Kaoru TAKARA (DPRI, Kyoto University)

Paleohydrology combined with modern technologies for considering water resources issues in the Nile Valley and Delta

Research Activity

Targets:

- To reproduce hydrological regimes in an arid region from ancient times by paleo-flood analysis;
- To estimate the historically significant irrigation system and natural fertilization processes with flooding and sedimentation of the ancient Nile;
- To consider the issues in the present water resources in the Nile Valley and Delta under the impact of re-organization of the water management system;
- To predict climate change impacts in the future and to consider adaptation methods for a sustainable and survivable (or “futurable”) Nile River basin.

Methods:

- Literature review
- Historical data collection including old documents
- Rainfall-runoff analysis of the ancient Nile with hydrological modeling
- Using ancient climate information reproduced by GCM (Global Climate Models)
- Frequency analysis of hydrological regimes of the Nile

Paleohydrology combined with modern technologies for considering water resources issues in the Nile Valley and Delta

Kaoru TAKARA
Professor, Disaster Prevention Research Institute;
Assistant to the Executive Vice-President,
Kyoto University

2011/11/13

A Global COE Program supported by MEXT
(Ministry of Education, Culture, sports, Science and Technology)

Ancient Egypt

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Kyoto University and Egypt

- KU is the first university establishing archeology laboratory in Japan in 1916
- Mr. Hamada (1881-1938) introduced a number of archeological specimens of Egypt from England by the support of the Egypt Exploration Fund (EEF) since 1909.
- Prof. Hamada first visited London in 1913-1916 and Egypt in 1928.

KU Museum Special Exposition

Oct. 19
to
Dec. 18,
2011

Egyptian Antiquities of Kyoto University
Entrusted Dreams from Petrie to Hamada, Two Giants of Archaeology

京都大学総合博物館開館10周年記念企画展図録

エジプト　こうこ
埃及考古

—ペトリーと濱田が京大エジプト資料に託した夢—

監修
中野智章

編集
京都大学文学研究科考古学研究室
京都大学総合博物館

DPRI-KU

William M.F. Petrie (1853-1942) and Kosaku Hamada (1881-1938), Initiator of KU Archeology

ロンドンの濱田耕作

Ancient Boat and Traditional Fishing in the Nile

葬祭船の模型（中王国時代）

ハトシェプスト女王葬祭殿の南側に発見されたメンチュヘテプ2世の葬祭複合体からは、葬祭船の模型が多く出土した。©EES

伝統的な葦舟（あしぶね）にのって漁をする男性 ©EES

Japanese-Egyptian Hydro Network (JE-HydroNet)
Joint Project in Science and Technology

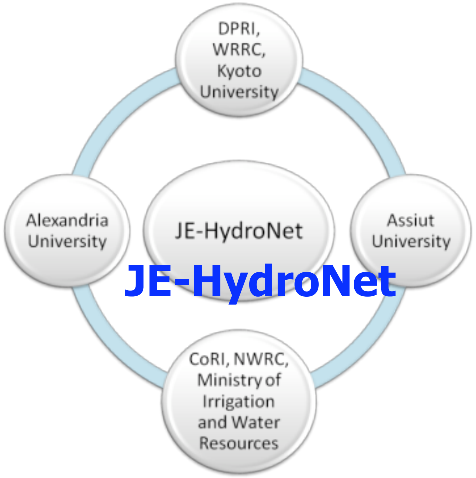
Establishment of JE-HydroNet for the betterment of integrated water resources management in the Nile Delta

JE-HydroNet

Research Topics Examples:

- Countermeasures for recent Flash Floods due to climate change in Wadi flowing into the Nile
-Application of an integrated river basin simulation model (Hydro-BEAM) to arid river basins and Flash Flood control

Wadi Flash Flood



DPRI, WRRC, Kyoto University

Alexandria University

JE-HydroNet

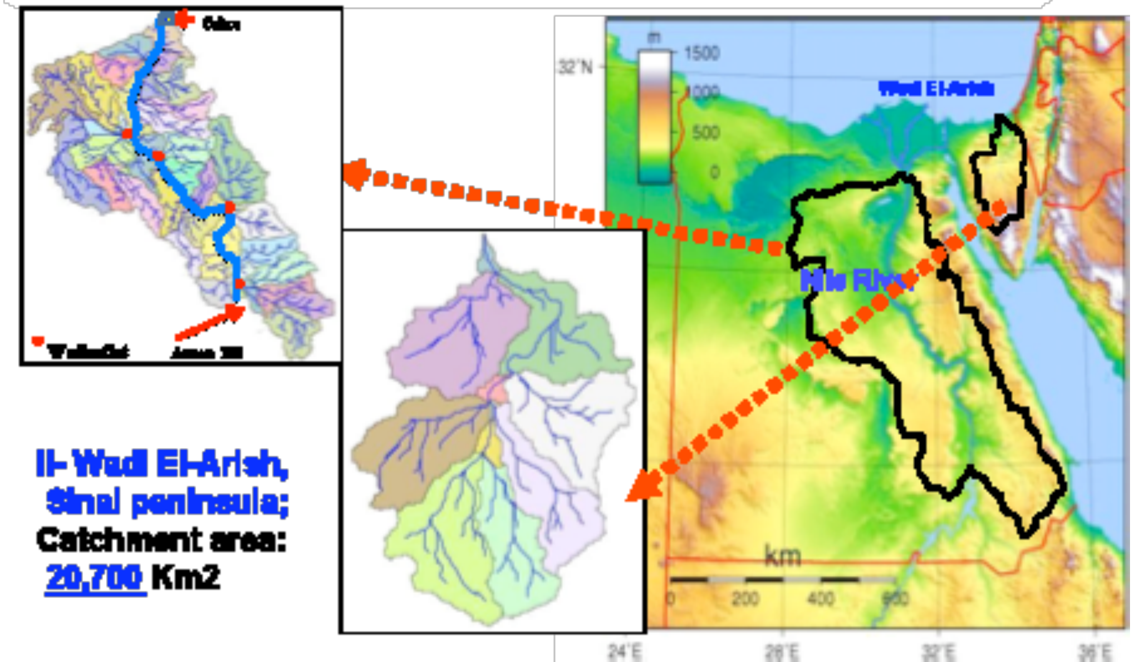
Assiut University

CoRI, NWRC, Ministry of Irrigation and Water Resources

JE-HydroNet

Flash flooding simulation of Wadi basins:

I- Nile River; Catchment area: 184,000 Km2



II- Wadi El-Arish, Sinai peninsula; Catchment area: 20,700 Km2

Japanese-Egyptian Hydro Network (JE-HydroNet)
Joint Project in Science and Technology

MODERN METHODOLOGIES FOR THE MANAGEMENT, MONITORING AND PLANNING OF INTEGRATED WATER RESOURCES IN NILE DELTA, EGYPT

“Problems Facing Nile River System and Delta of Egypt”

First Mini-Symposium
Joint Project in Science and Technology

October 26th (Tuesday), 2010
Uji campus, Kyoto University

Organized by Water Resources Research Center,
Disaster Prevention Research Institute, Kyoto University

Background and Objectives

- Under the umbrella of GCOE-ARS project at Kyoto University, a joint project for research and education was established between Kyoto University and three institutional research units in Egypt (Assiut and Alexandria Universities, and National Water Research Center (NWRC), Ministry of Water Resources and Irrigation (MWRI)).
- Japan Egypt-Hydro Network (JE-HydroNet) was initiated after the visit of DPRI research group on March 2009 to setup research projects concerning the Nile River and the Nile Delta of Egypt.

- *Discussions with Ministry of Land, Infrastructure, Transport and Tourism (MLIT), JICA. April, 2010.*
- *Submission to JSPS and STDF for Joint Seminar Proposal, September, 2010.*

Background and Objectives

- On 26 October 2010, the first mini-symposium is organized at Uji campus, Kyoto University. The first symposium will serve the exchange of information about the latest state of research of water resources problems facing Nile Delta and encourage the discussion about joint research project activities.

- *The technical program consists of three topics concerning to flash flood and water resources, ground water, sediment and coastal managements in the Nile River of Egypt.*

- *The final closing discussion will highlight and discuss the importance of climate change impacts on the Nile River Basin and the Delta of Egypt.*

Flash flood and water resources

- Flash floods are the result of short period heavy storms and the velocity of floodwater depends mainly on topography of the Wadi and soil characteristics.
- Flash flood can cause severe damage and loss of life in desert areas and they also represent a constraint to regional development.
- Until today, no proper protection from flash floods proposed for all Wadi basins in Egypt.

- On the other hand, however, floodwater can be an important source of water replenishment in arid regions.
- The wise use of floodwater in these areas is therefore important for the sustainable management of water resources.
- An overall aim of the research project is to achieve sustainable management of water resources in some selected study area.

Ground water

- Another problem is the salt water intrusion to groundwater in Nile delta regions.

- With the decrease in the cyclic behavior of groundwater that was taking place before the Aswan High Dam construction and the increase in cropping intensities and perennial irrigation applications, drastic impacts on groundwater flow and its salinity which might be critical for sustainable development in delta area.

- Climate change impact has big influences on ground water resources.

Sediment and coastal management

- Lake Nasser is causing flow and sediment flow regimes, and reservoir sedimentation is causing serious impacts on river morphology and scouring of delta and coastal region.

- Moreover, it is important to predict the response of Aswan High Dam reservoir and the Nile Delta of Egypt to reservoir sedimentations in the newly constructed or planned dams on the upstream regions of the Nile basin.
- Moreover, how these dams will affect on the sediment management and operation of AHD should be studied.

- The worldwide sediment management techniques consist of three basin strategies: sediment yield reduction, sediment routing, and sediment removal.

Climate change impacts

- Climate Change Adaptation strategies will be vital for country as Egypt. Adaptation options for water resources are closely intertwined with Egypt’s development choices and pathways.
- Adapting to climate change will have close resonance with adapting to water scarcity and is likely to require implementation of water demand management strategies which may require capacity building and awareness raising across institutions and society.

- Adaptation measures on the supply-side include ways to improve rain-harvesting techniques, increasing extraction of ground water, water recycling, desalination, and improving water transportation.
- In addition, regular reviewing and updating of drought responses and research into improved long-term forecasting is essential.

