

# Integrating land and water management in mountain watersheds for optimized downstream water services

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# International Centre for Integrated Mountain Development (ICIMOD) [www.icimod.org](http://www.icimod.org)



## ICIMOD's vision:

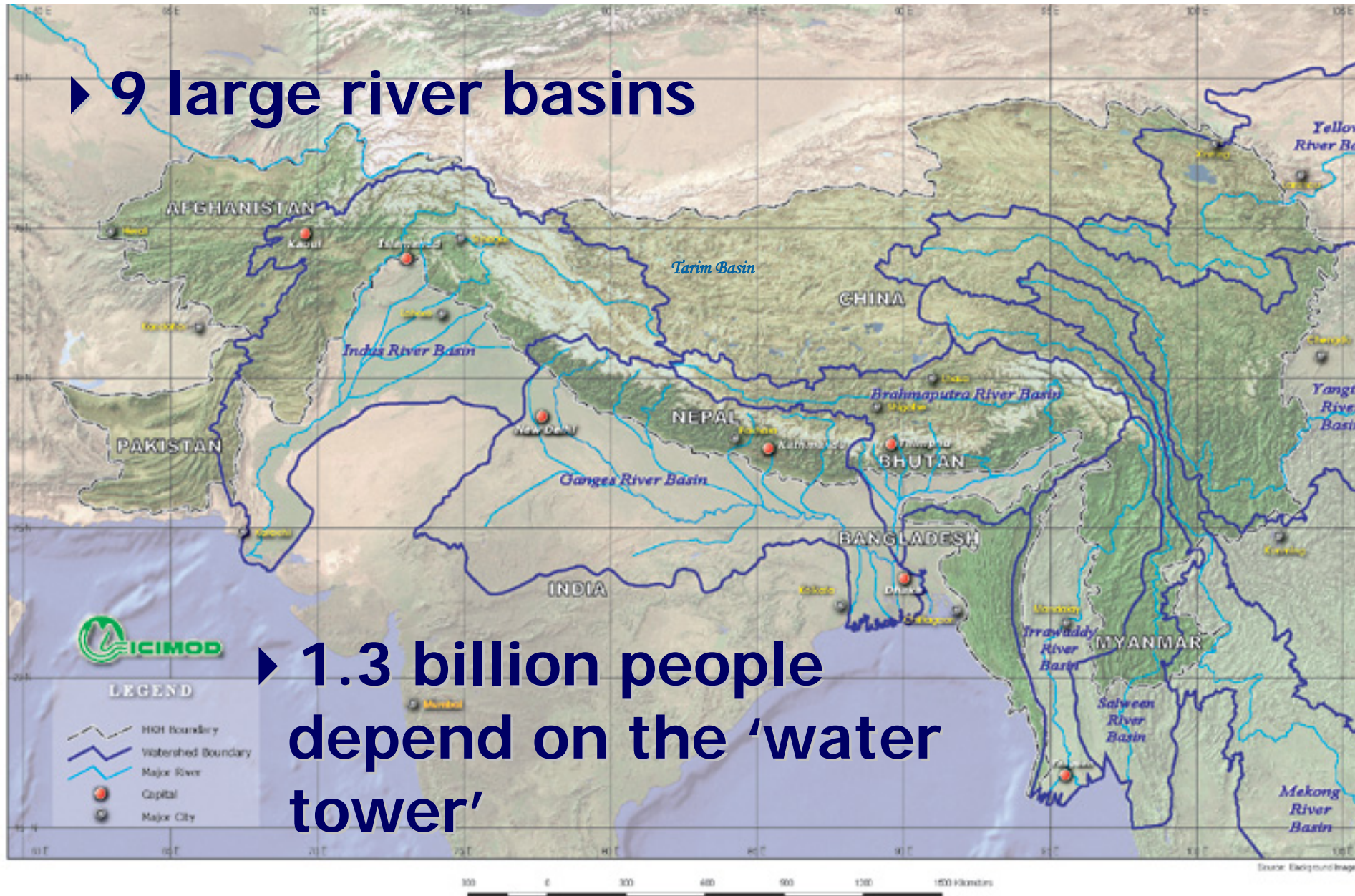
*'Prosperous and secure mountain communities  
Committed to peace, equity and environmental  
sustainability'*



# Himalayan Mountain – the 'Water Tower'

▶ 9 large river basins

▶ 1.3 billion people depend on the 'water tower'



