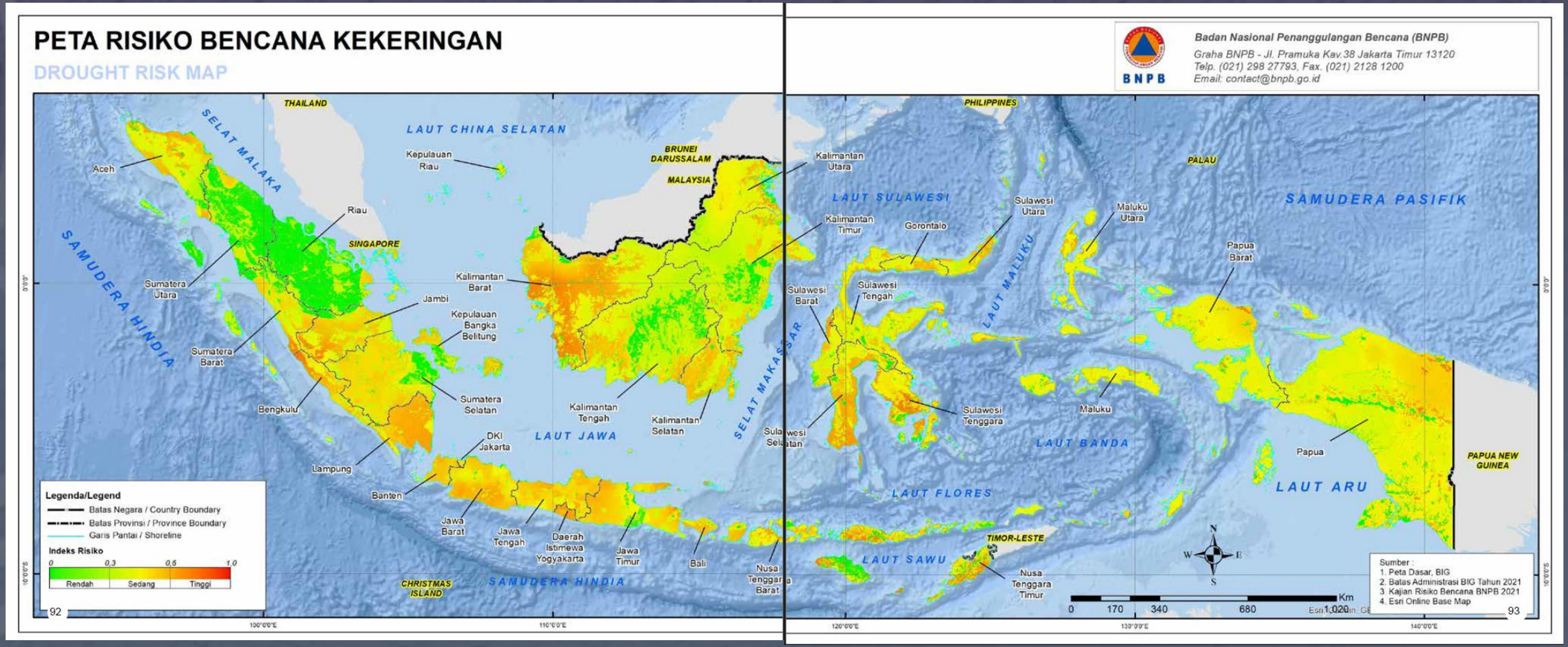
(BNPB 2023)



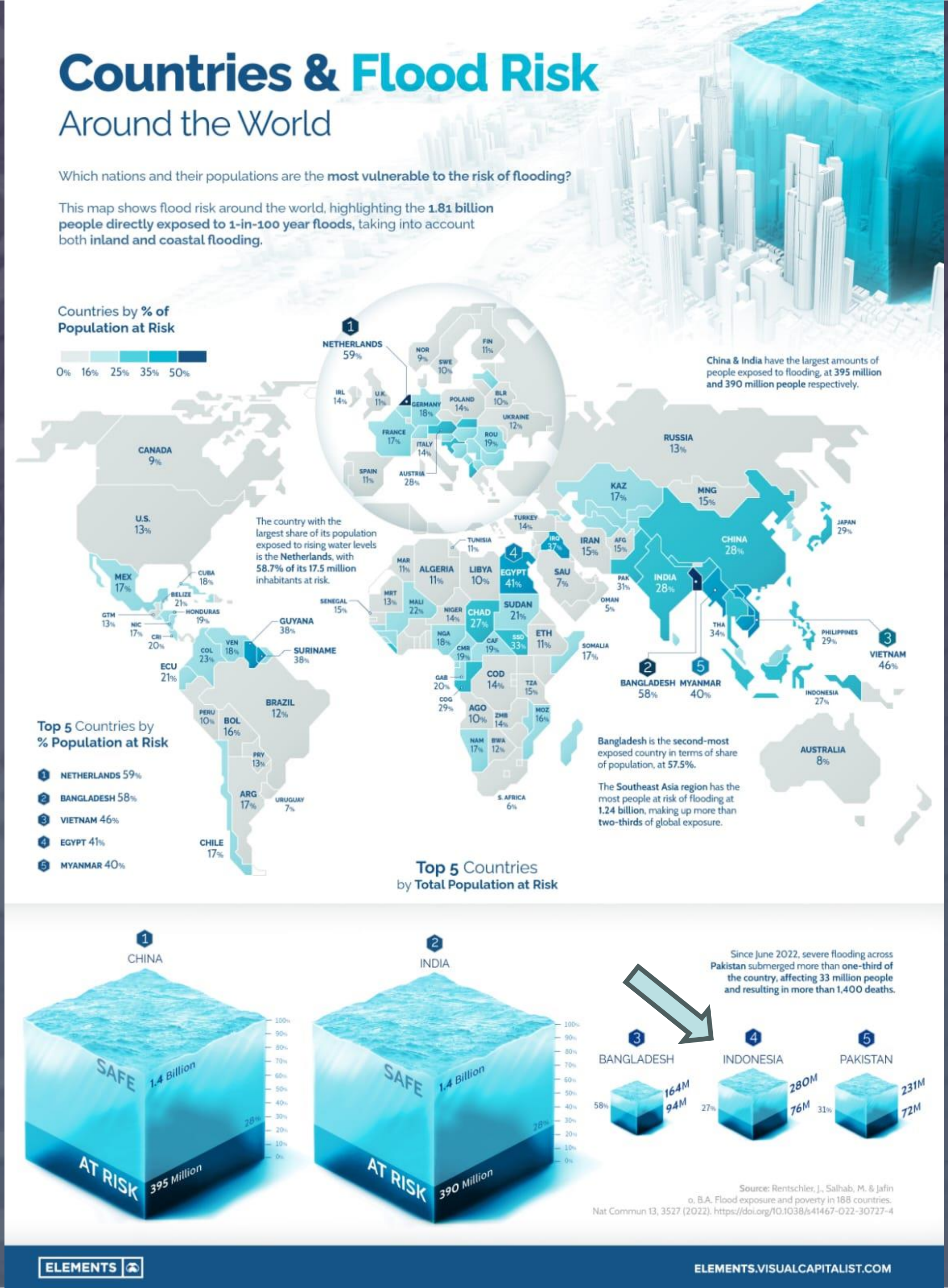
(Sudradjatt, Nastiti, Barlian, Angga 2020)