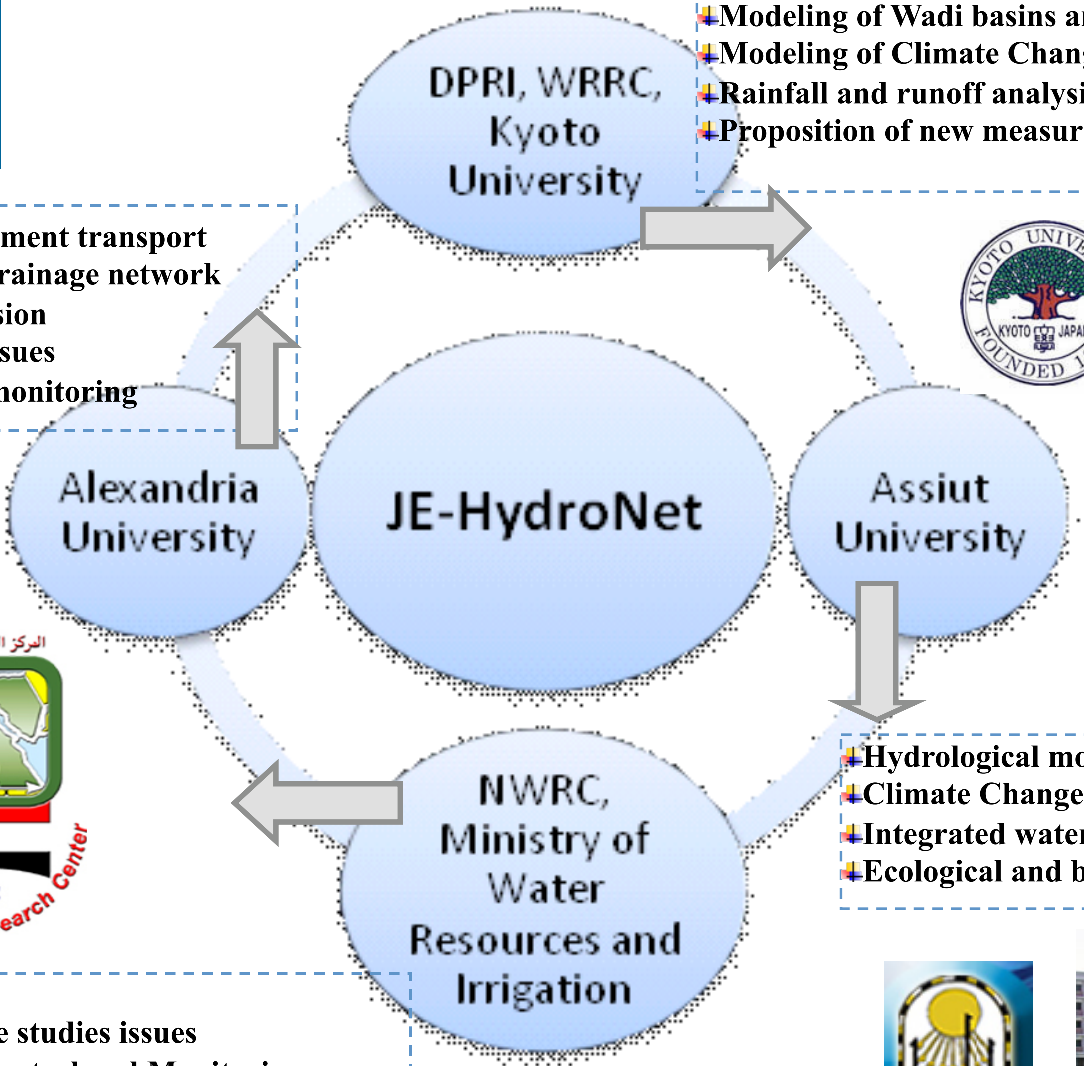
Problems Facing Nile River System & Delta of Egypt

Vulnerability of the Nile River and Delta of Egypt

- **Upstream and in Nasser Lake**
  - Environmental risks
  - Sedimentation
  - Evaporation
- **Downstream of Aswan High Dam**
  - Social behavior
  - Water quality and water pollution
  - Global warming and climate change
  - Traditional irrigated system
  - Limited available water resources
  - water-logging
  - Rise in groundwater levels
- **Delta, Irrigation and Drainage Networks**
  - Nile Delta flooding by sea
  - Environmental degradation
  - Competing uses of land
  - Inefficient natural resources management
  - Salt water intrusion
  - Negative impact of free crop pattern
  - Degradation of agricultural soil fertility
  - Excessive pumping
- **Coastal**
  - Potential impact of sea level rise
  - Coastal erosion
  - Sea level rise
  - Negative effects on fisheries

Project Partners and Main Tasks

JE-HydroNet



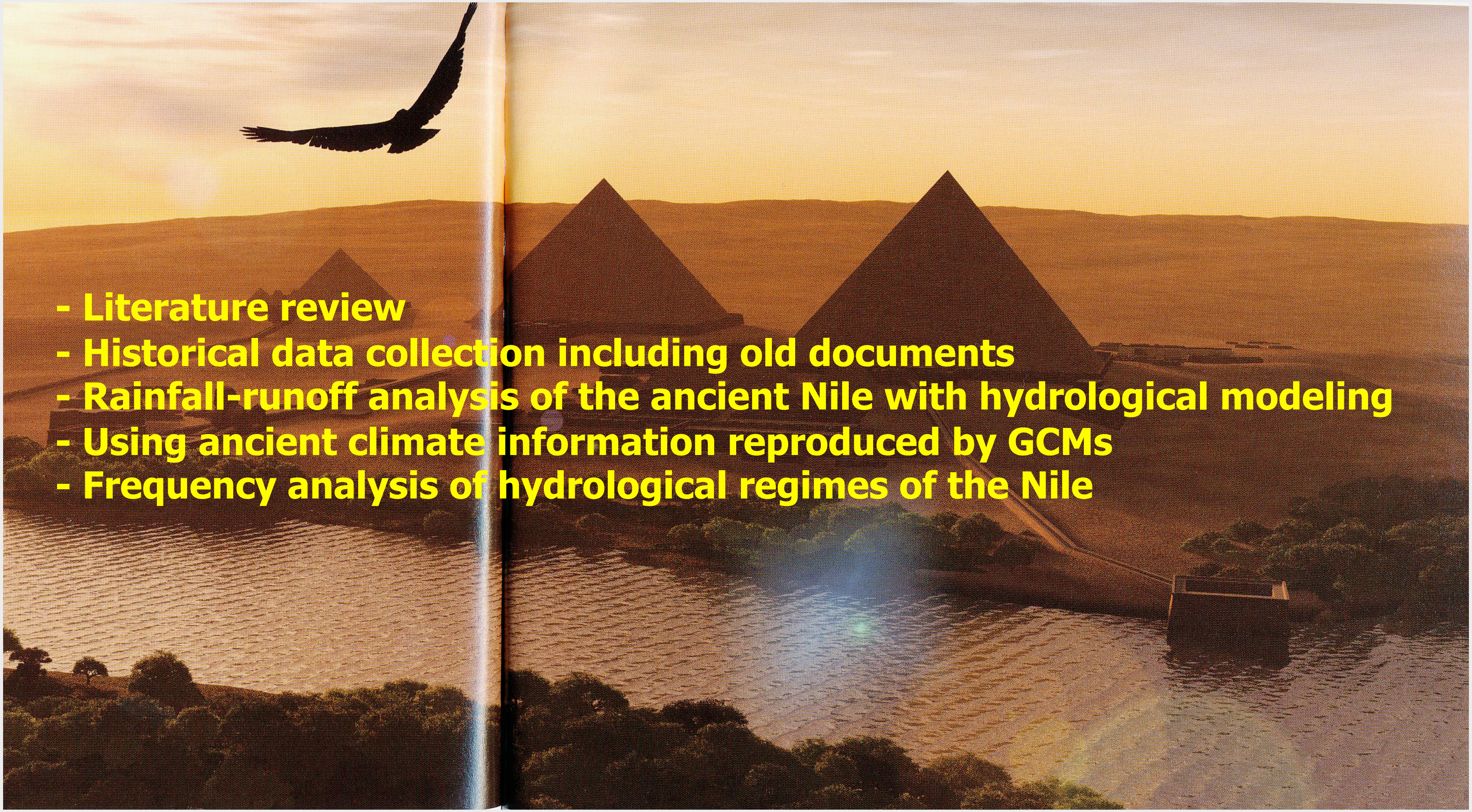
- General coordinator
- Hydro-BEAM model
- Modeling of Wadi basins and Ground Water
- Modeling of Climate Change Adaptation scenarios
- Rainfall and runoff analysis
- Proposition of new measures for sediment management

- Coastal and sediment transport
- Irrigation and drainage network
- Salt water intrusion
- Ground water issues
- Validation and monitoring

- Hydrological modeling
- Climate Change Adaptation
- Integrated water resources management
- Ecological and biological issues

- Available data
- State of art for the studies issues
- Measurements, Control and Monitoring
- Hydrological and meteorological measurements
- Facilitate accessing to the River, and dam sites

Methods in the RIHN Project



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DPRI-KU

Temperature and Precipitation Changes GCM Estimates (OECD, 2004)

Table 1. GCM estimates of temperature and precipitation changes for Egypt[4]

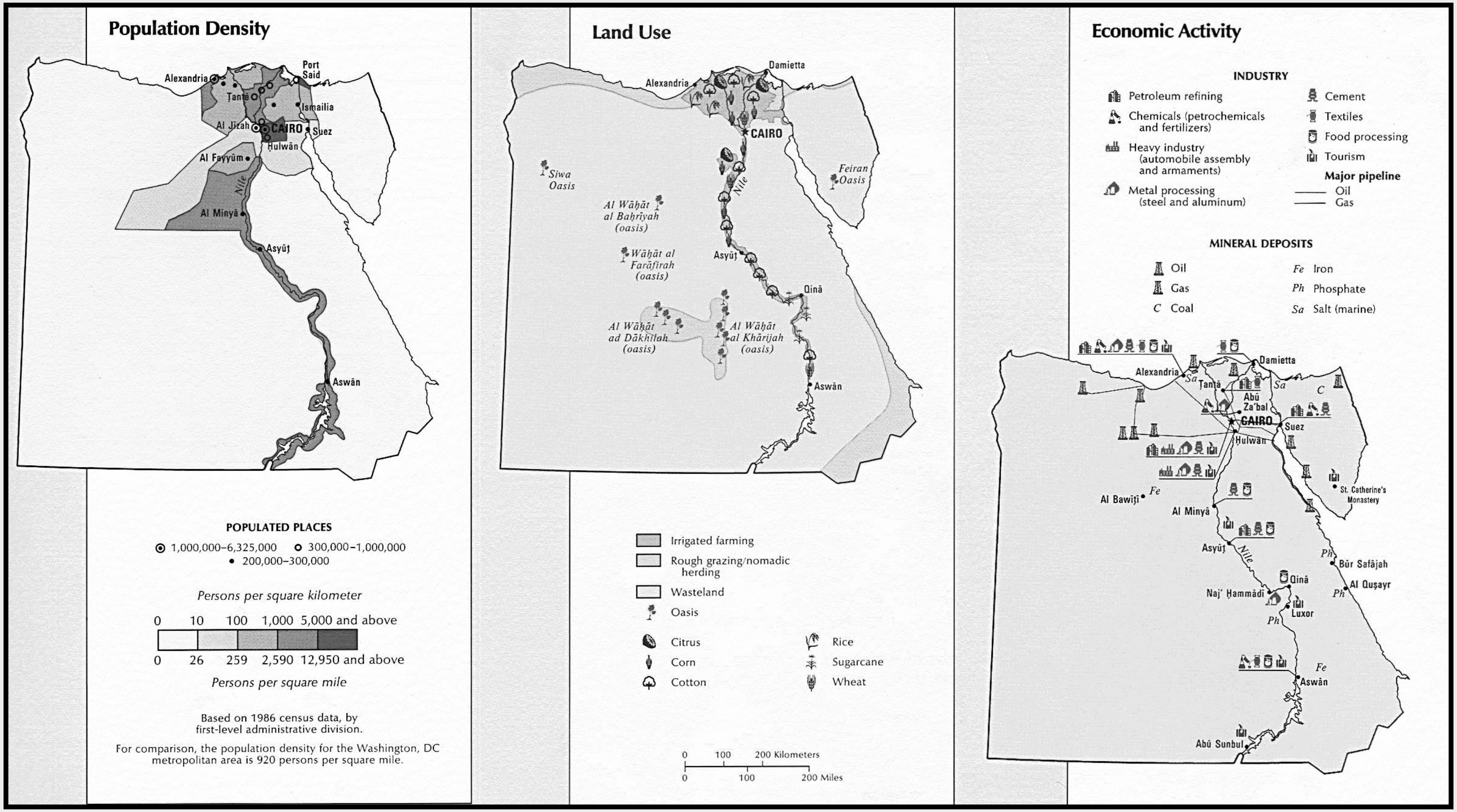
Year	Temperature change (°C) mean (standard deviation)			Precipitation change (%) mean (standard deviation)		
	Annual	DJF[5]	JJA[6]	Annual	DJF	JJA
2030	1.0 (0.15)	0.8 (0.21)	1.1 (0.18)	-5.2 (7.93)	-8.9 (3.01)	10.7 (26.35)
2050	1.4 (0.22)	1.2 (0.30)	1.7 (0.26)	-7.6 (11.46)	-12.8 (4.35)	15.4 (38.07)
2100	2.4 (0.38)	2.1 (0.52)	2.9 (0.45)	-13.2 (19.95)	-22.3 (7.58)	26.9 (66.28)