# Water in these basins provide life, livelihoods ...and death!

## Services

- Water supply
- Environment flow
- Hydropower
- Climate regulation

## Hazards

- Floods/Flash floods
- Sediment
- Drought
- Water pollution

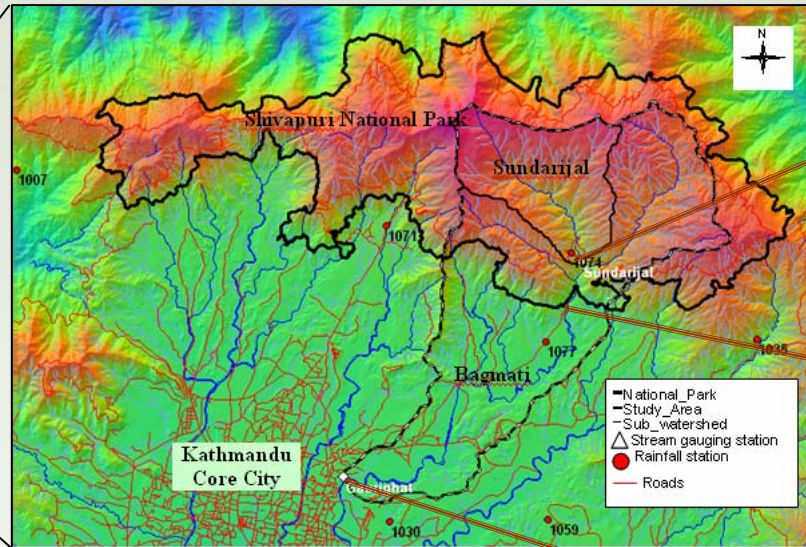
Integrated land, water and hazard management -  
a strategic thrust proposed for the next MTAP of  
ICIMOD

# A Case Study – The Shivapuri Watershed

- ▶ Based on the study **‘Investigating the Delivery of Ecosystem Economic Benefits for Upland Livelihoods and Downstream Water Users in Nepal’** jointly conducted by IUCN and ICIMOD
- ▶ This paper highlights land use and catchment water delivery scenario from the Sundarijal sub-watershed



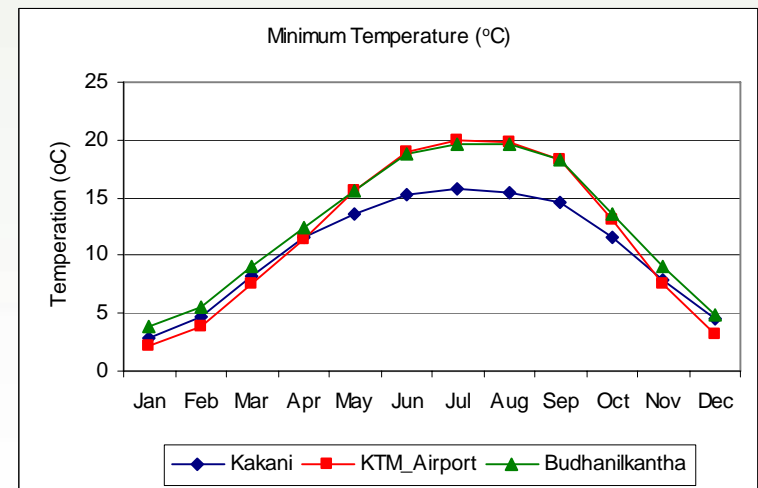
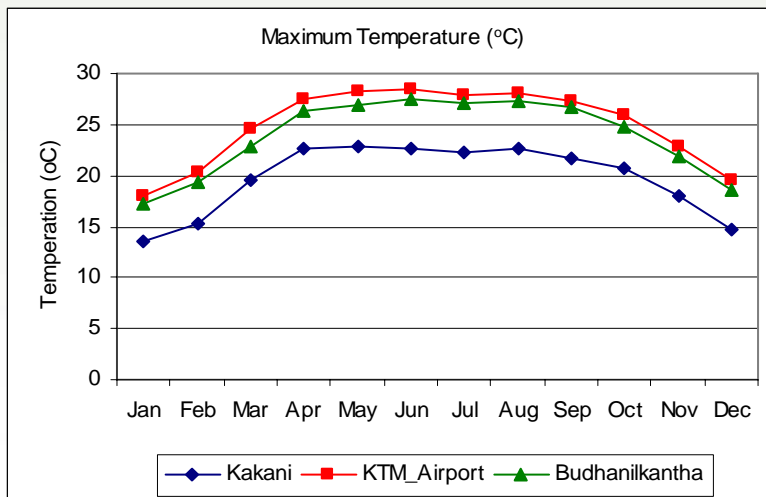
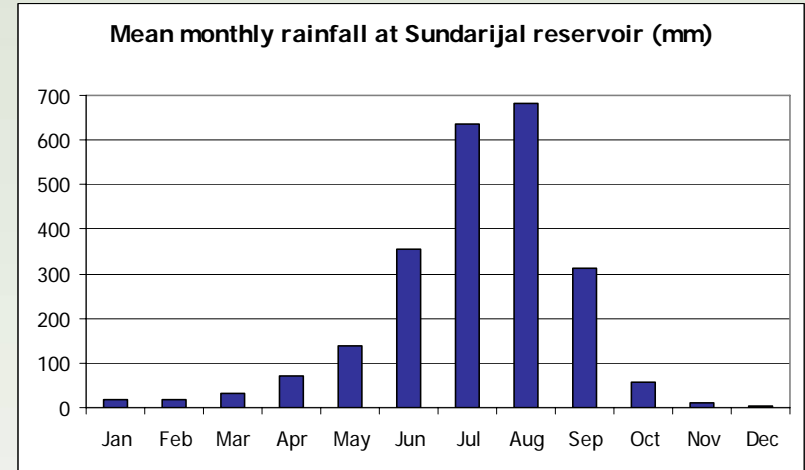
# The Study area - location



- Northern fringe of Kathmandu valley – middle mountain physiographic zone
- Elevation – about 1300 – 2700m asl