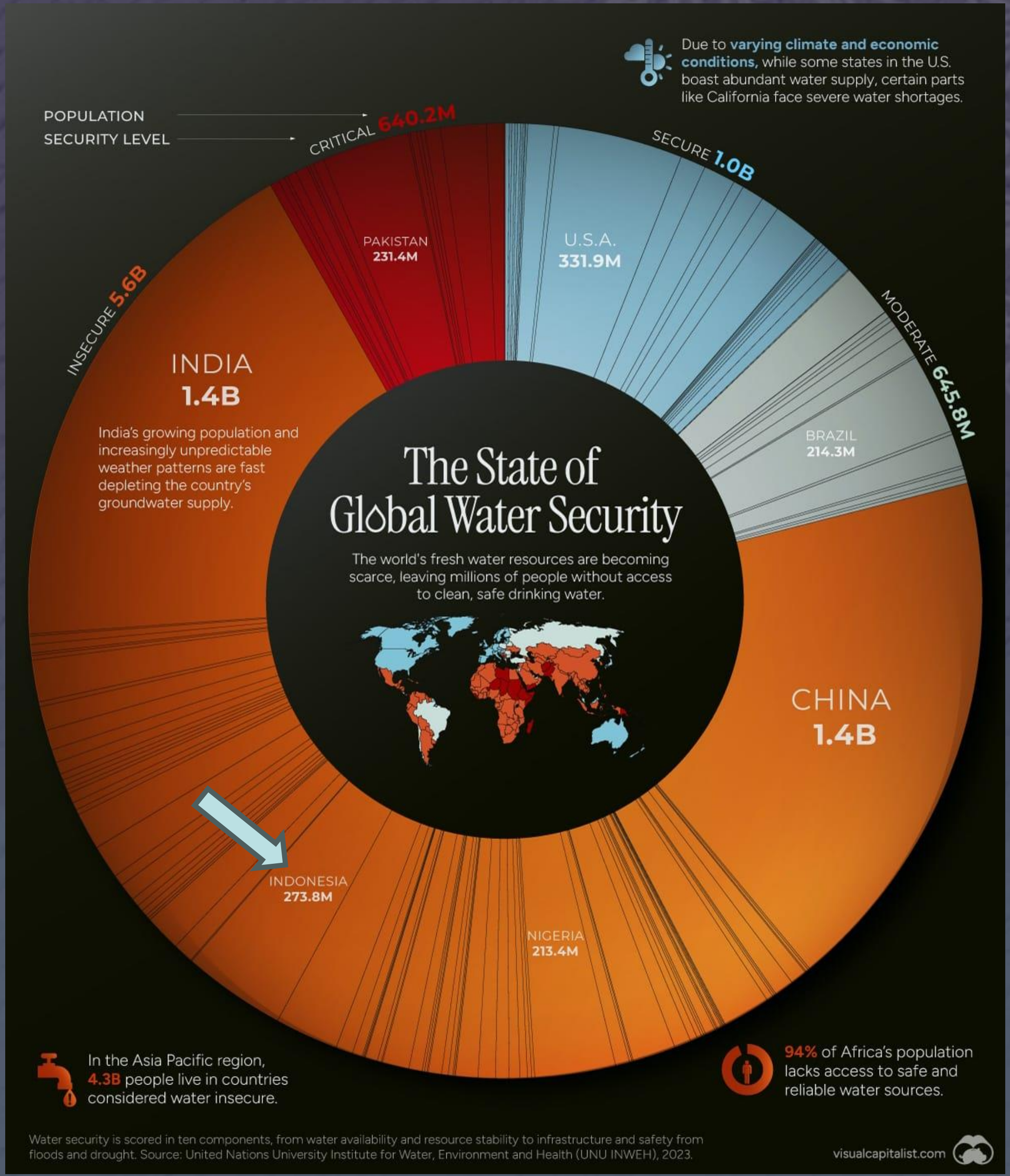


(BMKG 2021)



(BNPB 2023)


Countries & Flood Risk
Around the World
Which nations and their populations are the most vulnerable to the risk of flooding?
This map shows flood risk around the world, highlighting the 1.81 billion people directly exposed to 1-in-100 year floods, taking into account both inland and coastal flooding.
Countries by % of Population at Risk
0% 16% 25% 35% 50%
China & India have the largest amounts of people exposed to flooding, at 395 million and 390 million people respectively.
The country with the largest share of its population exposed to rising water levels is the Netherlands, with 58.7% of its 17.5 million inhabitants at risk.
Bangladesh is the second-most exposed country in terms of share of population, at 57.5%.
The Southeast Asia region has the most people at risk of flooding at 1.24 billion, making up more than two-thirds of global exposure.
Top 5 Countries by % Population at Risk
1 NETHERLANDS 59%
2 BANGLADESH 58%
3 VIETNAM 46%
4 EGYPT 41%
5 MYANMAR 40%
Top 5 Countries by Total Population at Risk
1 CHINA
SAFE 1.4 Billion
AT RISK 395 Million
2 INDIA
SAFE 1.4 Billion
AT RISK 390 Million
3 BANGLADESH 164M 94M 58%
4 INDONESIA 280M 76M 27%
5 PAKISTAN 231M 72M 31%
Since June 2022, severe flooding across Pakistan submerged more than one-third of the country, affecting 33 million people and resulting in more than 1,400 deaths.
Source: Rentschler, J., Salhab, M. & Jafino, B.A. Flood exposure and poverty in 188 countries. Nat Commun 13, 3527 (2022). https://doi.org/10.1038/s41467-022-30727-4
ELEMENTS
ELEMENTS.VISUALCAPITALIST.COM


Due to varying climate and economic conditions, while some states in the U.S. boast abundant water supply, certain parts like California face severe water shortages.
POPULATION
SECURITY LEVEL
CRITICAL 640.2M
SECURE 1.0B
MODERATE 645.8M
INSECURE 5.6B
PAKISTAN 231.4M
U.S.A. 331.9M
BRAZIL 214.3M
INDIA 1.4B
India's growing population and increasingly unpredictable weather patterns are fast depleting the country's groundwater supply.
The State of Global Water Security
The world's fresh water resources are becoming scarce, leaving millions of people without access to clean, safe drinking water.
CHINA 1.4B
INDONESIA 273.8M
NIGERIA 213.4M
In the Asia Pacific region, 4.3B people live in countries considered water insecure.
94% of Africa's population lacks access to safe and reliable water sources.
Water security is scored in ten components, from water availability and resource stability to infrastructure and safety from floods and drought. Source: United Nations University Institute for Water, Environment and Health (UNU INWEH), 2023.
visualcapitalist.com

PROYEKSI KE DEPAN INDONESIA

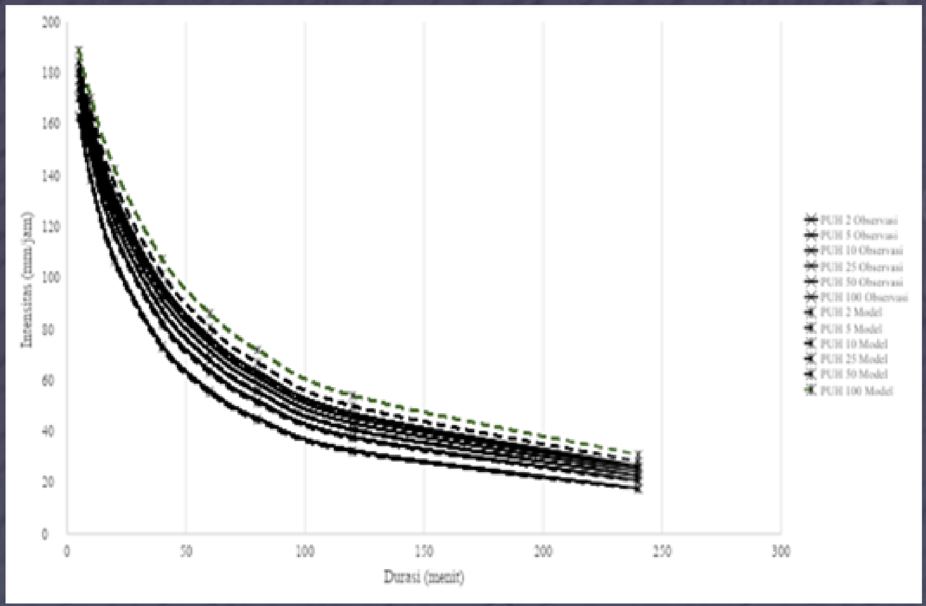
DATA GCMs CURAH HUJAN CITARUM HULU

- Data hasil simulasi GCMs merupakan data utama "terbaik" saat ini untuk prediksi variabilitas dan perubahan interdekadal jauh ke masa depan.
- Akan tetapi, resolusi spasial dan temporal GCMs masih belum sedetail sistem hujan konvektif
- Ilmu pengetahuan masih berkembang

Misal:

Untuk DAS Citarum Hulu : (Aini dan Sudradjat 2022)

(Aini dan Sudradjat 2013)