Table 2. GCM estimates of temperature and precipitation changes around source waters of the Nile [8]

	Temperature change (°C) mean (standard deviation)			Precipitation change (%) mean (standard deviation)		
Year	Annual	DJF[9]	JJA[10]	Annual	DJF	JJA
2030	1.0 (0.19)	1.0 (0.22)	1.0 (0.23)	1.5 (2.37)	16.6 (18.75)	-0.5 (9.47)
2050	1.4 (0.27)	1.5 (0.32)	1.5 (0.33)	2.1 (3.43)	24.0 (27.09)	-0.7 (13.69)
2100	2.5 (0.47)	2.5 (0.56)	2.6 (0.57)	3.7 (5.97)	41.7 (47.17)	-1.2 (23.83)

Population, land-use and economic activity (OECD, 2004)

Figure 3. Spatial distribution of population, land-use, and economic activity in Egypt



Key Climate Impacts (OECD, 2004)

Table 3. Ranking of key climate change impacts and vulnerabilities in Egypt

– Resource/ risk ranking	– Certainty of impact	– Timing of impact	– Severity of impact	– Importance of resource
Coastal resources	High-medium	Medium-low	High	High
Water resources	Medium	Medium	High	High+
Agriculture (indirect impacts - mediated by sea level rise and water resource)	High-medium	Medium-low	High-Medium	High-medium
Agriculture (direct impacts-temperature, rainfall)	Low	Medium-low	Low	High-medium
Energy resources	Medium-low	Medium-low	Medium-low	Medium-low

Literature Review: CC and its impacts on Nile flows

Abu-Zeid, M. and Biswas, A.K. (1991), Some major implications of climatic fluctuations on water management. Water Resources Development 7, 74-81.

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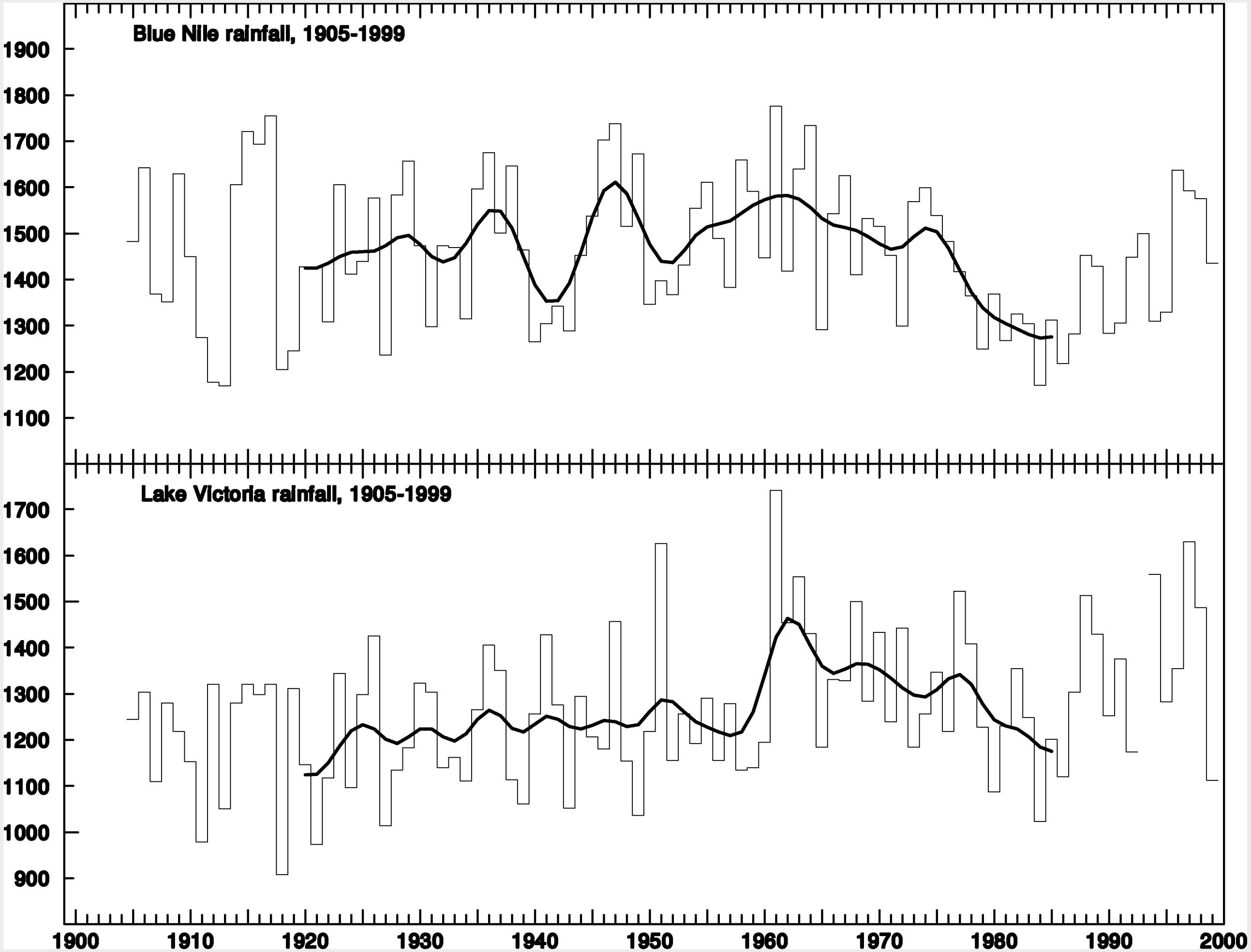
Average annual rainfall 1901-1999

Figure 8. Average annual rainfall 1901-99 in the Blue Nile and Lake Victoria catchments



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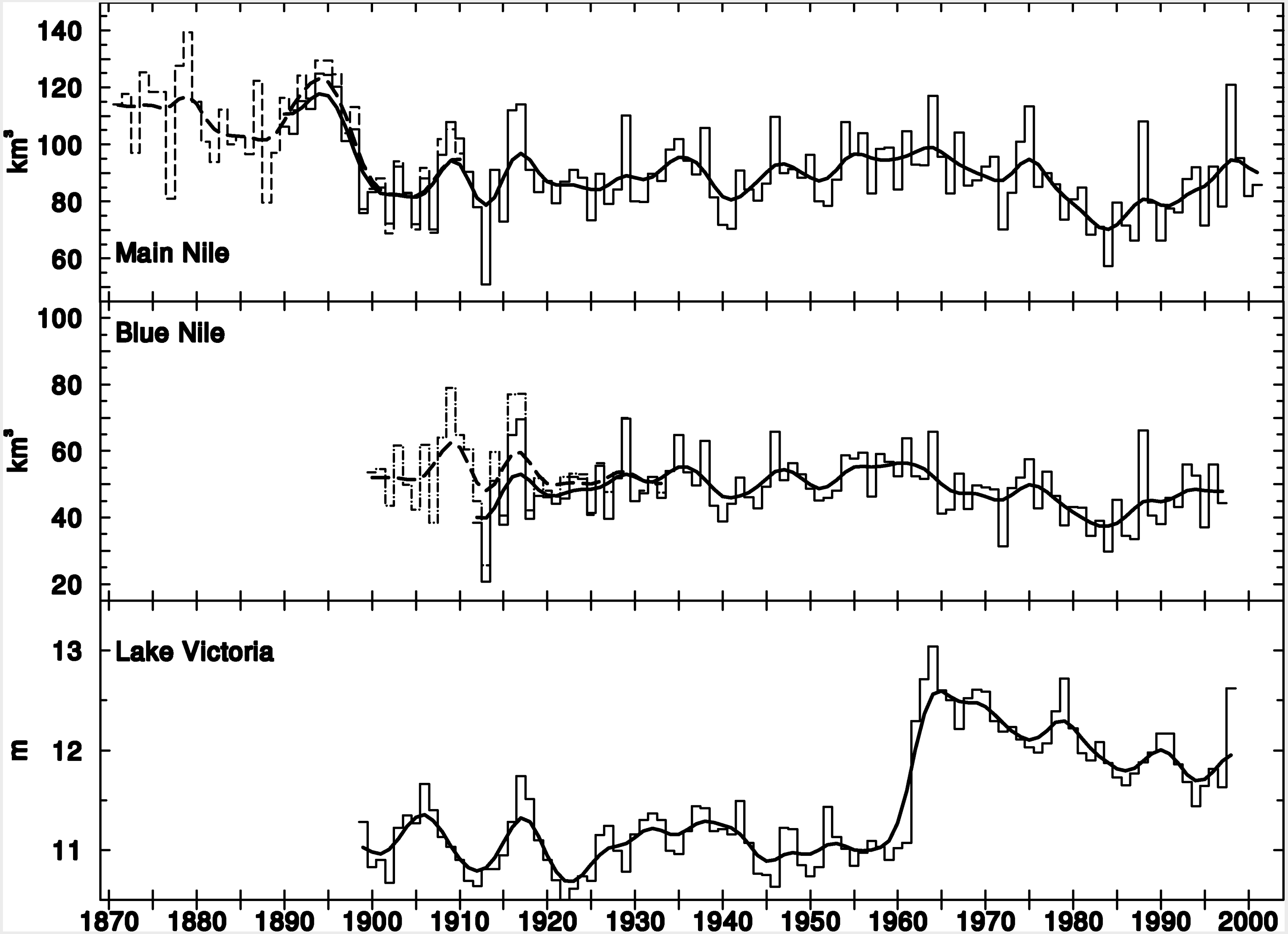
[23] Bold line represents period with best data coverage using a 10-year Gaussian filter.