# Climate

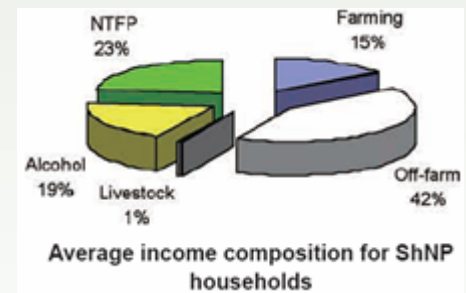
- ▶ **Transition zone**  
between sub-tropical  
and temperate
- ▶ **Monsoonal climate** -  
distinct rainy and dry  
seasons



# Major Services from Shivapuri watershed

## ► Provisioning services:

- **Drinking water** - 21% of the city's total piped water supply of Kathmandu
- **Irrigation** - 3 systems with 753ha actual irrigated area
- **Hydro-power** - Sundarijal HP - about 4000 MWh annually
- **Livelihoods** - 400 hh or 2,500 people living within park boundary and more than 100,000 people living around depend on its resources (Water and NTFP)





# Major Services from Shivapuri watershed

## ► Regulating services:

- Source of the sacred Bagmati and Bishnumati rivers
- Main ground water recharge zone in Kathmandu



Photo: [www.sawan.icimod.org](http://www.sawan.icimod.org)

# Major Services from Shivapuri watershed

## ▶ Supporting services:

- Wildlife habitat – host more than 2,000 plant species, 21 mammals and 180 birds
- Environmental flows – maintenance of river flow regime in the sacred Bagmati and Bishnumati rivers



# Major Services from Shivapuri watershed

## ► Cultural & amenity services:

- Contains the sacred Shipocho peak, Sundari mai
- Popular place for recreation – picnic, excursion, trekking
- More than 25,000 visitors in recent year



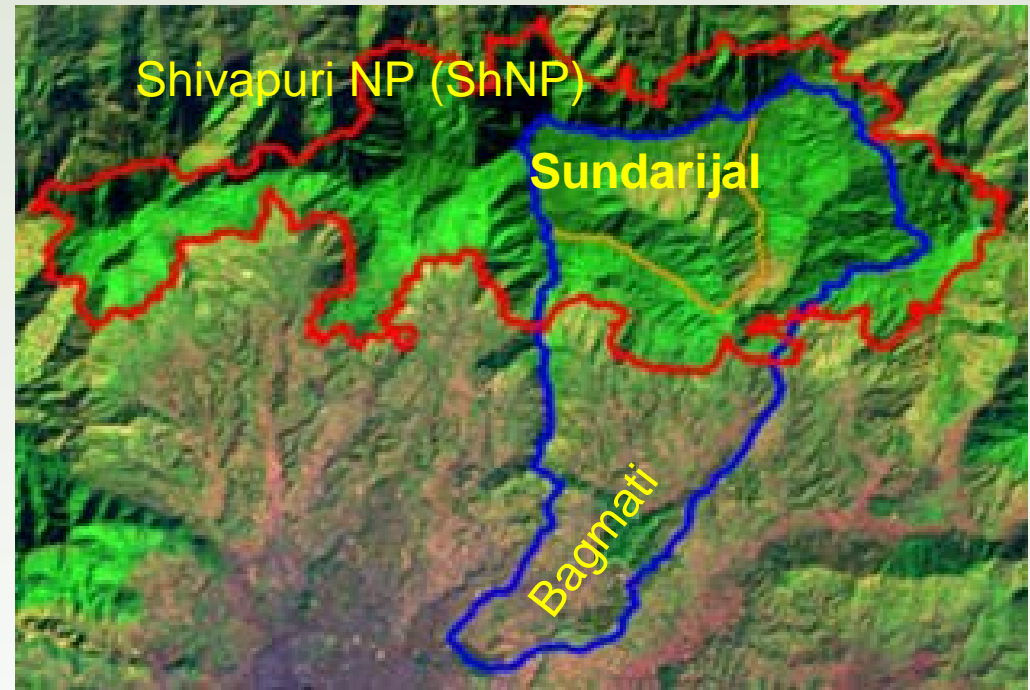
# Drivers (major events)

- ▶ **1976** - declaration as **Shivapuri Watershed Reserve**
- ▶ **1985** - declared as **Shivapuri Wildlife Reserve** with the Shivapuri Watershed Management and Fuelwood Plantation Project in 1985
- ▶ **1981 and 1993** - over **600 ha** of land was converted to forest from agricultural, grass, and shrub land (DNPWC, 1995).
- ▶ **2002** - gazetted as Ninth **National Park** (144 Km<sup>2</sup> ) of Nepal



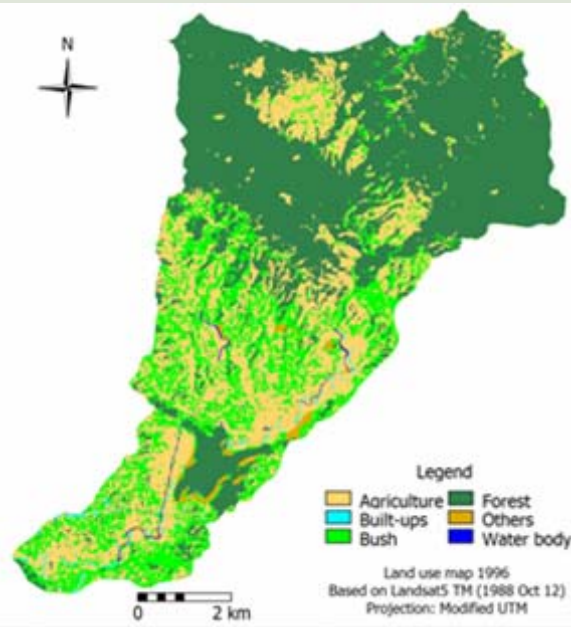
# Current analysis

Catchment	Area (km <sup>2</sup> )
ShNP	95.5
ShNP area within Bagmati	38.6
<i>Bagmati</i> ( <i>Gaurighat</i> outlet)	67.0
<b><i>Sundarijal</i></b> <b>sub-</b> <b>watershed</b>	<b>15.8</b>