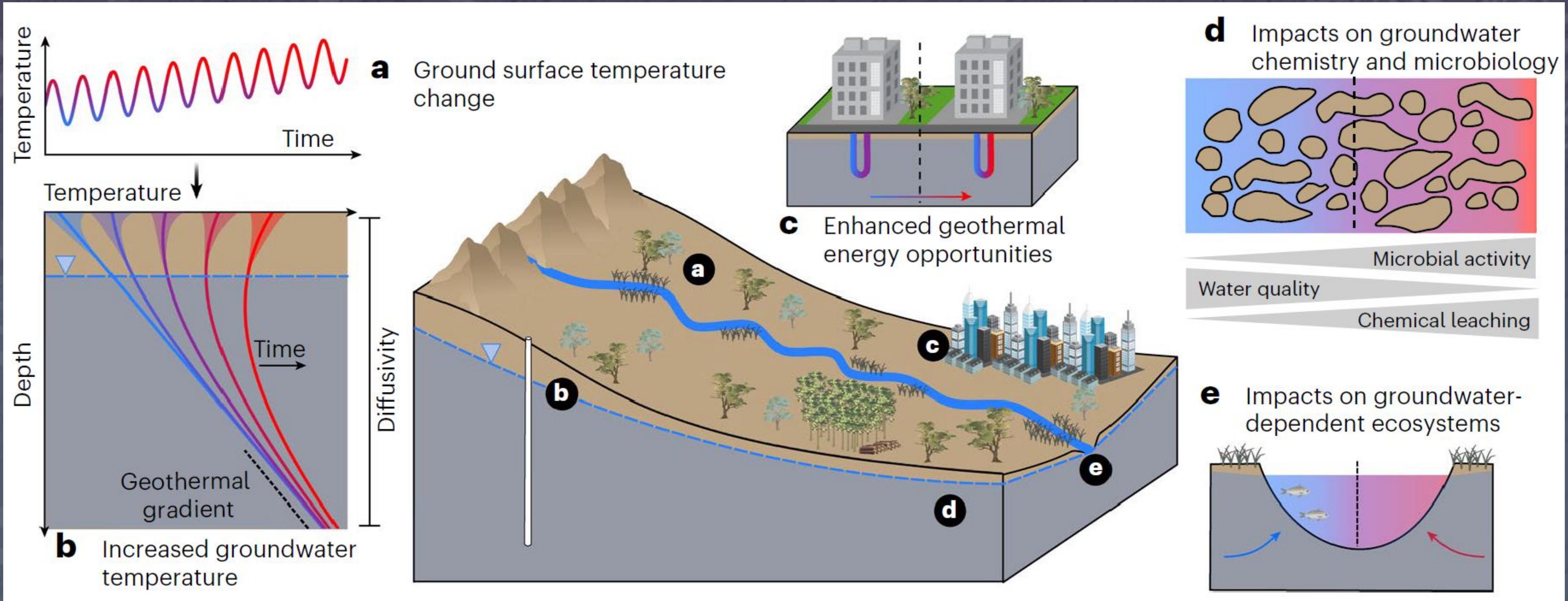
Kombinasi dampak dengan kenaikan koefisien limpasan? polusi? *biodiversity loss*? DDDT SDA?

Terindikasikan perubahan PUH ~ (-2%-16%), ekstrimitas debit, dan penurunan suplai air ~ 35% hingga 2040 (CMIP 6 GFDL-ESM4 SSP2-4.5)

- DAS Citanduy Hulu juga mengindikasikan penurunan suplai air (Radiyah dan Sudradjat 2020)
- DAS Cikapundung juga mengindikasikan penurunan suplai air (Darmawan dan Sudradjat 2024)

AIR TANAH

- Pengimbuhan dan pengambilan tidak berkelanjutan → penurunan muka air tanah
- Temperatur air tanah



(Benz 2024)

IKLIM KE DEPAN DARI BERBAGAI LITERATUR

IPCC (2021) : Climate Change 2021: The Physical Science Basis

- ❖ Siklus air global berubah akibat perubahan iklim global: peningkatan kelembaban udara dan intensitas hujan (yang disertai penurunan hari hujan) serta hujan ekstrim
- ❖ Sabuk hujan tropis berpindah ke arah Selatan
- ❖ Perubahan hujan monsoon di Asia Selatan dan Timur terbatas oleh berbagai umpan balik
- ❖ Variabilitas hujan akibat ENSO akan menguat
- ❖ Perubahan tata guna lahan dan pengambilan air tanah untuk pertanian mempengaruhi respon lokal dan regional dalam siklus air
- ❖ Urbanisasi → intensitas limpasan
- ❖ Kemampuan model-model masih memiliki keterbatasan untuk siklus air
- ❖ Variabilitas internal hujan adalah sumber ketidakpastian dalam prediksi ke depan

Staal et al. (2020), Smith et al. (2023) : deforestasi di wilayah tropis menyebabkan penurunan curah hujan (tahunan 6.2 ± 2.5 mm per bulan di tahun 2100 dengan 30% deforestasi) di Asia Tenggara dan kekeringan wilayah. Dampak tersebut semakin besar sesuai dengan skala spasial.

Wei et al. (2024) : deforestasi terutama di wilayah Indonesia, mempengaruhi ENSO, dengan meningkatkan kemungkinan diikutinya El Nino langsung oleh La Nina.

Cai et al. (2020) : perubahan iklim menaikkan frekuensi kejadian IOD positif kuat dan menurunkan frekuensi kejadian IOD positif menengah

Cai dan Cowan (2009) : perubahan iklim meningkatkan frekuensi kejadian IOD positif secara berurutan

Cai et al. (2023) : frekuensi kejadi El Niño dan La Niña kuat meningkat setelah 1960

Byrne et al. (2018) : ITCZ diprojeksikan menyempit dan melemah

Zhang (2023) : pemanasan global memungkinkan kejadian La Niña multi-tahun

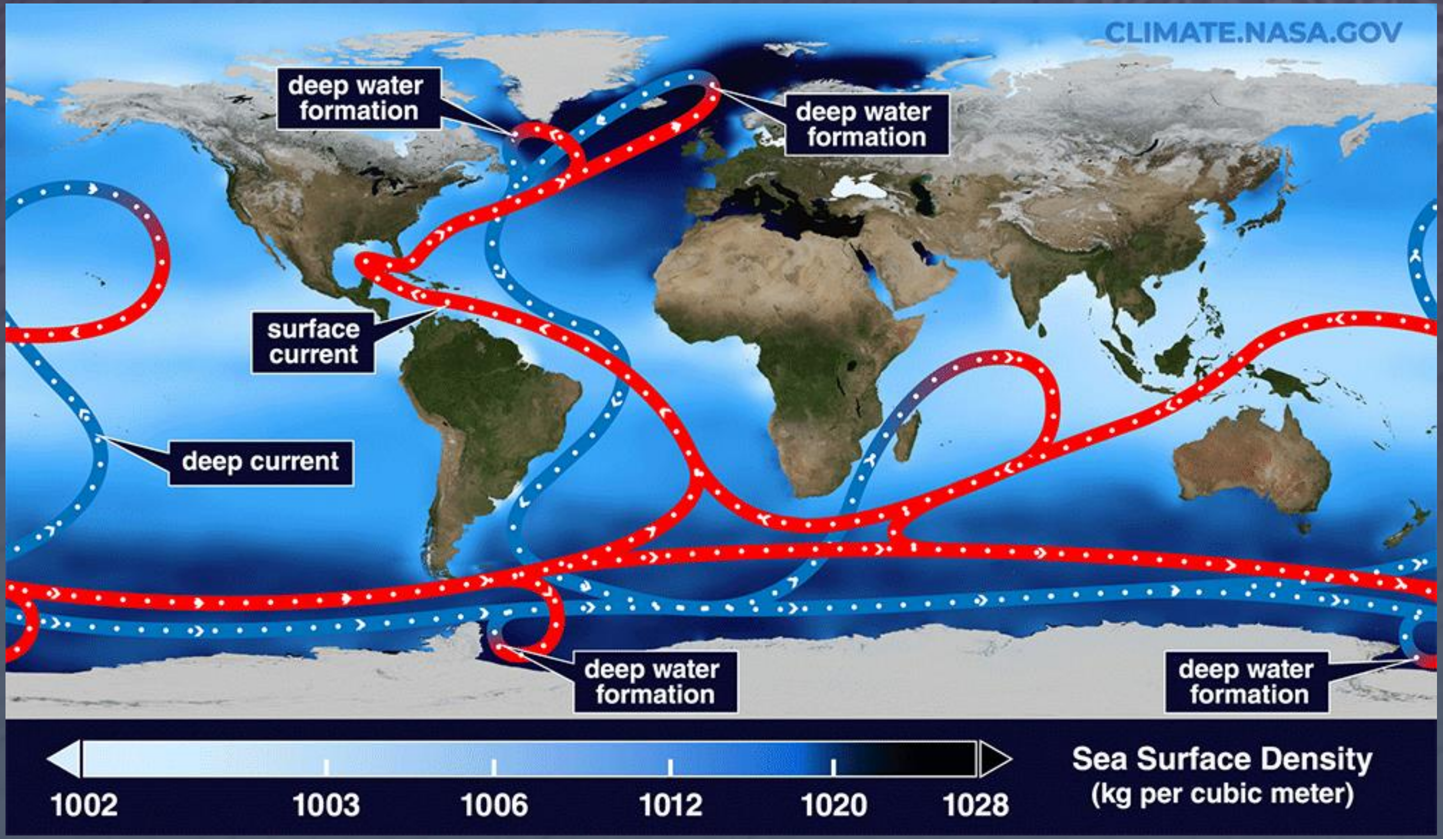
Liu et al. (2024) : ITCZ bergerak ke utara selama 20 tahun ke depan, selanjutnya bergerak ke selatan

GLOBAL COOLING?

