

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

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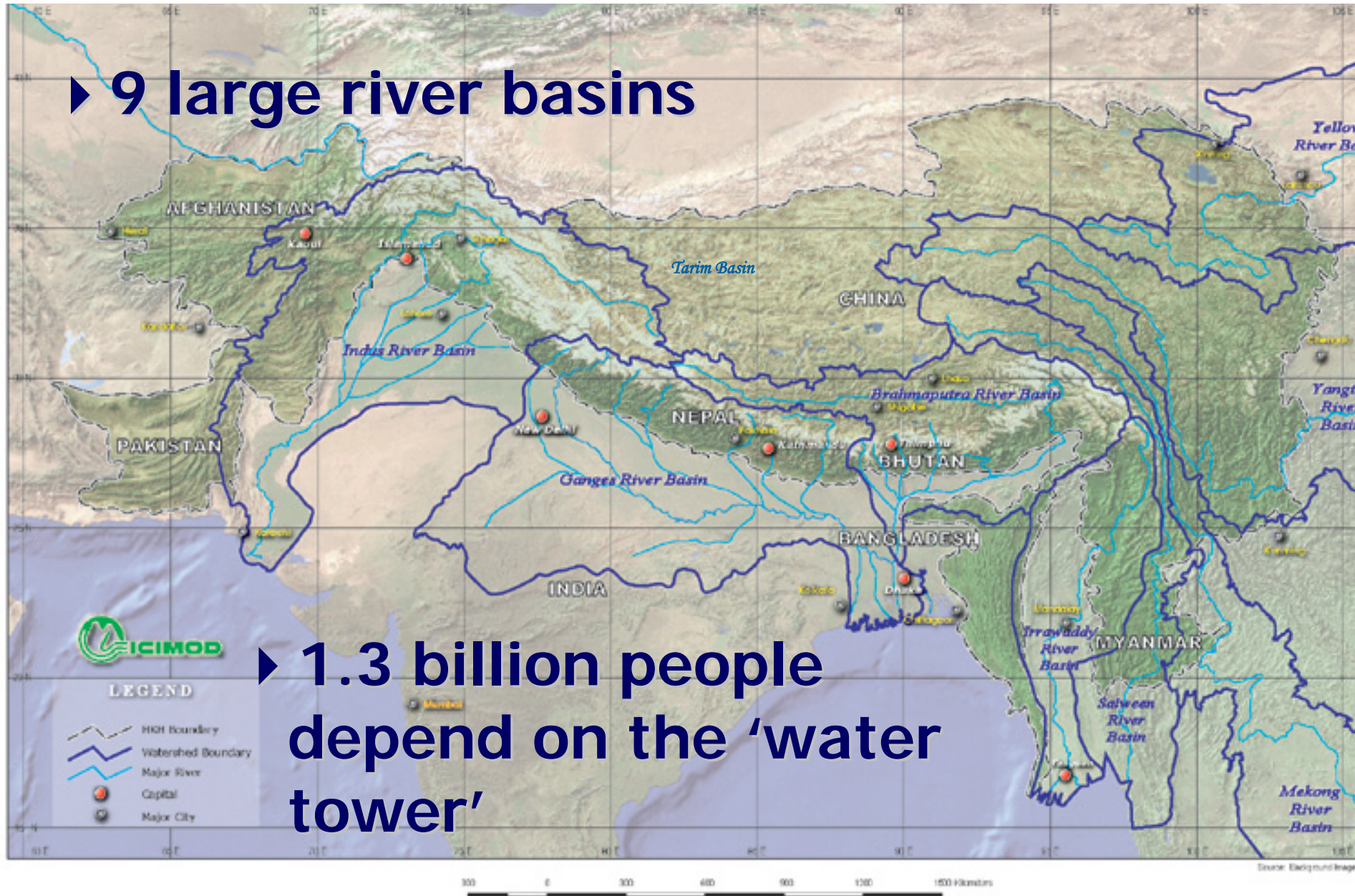
ICIMOD's vision:

*'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

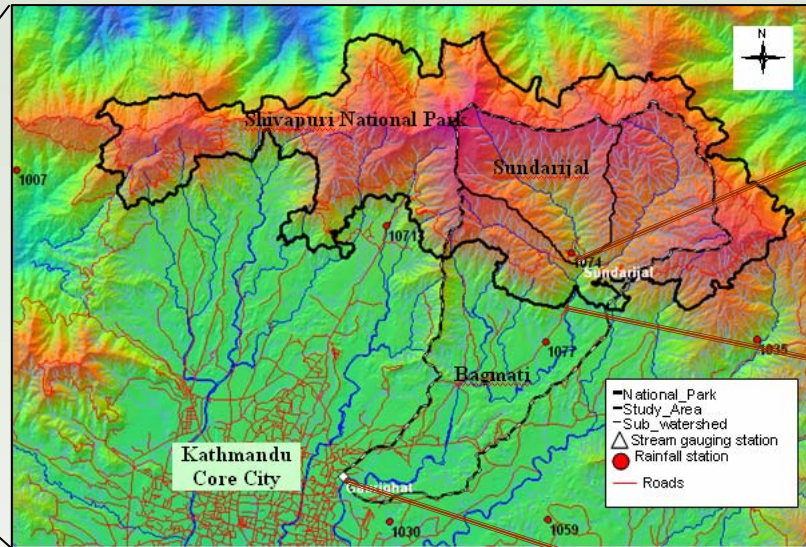
- Floods/Flash floods
- Sediment
- Drought
- Water pollution

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 Sundarikal sub-watershed

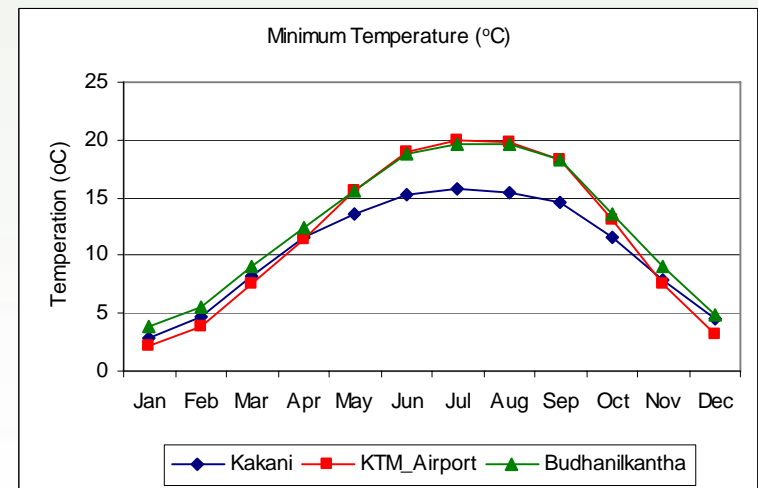
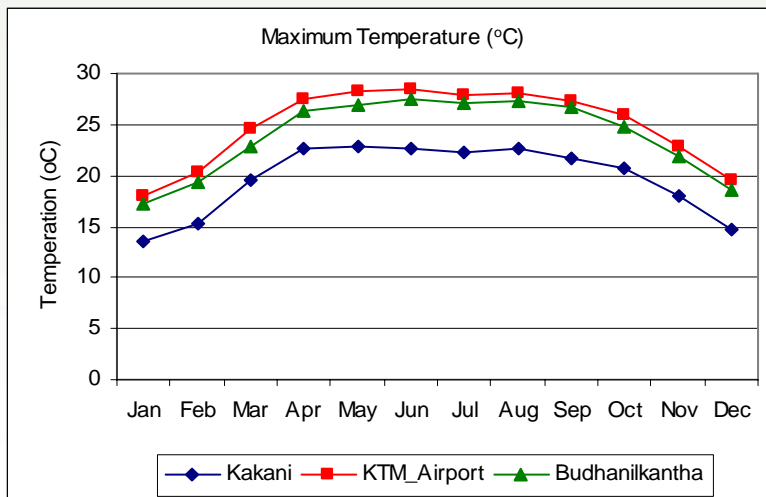
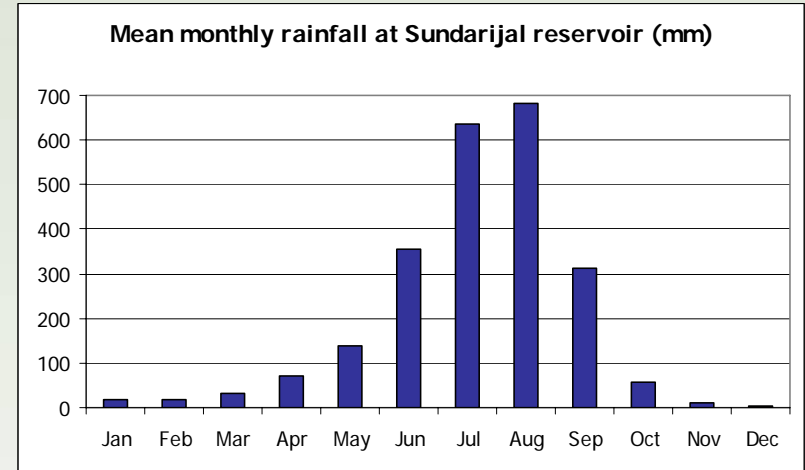
The Study area - location