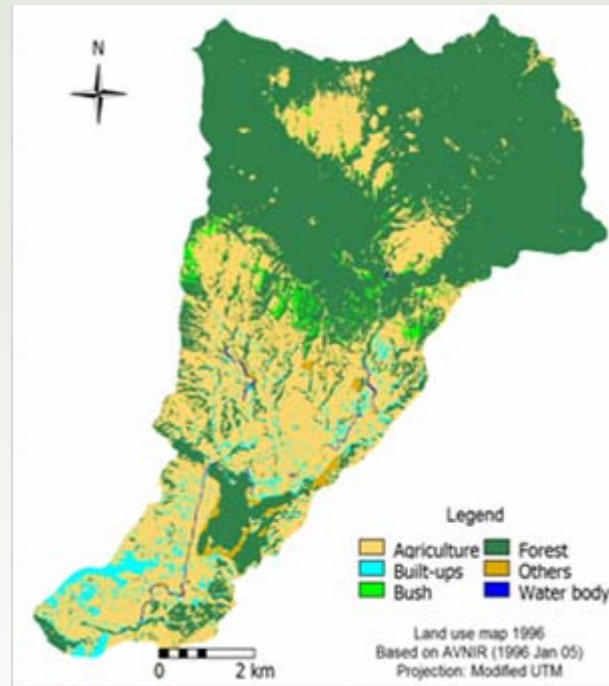


# Land use and land cover change – Remote Sensing

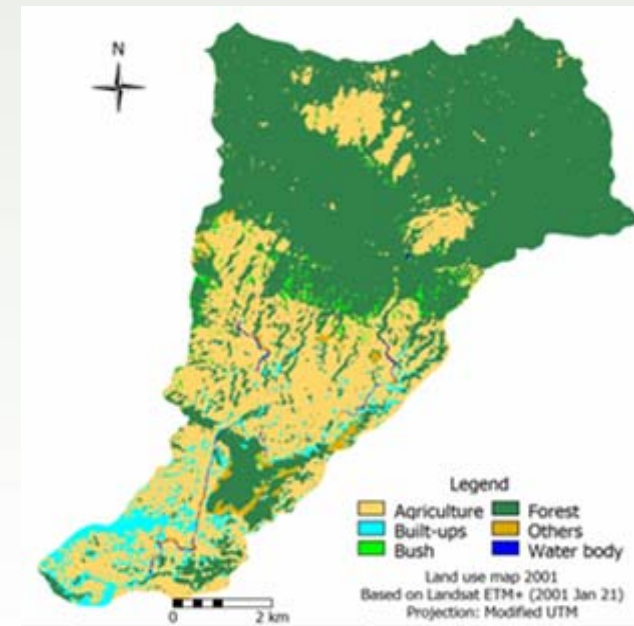
1988



1996

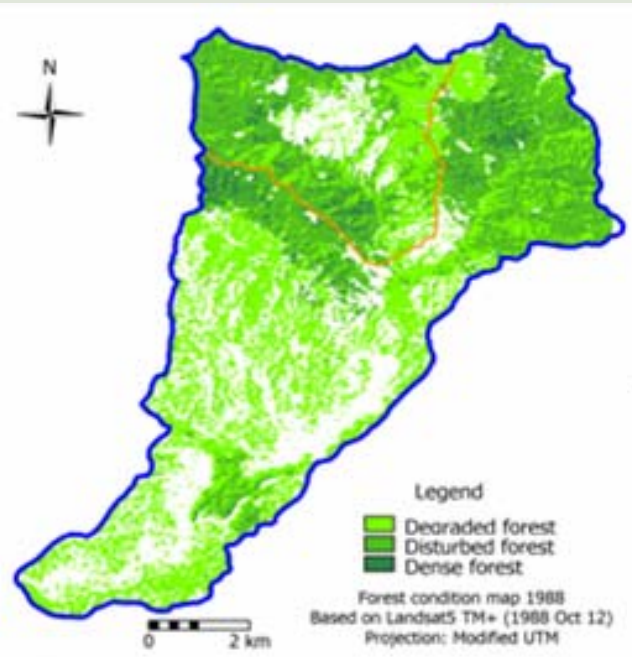


2001

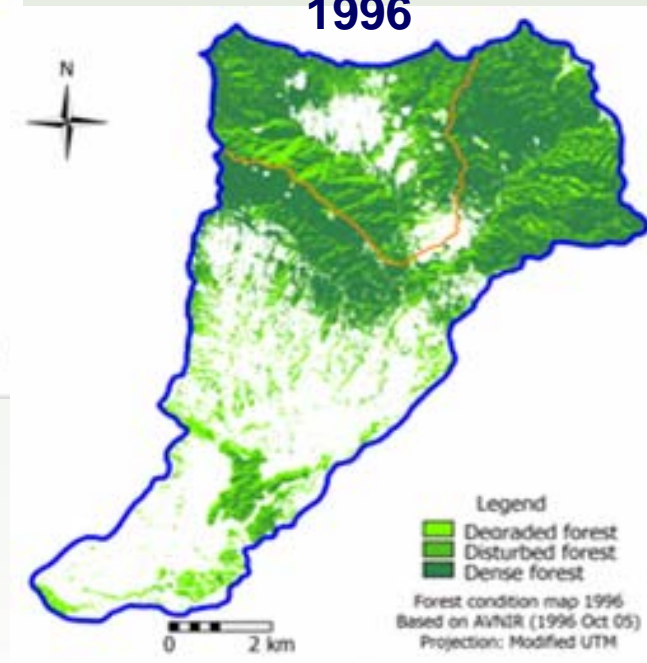


# Forest status (NDVI)

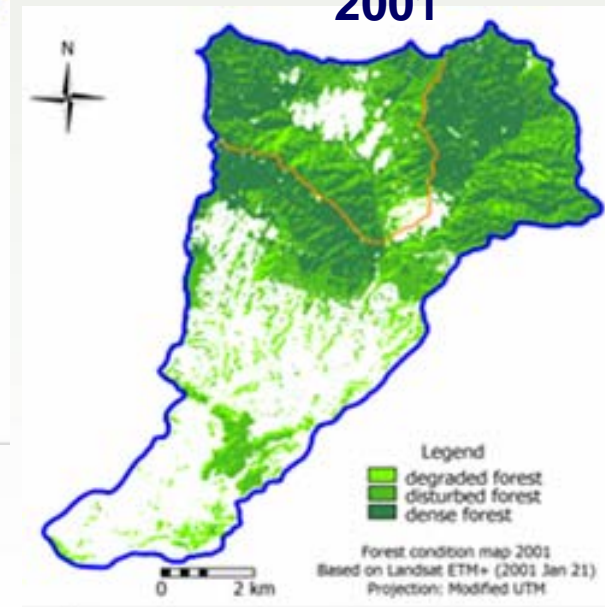