"very likely cause abrupt shifts in regional weather patterns and the water cycle … include a southward shift in the tropical rain belt, weakening of the African and Asian monsoons, strengthening of Southern Hemisphere monsoons, and drying in Europe … impacts that would greatly alter food production worldwide."

https://science.nasa.gov/earth/earth-atmosphere/slowdown-of-the-motion-of-the-ocean/

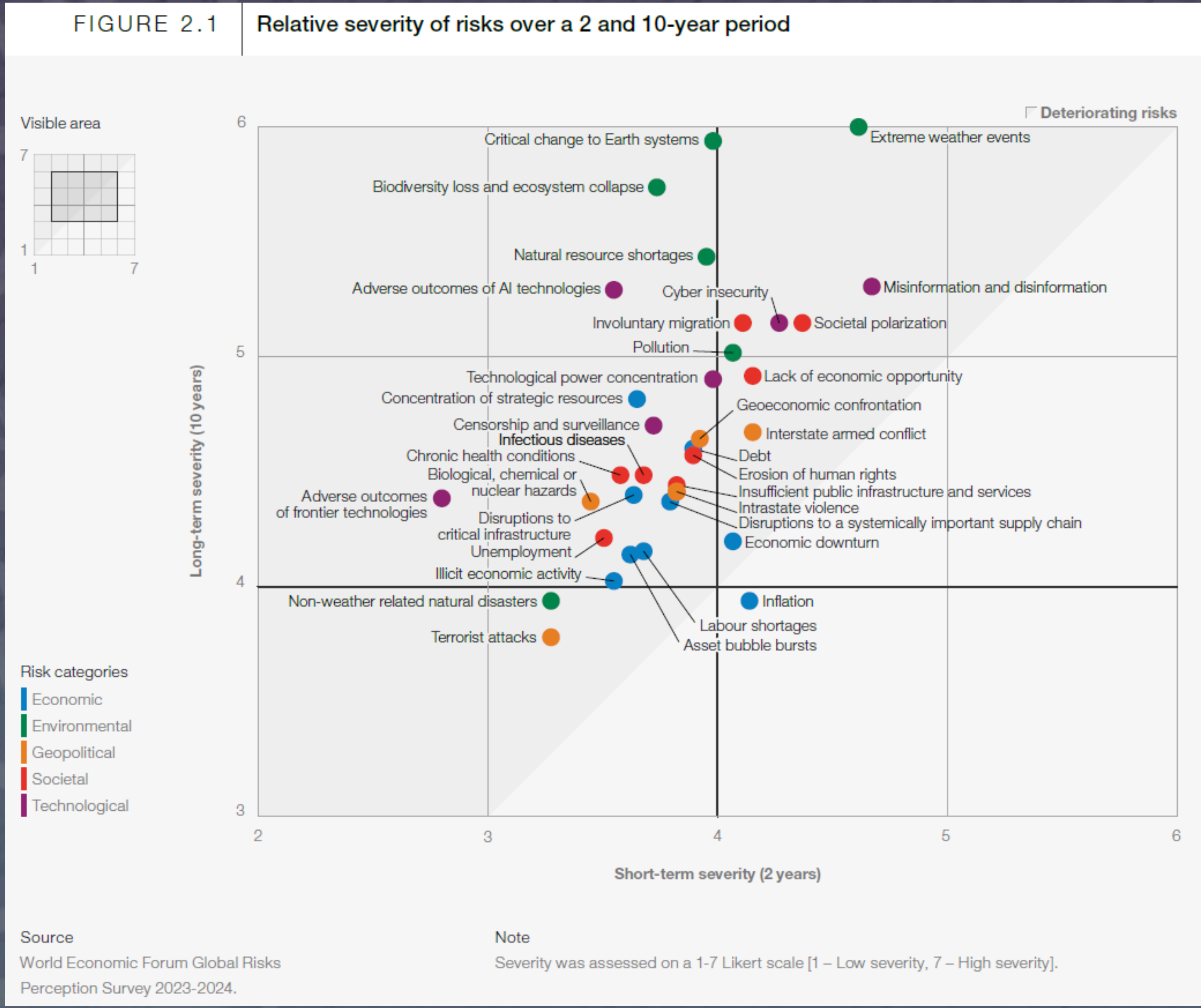
"We estimate a collapse of the AMOC to occur around mid-century under the current scenario of future emissions." (Ditlevsen dan Ditlevsen 2023)



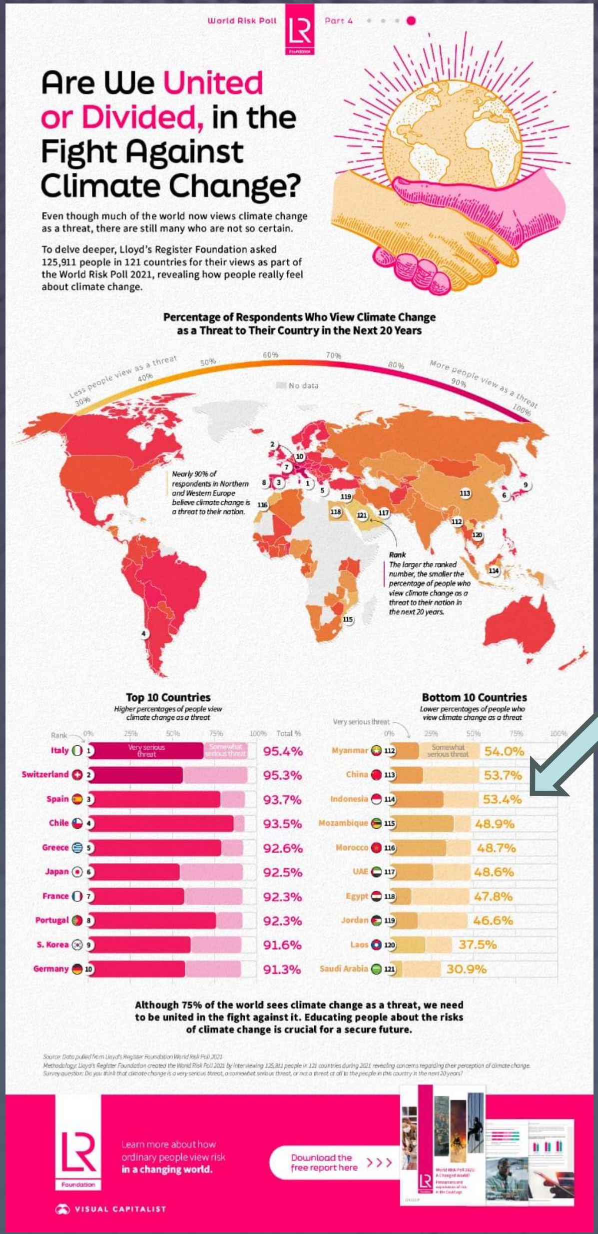
MEMBANGUN PENGELOLAAN AIR BERKETAHAN IKLIM

SURVEY

- Para ahli: Keparahan relatif berbagai ancaman global untuk periode 2 dan 10 tahun ke depan.
- Masyarakat: Perubahan iklim sebagai ancaman 20 tahun ke depan?