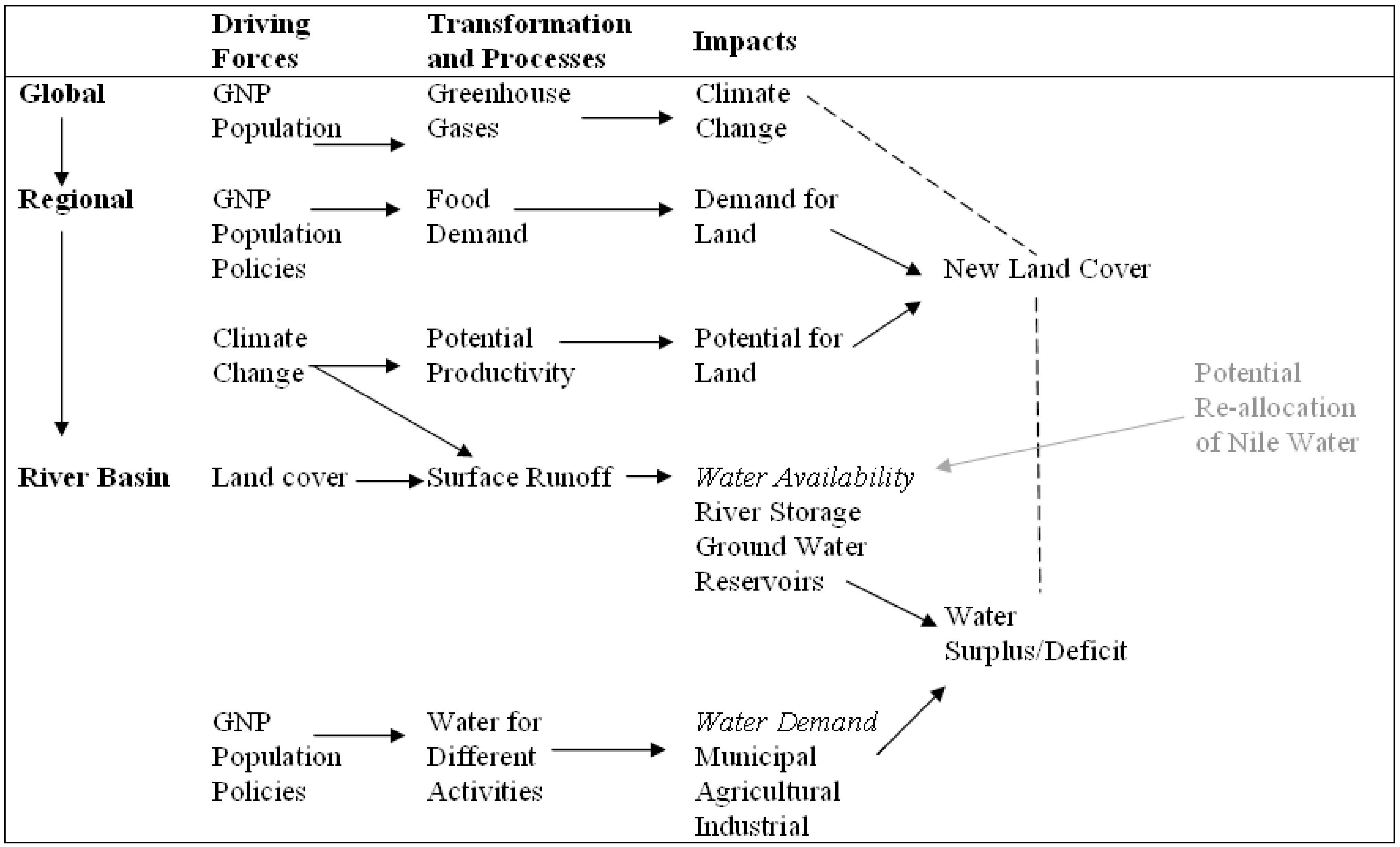
Average river flows and lake levels

Figure 9. Average river flows in the Main and Blue Nile and lake levels in Lake Victoria



Multi-scale drivers affecting Nile water availability

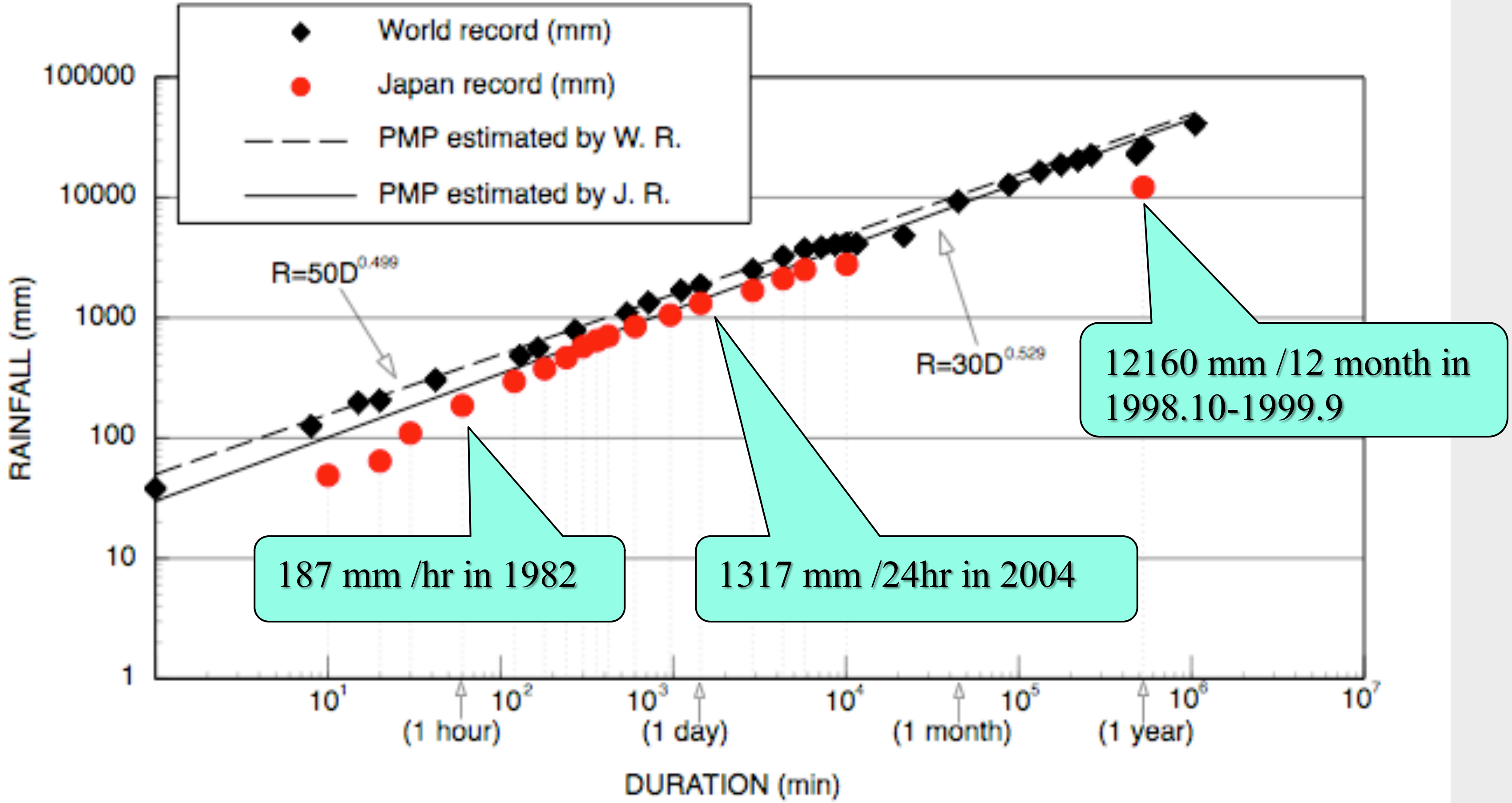
Figure 10. Multi-scale drivers affecting Nile water availability in Egypt



	Driving Forces	Transformation and Processes	Impacts	
Global	GNP Population	Greenhouse Gases	Climate Change	
Regional	GNP Population Policies	Food Demand	Demand for Land	New Land Cover
	Climate Change	Potential Productivity	Potential for Land	Potential Re-allocation of Nile Water
River Basin	Land cover	Surface Runoff	*Water Availability* River Storage Ground Water Reservoirs	Water Surplus/Deficit
	GNP Population Policies	Water for Different Activities	*Water Demand* Municipal Agricultural Industrial	

Adapted from Conway et al. 1996

Precipitation records in the World and in Japan and the probable maximum precipitation (PMP)