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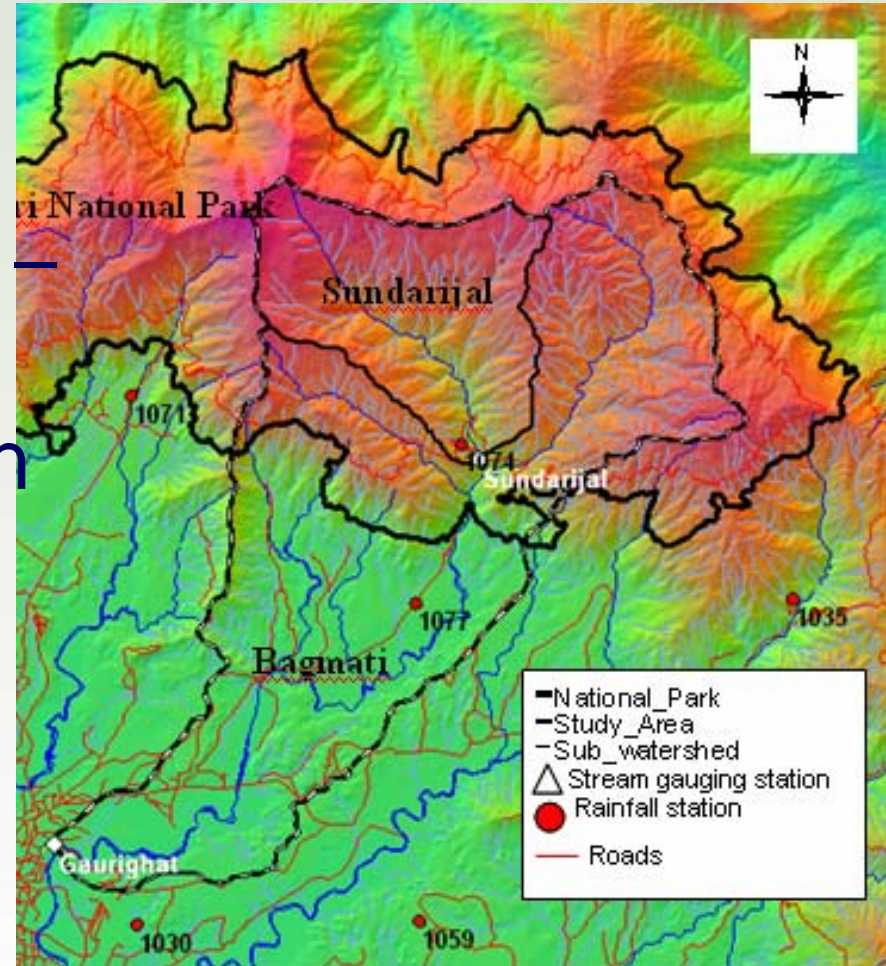
2001





# Water accounting

- ▶ Inflow – rainfall (DHM)
- ▶ Depletions
  - Evaporative depletion – FAO cropwat model
  - Domestic consumption – population
  - Transfer – SWWR inf. brochure and energy generation record
- ▶ Outflow – discharge at Sundarijal and Gaurighat (DHM)





