Evaluationg and dealing with droughts in the wake of climate change: Approaches and solutions adapted to Thailand

UNIKASSEL VERSITÄT
Geohydraulik und Ingenieurhydrologie

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Mae Chang reservoir in Lampang province

Jao Jed irrigation canal in Ayutthaya's Phak Hai district

Table of contents

1. Introduction/
   Thailand general climate and hydrological characteristics
   Thailand 2020 drought situation

2. Drought /definition/overview

3. Types of drought

4. Causes of drought

5. Consequences of drought

6. Quantitative evaluation of droughts
   Drought indices
   The global forecast drought tool

7. Drought mitigation and relief
   Thailand generally
   Thailand/Bangkok

8. Conclusions

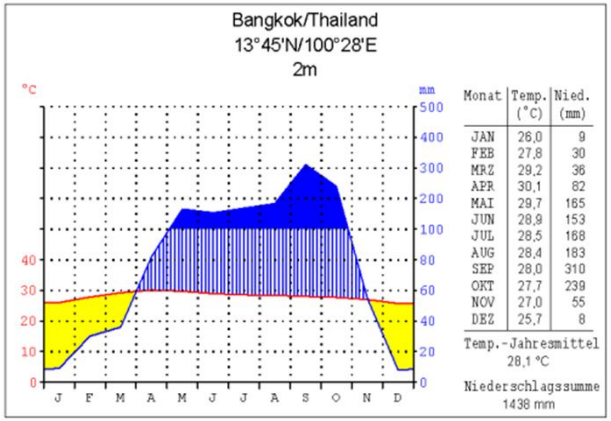
1. Introduction/ Thailand's general climate/hydrological characteristics

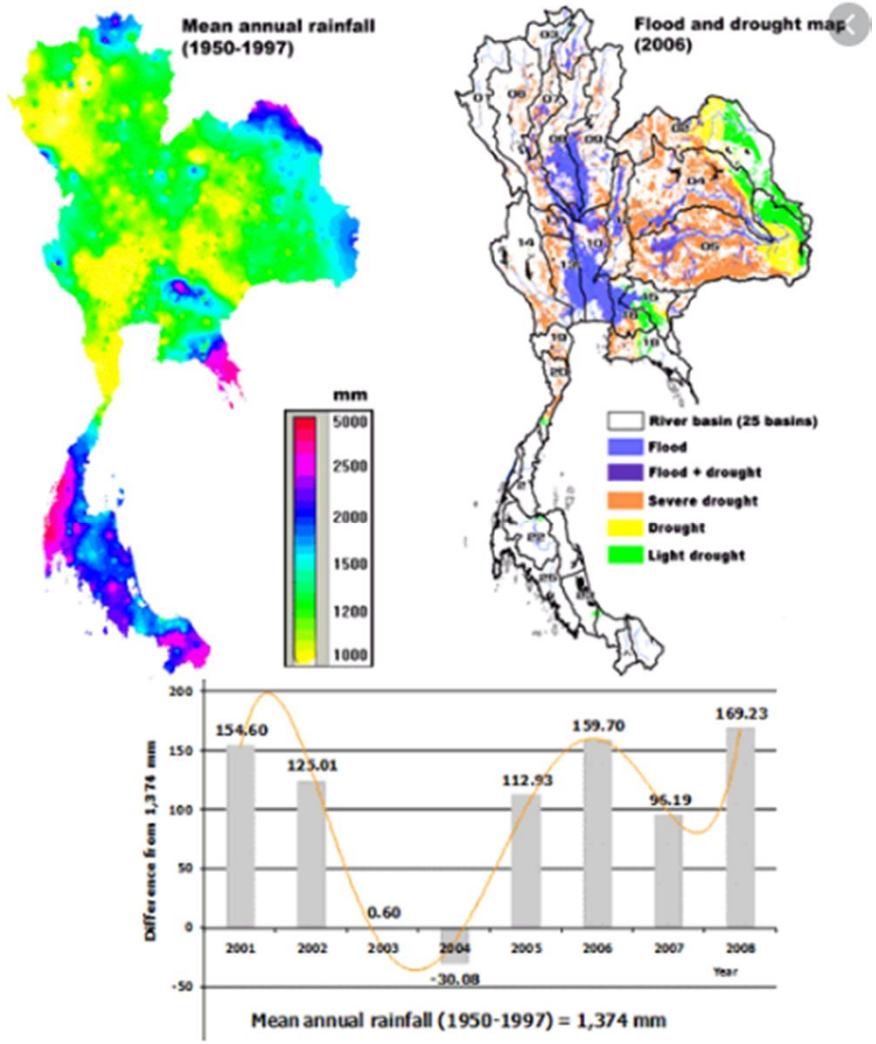
Most of Thailand has a "tropical wet and dry or savanna climate" type (Köppen's Tropical savanna climate).

Majority of the south as well as the eastern tip of the east have a tropical monsoon climate.

Climate of Thailand is divided into three seasons.

1) Rainy or southwest monsoon season (mid-May to mid-October) with abundant rain (also by cyclones) in August and September (=> floods!!).
2) Winter or the northeast monsoon starts from mid-October until mid-February. Most of the country experiences dry weather with mild temperatures (=> droughts!)
3) Summer or the pre-monsoon season (mid-February to mid-May) is characterized by warmer weather

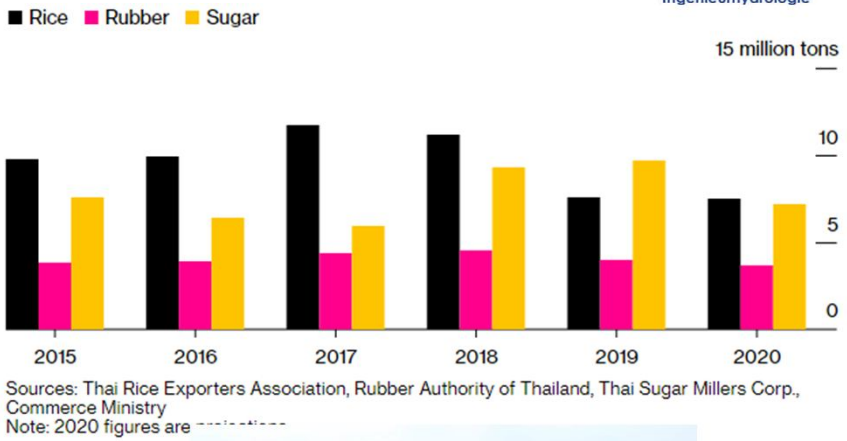




1. Introduction/ Thailand 2020 drought situation

Thailand has been hit with its worst drought in 40 years and declared disaster zones in 20 provinces in central, northern and northeastern regions.