187 mm /hr in 1982

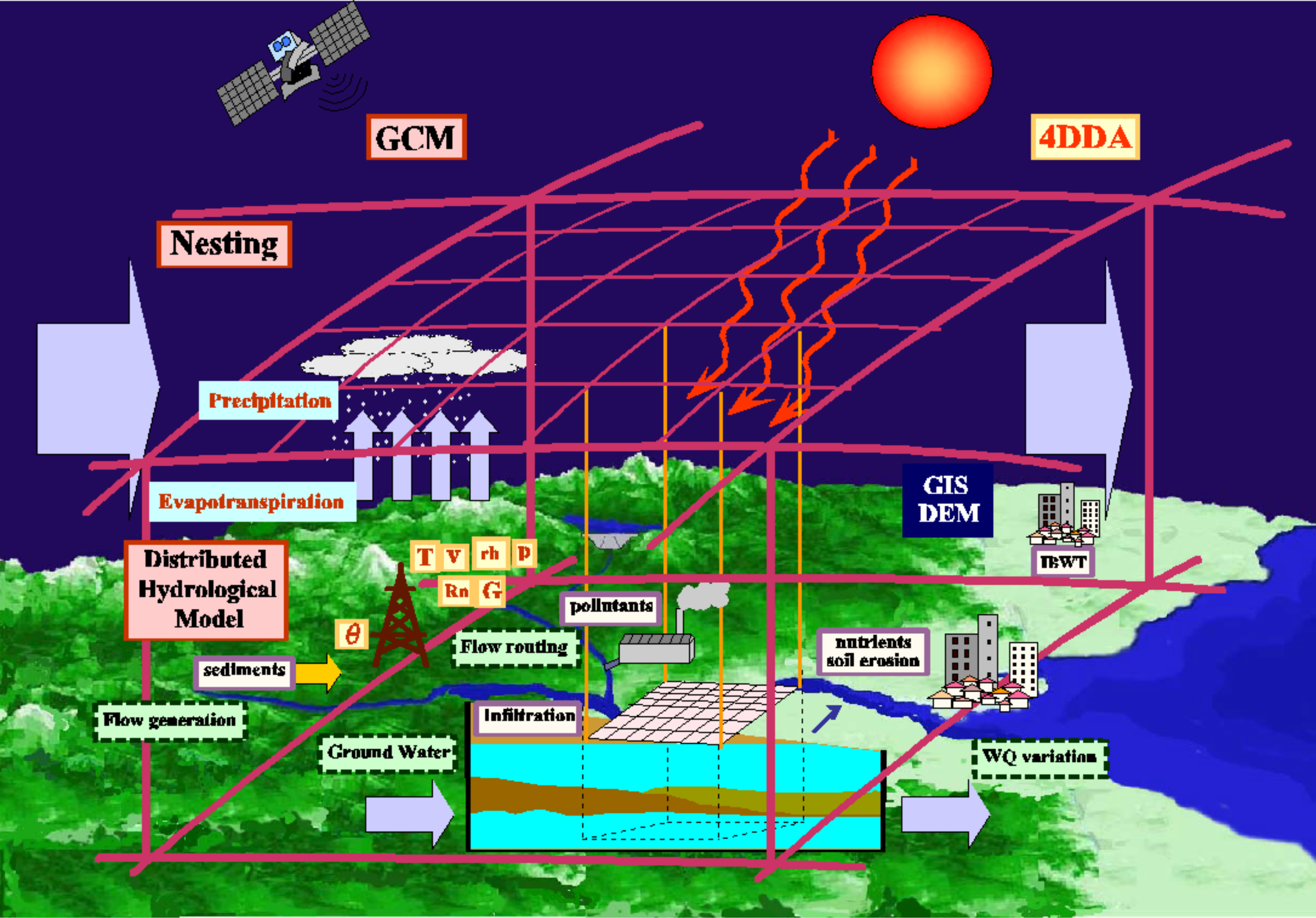
1317 mm /24hr in 2004

12160 mm /12 month in 1998.10-1999.9

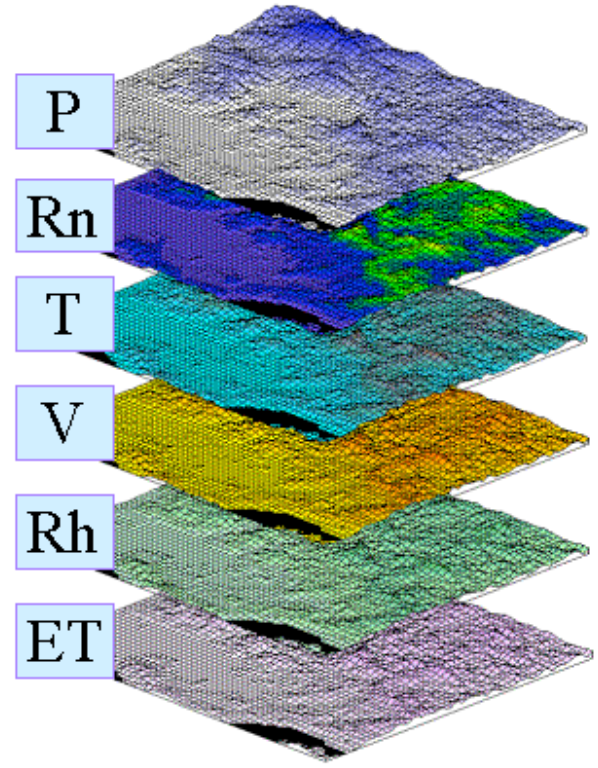
Recent record-breaking precipitations in Japan are also indicated.

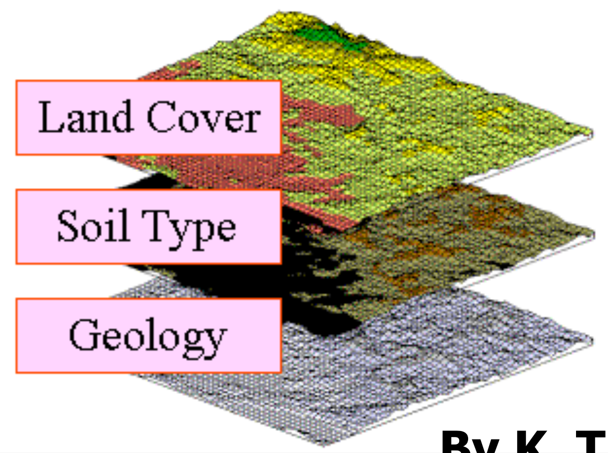
Hydrological Analyses

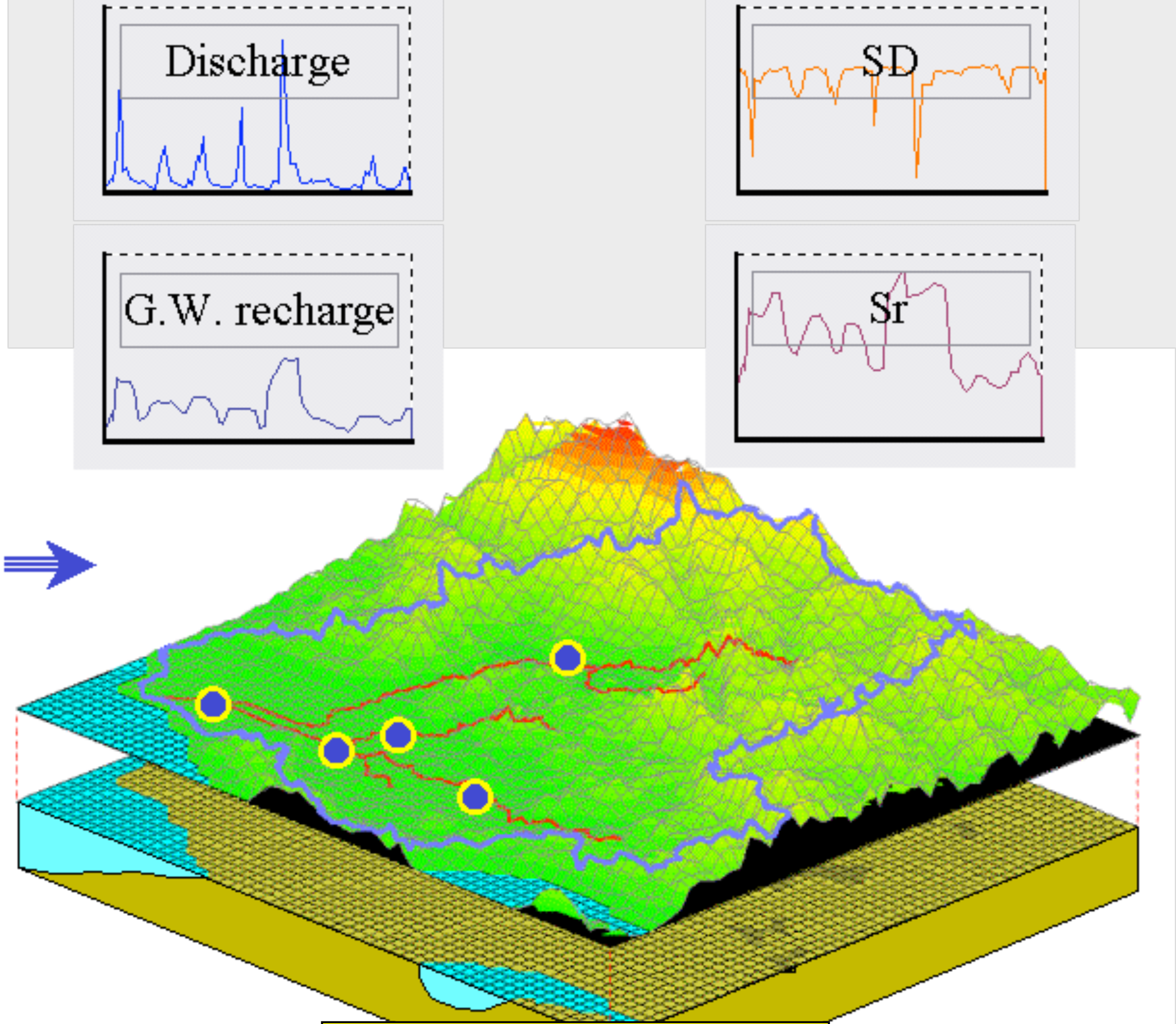
- Hydrological Modeling Using Various Spatial Information (incl. GCM outputs)
- Rainfall-Flood-Sediment-Runoff modeling
- Flood-Sediment Routing
- Frequency Analysis of Hydrological Extreme Events


GCM
4DDA
Nesting
Precipitation
Evapotranspiration
GIS
DEM
Distributed
Hydrological
Model
T
V
rh
p
Rn
G
θ
IBWT
pollutants
Flow routing
sediments
nutrients
soil erosion
Flow generation
Infiltration
Ground Water
WQ variation

Hydrological models → Flood forecasting, Water resources management







Hydrological Modeling

By K. Takeuchi

A GEOTECHNICAL-HYDROLOGICAL APPROACH FOR DEFINING CRITICAL RAINFALL-INDUCED SHALLOW LANDSLIDES UNDER NEAR-STEADY STATE CONDITION


Cempaka's Landslide,
Nov 2008

APIP and K. TAKARA
KYOTO UNIVERSITY

Abstract

This study proposes a novel method that combines deterministic slope stability model and hydrological approach for predicting critical rainfall-induced shallow landslides. The method first uses the slope stability model to identify “where” slope instability will occur potentially; the catchment is characterized into stability classes according to critical soil saturation. The critical saturated soil depth calculated from local topographic components and soil attributes. Then spatial distribution of critical rainfall is determined based on a hydrological approach under near-steady state condition as function of local critical saturated soil depth, slope geometric, and upstream contributing drainage areas. The critical rainfall mapping is bounded by the areas predefined as theoretically stable or unstable. To shows how the method works, observed landslides (1985-2008) and a satellite-based rainfall estimates associated with a past new shallow landslide in the Upper Citarum River catchment, Indonesia were used to validate the model. The proposed study is useful for rainfall-triggered shallow landslide disaster warning at large catchment scale.

Background

- It is well known that many shallow landslides are triggered by rainfall when shear strength is reduced because of an increase in pore-water pressure.
- the scarcity of rain gauges has been common problem of using rainfall for shallow landslide prediction and warning, especially in mountainous areas.
- Recent advances in satellite-based precipitation observation technology and increasing availability of its product in high-resolution is providing an opportunity to provide an alternative to rain gauges in sparsely gauged areas and ungauged.
- Previous researchers working with satellite- based rainfall data to identify landslide potential in response to a heavy rainfall event at large and global scales The difference between the critical rainfall threshold and estimated radar/satellite imagery-based rainfall intensity has been used for computing shallow landslide occurrence probabilities.
- Therefore this study focuses on the derivation of critical rainfall model and to evaluate its efficiency for shallow landsliding prediction and warning in mountainous areas of large catchment scale

Innovative Aspect

- The innovative aspect of the method that the produced critical rainfall rate (mm hr^{-1}), which is the minimum steady-state rainfall predicted to cause instability, has higher temporal resolution than the current existing critical rainfall model (mm day^{-1}).
- In combination with global near real-time satellite-based rainfall estimates and global topographic-hydrographic datasets it is possible to expand the method for rainfall-triggered shallow landslide disaster preparedness and mitigation across the large catchment areas.