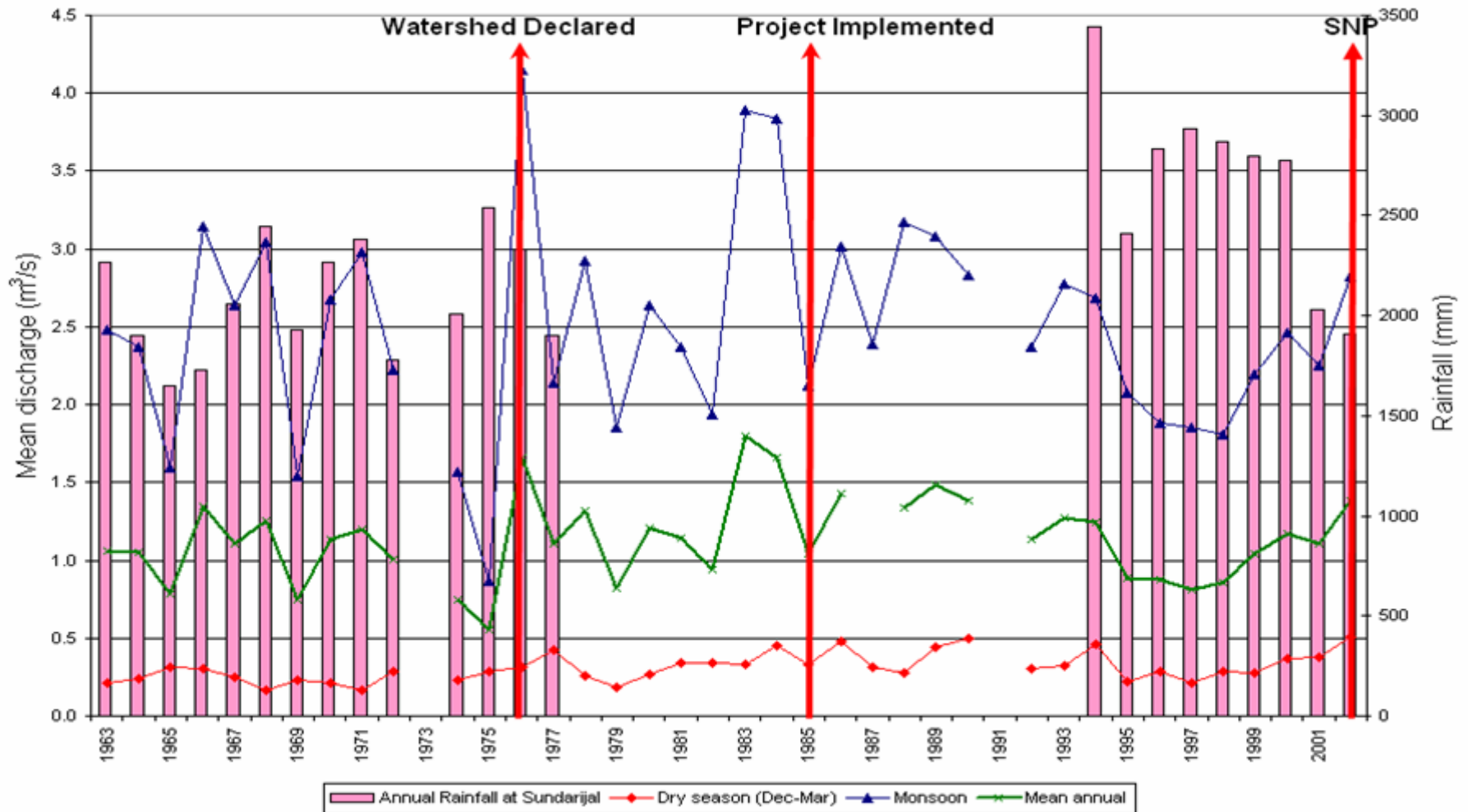
## General Water Accounts (values are in million m<sup>3</sup>)

S.N.	Component	Sundarijal (upstream of the reservoir)	Bagmati (including Sundarijal)
<b>1</b>	<b>Inflow (Rainfall)</b>	<b>43.8</b>	<b>162.4</b>
<b>2</b>	<b>Depletion</b>	<b>9.8</b>	<b>48.3</b>
2.1	Evaporative depletion by crops	1.5	21.0
2.2	Evaporative depletion by forest and bush_grass	8.3	26.6
2.3	Domestic consumption	0.01	0.64
<b>3</b>	<b>Transfer to Kathmandu</b>	<b>--</b>	<b>7.0</b>
<b>4</b>	<b>Out flow (stream discharge)</b>	<b>33.1</b>	<b>100.9</b>
5	Estimation Error	0.9	6.3