⇒ Pummelling sugar production in one of the world's biggest exporters of the sweetener, with output tummbling about 30% to 9 million tonnes



Sources: Thai Rice Exporters Association, Rubber Authority of Thailand, Thai Sugar Millers Corp., Commerce Ministry
Note: 2020 figures are

Particularly adversely impacted is Phayao district

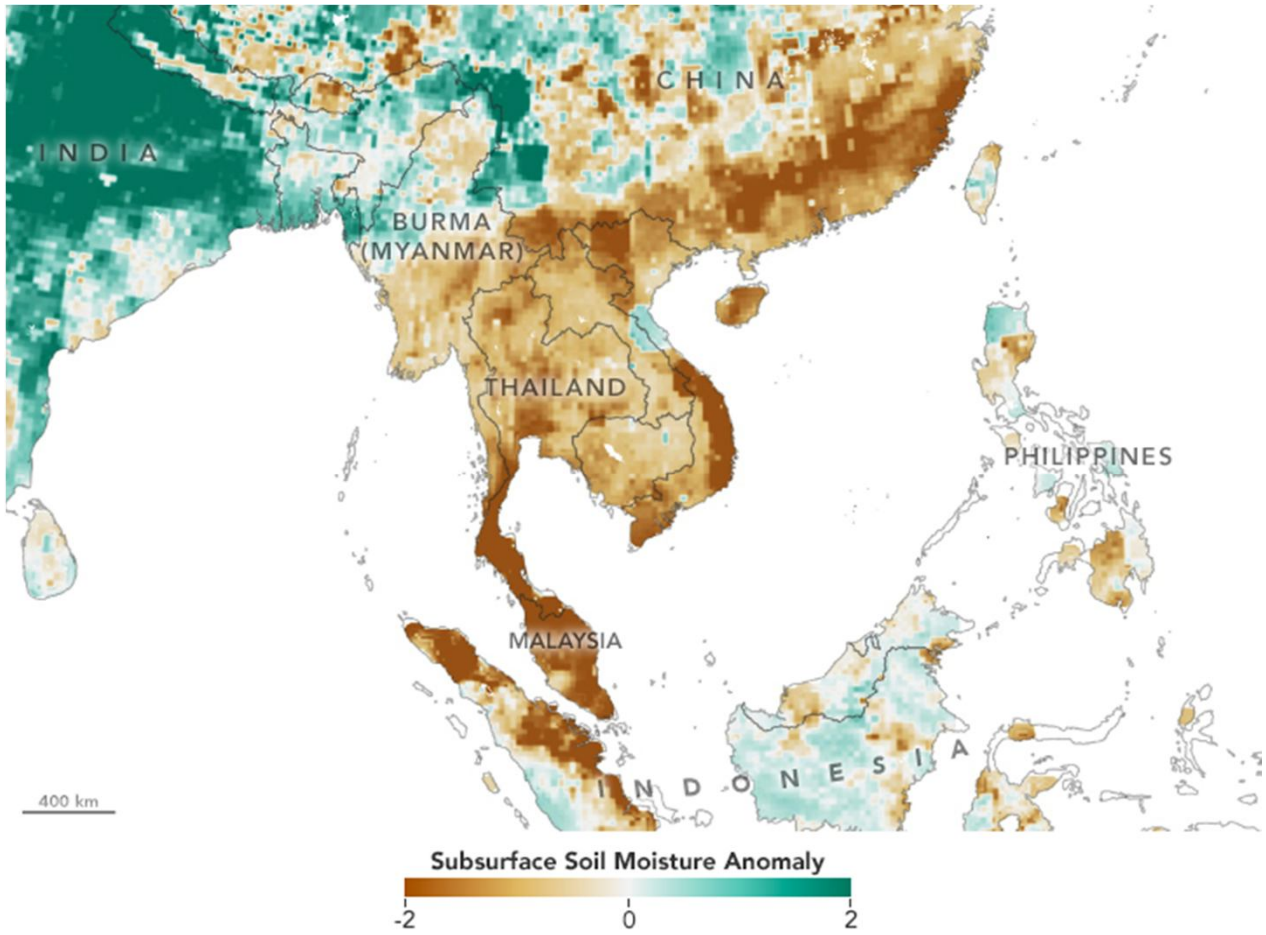
=> Remedial short term initiative is to dredge Nong Leng Sai watershed area clogged by ediments.

Parched rice and sugar cane fields in northern provinces

1. Introduction/ Thailand 2020 drought situation

Soil Moisture Active Passive (SMAP) mission, the first NASA satellite dedicated to measuring the water content of soils.

SMAP's radiometer can detect water in the top 5 centimeters of the ground allowing to estimate how much water is present even deeper in the root zone important for agriculture.



1. Introduction/ Thailand 2020 drought situation

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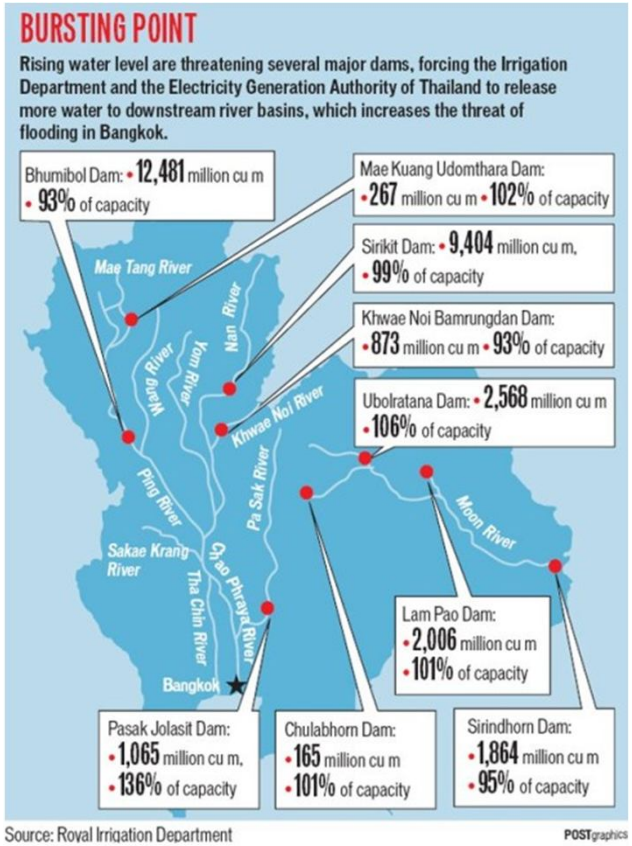
Dam situation

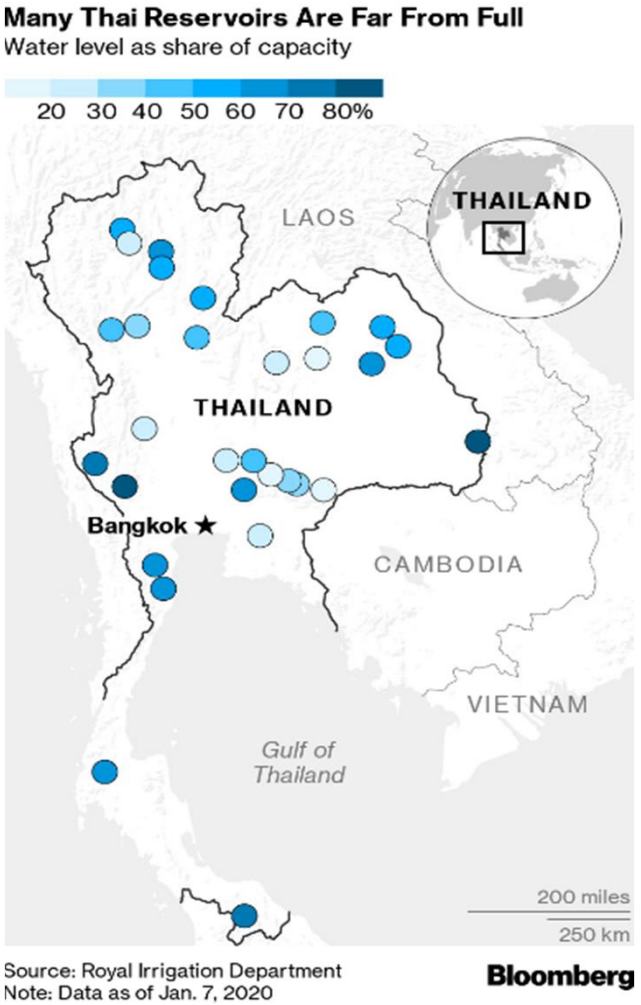
October 2011 flood season



Bhumibol 2011

Bhumibol now?

