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"Understanding potential conflicts among sectors due spatial and seasonal water use and availability in Bali, Indonesia"

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- **Study context**
- **Methodology**
- **Results**
  - Water demand
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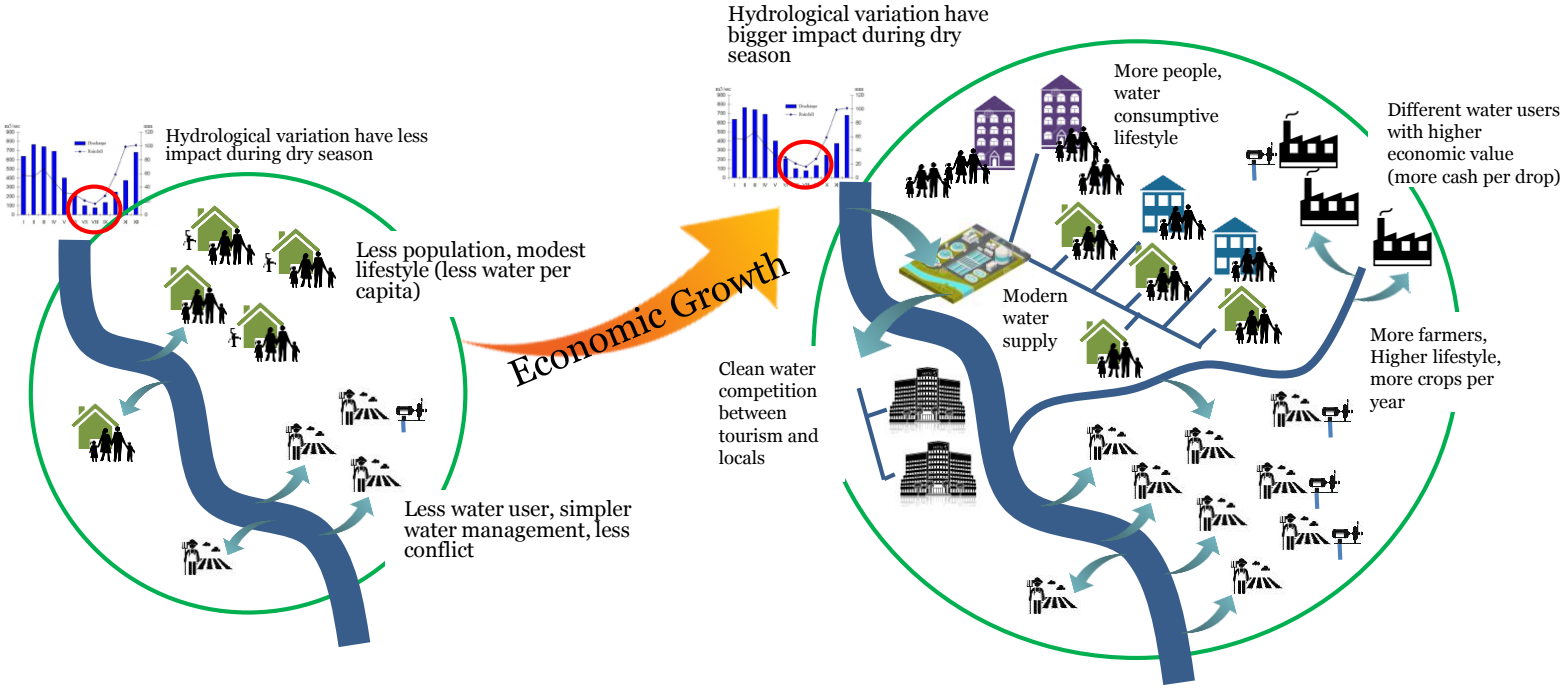
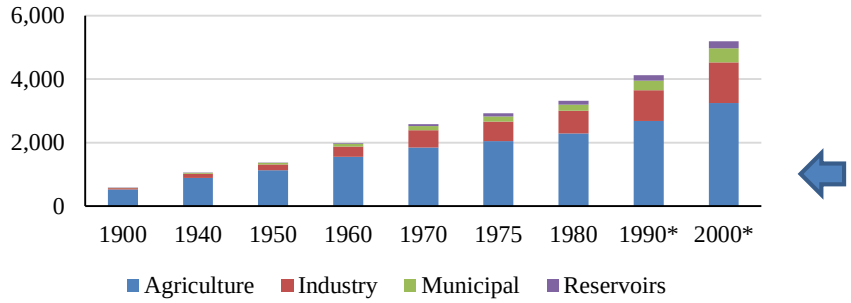
- **Conclusions**

Economic growth and water reallocation

Population Growth → Urbanization

Industrialization → Economic diversification





Water withdrawal in the world (km³/year) (Shiklomanov, 1993)

*) Estimation

Economic growth and water reallocation

- Industrialization and urbanization are currently taking place in most of developing countries in the world. Inevitably, water transfers to the growing urban centers and inter-sectorial water allocation are likely to happen (Komakech, Van Der Zaag, & Van Koppen, 2012; Wang, Fang, & Hipel, 2003);

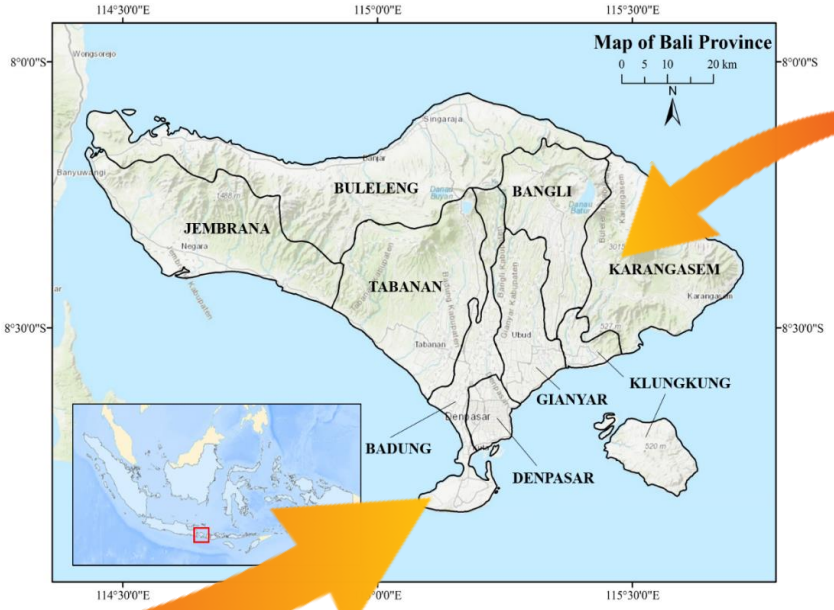
- "Water is too often devoted to economically inefficient, low return (usually agricultural) uses and that reallocation to more efficient, high return (usually urban) uses would increase total economic welfare."(Molle, 2006);

- Water reallocation due to limited amount of resources has been known as source of conflicts among sectors;

- **Water scarcity condition creates higher vulnerability for conflict due to water transfer which may escalates to destruction and fights among water users**