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

Climate

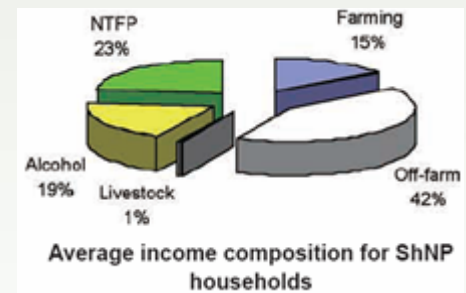
- ▶ **Transition zone**
between sub-tropical
and temperate
- ▶ **Monsoonal climate** -
distinct rainy and dry
seasons



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

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

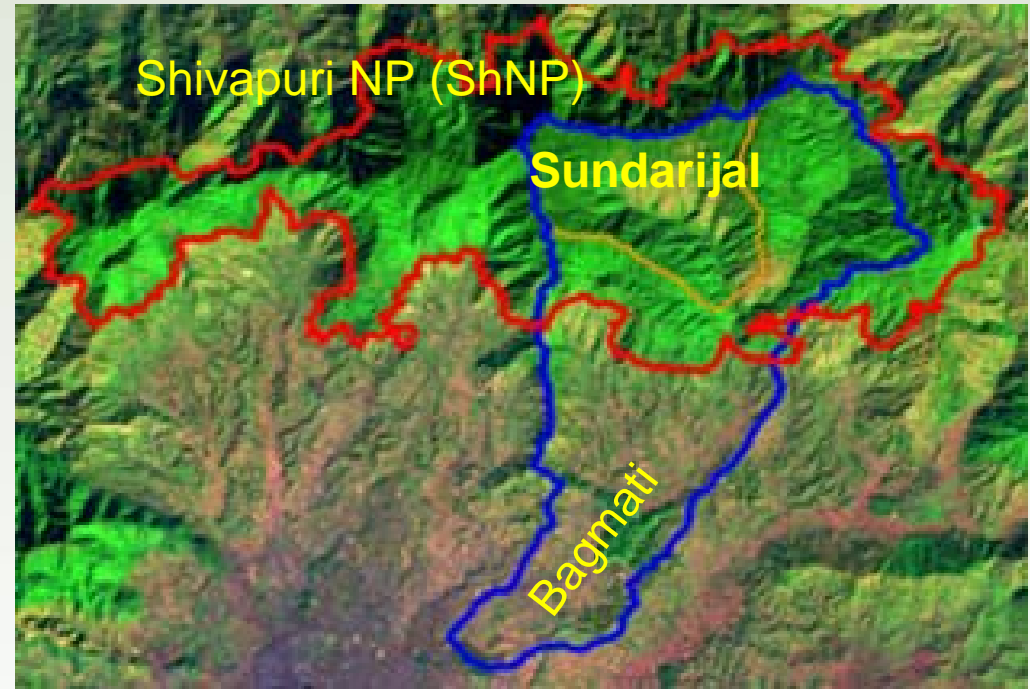


Drivers (major events)