January 2020 drought



1. Introduction/ Thailand 2020 drought situation

Water in the Chao Phraya dam reservoir, Chai Nat provinc,
is at a critically low level of only 13.45 metres, below the standard retention level of 16.50m.

Chao Phraya dam is currently discharging water at a of 75 million cubic metres per second – only enough to maintain the ecological system and push back salty water in the Chao Phraya river.

To sustain this flow an to ease influx of sea water into the Chao Phraya River, water from the Mae Klong River, Ratchaburi province, will be diverted through a network of canals (Klong Ban Nong) into the river.

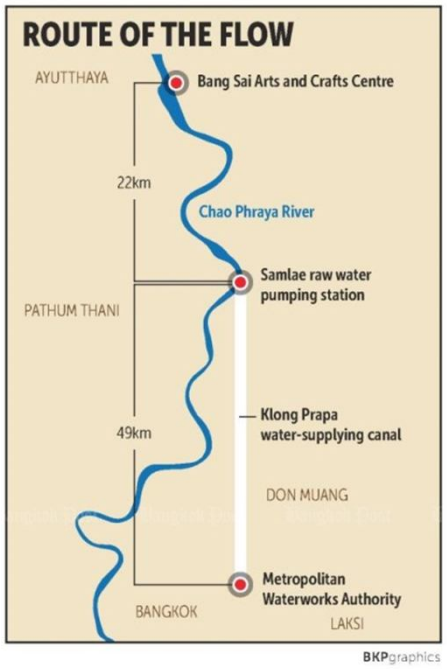
1. Introduction/ Thailand 2020 drought situation

Samlae water pumping station on high alert because of entering salty raw water leading to salinity levels of 520 mg/L (WHO standard: 250 mg/L) .

⇒ Replenishing of water into the Chao Phraya River by diverting water from the Mae Klong River to Tha Chin River via the Phraya Banlue canal and then to Chao Phraya River, Ayutthaya province, of about 200,000 cbm/day needed to maintain quality of tap water?

⇒ Increasing flow of water from the Chao Phraya dam to 100cbm/sec and from Pasak Jolasid dam to 11 cbm/second.

⇒ Substitute intake of Samlae pumping station by intake upstream at Bang Sol Centre.



2. Drought /definition/overview

A **drought** is an event of prolonged shortages in the water supply, whether atmospheric (below-average precipitation), surface water or ground water. A drought can last for months or years, or may be declared after as few as 15 days. It can have a substantial impact on ecosystem and agriculture of the affected region[and harm the local economy.

Annual dry seasons in the tropics significantly increase the chances of a drought developing and subsequent bush fires.

Periods of heat can significantly worsen drought conditions by hastening evaporation of water vapour.

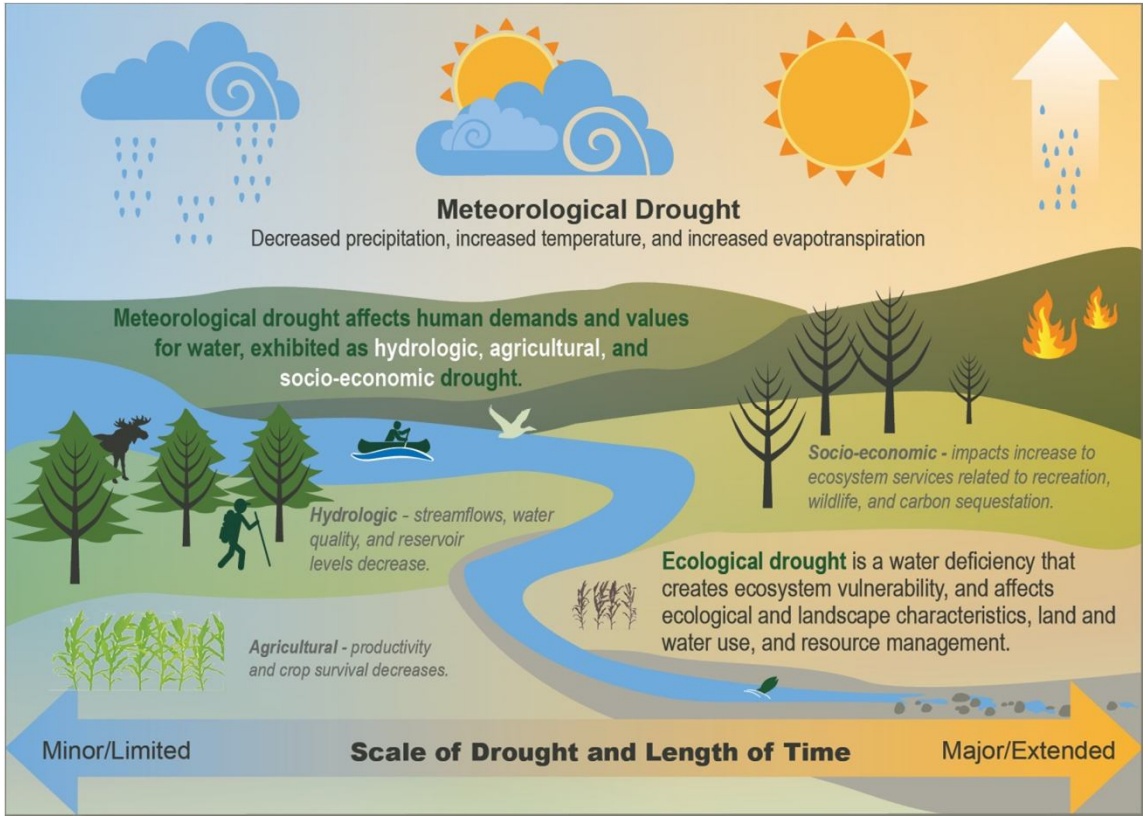
https://video.nationalgeographic.com/video/00000144-0a2c-d3cb-a96c-7b2d6b200000

3. Types of droughts

Meteorological drought occurs when there is a prolonged time with less than average precipitation. It usually precedes the other kinds of drought.

Agricultural droughts affect crop production or the ecology of the range. Can also arise independently, irrespective of precipitation levels when increased irrigation or soil conditions and erosion triggered by poorly planned agricultural endeavors cause a shortfall in water available to the crops. However, it is normally caused by an extended period of low precipitation.

Hydrological drought is brought about when the water reserves available in sources such aquifers, lakes and reservoirs fall below a locally significant threshold. Hydrological drought tends to show up more slowly because it involves stored water that is used but not replenished.



4. Causes of drought

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1) Precipitation deficiency

a) Seasonal cycle variations of atmospheric pattern ,namely, in tropical regions, with wet and dry seasons emerging due to the movement of the Intertropical Convergence Zone or Monsoon trough.

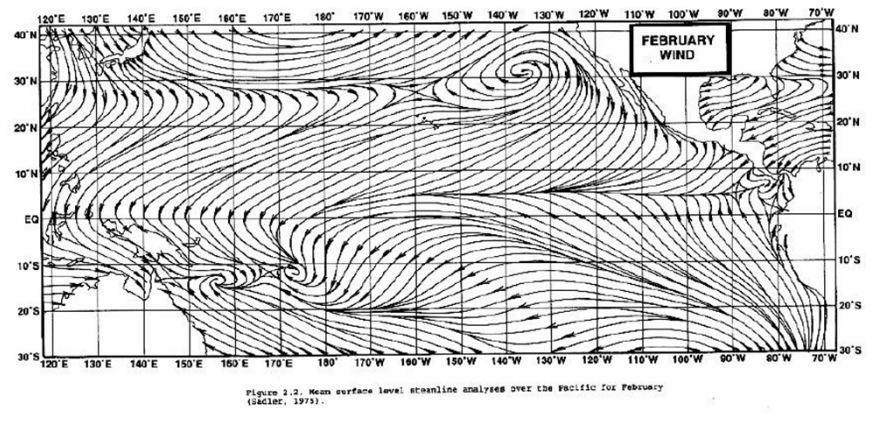

Figure 2.2. Mean surface level streamline analyses over the Pacific for February (Sadler, 1975).