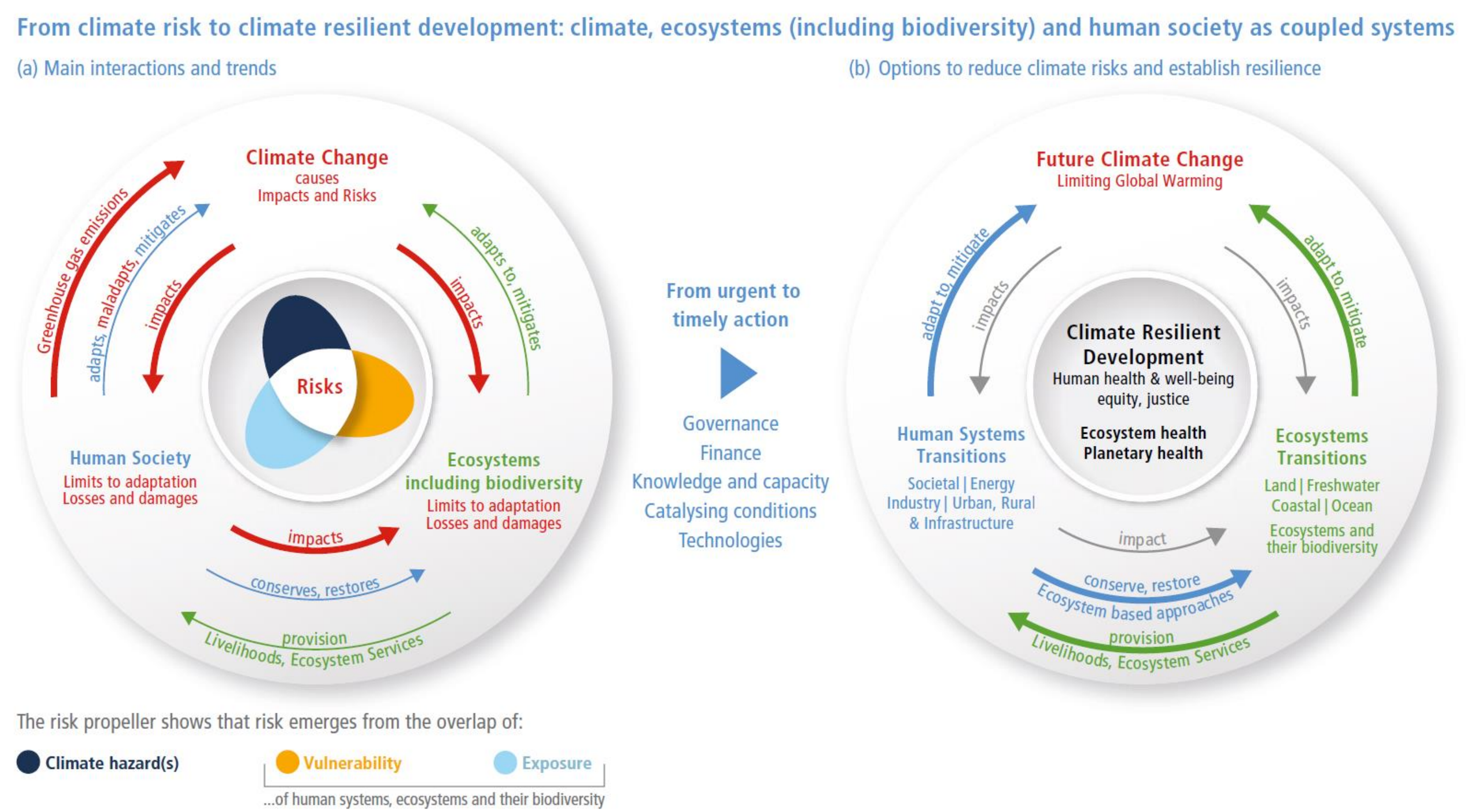
(WEF 2024)



BERKETAHANAN IKLIM

Pengembangan ketahanan berbasis sistem (alami dan manusia) dan meliputi :

- ❖ Kegiatan : Konservasi, Pendayagunaan, Pengendalian Daya Rusak
- ❖ Komponen : *Reflect, Relief, Resist, Response, dan Recovery,* plus *Remodeling* untuk *transformation*
- ❖ Dimensi : lingkungan, fisik, ekonomi, sosial, dan institusional-tata kelola
- ❖ Level : individu-nasional, subharian-dekadal, subkilometer-nasional
- ❖ Tujuan : *Learn, Survive, Adapt, Recover, Thrive & Sustainable*.



(IPCC 2022)

DPSIR Sistem Sumber Daya air-Lingkungan-Manusia Ex.

Drivers

- Pertumbuhan penduduk
- Kegiatan ekonomi (termasuk globalisasi dan FDI)
- Urbanisasi
- Pembangunan infrastruktur dan permukiman
- Inovasi
- Variabilitas dan perubahan iklim

Pressures

- Konsumsi SDAir & lainnya
- Pencemaran SDAir, tanah, udara
- Perubahan LULC, termasuk deforestasi
- Variabilitas dan perubahan suhu, hujan, fenomena iklim
- Kenaikan muka air laut

State

(belum tentu semua DAS di Indonesia)

- Status 4K & karakteristik fikibi SDAir & air minum & peruntukkan lainnya
- Status koefisien limpasan
- Status *water security*
- Status DDDT SDAir

Impact

- Polusi, deplesi, integritas ekologis SDAir
- Banjir dan kekeringan
- Penurunan muka tanah
- Kerusakan fisik bangunan & infrastruktur
- Penurunan kesehatan masyarakat
- Degradasi ekosistem
- Eksternalitas
- Konflik (isu kesetaraan dan keadilan)
- Kesejahteraan

Responses

- Penelitian
- Pengajaran
- Pengabdian kepada masyarakat

Jaman Anthropocene
Abad Urban

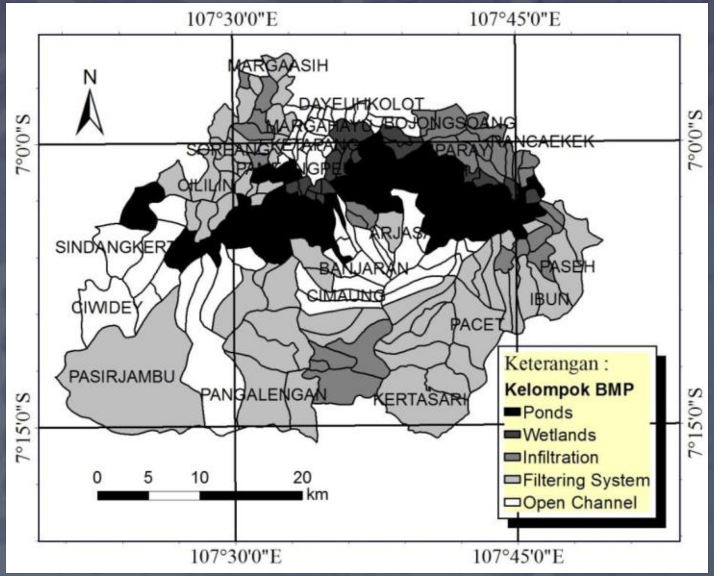
RESPON KE DEPAN?

TRANSFORMASI BERSAMA

Keilmuan:

- Data (lapangan, satelit, model) dan analisis
- Indikator & metrik ketahanan iklim
- Proyeksi iklim, hidrologi, ketahanan

(panduan; sesuai skala waktu dan spasial yang dibutuhkan; AI)



(Hanastasia dan Sudradjat 2016)