# Land use and Hydrologic Response

## Hydro-meteorological observations at Sundaridal

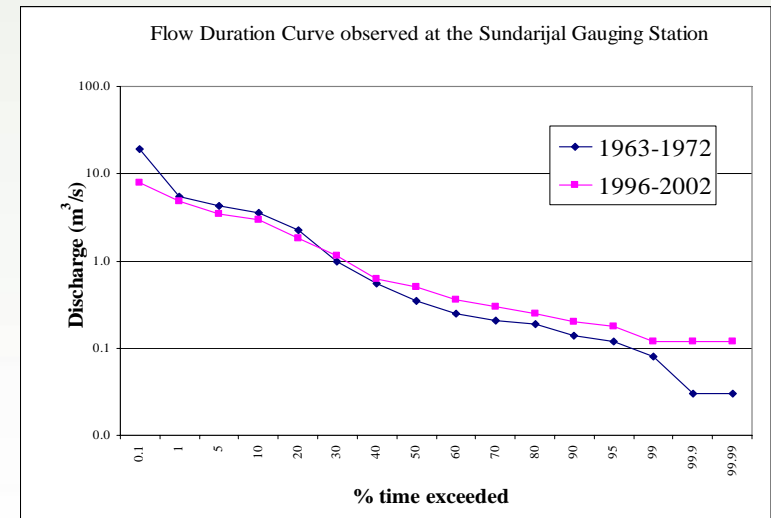
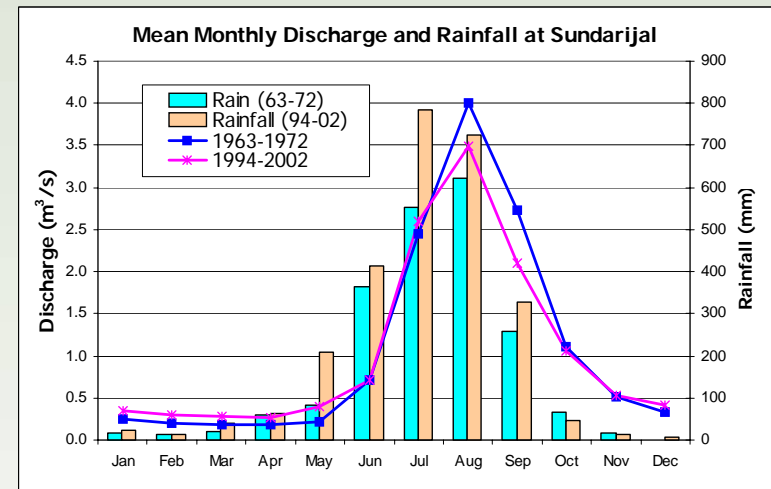
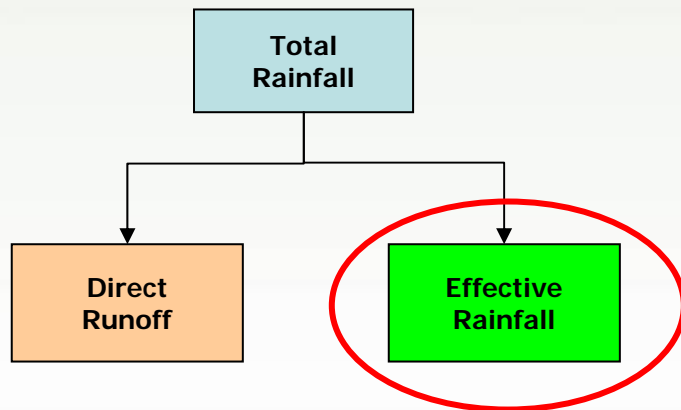
Mean seasonal flows and annual rainfall observed at Sundaridal



# Modeling LUCC impact on hydrologic response

## ► Simple approach:

- Hydrographs (seasonal flow) and Flow Duration Curves analysis
- Rainfall partition – impact of different land uses on direct runoff (SCS CN method)



# Scenario Analysis - Sundarikal

- ▶ 1998 considered as average year – daily rainfall
- ▶ Assumption for rainstorm using daily rainfall data – if daily rainfall is less 20mm then there was a break in rainfall storm otherwise continuous rainy days are considered as a single storm