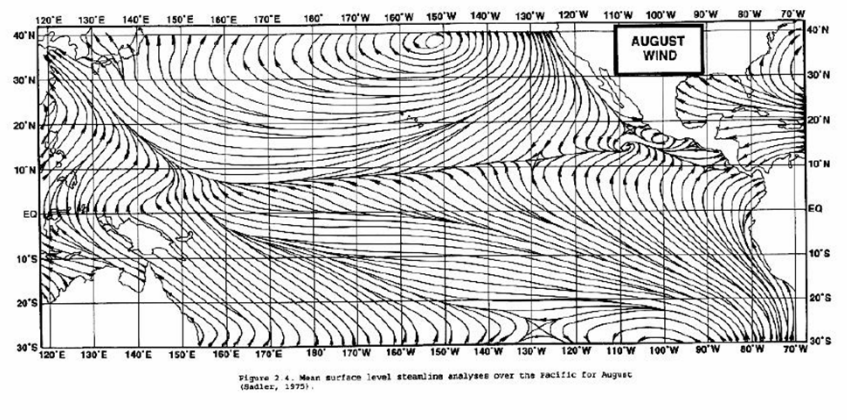

Figure 2.4. Mean surface level streamline analyses over the Pacific for August (Sadler, 1975).

4. Causes of drought

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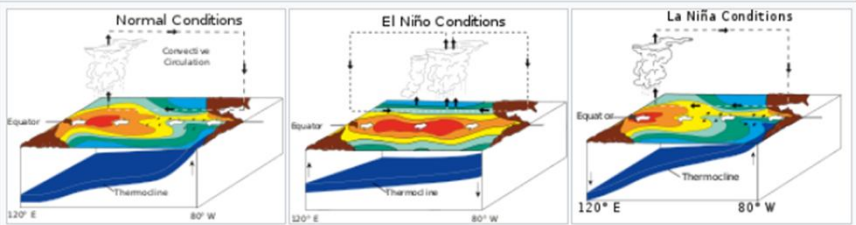
1) Precipitation deficiency (mainly eastern and western Pacific regions)

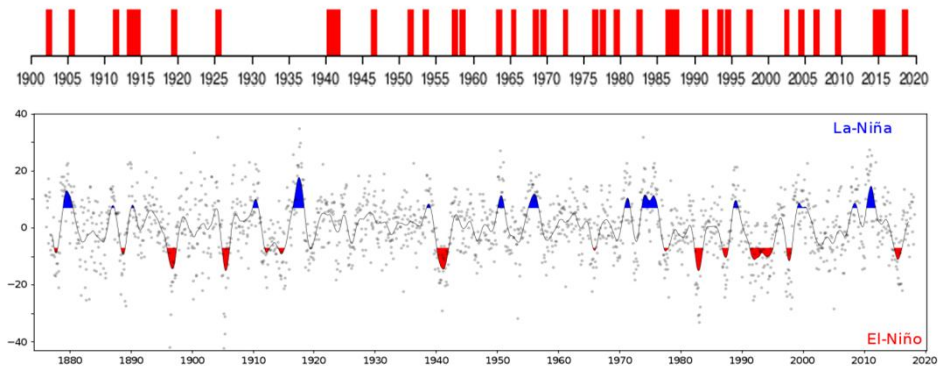
b) ENSO (El Nino-La Nina) Pacific atmospheric/oceanic multiyear pattern

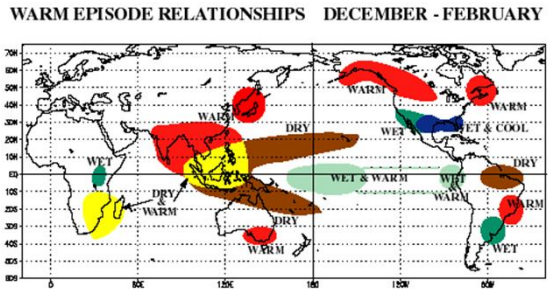


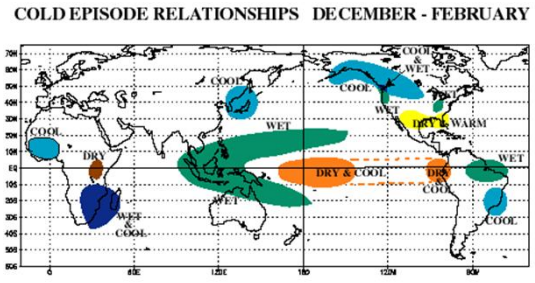
Normal Pacific pattern: Equatorial winds gather warm water pool toward the west. Cold water upwells along South American coast. (NOAA / PMEL / TAO)

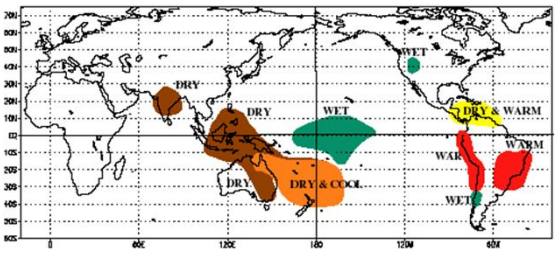
El Niño conditions: Warm water pool approaches the South American coast. The absence of cold upwelling increases warming.

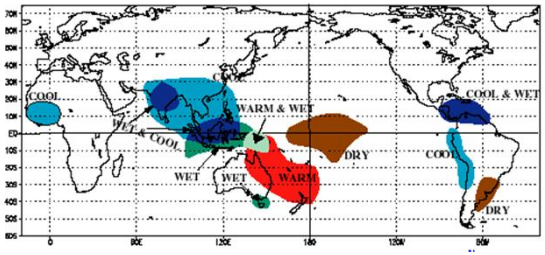
La Niña conditions: Warm water is farther west than usual.

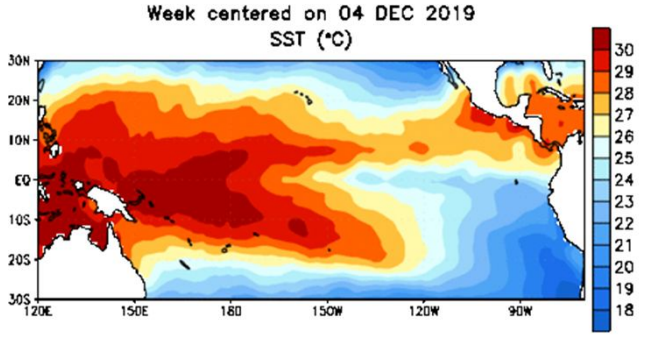












https://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/enso.shtml#history

4. Causes of (agricultural, hydrological) drought

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2) Erosion and human activities

- Over farming,
- excessive irrigation (salinization of soil)
- deforestation,
- erosion adversely impact the ability of the land to capture and hold water. In arid climates, main source of erosion is wind which leads to abrasion of soils, namely, Loess which under normal climate conditions is very fertile .

Wind erosion accentuated by drought.