Study Context : Bali, Indonesia

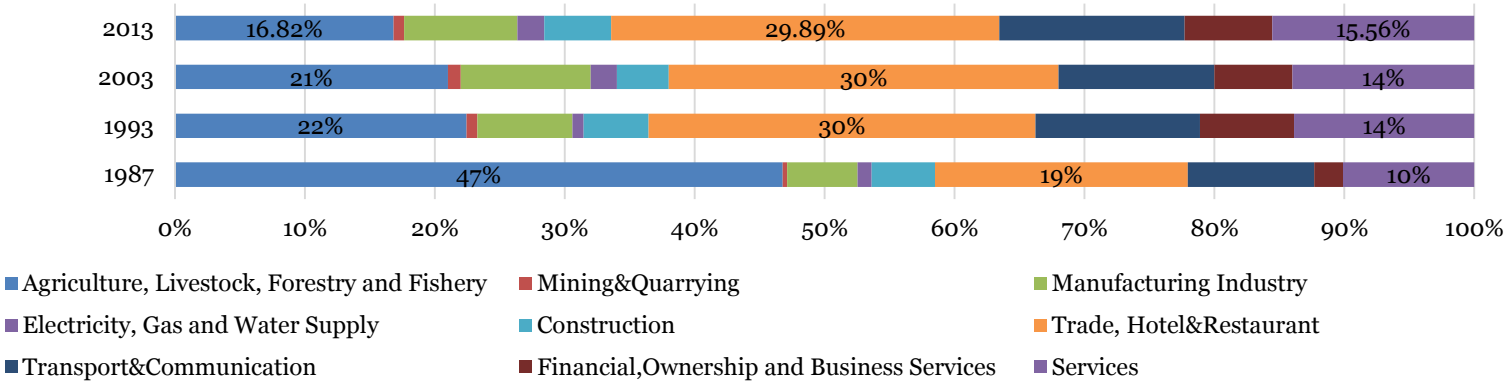
Merdeka.com (September 2014)



Suara Pembaruan Newspaper (September 2015)

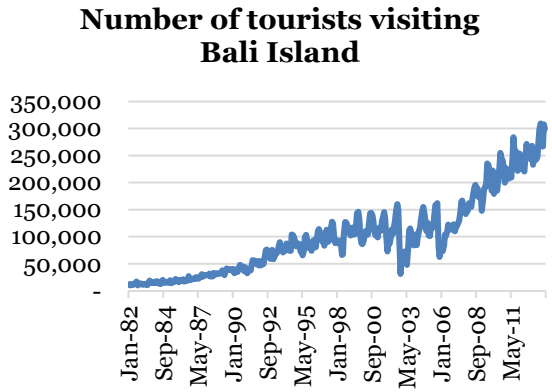
1. Area : 5,634.40 km² [1)]
2. Population (2014): 4,104,900 [2)]
3. 8 regencies and 1 city

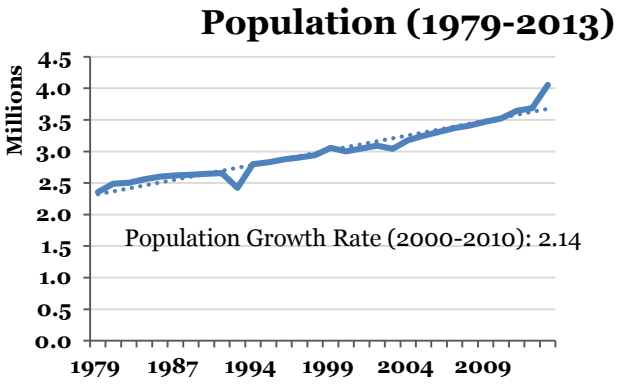
Gross Domestic Product (GDP) of Bali Province

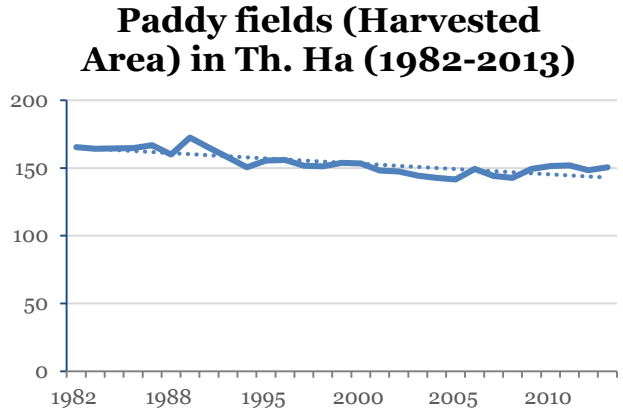


Sources: [1)] Bali Provincial Government; [2)] Bali Statistical Agency

Study Context : Bali, Indonesia





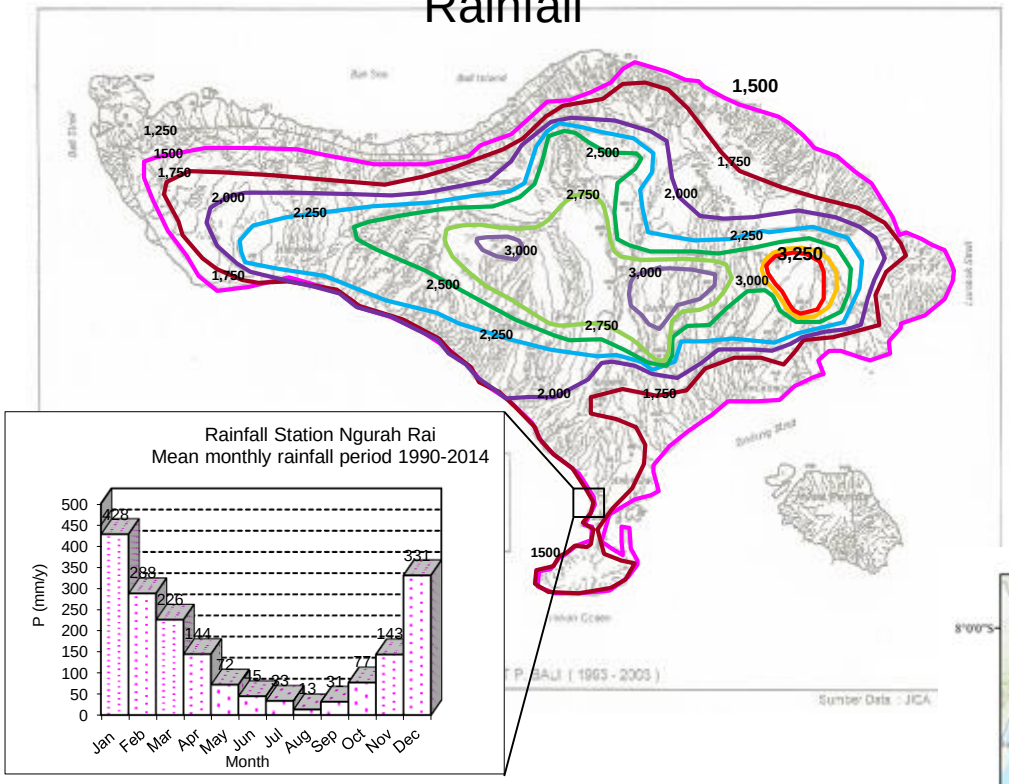


- This study takes an example of rapid development in Bali as one of the world's tourist destinations
- The shifting water distribution from agriculture which is mostly owned by the locals to tourism industries about 85% of which is owned by non-Balinese (MacRae, 2010) is one of the examples of a conflict ridden process;
- Research on water conflicts in Bali were mostly discussed through social and political perspectives (Cole, 2012; Tarigan, Dharmawan, Tjondronegoro, & Suradisastra, 2014; Trisnawati, 2012);
- Very little research were published about the scientific reasons behind these conflicts;