GEOTECHNICAL-HYDROLOGICAL MODEL

- **Safety Factor of Infinite Slope Stability**

$$FS = \frac{c + \cos\theta\left[1 - r_u\right]\tan\phi}{\sin\theta}; \begin{cases} c = \dfrac{c_s}{\rho_s\, g\, h} \\ r_u = \dfrac{h_w\, \rho_w}{h\, \rho_s} \end{cases}$$

The ratio ($m = h_w/h$) shows the relative saturated depth is time-dependent (a parameter between 0 and 1). Whenever $FS < 1.0$, the driving forces prevail and the potential for failure is high. Through an inversion of the standard factor of safety, a fixed time-invariant critical relative soil saturation (m_c) triggering slope instability (i.e. relative soil saturation that yields $FS = 1.0$) for each grid element could be approximated as:

$$m^c = \left(\frac{h_w}{h}\right)^c = \frac{\rho_s}{\rho_w}\left(1 - \frac{\tan\theta}{\tan\phi}\right) + \frac{c_s}{h\, \rho_w\, g \cos\theta \tan\phi}$$

GEOTECHNICAL-HYDROLOGICAL MODEL

- **Infinite Slope Stability Model**

Slope Stability Classes Mapping

$$\underbrace{\tan\phi\left(1-\frac{\rho_w}{\rho_s}\right)+\frac{c_s}{h\,\rho_s\,g\cos\theta}}_{\text{Theoretically “stable”}}\underbrace{\le\tan\theta<}_{\text{Potentially “stable/unstable”}}\underbrace{\tan\phi+\frac{c_s}{h\rho g\cos\theta}}_{\text{Theoretically “unstable”}}$$

Theoretically “stable”

It is addressed for those slopes are stable even when saturated depth reaches the ground surface
-invariant critical relative soil saturation (m^c) triggering slope failure (i.e. relative soil saturation that yields $FS = 1.0$)

Potentially “stable/unstable”

$$m^c=\frac{h_w}{h}=\frac{\rho_s}{\rho_w}\left(1-\frac{\tan\theta}{\tan\phi}\right)+\frac{c_s}{h\,\rho_w\,g\cos\theta\tan\phi}$$

Theoretically “unstable”

It is addressed for slopes where suction is working, or they are rocks

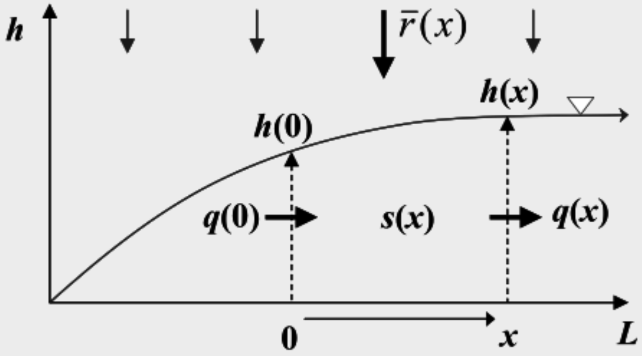
GEOTECHNICAL-HYDROLOGICAL MODEL

- ## Hydrological Model

Spatial lumping of a distributed kinematic wave rainfall-runoff model, considering three lateral flow mechanisms including (1) subsurface flow through capillary pore, (2) subsurface flow through non- capillary pore and (3) surface flow on the soil layer, developed by authors was used for hydrological approach in derivating critical rainfall-induced shallow landslides

The fundamental assumption of the lumping method is that the rainfall-runoff process of the catchment system reaches a steady state with spatially uniform rainfall input.

Basic Equations:



From the steady state assumption, the flux of water discharge per unit width in each grid cell can be given as follows:

$$\boxed{q(x) = q(0)/w + \bar{r}\int_0^x (x)\ dx = \bar{r}\,U/w + \bar{r}\,x}$$

GEOTECHNICAL-HYDROLOGICAL MODEL

Basic Equations:

Stage-discharge relationships, a general kinematic wave equation can be expressed as $q = g(h)$:

$$q = \begin{cases} v_m d_m (h_w / d_m)^{\beta}, & o \le h_w \le d_m \\ v_m d_m + v_a (h_w - d_m), & d_m \le h_w \le d_a \\ v_m d_m + v_a (h_w - d_m) + \alpha (h_w - d_a)^m, & d_a \le h_w \end{cases}$$

$$v_m = k_m i \quad v_a = k_a i \quad k_m = k_a / \beta \quad \alpha = \sqrt{i} / n$$

The critical saturated soil depth to cause instability is:

$$h_w^{\,c} = \frac{h \rho_s}{\rho_w} \left(1 - \frac{\tan \theta}{\tan \phi} \right) + \frac{c_s}{\rho_w \, g \cos \theta \tan \phi}$$

The subsurface critical inflow discharge per unit width into a grid element can be expressed as:

$$q^c = \begin{cases} v_m d_m (h_w^{\,c} / d_m)^{\beta}, & 0 \le h_w^{\,c} \le d_m \\ v_m d_m + v_a (h_w^{\,c} - d_m), & d_m \le h_w^{\,c} \le d_a \end{cases}$$

GEOTECHNICAL-HYDROLOGICAL MODEL

- **Basic Equations**

Finally, near steady-state critical rainfall rate, r_c (mm hr^{-1}), received by each grid can be computed as function of upslope contributing areas, slope length, topographic elements, soil properties, and critical saturated soil depth as follows:

$\bar{r}$

$$r^c(x) = \frac{q^c(x)}{\left(\frac{U}{w} + x\right)}$$

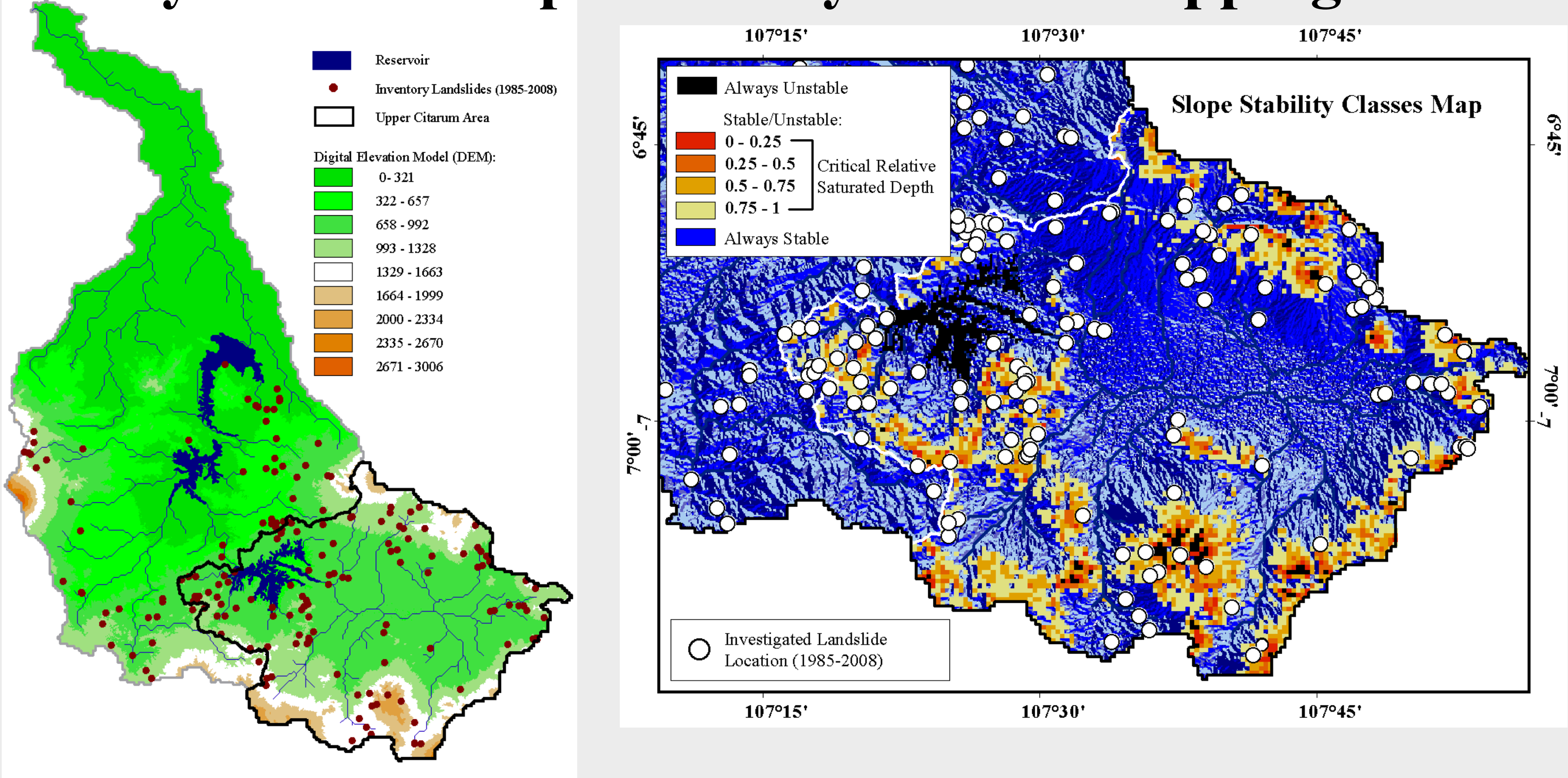
U is the upslope contributing area, x is the horizontal distance (slope length) from the upstream end of a grid cell, and w is the width of the grid cell.

Near steady state critical rainfall rate inducing slope instability of a grid element is defined as the total of rainfall rate from the upslope contributing areas and rainfall over the grid.

DPRI-KU

MODEL EVALUATION

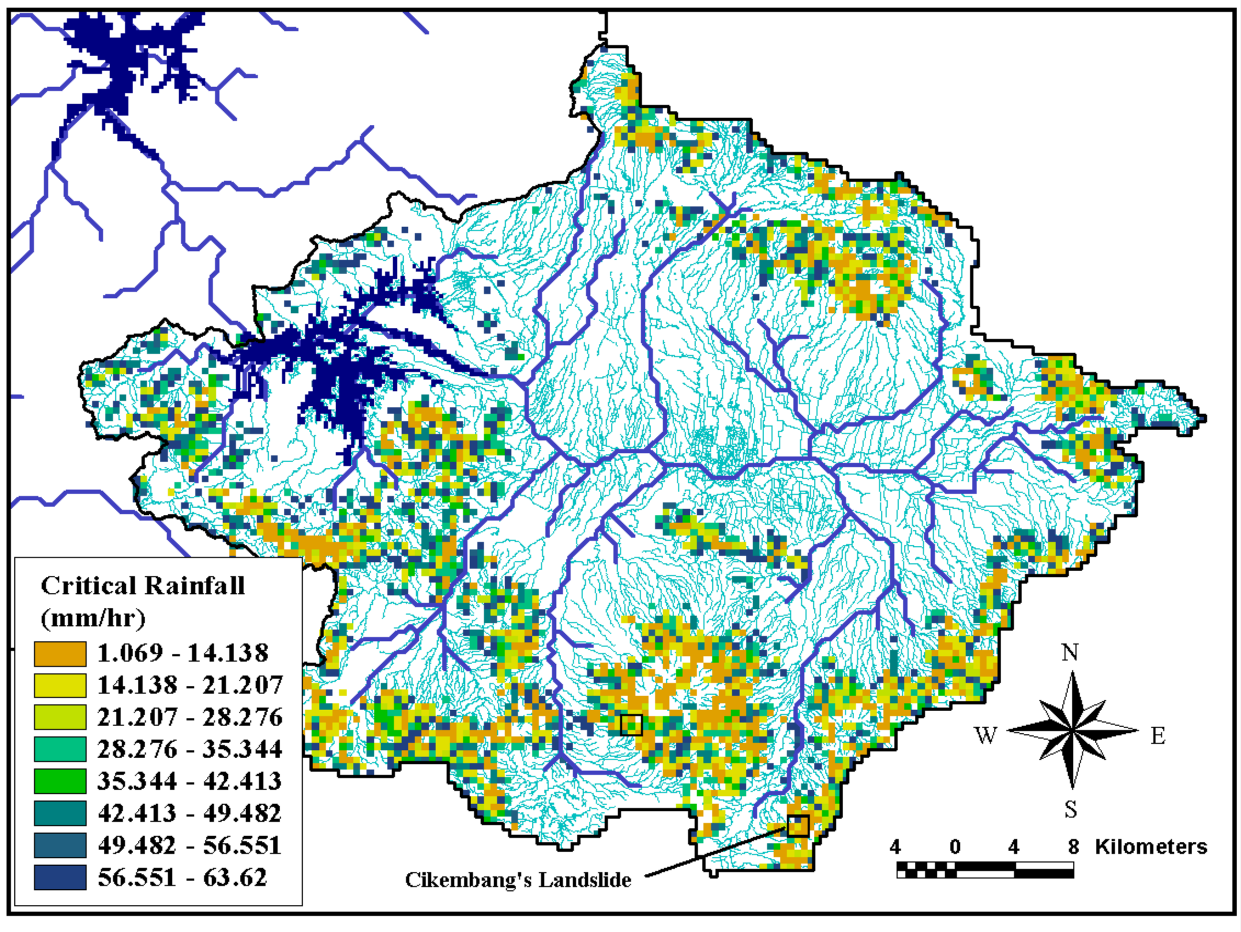
Study Site and Slope Stability Classes Mapping



(a) The location of the Upper Citarum River catchment over the whole DEM (90 x 90 m^2) Citarum River basin. The red points indicate the locations of landslides as inventoried by the Geological Agency of Indonesia (1985-2008), and (b) Comparison among spatial distribution patterns of estimated time-invariant slope stability classes mapping based on the critical relative saturated depth (m^c) and investigated landslide location patterns (1985-2008 as shown by white circles) in the Upper Citarum Catchment.