Example: the Great Plains , US, agricultural drought of the 1930's (**Great dust bowl**)

4. Causes of drought

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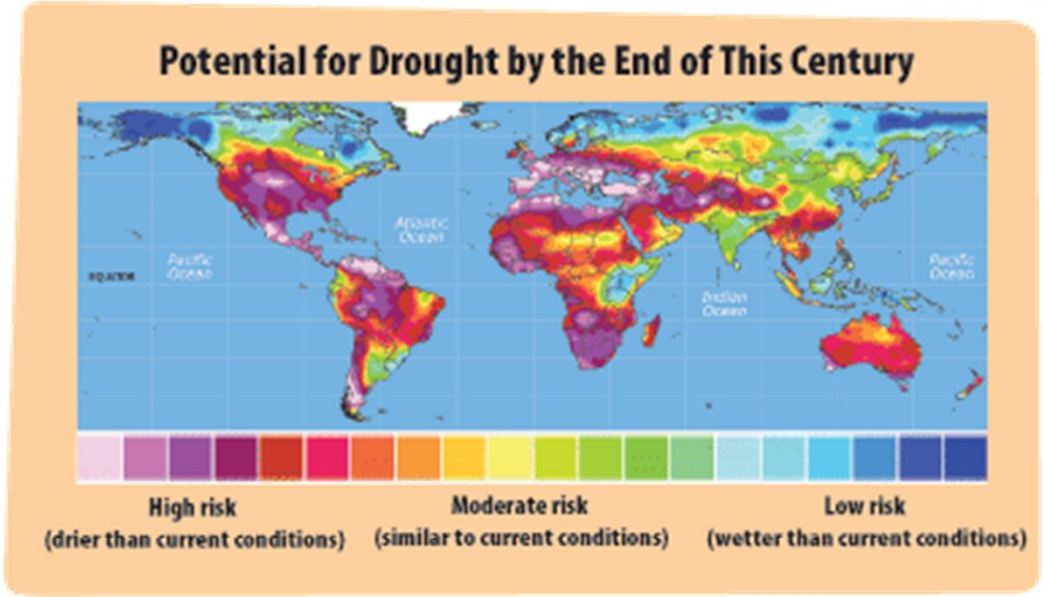
3) Climate change

Although global warming will overall result in increased world rainfall, there are many regions which will experience large seasonal variations of precipitation with longs spells of droughts, namely ,in large territories of Africa, Asia, Australia, South America.

No clear picture yet, as climate models do not always provide realistic forecasts of precipitation.

Nevertheless droughts in the wake of climate change appear to be more threatening than storms and/or floods



TOP CLIMATE CHANGE CONCERNS BY REGION

	Droughts or water shortages	Severe weather, like floods or intense storms	Long periods of unusually hot weather	Rising Sea Levels
LATIN AMERICA	59%	21%	12%	5%
AFRICA	59%	18%	16%	3%
U.S.	50%	16%	11%	17%
ASIA/ PACIFIC	41%	34%	13%	6%
MIDDLE EAST	38%	24%	19%	5%
EUROPE	35%	27%	8%	15%
GLOBAL	44%	25%	14%	6%

5. Consequences of droughts

1) **Environmental:**
- lower surface and subterranean water-levels,
- lower flow-levels (danger for amphibian life),
- increased pollution of surface water,
- drying out of wetlands,
- more and larger fires, higher deflation intensity,
- loss of biodiversity,
- worse health of trees and the appearance of pests and dendroid diseases.

2) **Economic:**
- lower agricultural, forests, game and fishing output,
- higher food-production costs,
- lower energy-production levels in hydro plants,
- losses caused by depleted water tourism and transport revenue,
- problems with water supply for the energy sector and industries ,
- disruption of water supplies for municipal economies.

3) **Social:**
- negative effect on the health of people,
- possible limitation of water supplies,
- increased pollution levels,
- high food-costs,
- stress caused by failed harvests

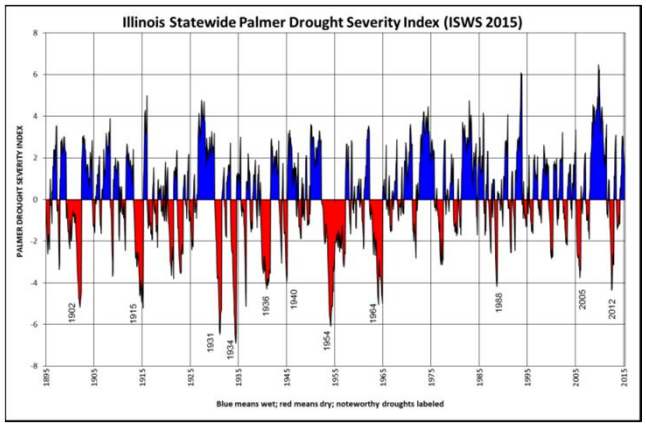
Drought consequences generally felt more negatively in poor countries

6. Quantitative evaluation of droughts

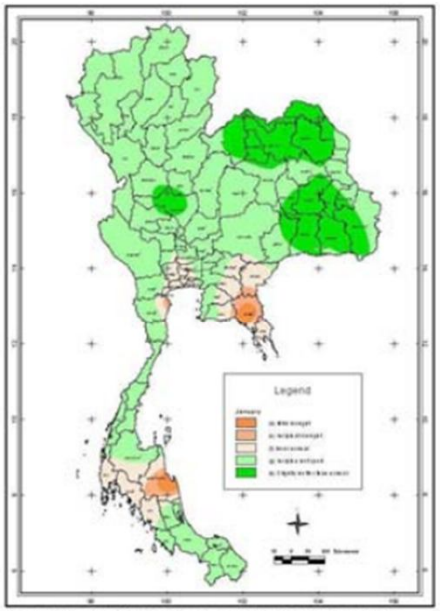
Drought indices/ Palmer Drought Severity Index (PDSI)

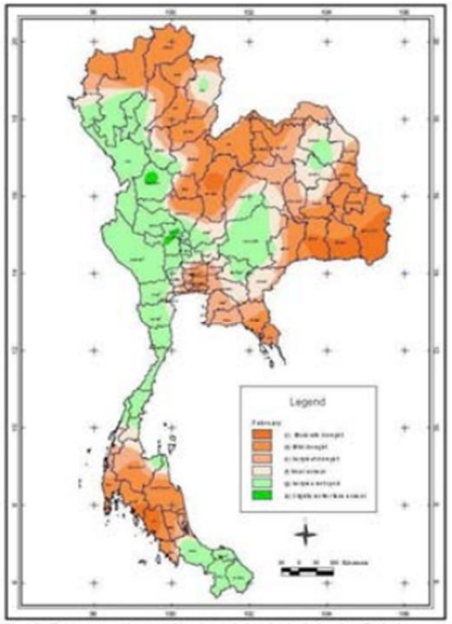
Indicates the severity of a wet or dry spell. PDSI is calculated based on precipitation and temperature data, as well as the local Available Water Content (AWC) of the soil.