- **The objective of this study is to understand conflicts between sectors in Bali by comparing the spatial and seasonal variabilities of water uses and availability.**

Water Resources and infrastructure

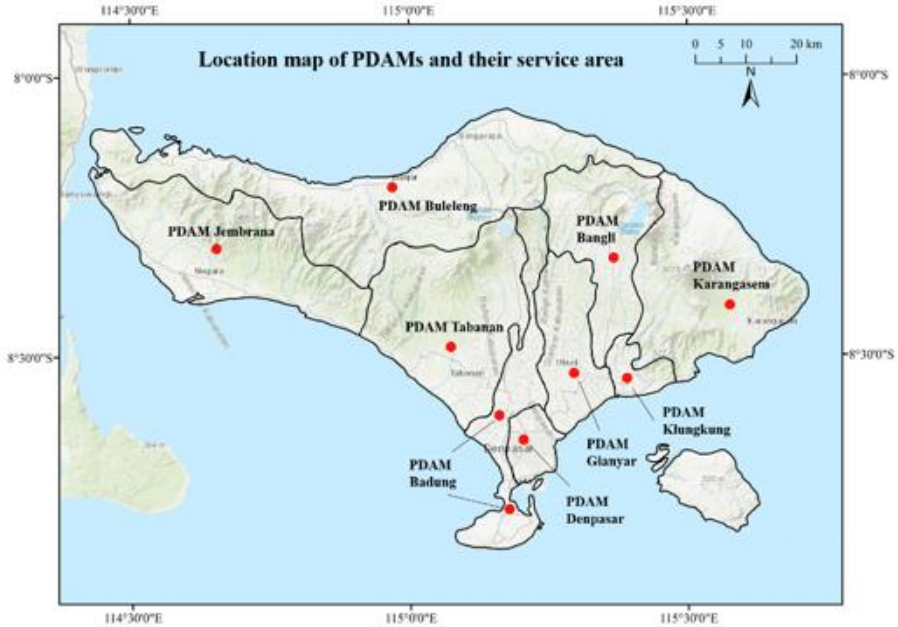
Rainfall



Dams : (total storage 14.37 million m^3)

- Palasari Dam (Jembrana Regency) - 8 million m^3
- Telaga Tunjung Dam (Tabanan Regency) - 1 million m^3,
- Gerokgak Dam (Buleleng Regency) -3.75 million m3 and
- Benel Dam (Jembrana Regency) -1.62 million m^3

(Ministry of Agriculture, 2017).

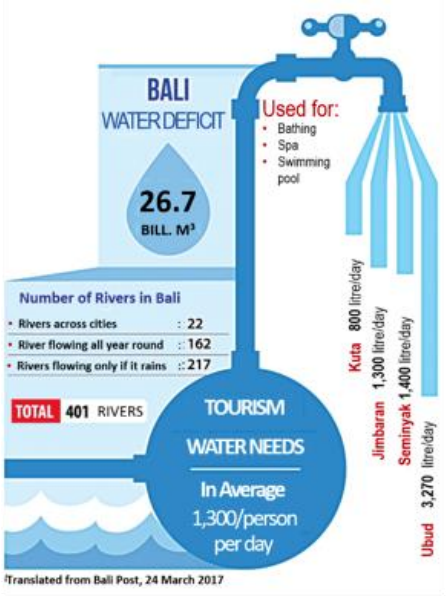


Clean water is supplied by Regional Drinking Water Companies (PDAM), which are managed by each regency/city.

Alternative water supply
Shallow wells (less than 12 m)
Deep wells (max. 60 m with less than 100 m^3/month)
Rivers

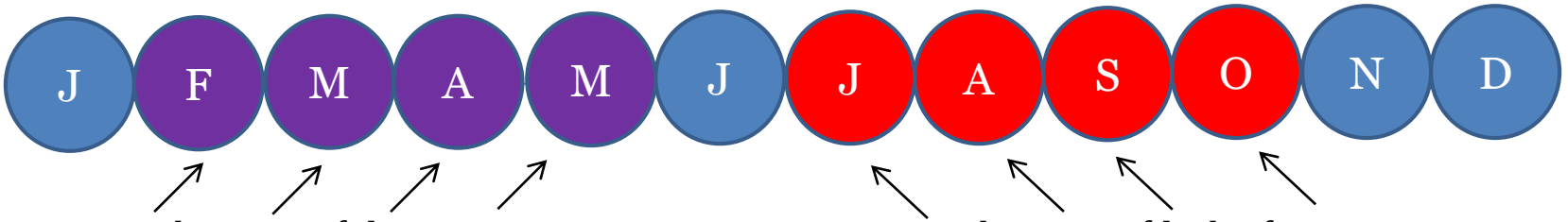
Data source:
Isohyet Map: JICA
Rainfall Data: BMKG
Location map of PDAM JICA

Water Crisis and Conflicts



Info-graphic in local newspaper (Bali Post) about Bali Water Deficit

Water crisis has been the media headline for the past decade in Bali.



Water crisis because of damage in infrastructure due to floods/landslides

Water crisis because of lack of water source

Social ⟷ Science

Complains from community:

I have to walk more than 2 km to find water during season"(Bali Post, 2015)

"The water in this "cubang" (water storage) is still enough before the peak of dry season, but after the peak, discharge decreased and we have to buy clean water (from water tank). This situation happened since a long time ago"(Bali Post, 2016c)

Complains from farmers:

" Drought happened because volume of water in irrigation channel is small"(Bali Post, 2017),

"I cannot do farming anymore. There is no water. I lost my source of income."(Bali Post, 2016b).

Some conflicts of water has been escalated from the crisis (Strauß, 2011; Tarigan et al., 2014) and some even lead to destruction of public property such as road and pipes (Bali Post, 2011b, 2011c). Conflicts happened between farmers and PDAM and fights among local population over clean water.