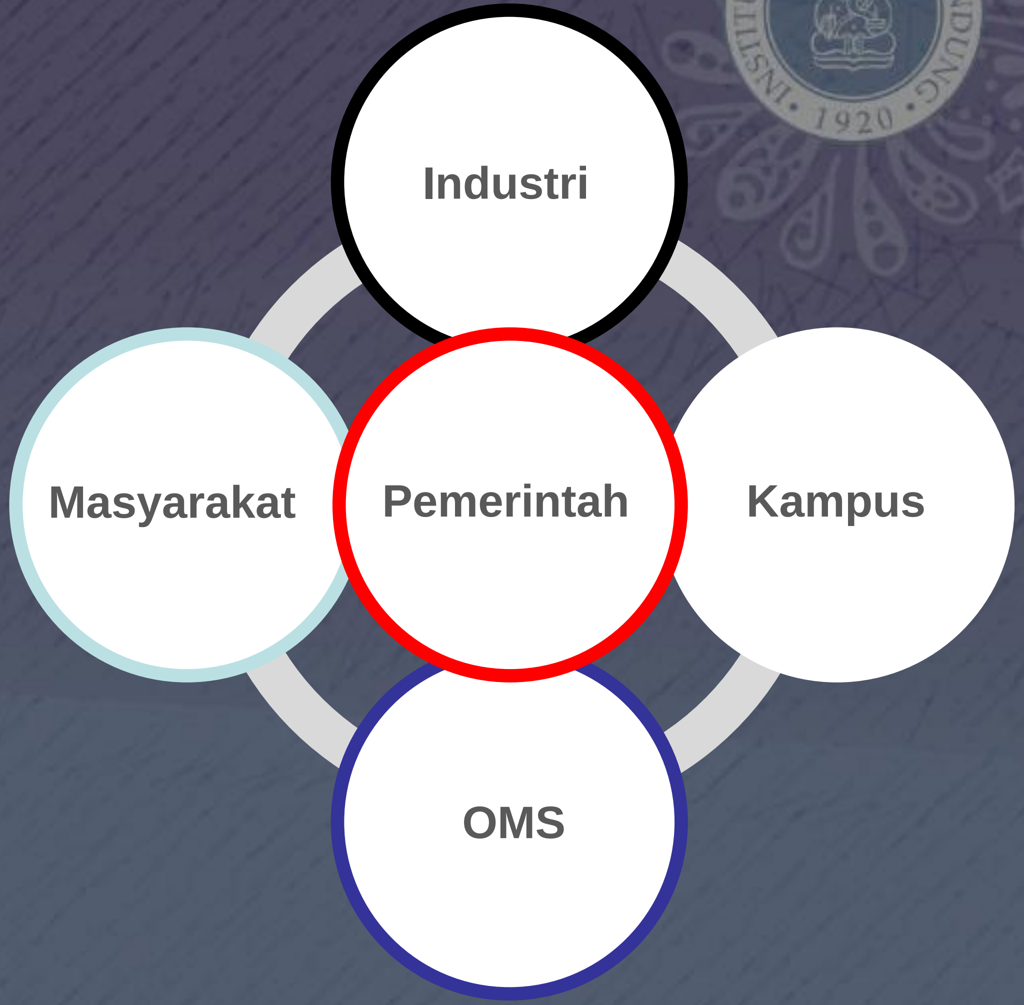
Kebijakan dan Pengelolaan

- Pengelolaan sumber daya air berketahanan iklim berbasis sistem
- Peningkatan peran individu dalam pengelolaan lingkungan
- Sistem data satu sumber
- Minimasi tapak karbon
- Minimasi tapak air (*demand*, efisiensi, suplai, bauran air)
- *Eco-Nature based solutions*, misal: *LID/GI*, yang terintegrasi dengan infrastruktur *grey*; rehabilitasi ekosistem; rehabilitasi air tanah; rehabilitasi pesisir; penyimpanan air tanah; *LULC*, dlsb.

kapasitas, sistem, ekosistem, *inclusive*, *equity*, *biodiversity*, *no greenwashing*

Pengabdian kepada Masyarakat

- Mendukung komponen-komponen *penta helix* untuk pengelolaan air yang berketahanan iklim dan berkelanjutan (bukan hanya kuantitas): strategi dan kebijakan, rencana pembangunan, regulasi, dan standar, serta implementasi
- Mitra : Bappenas, KLHK, Kemenkes, PUPR, WB, ADB, Pertamina
- Contoh : CRWSP, NPWI, Bauran Air Domestik, RPJMN/P 2015, 2020, 2025 dan 2025-2045, Rencana Teknokratis PUPR 2025-2030 dan 2025-2045, *eco-nature-based solutions*, *online monitoring* kualitas air permukaan, lokasi prioritas pengelolaan lingkungan.



Penelitian (SCOPUS: *h-index* 7 & sitasi 205)

Drivers

- Carbon footprint
- Kesesuaian lahan

Pressures

- Climate variability
- Water footprint

State

- Remote sensing
- Indices: Log Reduction Value, LID/GI I90, Flood and Drought Resilience Indices
- Perhitungan koefisien limpasan

Impact

- Statistical, physical, and dynamic systems modeling
- Precipitation statistical downscaling
- Teleconnection
- On water supply

Responses

- Valuasi
- Framework
- Strategy and policy
- GIS application
- DDDTSumber Daya Air

List: https://scholar.google.com/citations?hl=en&user=AKpaIlEAAAAJ&view_op=list_works&sortby=pubdate

Drivers

- Hidrologi dan Hidrogeologi
- Pengelolaan Lingkungan Air Terpadu
- Sustainability

Pressures

- Hidrologi dan Hidrogeologi
- PLAT
- Transport dan Transformasi Polutan

State

- Hidrologi dan Hidrogeologi
- PLAT
- TTP
- StatLing
- ESG

Impact

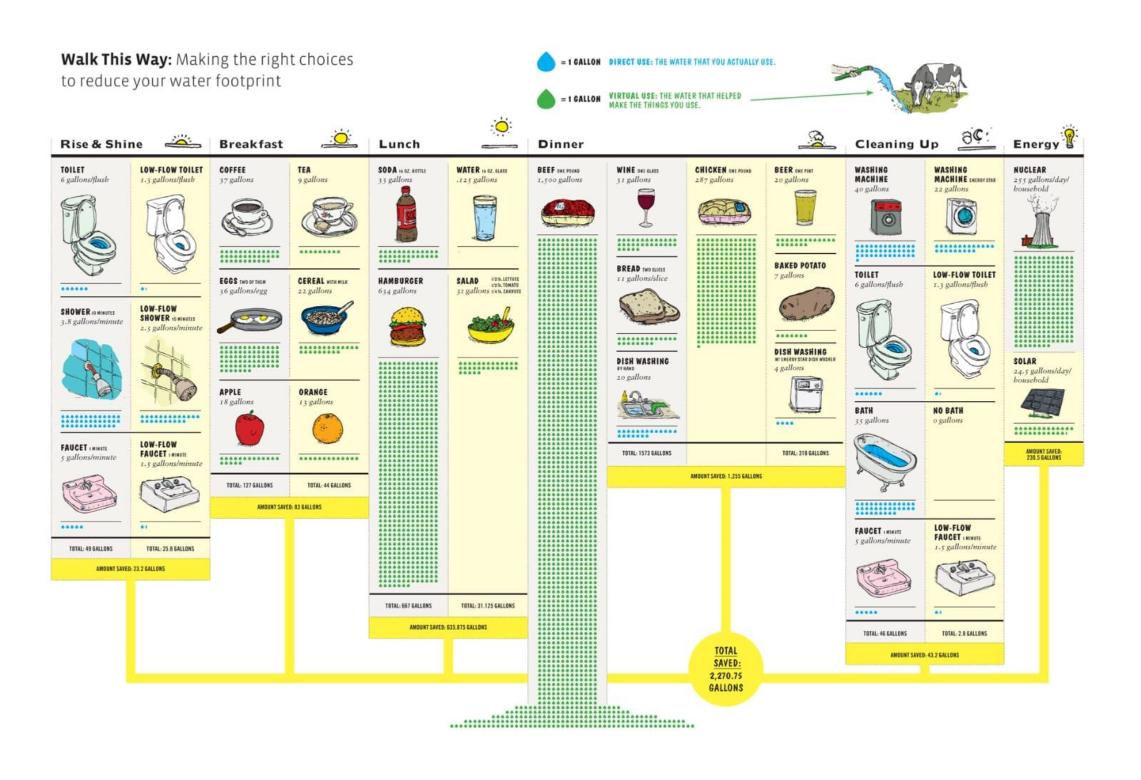
- StatLing
- Hidrologi dan Hidrogeologi
- PLAT
- Analisis Sistem Pengelolaan Lingkungan
- TTP
- Pemodelan Lingkungan
- Ekonomi Lingkungan dan Valuasi

Responses

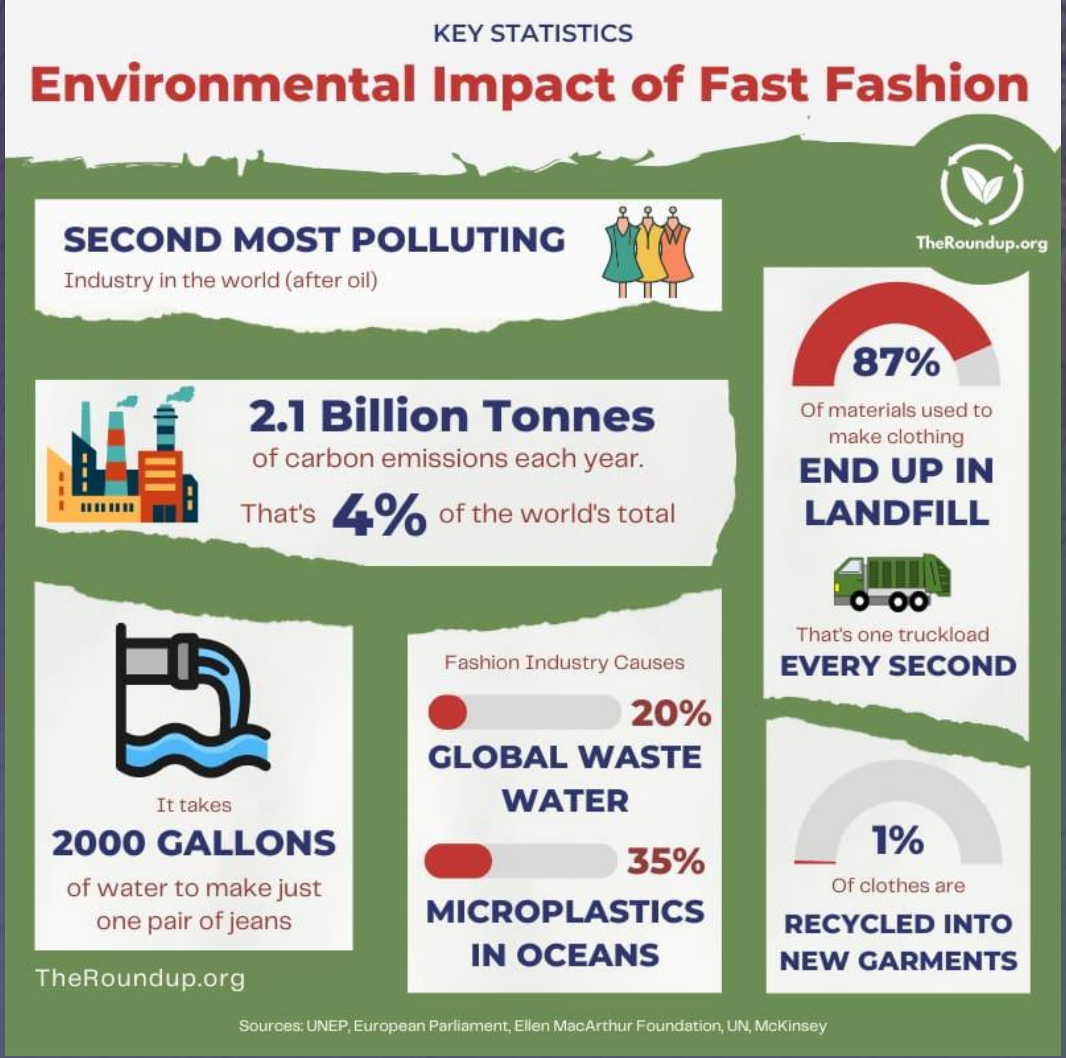
- Kebijakan Lingkungan
- EkLIngVal
- ASPL
- Penelitian Operasi
- PLAT
- Pembangunan Berketahanan Iklim
- Keamanan Air