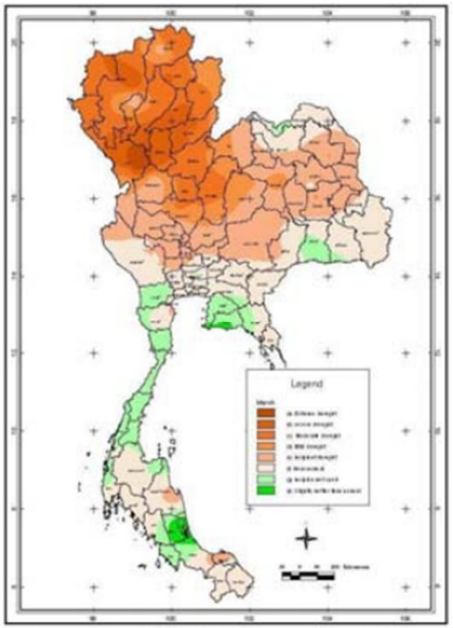
PDSI >0 = normal;
-0.5 to -1.0 = incipient drought;
-1.0 to -2.0 = mild drought;
-2.0 to -3.0 = moderate drought;
-3.0 to -4.0 = severe drought;
> - 4.0 = extreme drought



Average 1982-1985 January to March PDSI for Thailand
Source: Thailand Meteorological Department







6. Quantitative evaluation of droughts

Drought Indices/ Standardized precipitation/drought severity index (SPI)

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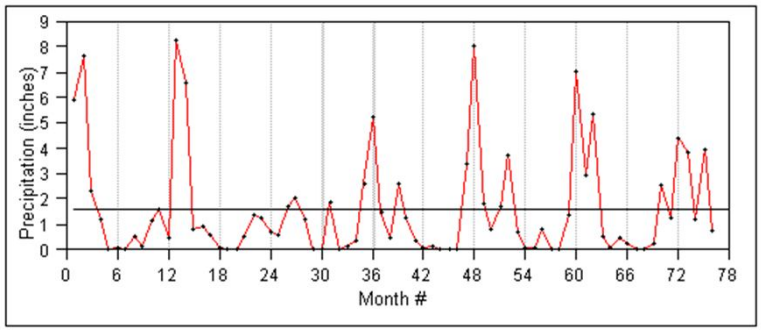
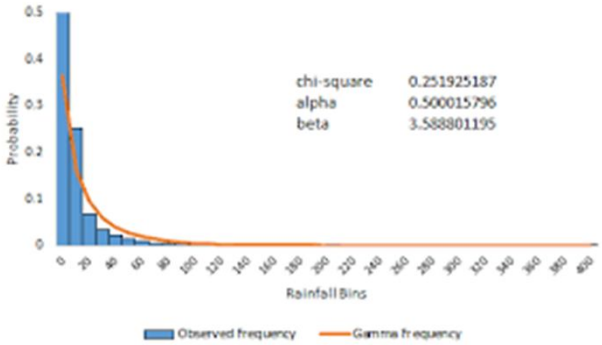
1) Generate monthly time series

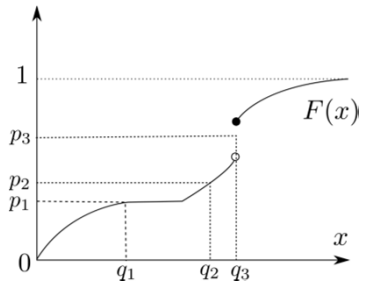


Monthly precipitation in Portola, Ca. Jan 1999 – Apr 2004

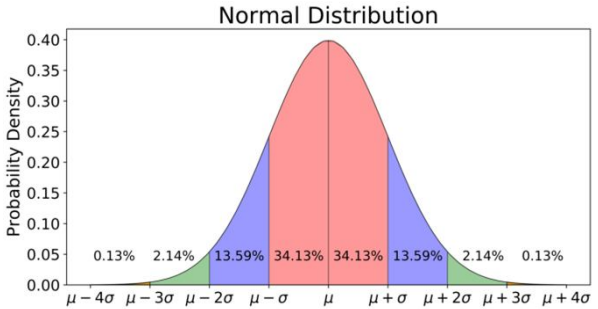
2) fit distribution function (Gamma, Pearson III) for each of the 12 months of the year of the whole time series



3) Run month by month through the timeseries by cumulating 1,3,6, 12 months prior to the month considered, compute the p=CDF(q) in the fitted CDF for that month



4) Do inversion with Normal distribution N(0,1), i.e. compute the quantile $q = F^{-1}(p)$



5) Locate q = SPI on the q-axis of N(0,1) and classify into the various SPI- bins

SPI6 Value	Drought Severity	Frequency
2.0	Severe Wetness	1 in 43-year event
1.5	Intermediate Wetness	1 in 23-year event
1.0	Moderate Wetness	1 in 11-year event
0.0	Normal	2 in 3-year event
-1.0	Moderate Dryness	1 in 11-year event
-1.5	Intermediate Dryness	1 in 23-year event
-2.0	Severe Dryness	1 in 43-year event

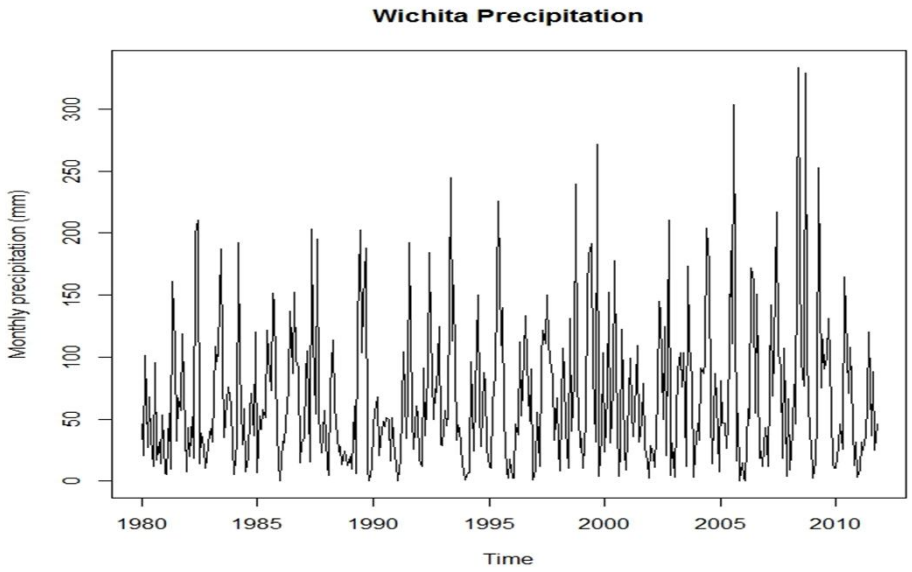
6. Quantitative evaluation of droughts

Drought Indices/ Standardized precipitation/drought severity index (SPI)

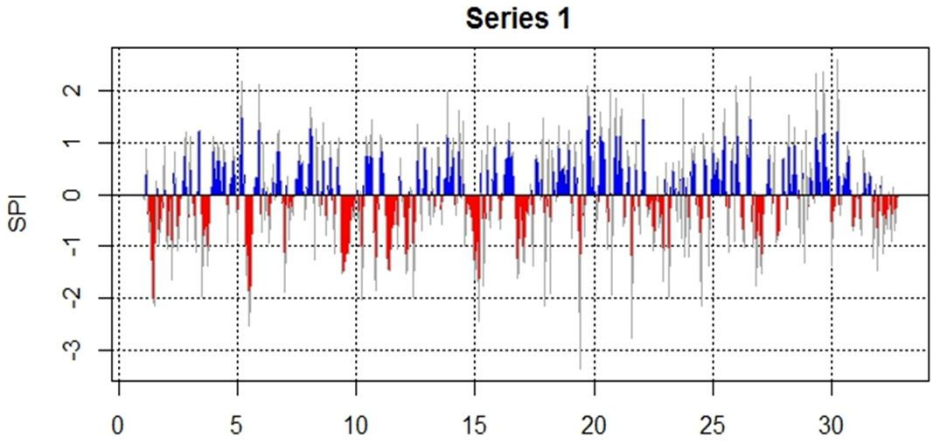
https://www.r-project.org/

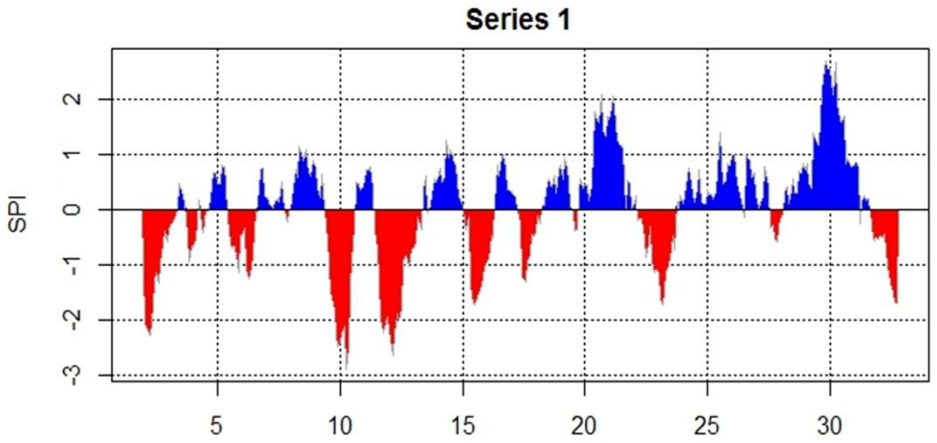
https://cran.r-project.org/web/packages/SPEI/index.html