Water Balance Calculation

- Period of calculation: 1994 to 2013 (20 years – monthly for every regency)

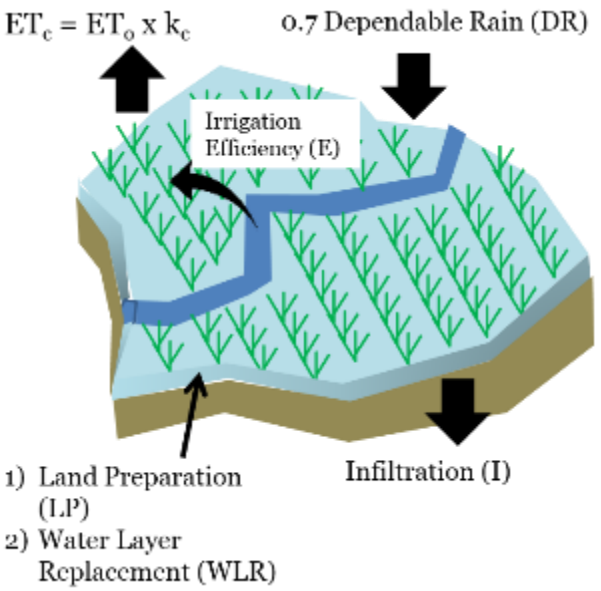
Water Use:	VS.	Water Availability:
1) Agriculture		1) Rivers
2) Domestic		2) Springs
3) Tourism		3) Groundwater

Water use	Data	Standard
Domestic	Population data (National population census)	1 person = 100 l/d (Indonesian National Standard/SNI)
Tourism	• Number of hotel rooms • Monthly occupancy rate (only occupied room were counted) (Bali Province Statistical Agency)	(unit in m^3/room/year) • 4-5 star = 1,424 • 1-3 star = 949 • Non-classified = 548
Agriculture	• Harvested Area (Bali Province Statistical Agency) • Rainfall data (Ministry of Public Work rain gauges) • Climatic data (BMKG climatic stations)	*) next slide

Agriculture water use

	JAN		FEB		MAR		APR		MAY		JUN	
	1	15	1	15	1	15	1	15	1	15	1	15
k_c	1.1	1.1	1.08	1.05	1	0.95	-	-	1.1	1.1	1.08	1.05
I	2	2	2	2	2	1	1	2	2	2	2	2
LP	-	-	-	-	3.33	6.67	3.33	-	-	-	-	-
WLR	1.67	1.67	1.67	1.67	-	-		1.67	1.67	1.67	1.67	1.67

	JUL		AUG		SEP		OCT		NOV		DEC	
	1	15	1	15	1	15	1	15	1	15	1	15
k_c	1	0.95	-	-	1.1	1.1	1.08	1.05	1	0.95	-	-
I	2	1	1	2	2	2	2	2	2	1	1	2
LP	3.33	6.67	3.33	-	-	-	-	-	3.33	6.67	3.33	-
WLR	-	-		1.67	1.67	1.67	1.67	1.67	-	-		1.67



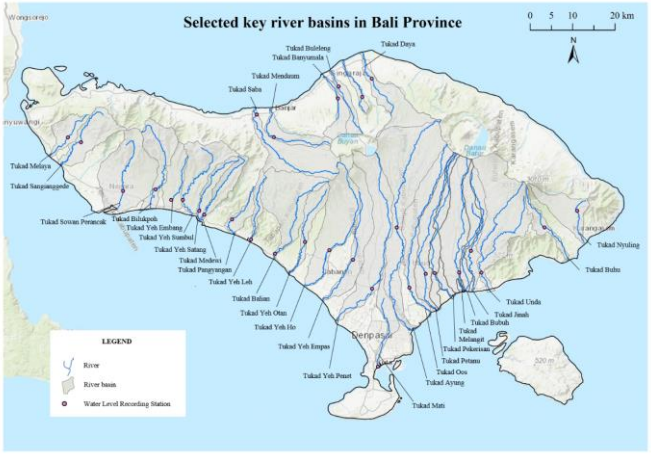
- Units: k_c (-), I (mm/d), LP (mm/d), WLR (mm/d), DR (mm/d), E (-)
- All constants were based on JICA et al. (2006)

$$IW = \frac{(ET_c + I + LP + WLR + 0.7DR)}{E}$$

	for <=23.33 mm, = 0.6 – 3.33 for >23.33 mm, = 0.8 – 6.00
	0.5

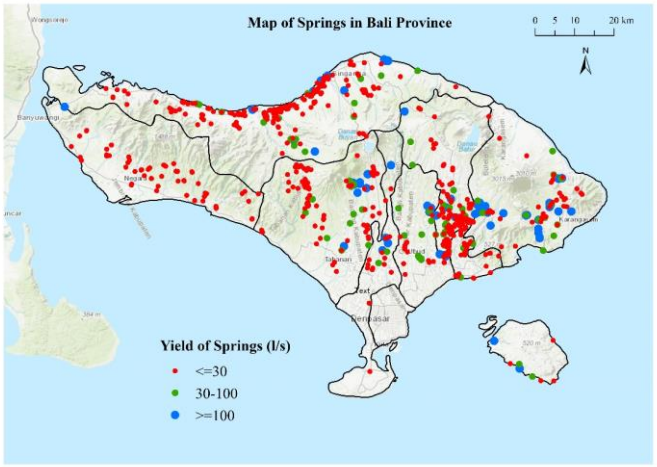
- Formula obtained from JICA et al. (2006)
- IW = Irrigation Water
- ET_o= Potential Evapotranspiration obtained by Penmann-Monteith equation

Water Availability



Rivers

- Estimated from daily river discharge of major 31 river catchments;
- Estimation method provided by Ministry of Public Works of Indonesia. (based on a water balance equation using daily rainfall and evapotranspiration) including related coefficients suitable for Bali's settings.



Springs

- Based on data inventory of springs' yield from Ministry of Public Works data.
- The spring water availability is calculated with the following equation:

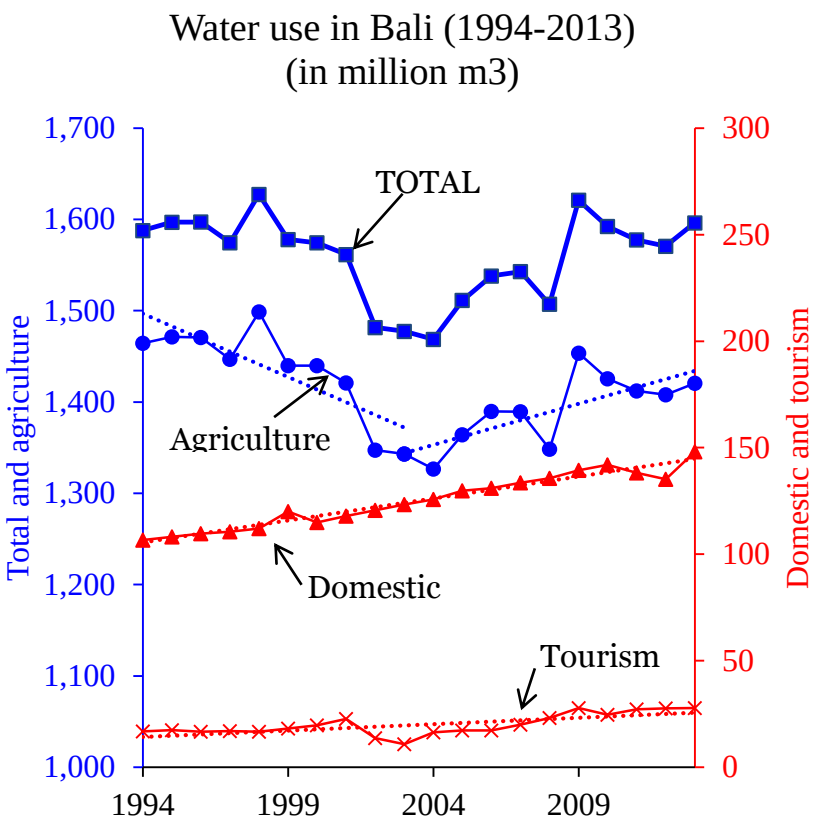
$$SW(m,r) = \sum_{j=1}^{j-n} Q_s(j,m)$$

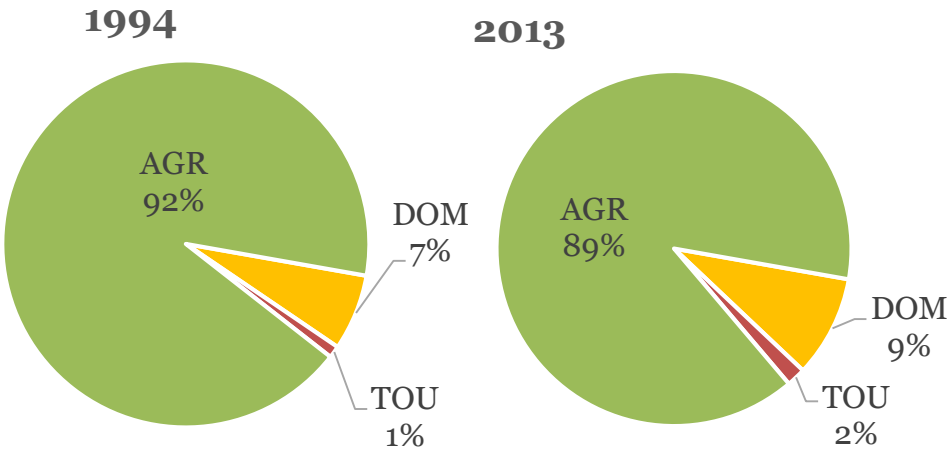
- SW = spring water ; Q_s is max. yield, n= is number of springs in one regency.

Groundwater

- Estimated groundwater availability of a regency/city used based from JICA's revision on the calculation from the Integrated Urban Infrastructure Development Program-Bali (IUIDP-Bali) Project.
- The recharge volume of each regency is calculated based on the proportion of each geological formation in the respective regency and the rainfall in the area and the exploitable limit is 10% of the recharge.

Annual Water Use (Bali)





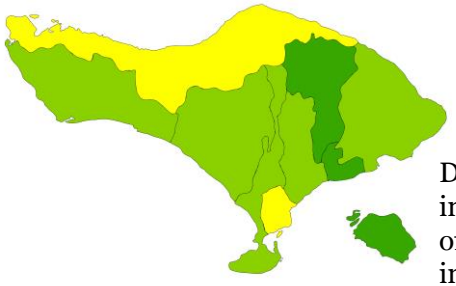
- Total water use increased by 0.01 billion m^3 (0.54%) in 20 years;
- Domestic Water Use increased by 0.04 billion m^3
- Tourism Water Use increased by 0.01 billion m^3
- Agriculture Water use decreased by 0.04 billion m^3

Water transfer:
Agriculture to Domestic (82%) and Tourism (18%)

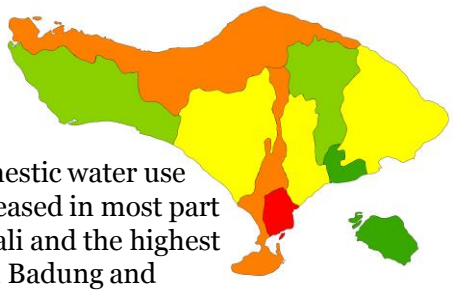
Spatial Water Use (9 Regencies/City)

Domestic

1994



2013



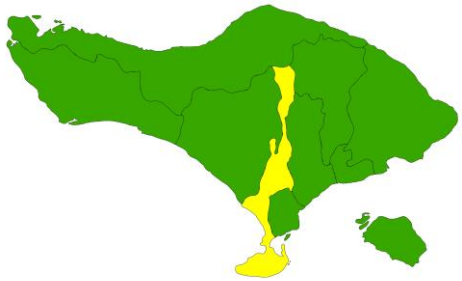
In million m^3

- <7
- 7-14
- 14-21
- 21-28
- >28

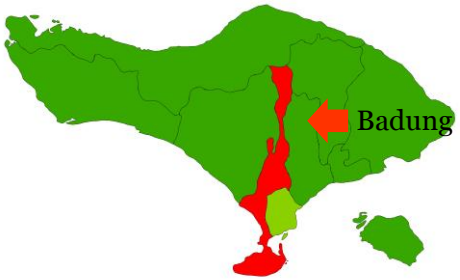
Domestic water use increased in most part of Bali and the highest in in Badung and Denpasar