JAGA AIR, HEMAT AIR, SIMPAN AIR.
Air dan kehidupan adalah dua sisi dari satu koin,
tiada salah satu satu tanpa yang lainnya.

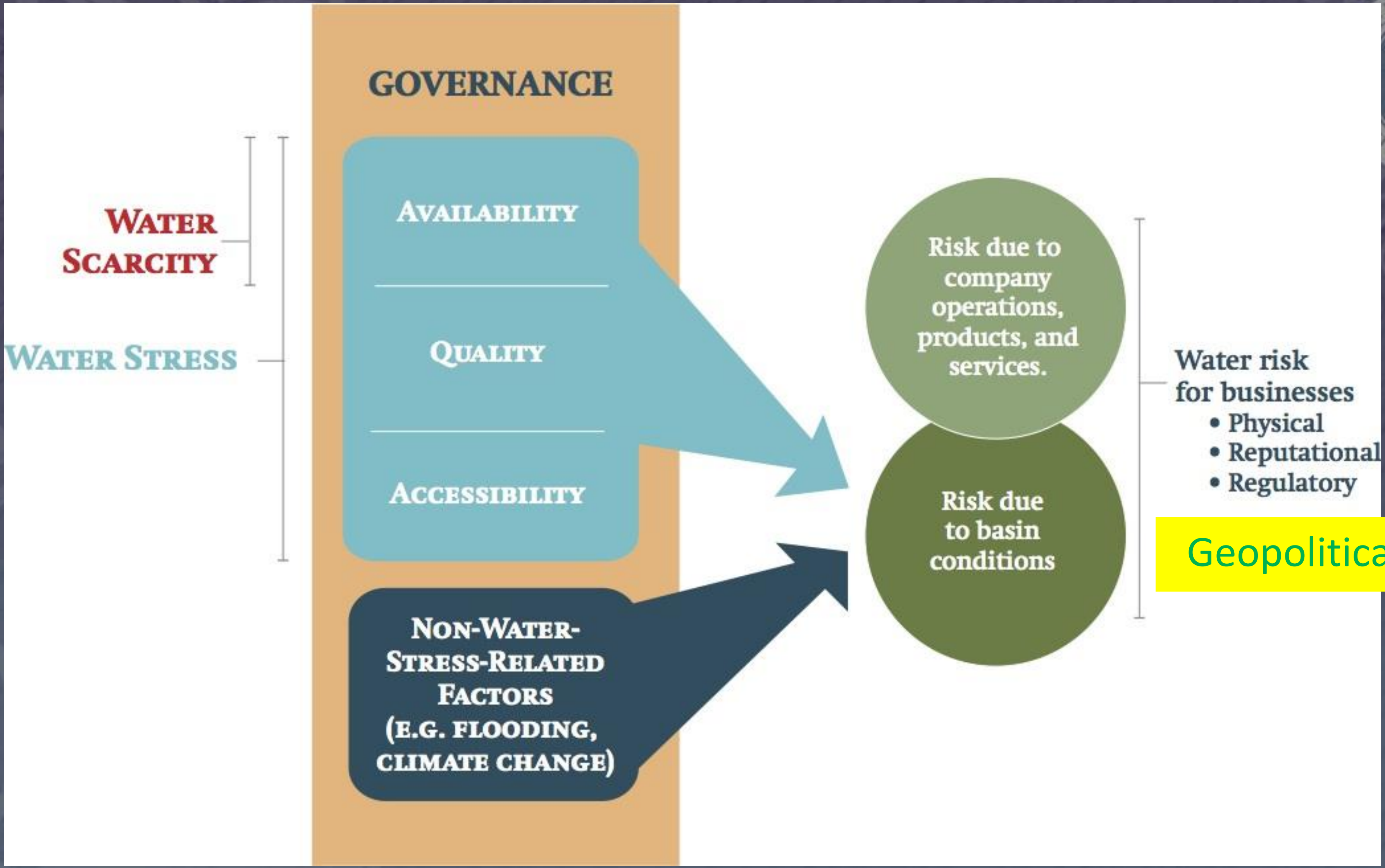
TERIMA KASIH



Walk This Way: Making the right choices to reduce your water footprint
= 1 GALLON DIRECT USE: THE WATER THAT YOU ACTUALLY USE.
= 1 GALLON VIRTUAL USE: THE WATER THAT HELPED MAKE THE THINGS YOU USE.
Rise & Shine
Breakfast
Lunch
Dinner
Cleaning Up
Energy
TOTAL SAVED: 2,270.75 GALLONS



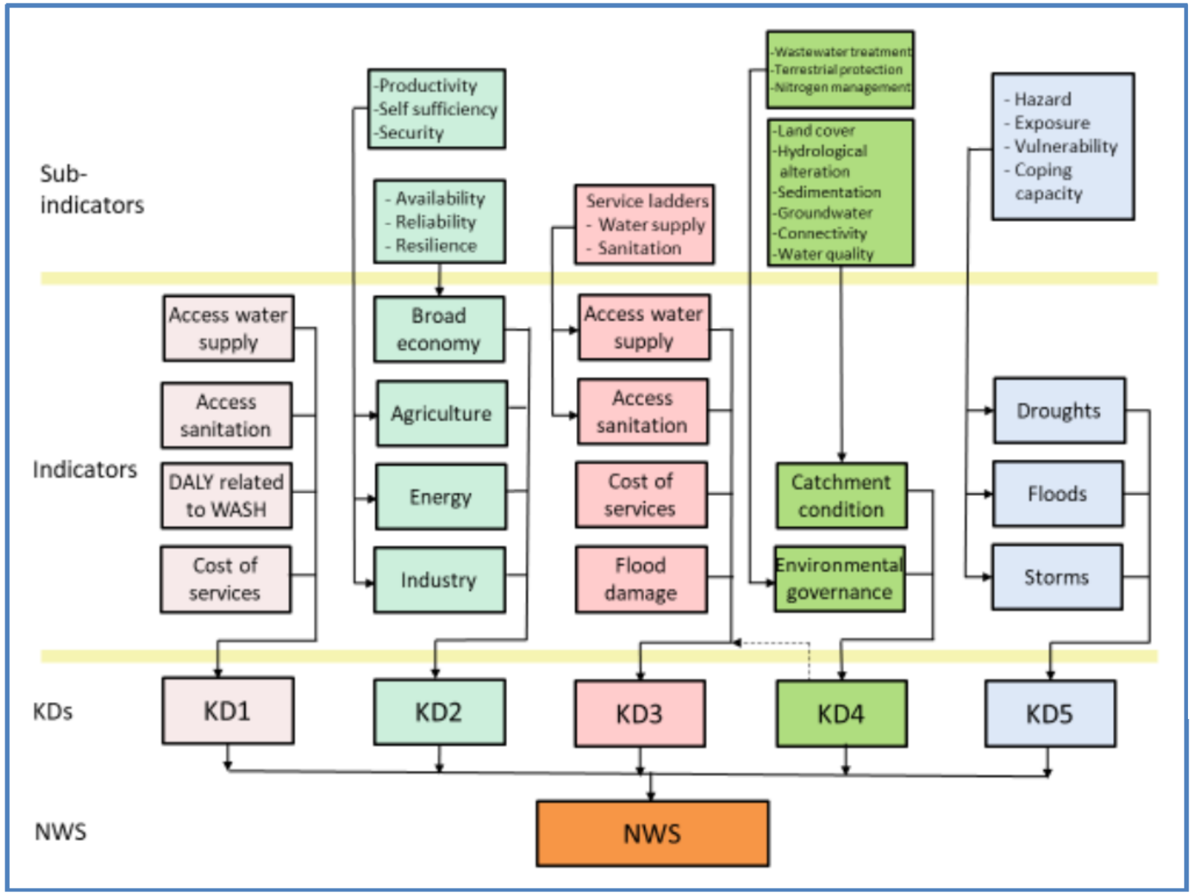
KEY STATISTICS
Environmental Impact of Fast Fashion
SECOND MOST POLLUTING
Industry in the world (after oil)
TheRoundup.org
2.1 Billion Tonnes
of carbon emissions each year.
That's 4% of the world's total
87%
Of materials used to make clothing
END UP IN LANDFILL
That's one truckload
EVERY SECOND
It takes
2000 GALLONS
of water to make just one pair of jeans
Fashion Industry Causes
20%
GLOBAL WASTE WATER
35%
MICROPLASTICS IN OCEANS
1%
Of clothes are
RECYCLED INTO NEW GARMENTS
TheRoundup.org
Sources: UNEP, European Parliament, Ellen MacArthur Foundation, UN, McKinsey