Example: Wichita, Kansas 1980-2011 Precipitation



Monthly precipitation for Wichita, Kansas





Year from 1980 on

SP1 and SP6 for Wichita from years 1980- 2011

6. Quantitative evaluation of droughts

Drought indices/Standardized precipitation/drought severity index (SPI)

https://iridl.ldeo.columbia.edu/maproom/Global/Precipitation/SPI.htm

6-month Standardized Precipitation Index (SPI6) forecast combines the prior 3 months of observed precipitation and forecasted upcoming 3 months of seasonal rainfall.

SPI6 Value	Drought Severity	Frequency
2.0	Severe Wetness	1 in 43-year event
1.5	Intermediate Wetness	1 in 23-year event
1.0	Moderate Wetness	1 in 11-year event
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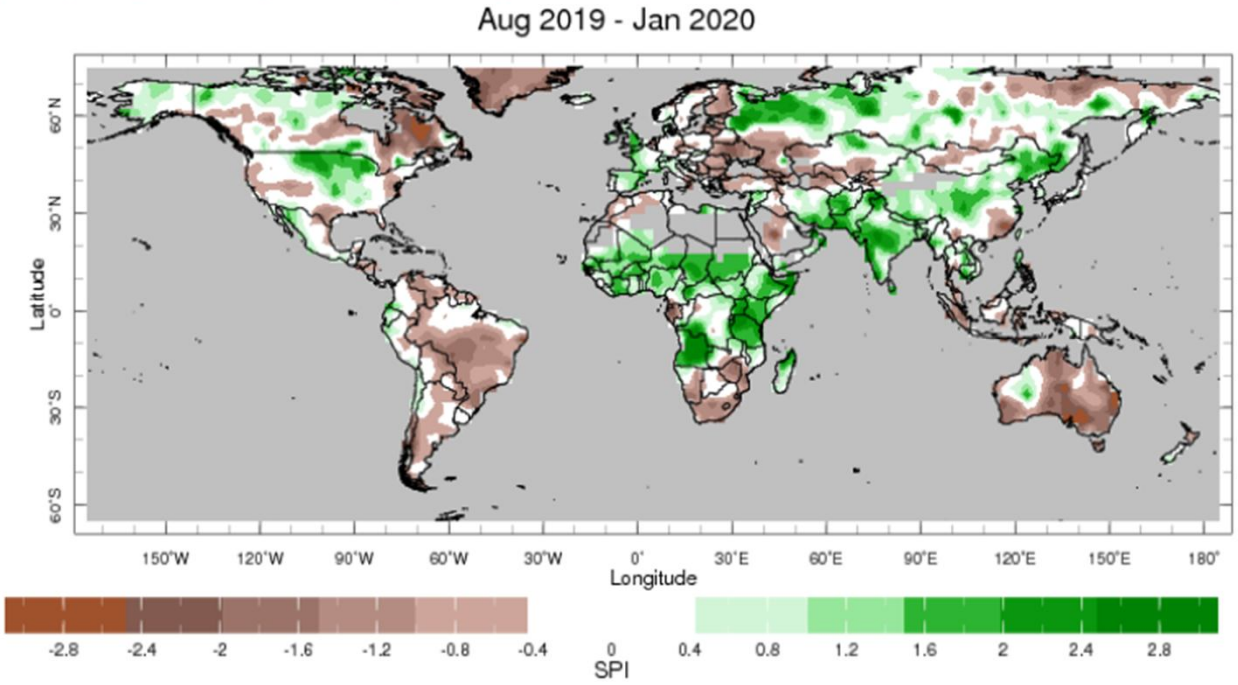
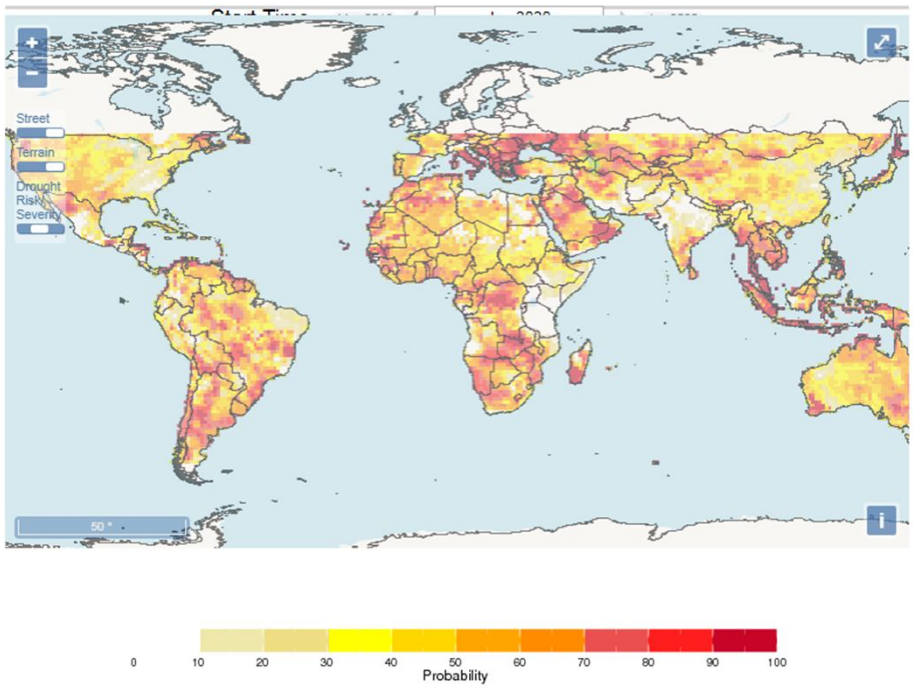
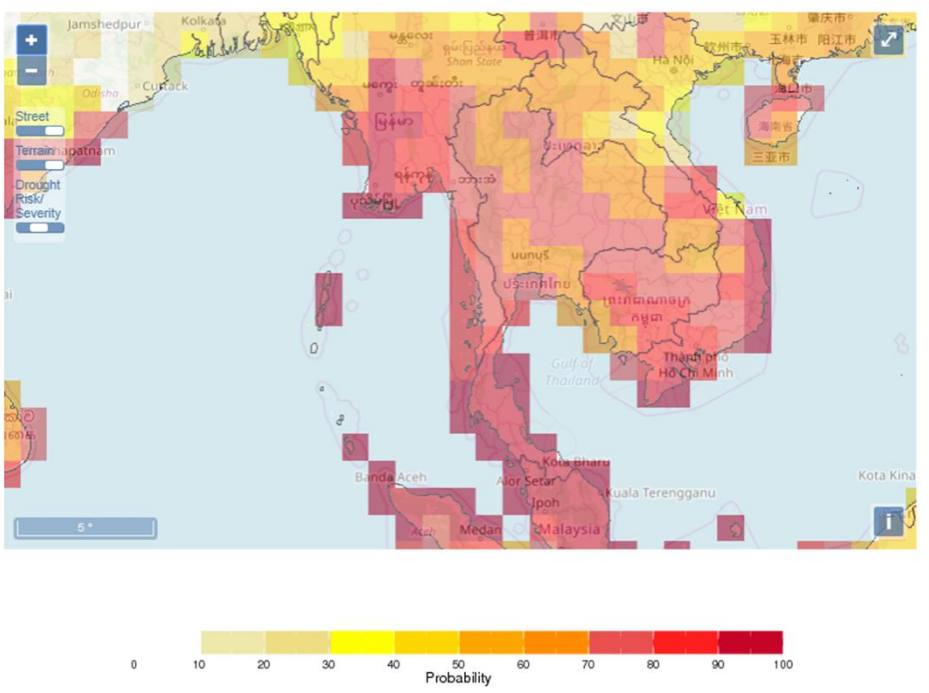
-1.0	Moderate Dryness	1 in 11-year event
-1.5	Intermediate Dryness	1 in 23-year event
-2.0	Severe Dryness	1 in 43-year event