Tourism

1994



2013

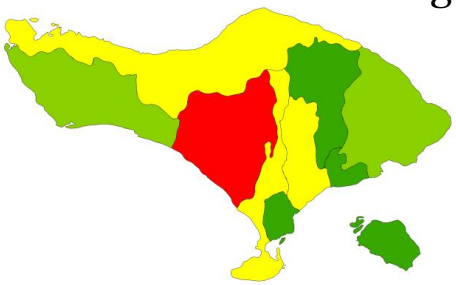


In million m^3

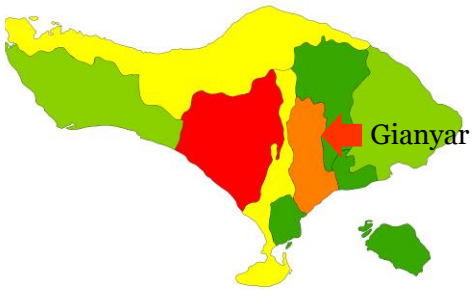
- <4
- 4-8
- 8-12
- 12-16
- >16

Agriculture

1994



2013

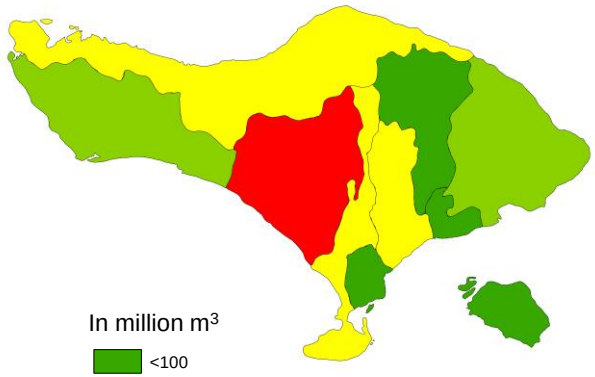


In million m^3

- <80
- 80-160
- 160-240
- 240-320
- >320

Total

1994

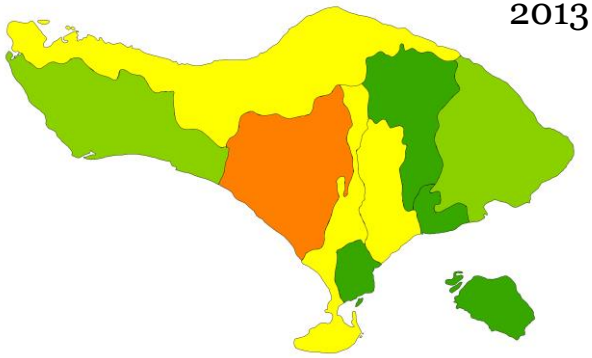


In million m^3

- <100
- 100-200
- 200-300
- 300-400
- >400

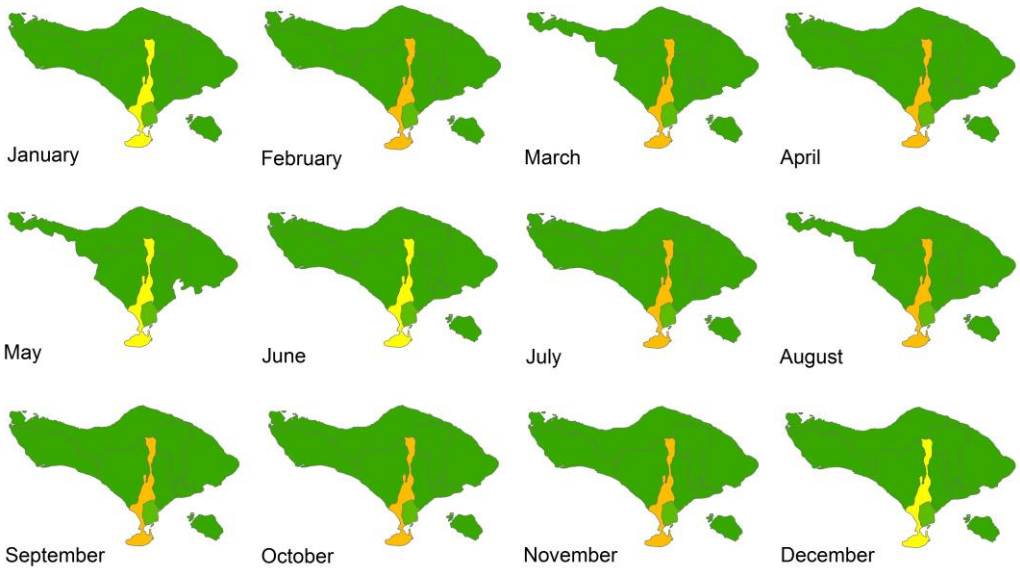
Overall the highest water use is still in Tabanan area

2013



Tourism seasonal water use

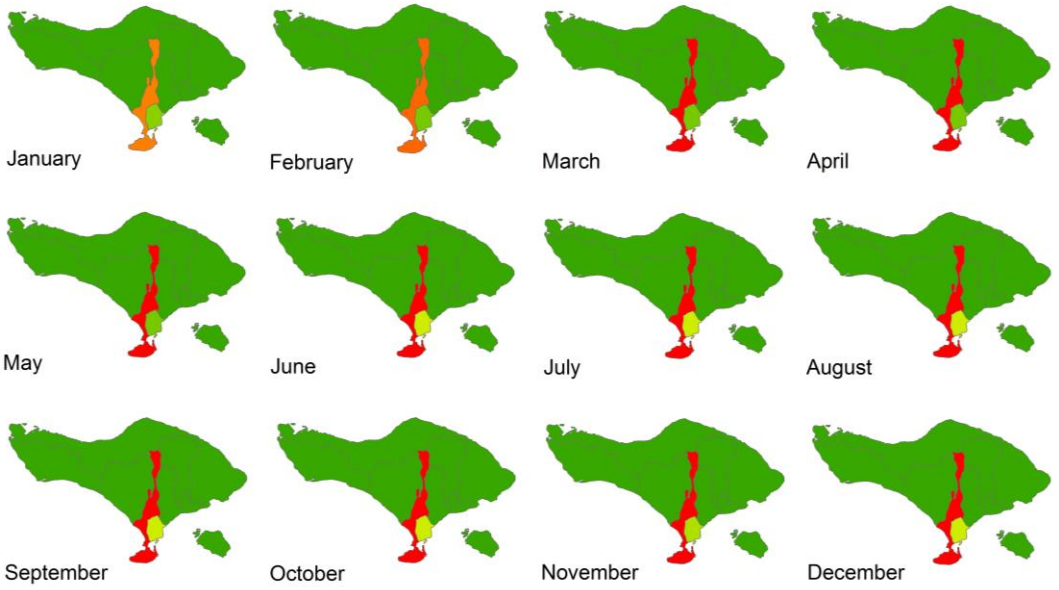
1994



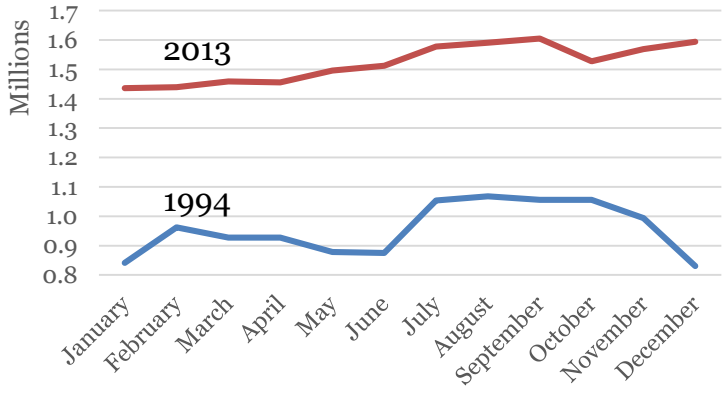
In million m3

< 0.18	0.72 - 0.90
0.18 - 0.36	0.90 - 1.09
0.36 - 0.54	1.08 - 1.26
0.54 - 0.72	1.26 - 1.44
	> 1.44