# Scenario Analysis - Sundarijal

## ▶ Hypothetical scenarios:

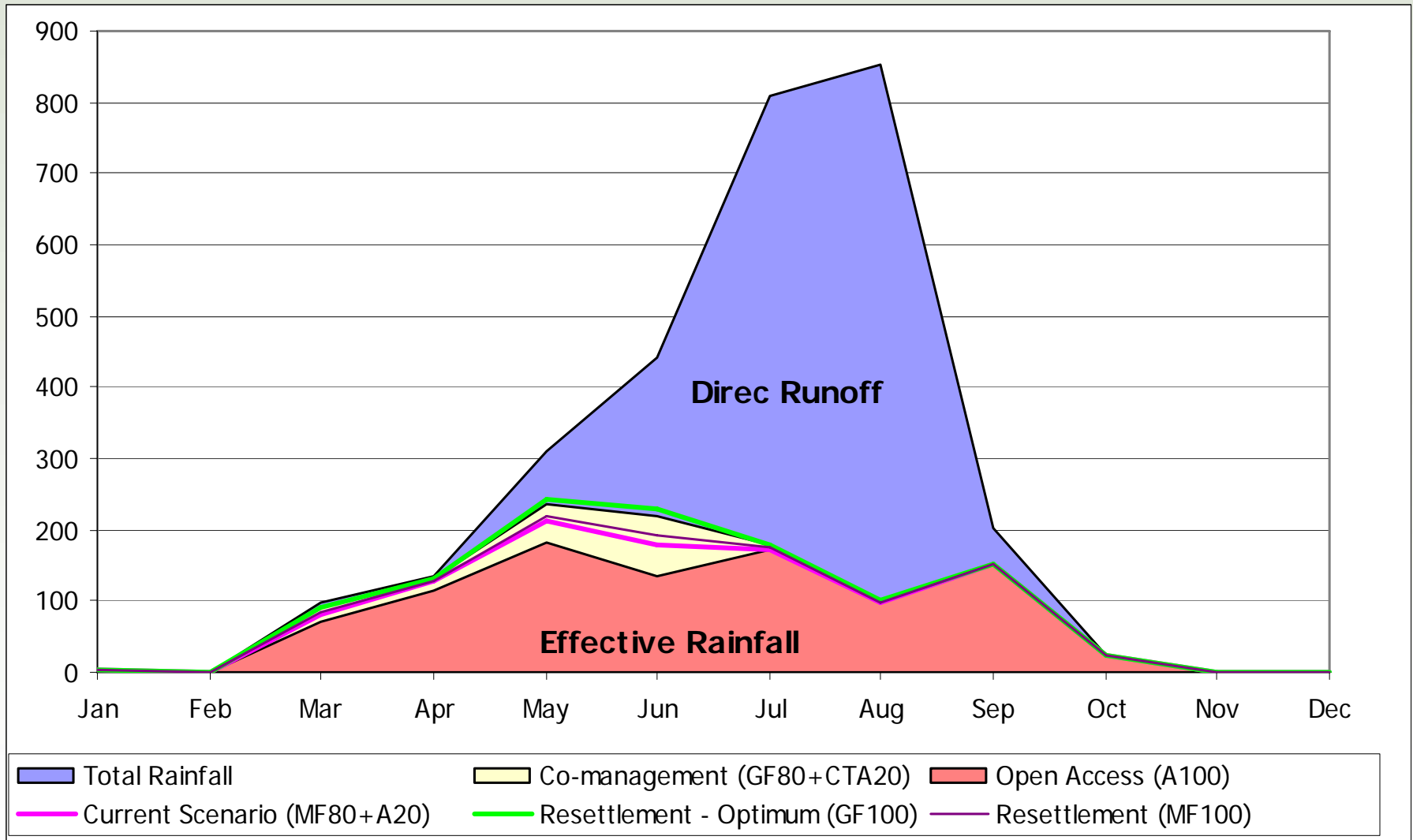
- **Status quo** – 80% moderate forest and 20% agricultural without conservation treatment
- **Co-management** – 80% good forest and 20% agriculture with **conservation treatment**
- **Resettlement** – 100% moderate forest
- **Resettlement optimum** – 100% good forest
- **Open access** - 100% Agricultural area

# Scenario results - Sundarikal

Catchment area: 15.76 km<sup>2</sup>

Month	Total Rainfall	Current Scenario (MF80+A20)		Co-management (GF80+CTA20)		Resettlement - Optimum (GF100)		Resettlement (MF100)		Open Access (A100)	
		Direc runoff	Effective Rainfall	Direc runoff	Effective Rainfall	Direc runoff	Effective Rainfall	Direc runoff	Effective Rainfall	Direc runoff	Effective Rainfall
	P (mm)	Qd (mm)	Pe (mm)	Qd (mm)	Pe (mm)	Qd (mm)	Pe (mm)	Qd (mm)	Pe (mm)	Qd (mm)	Pe (mm)
Jan	2	0	2	0	2	0	2	0	2	0	2
Feb	0	0	0	0	0	0	0	0	0	0	0
Mar	97	15	82	7	90	5	92	12	85	28	69
Apr	133	7	127	1	132	0	133	5	129	18	115
May	309	97	212	72	237	65	243	90	219	128	180
Jun	440	260	180	220	220	209	231	249	192	306	134
Jul	808	635	173	631	177	629	179	634	174	637	171
Aug	852	753	99	752	100	752	100	753	99	753	99
Sep	204	51	153	51	153	51	153	51	153	51	153
Oct	22	0	22	0	22	0	22	0	22	0	22
Nov	0	0	0	0	0	0	0	0	0	0	0
Dec	0	0	0	0	0	0	0	0	0	0	0
<b>Total</b>	<b>2867</b>	1817	<b>1050</b>	1734	<b>1134</b>	1712	<b>1155</b>	1793	<b>1074</b>	1921	<b>946</b>
Increase in effective rainfall compared to current scenario					83		104		24		-105
Total increase in water volume (million liters)					1313		1645		377		-1649
Qd/P		63.4		60.5		59.7		62.5		67.0	

# Scenario analysis - Sundaridal



## Summary – scenario result

Land use scenario	Increase in water service (million m <sup>3</sup> )	% increase as of current scenario	Net benefit from increased water (thousand \$)*
Current	--	--	--
Co-management	1.3	8	47.83
Optimum	1.6	10	58.87
Resettlement	0.4	2	14.72
Open access	-1.6	-10	(58.87)

- Net benefit of water services downstream from Sundarijal = NRs. 2.39/m<sup>3</sup> (DW 1.25+HP1.14), calculated based on the O&M costs, **actual energy produced** by Sundarijal HP, and **actual revenue collected** for drinking water supply (excluding Tanker water supply which cost ~NRs. 150/m<sup>3</sup>).
- The benefit from irrigation water use is not accounted.



# Conclusion

- ▶ Resettlement with forest complete recovery gives optimum result
- ▶ Co-management appears optimistic approach for conservation based on scenario analysis
- ▶ Impact of land use land cover change on water quality – further study required

A land use decision...

...is also a water decision!

- M. Falkenmark



Thank you!