MODEL EVALUATION

Spatial distribution of critical rainfall rate-induced slope instability within the areas predefined as potentially “stable/unstable”:

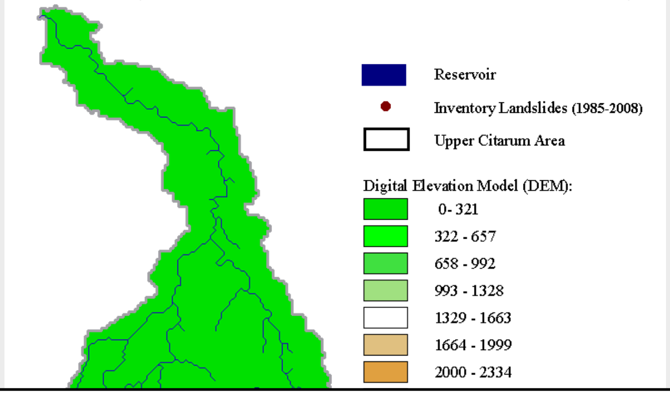


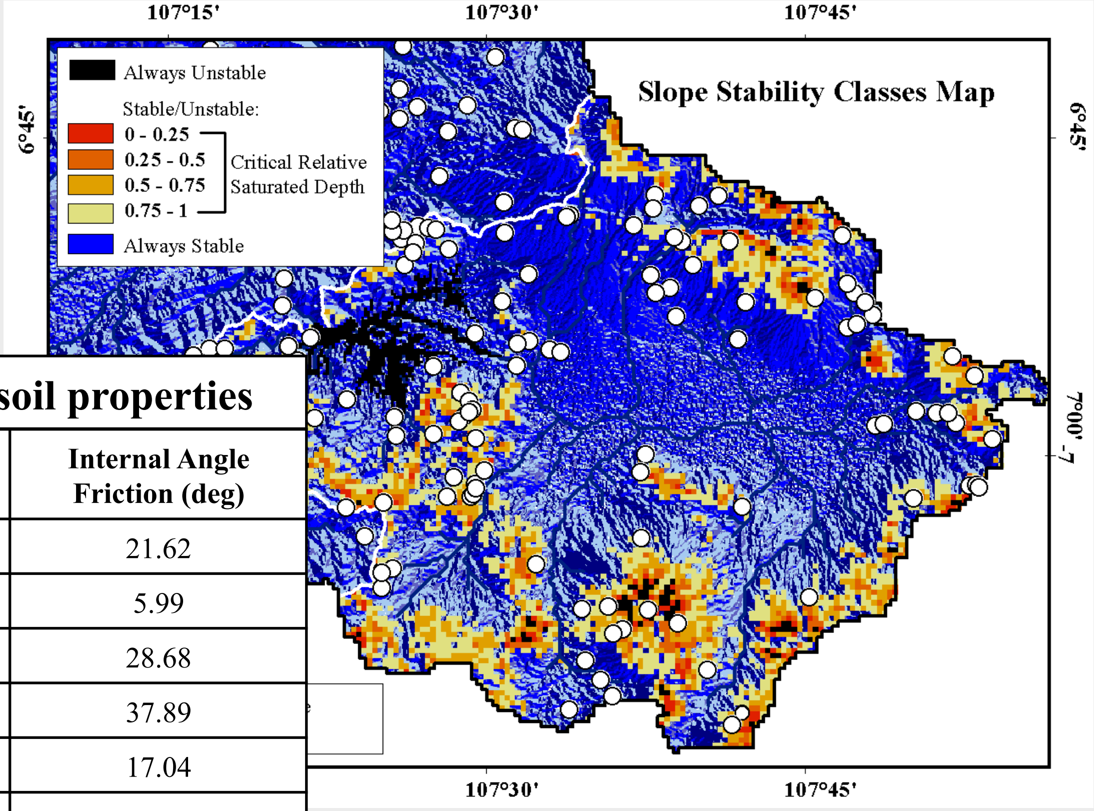
The method measures the rainfall intensity difference (RID): the amount of rainfall intensity is above (or below) the critical rainfall.

It is assumed that slope failures will more likely occur in areas where (RID) is positive

MODEL EVALUATION

Study Site and Slope Stability Classes Mapping



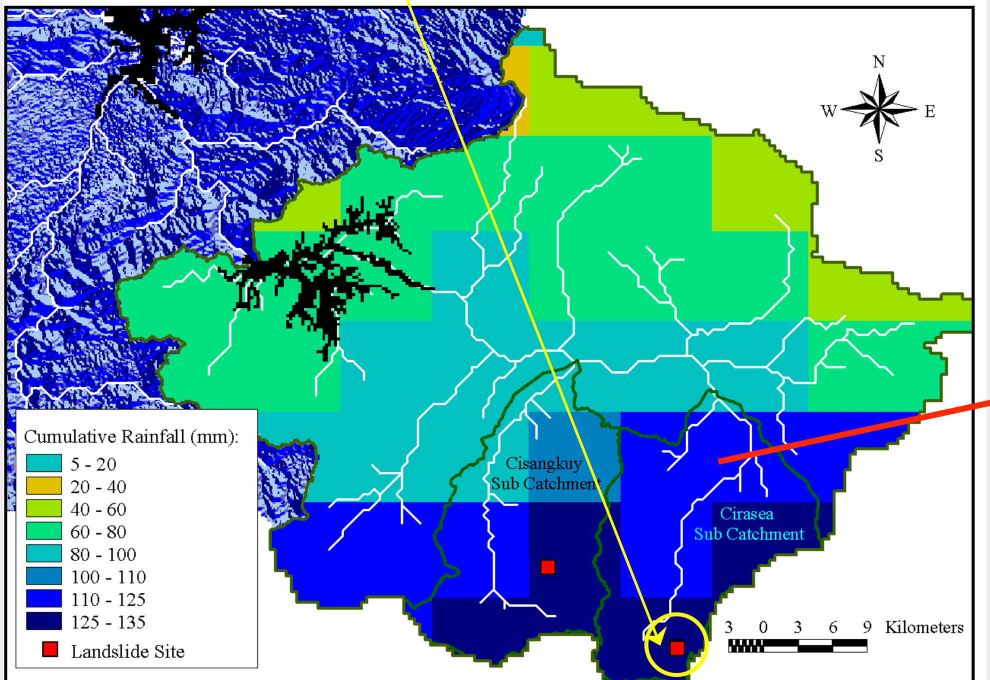


Laboratory test results for geotechnical soil properties

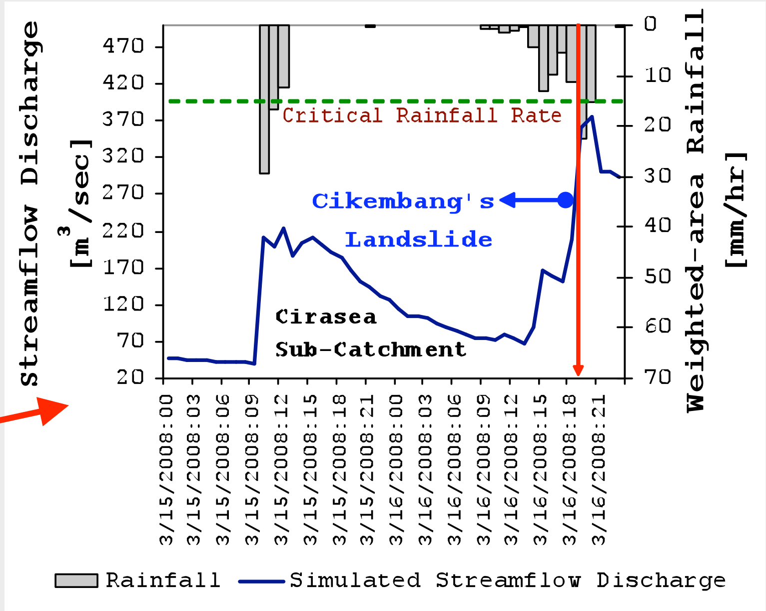
Location	Density of Soil (kN/m³)	Soil Cohesion (kPa)	Internal Angle Friction (deg)
Soil Sample 1	12.82	7.284	21.62
Soil Sample 2	13.86	1.585	5.99
Soil Sample 3	13.17	4.490	28.68
Soil Sample 4	12.80	10.901	37.89
Soil Sample 5	12.85	6.287	17.04
Soil Sample 6	13.23	5.689	33.30

(a) The location of the Upper Citarum River catchment over the whole DEM (90 x 90 m^2) Citarum River basin. The red points indicate the locations of landslides as inventoried by the Geological Agency of Indonesia (1985-2008), and (b) Comparison among spatial distribution patterns of estimated time-invariant slope stability classes mapping based on the critical relative saturated depth (m^c) and investigated landslide location patterns (1985-2008 as shown by white circles) in the Upper Citarum Catchment.