2013



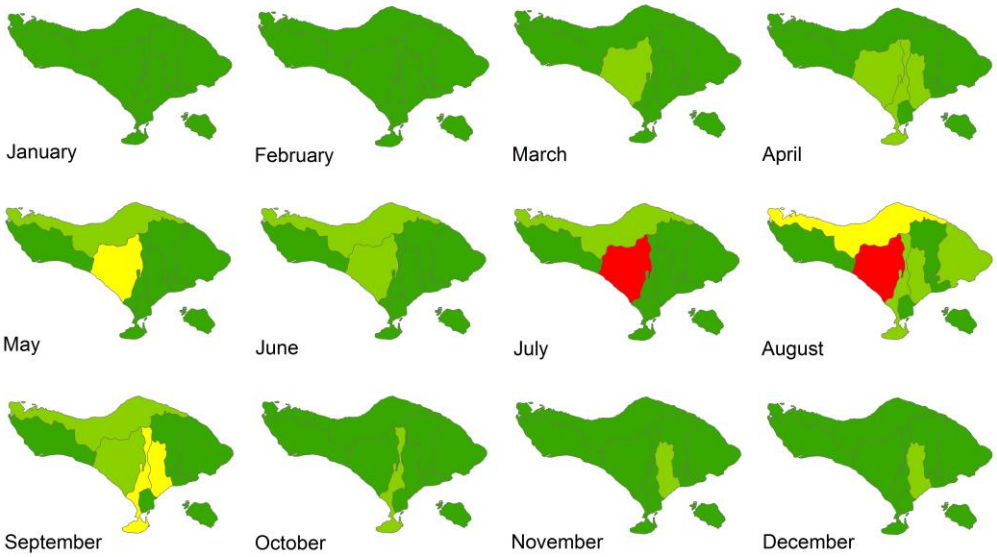
Badung Regency

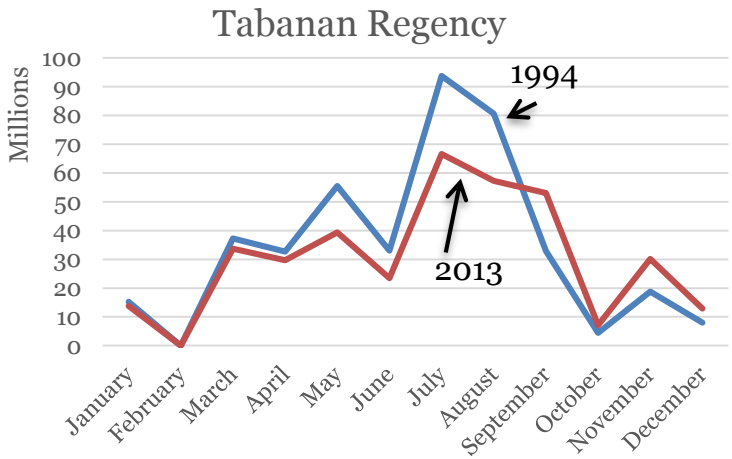


In the peak periods, water used 1.05 times higher than the average. This value is lower in 2013 than in 1994

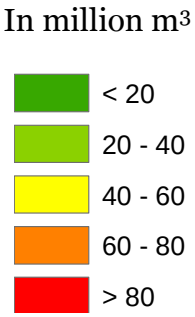
Agriculture seasonal water use

1994

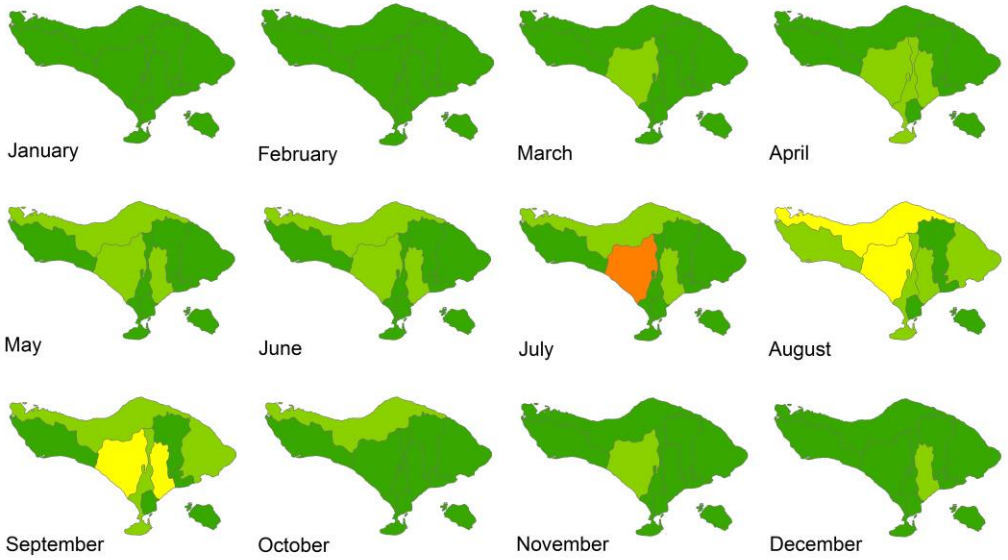




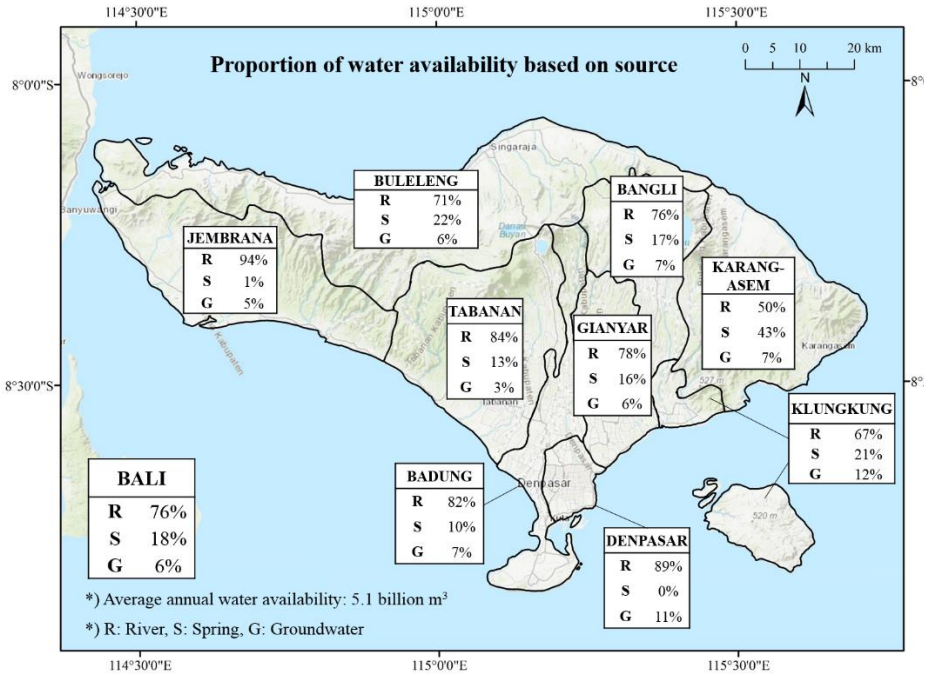
In 1994, peak happened only in Tabanan and Buleleng but in 2013 it also happened in Gianyar