6. Quantitative evaluation of droughts

The Global Forecast Drought Tool





https://iridl.ldeo.columbia.edu/maproom/Global/World_Bank/Drought_Monitor/index3.html

7. Drought mitigation and relief /Thailand generally

- Thailand's water management system has been notoriously inefficient, prompting a seasonal cycle of drought followed by flooding.

- An example of this is Ubon Ratchathani in the northeast, now on the list of provinces struck by drought, yet only two months ago suffered heavy damage from major flooding.

- In theory, the idea of creating a more unified approach to combating these twin weather-related threats is commendable. Piecemeal schemes operated on an ad-hoc basis by various organisations are a waste of time, effort and budget.

- Weather and water-related issues that are only likely to worsen due to climate change require holistic solutions. Otherwise, solving a problem in one area may ultimately only worsen the situation in another.

  => Water diversion in certain areas, such as from the Mae Klong River into the Chao Phraya basin as demand for water in the outskirts of Bangkok has grown, turn out to be detriment to local farmers, namely in Samut Songkhram who need fresh water for their plantations.

  => Another big water diversion scheme planned in the north to refill Bhumibol dam, may as well be doomed for such reasons.

7. Drought mitigation and relief /Thailand/Bangkok

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Demand side

- Regulate water consumption in high rise buildings by reducing water pressure.
- Shopping malls should be required to recycle water, use smaller flush cisterns and self-regulate taps.
- Water tariffs should be raised to a point that people will conserve water while guaranteeing lower income households of a minimum level of consumption, particularly, during periods of water crisis.
- Water rationing may be considered in worst-case scenarios. However, people should be warned in advance to not cause panic.
- With 9 million registered cars in Bangkok, car washing should be regulated if not banned.
- Industries are major consumers of water but are not motivated to save water because of its low cost. Thus, industry water benchmarking should be introduced to raise awareness of water conservation.
- Government should embark on an ambitious target to reduce water leaks and losses, currently at 25% in Bangkok, compared with Manila and Singapore where it is 11% and 4%, respectively.

Supply side

- Solutions to that regard are more expensive and long term.
- Increase recycling and reuse of water, including capturing and reusing stormwater, greywater, and wastewater
- Desalination and cleaning of waste water are expensive, consuming more than 10 times the energy cost of conventional water sources.
- Developing more ground water sources, but this has limitations for Bangkok which is already sinking, worsening the problem of saline intrusion
- Moving upstream the water intake at the Samlae station from the Chao Phraya River to reduce the amount of salty water from salt water intrusion
- Reduce salt water intrusion into the Chao Praya River by installing a barrage at its mouth, similar to the Marina Barrage of Singapore; this makes sense in the long run because of rising sea levels
- Studying feasibility of levees and reclaiming land in the Gulf of Thailand to raise the land above rising sea levels.
- Shifting from water intensive rice farming to less water intensive crops.

8. Conclusions

- Although 70% of the earth's surface is covered by water, only 3% of that amount is fresh water and only about 1.2% can be used for drinking.
- Renewable or sustainable water available for livelihood in general is that part of the fresh water resource which cycles through the hydrosphere, i.e. which is sustained by precipitation.
- Precipitation so is, depending on the geographical climate zone considered, spatially and temporally highly variable, there may be times of excessive abundance - leading to floods - , or of long periods of rainfall deficiencies, provoking a general shortage of the water supply, a phenomenon called a drought.
- The two extreme hydrological events, floods and droughty are usually particularly pronounced in those climate regions of the world, where seasonal weather patterns are prevalent, namely, sub-tropical and tropical climate regions, comprising mostly emerging or developing countries which, in addition, experience rapid population growth, industrial and agricultural development and urbanization that have sent water demand soaring in recent years
- Out of the two hydrological extremes mentioned, droughts appear to be by any means the most threatening events, impacting millions of people in these parts of the world on a recurrent basis
- Drought-related risks are a pressing issue in Southeast Asia where millions depend on the rivers and seas for their livelihood.
- Rainfall patterns, once fairly predictable, are becoming increasingly erratic, while the frequency and severity of droughts - and of floods, as in Jakarta, Indonesia, which just at the end of year 2019 experienced a century- flood from heavy rainfall - is increasing, all as a result of climate change.

8. Conclusions /continued

UNIKASSEL VERSITÄT
Geohydraulik und Ingenieurhydrologie

- Thailand, for example, is currently facing its worst drought of the last 40 years, as unusual low rainfall during the 2019 wet season led to very low water levels in major reservoirs and rivers, insufficient to sustain crop water requirements of rice and sugar cane, so that the country's sugar output is expected to tumble about 30% to a nine-year low.
- Tap water for Bangkok has become saline as seawater pushes up the depleted Chao Phraya River.
- Solutions to cope with the drought include steps to reduce water use along with regulations limiting the amount of water that households, businesses and government can use, water reclamation (groundwater extraction, rainfall harvesting, desalinization), and a better maintenance of existing infrastructure to reduce excessively high water losses.
- In the long run, it will be necessary o identify new sustainable sources of water and employ smart technology to alleviate possible drought-related water scarcity risks.
- As irrigation-fed agriculture is still the major water user in Thailand, its water use needs to be made more efficient, productive, equitable and environmentally friendly, by, for example, changing to crops that produce food with less water, increasing the resilience of farming communities to cope with floods, droughts and climate change, and incorporating clean water technologies (filtering and desalinization).
- It appears that Thai authorities may learn something regarding these issues from Singapore, whose success in water management is rooted in diversification of supplies, innovation and investment in technology and, so, becoming independent from water resources of adjacent countries (Malaysia).

8. Conclusions /continued

- Thailand should depend in the north and northeast less on transboundary water resources from the Mekong River, i.e. a resource shared by six countries, with China as the ultimate upstream gate-keeper, who does not shy away by exerting its leverage (willfully or out of necessity by building new dams) on the waters of the lower catchment areas.
- As it is not clear to what extent these somewhat "egoistic" Mekong river water uses can be alleviated by the Mekong River Commission, it makes it all the more necessary for Thailand to become more water-self-sustained and –resilient by implementing a so-called "water governance" strategy.
- Water governance may include, for example, the exploration of more groundwater abstraction options, building of a more efficient water infrastructure, development of a better hydrological database, and improved water management, particularly, in agriculture.
- All this becomes the more imminent as the effects of climate change on the existing water resources become more unpredictable albeit, most likely, more adverse in terms of more extreme hydrological events.

- For Thailand the statement still holds: **"After the drought there comes the next flood"**.