Geopolitical?

(CEO Water Mandate, 2014)

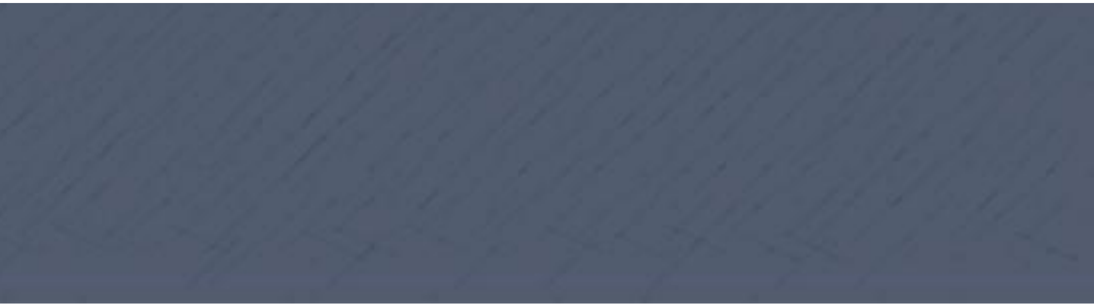
(UNU-INWEH 2023)



DALY = disability-adjusted life year; KD = key dimension; NWS = national water security; WASH = water, sanitation, and hygiene.
Source: Asian Development Bank.

Table 1. Water security components, indicators, and data sources assessed at a national level.

	Water Security Component	Indicator(s) Used in this Assessment	Associated SDG Indicator(s)	Data Sources
1	**Drinking water**	Proportion of the population using basic to safely managed drinking water (%)	6.1.1: Proportion of the population using safely managed drinking water services	JMP (WHO and UNCICEF)
2	**Sanitation**	Proportion of the population using basic to safely managed sanitation (%)	6.1.2a: Proportion of the population using safely managed sanitation services	JMP (WHO and UNCICEF)
3	**Good health**	Mortality rate attributed to exposure to unsafe Water Sanitation and Hygiene (WASH) (deaths per 100,000 population)	3.9.2: Mortality rate attributed to unsafe water, unsafe sanitation, and lack of hygiene (exposure to unsafe Water, Sanitation, and Hygiene for All (WASH) services)	WHO
4	**Water quality**	Proportion of household wastewater treatment (%)	6.3.1: Proportion of domestic and industrial wastewater flows safely treated	WHO; Jones et al., 2021
5	**Water availability**	Level of water stress: freshwater withdrawal as a proportion of available freshwater resources (%)	6.4.2: Level of water stress: freshwater withdrawal as a proportion of available freshwater resources	FAO AQUASTAT
6	**Water value**	Water Use Efficiency (USD/m^3)	6.4.1 Change in Water Use Efficiency over time	FAO AQUASTAT
7	**Water governance**	Degree of Integrated Water Resource Management (%)	6.5.1 Degree of Integrated Water Resource Management (%)	IWRM data portal UNEP / DHI
8	**Human safety**	Mortality due to water-disasters (deaths per 100,000 population)	1.5.1, 11.5.1, 13.1.1 Number of deaths, missing persons, and directly affected persons attributed to disasters per 100,000 population	EM-DAT IHME
9	**Economic safety**	Modelled economic impact of floods (% of national GDP) Modelled drought risk (non-dimensional integer)	1.5.2, 11.5.2: Direct economic losses attributed to disasters in relation to global gross domestic product (GDP)	WRI Aqueduct
10	**Water resource stability**	Interannual variability (non-dimensional integer) Large dam storage /capita (m^3/capita)	None None	WRI Aqueduct ICOLD WRD



(ADB 2020)

Risk			
HIGH	Medium Combined Vulnerability and Risk	High Combined Vulnerability and Risk	High Combined Vulnerability and Risk
MED	Low Combined Vulnerability and Risk	Medium Combined Vulnerability and Risk	High Combined Vulnerability and Risk
LOW	Low Combined Vulnerability and Risk	Low Combined Vulnerability and Risk	Medium Combined Vulnerability and Risk
	LOW	MED	HIGH
	Vulnerability		

(a) Example flooding rulesets for the components of vulnerability.

Level	Sensitivity	Adaptive Capacity
High	Structure in inundation extent & criticality of impact is high	Building in floodplain, most recent floodplain development regulations apply or no structure in floodplain
Medium	Structure in inundation extent	Building in floodplain built after flood-plain development requirements were put in place, some regulations apply
Low	No structure in inundation extent (land only)	Building in floodplain built before any floodplain development requirements were in place

(a) Example high, medium, and low rulesets for a flooding assessment

Level	Probability	Magnitude of Impact
High	Structure in inundation extent & criticality of impact is high	Structure exposed to potential flood depth 1.5ft or greater in wave action zones OR 3ft or greater in stillwater zones
Medium	Structure in inundation extent	Potential flood depth between -2 ft to 1.5ft in wave action zones OR 1ft to 3ft in stillwater zones
Low	No structure in inundation extent (land only)	Potential flood depth less than -2ft in wave action zones OR less than 1ft in stillwater zones

(b) Vulnerability classification into three groups.

Sensitivity			
HIGH	Medium Vulnerability	High Vulnerability	High Vulnerability
MED	Low Vulnerability	Medium Vulnerability	High Vulnerability
LOW	Low Vulnerability	Low Vulnerability	Medium Vulnerability
	HIGH	MED	LOW
	Adaptive Capacity		

(b) Classifications of risk. Source: Fernleaf.

Probability			
HIGH	Medium Risk	High Risk	High Risk
MED	Low Risk	Medium Risk	High Risk
LOW	Low Risk	Low Risk	Medium Risk
	LOW	MED	HIGH
	Magnitude of Impact		

Hazards	Climate Stressors	Non-climate Stressors
Tidal Flooding	Sea level rise	Aging infrastructure
	Heavy precipitation	Increased development/impervious surfaces
Storm Surge	Sea level rise	Aging infrastructure
	Tropical systems	Increased development/impervious surfaces
Floodplain Inundation	Sea level rise	Increased development/impervious surfaces
	Increase in rainfall frequency/intensity	Aging/undersized infrastructure
Extreme Heat	Temperature variability	Increased development/impervious surfaces
		Socioeconomic vulnerability
Wildfire	Drought (water shortage and vegetation dessication)	Wildland-Urban Interface/fuels & vegetation, historic fire suppression
	Temperature variability	Human-caused ignitions, historic fire suppression
Landslides	Increase in rainfall frequency/intensity, high temperatures, and snowstorms	Development/vegetation removal

Community Assets	Hazards			
	Flooding	Landslides	Wildfire	Extreme Heat
City-owned Facilities	×	×		×
Commercial Properties	×	×	×	
Residential Properties	×	×	×	
Endangered Fish Population	×			×

(Gardiner et al. ed. 2022)