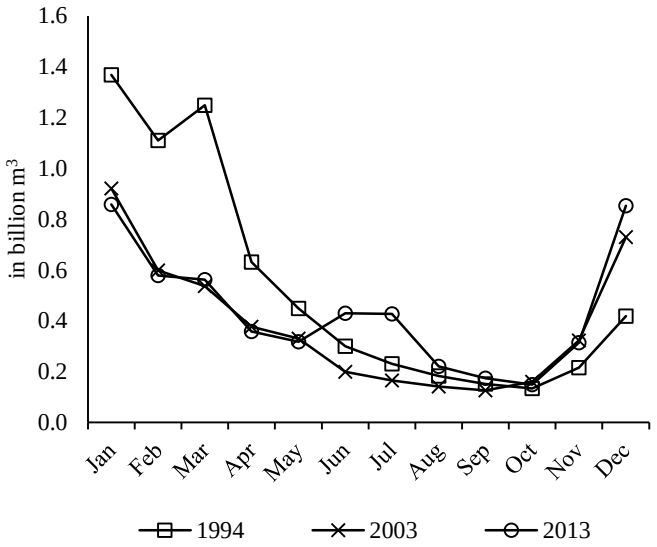


2013



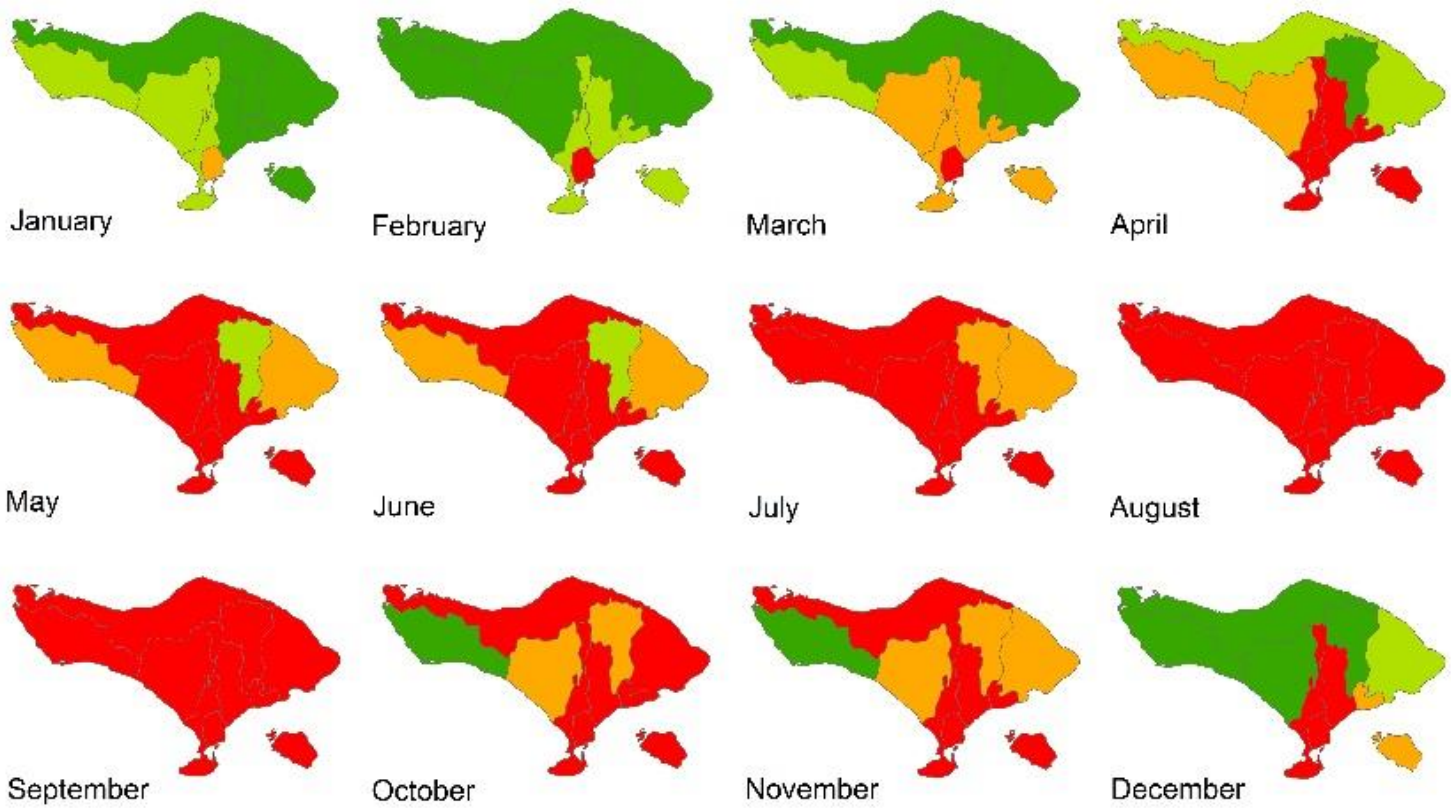
Seasonal Water Availability





- Annual water availability in Bali is ranged between 3.5 billion m³ to 7.1 billion m³.
- Most of water resources (76%) comes from rivers, 18% from springs and 6% is from groundwater (exploitable limit)
- The comparison of seasonal water availability in 1994, 2003, and 2013 (above picture) shows yearly and monthly variation of water availability. The lowest water availability is from August to October.

Water use vs. water availability



Water Use/Availability	Stress Level
<0.1	Low
0.1 – 0.2	Moderate
0.2 -0.4	High
>0.4	Extreme

Conclusions

- Most water crisis which were reported in the local newspapers during **July to October were caused by lack of water resources** while those which were reported during **February to April were caused by damage in water infrastructures (due to landslides or floods)**. Some of the reported crisis were escalated to conflicts and destructions of public properties (Bali Post, 2011b, 2011c, 2016) happened in **Badung (July 2011), Karangasem (July 2011), Gianyar (October 2017), Klungkung (November 2016), and Tabanan (October 2009).** All of these conflicts happened when water stress level in extreme condition.

- This study suggested that even though the Bali's GRDP shows a change in regional income from agriculture to tourism, but agriculture water use was only slightly decreased (2.73%) from 1994 to 2013. It even shows increasing trend since 2003. As the original income for the Balinese, this may cause conflicts between farmers and other sectors. It should be therefore well regulated in terms of timing and location based on available water resources. Accurate information with scientific evidence on spatial and temporal availability of water as well as suggestion on planting schedule should be communicated through proper method such as through the traditional *subak* system.

Conclusions

- Urbanization and tourism development happened in **Badung Regency and Denpasar City** and water was reallocated from agriculture sector (decreased by 62.78 million m3) to tourism and domestic (increased by 33.83 million m3). Furthermore, **these regencies have in nature smaller water availability compare to other regencies (9% of all Bali).** This situation makes these regions **prone to conflict due to hydrological variation** especially in prolonged dry period.
- The use of relatively stable water sources such as springs and groundwater should be therefore regulated and monitored in a better way to avoid uncontrolled use during dry period. On the other hand, assessment on the sustainable limit of the use of these resources particularly for these regency and city should be done more carefully to allow access during dry period.

Acknowledgement

lpdp
lembaga pengelola dana pendidikan

KYOTO UNIVERSITY
GSS
Global Survivability Studies

Thank you…..