Application to Cikembang's Shallow Landslide Event
March 16, 2008



Cumulative rainfall depth during the rainfall events of 15-16 March 2008 extracted from satellite-based rainfall estimates



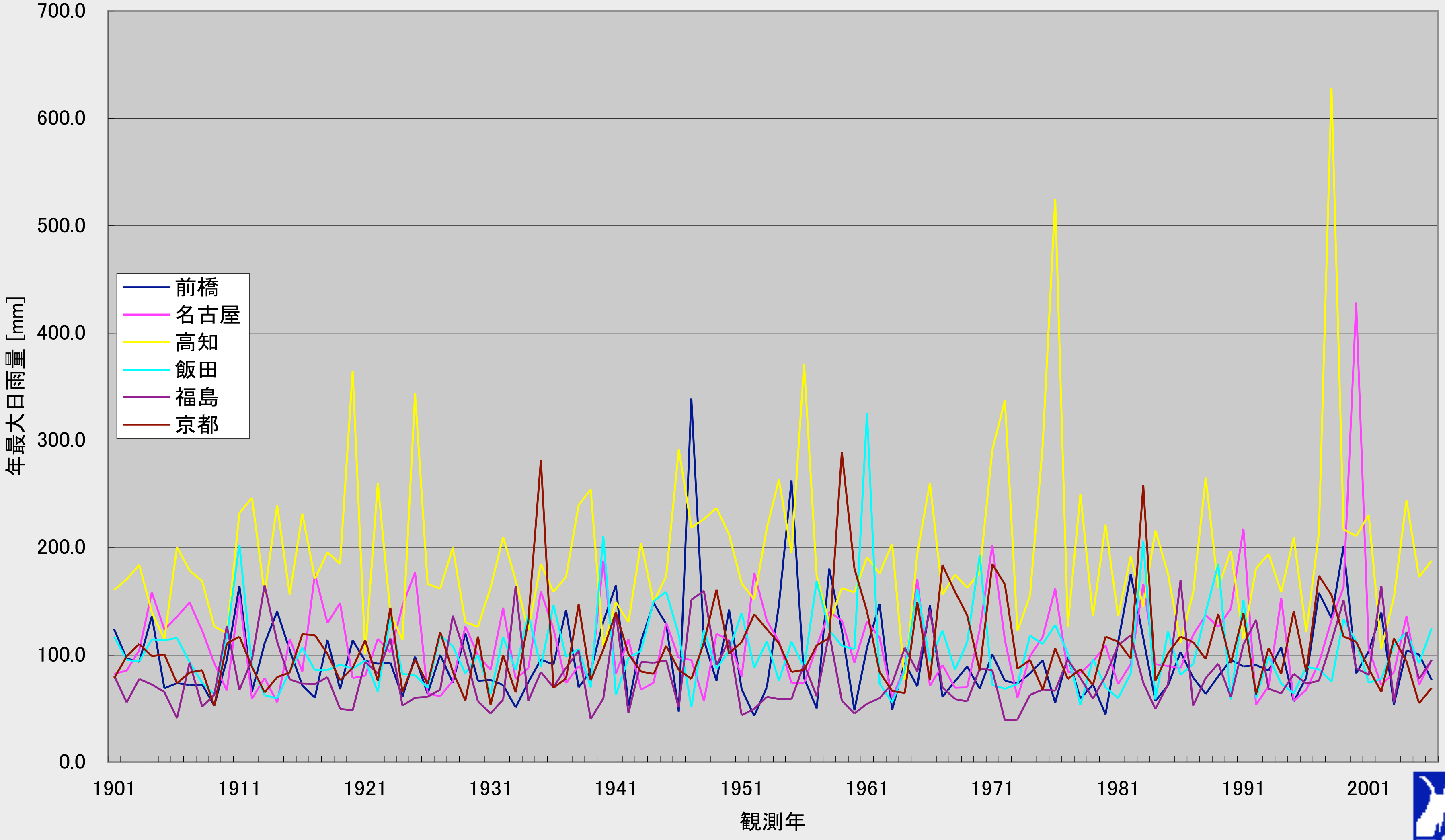
Weighted-area hyetograph on 15-16 March 2008 and its simulated river hydrograph at the outlet of sub-catchment where the past "Cikembang's" shallow landslides occurred.

The past new "Cikembang's" landslide with the critical rainfall rate is estimated approximately 15.03 mm/hr, several hours before landslides initiation, the model predicts the grid over and nearby to this observed shallow landslides were found in unstable conditions in this study.

The time for weighted-area rainfall intensity > than critical rainfall rate to occur in the sub-catchment approximated to the time of landslide occurrence as recorded. A cumulative rainfall depth of 130.0 mm was detected at Cikembang Village on that time.

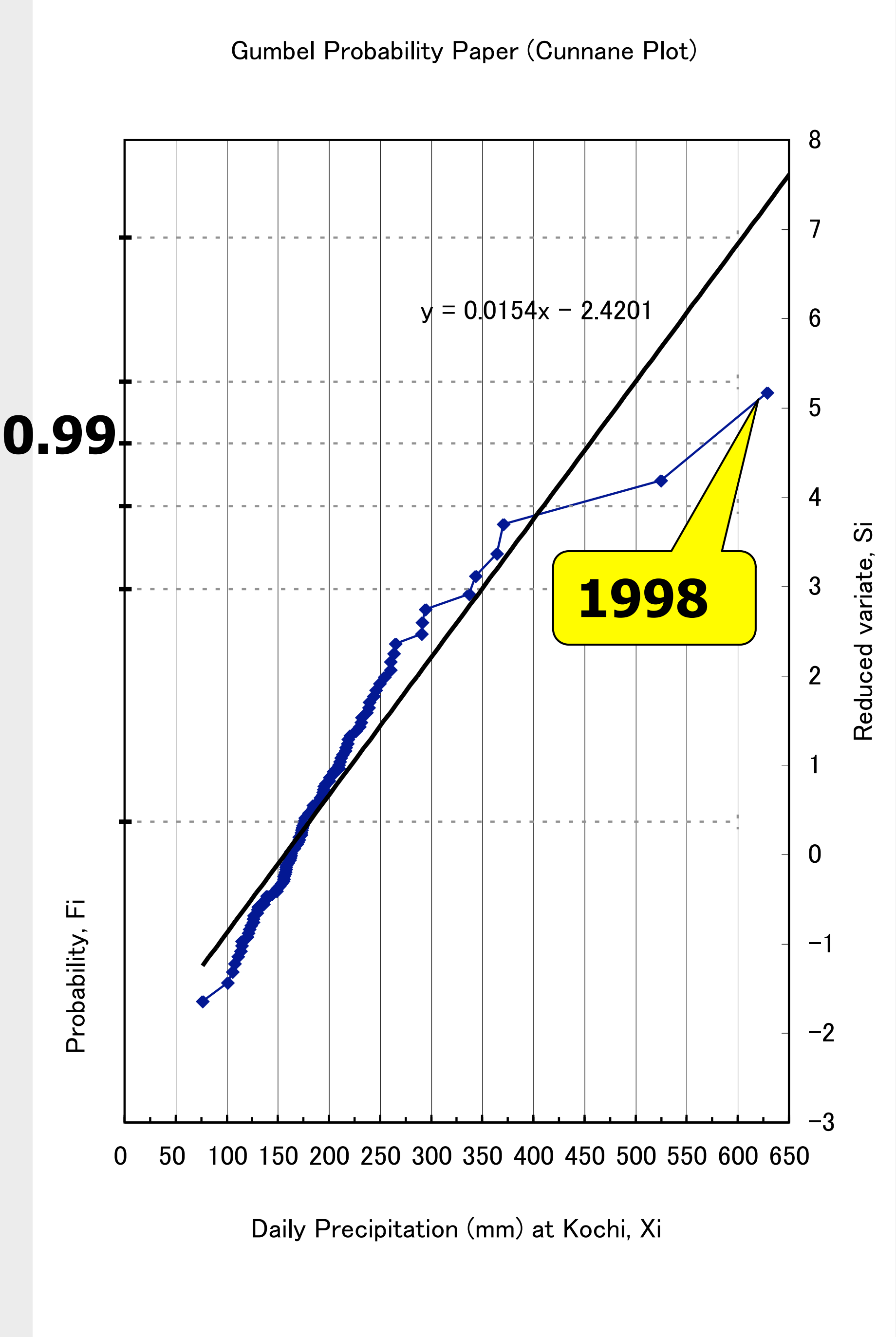
年最大降水量系列

Annual Maximum series at Maebashi, Nagoya, Kochi, Iida, Fukushima and Kyoto: 1901-2006



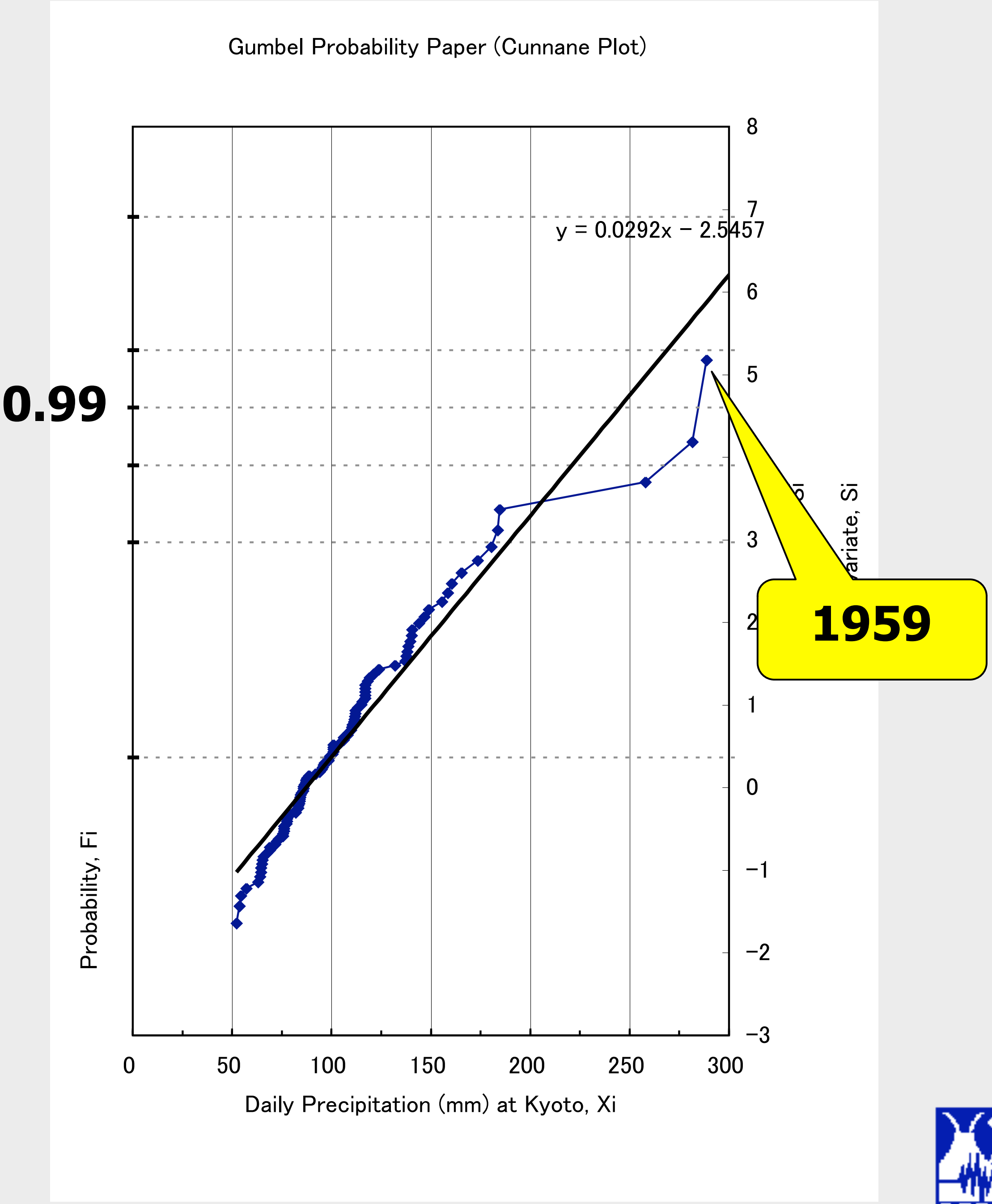
Kochi

Non-parametric: 580.5 mm



Kyoto

Non-parametric: 285.4 mm



Research Team

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- Kyoto Univ.: Kaoru Takara and some other members

- Counterparts: ***