- ▶ **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 Km²) of Nepal

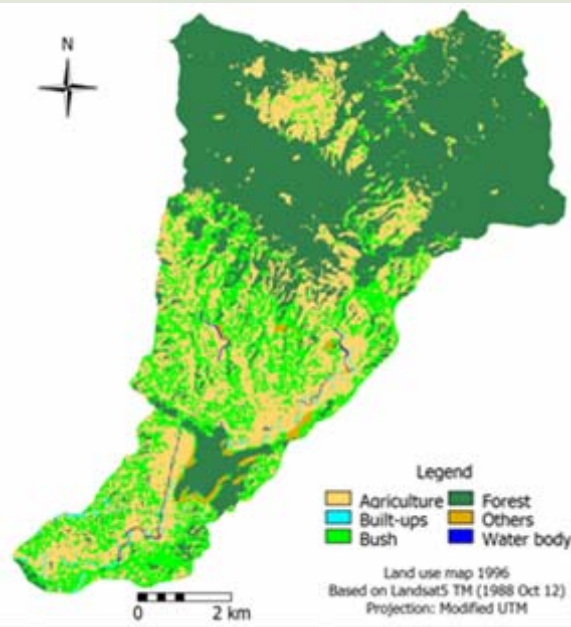
Current analysis

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

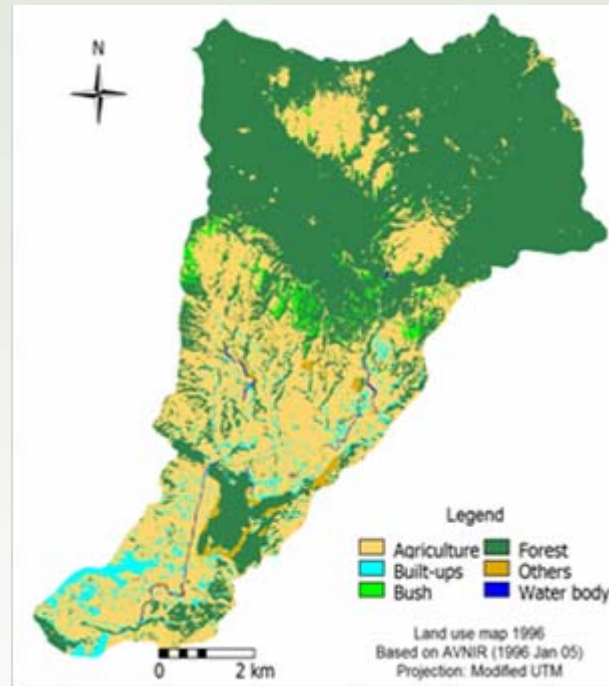


Land use and land cover change – Remote Sensing

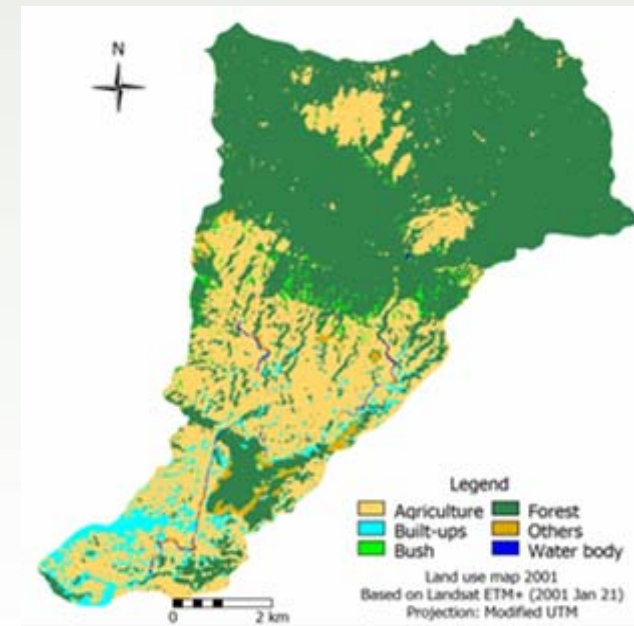
1988



1996

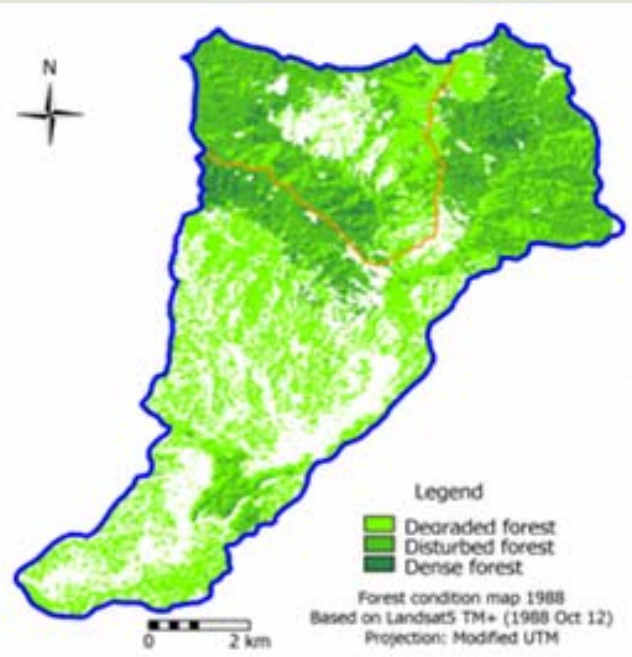


2001

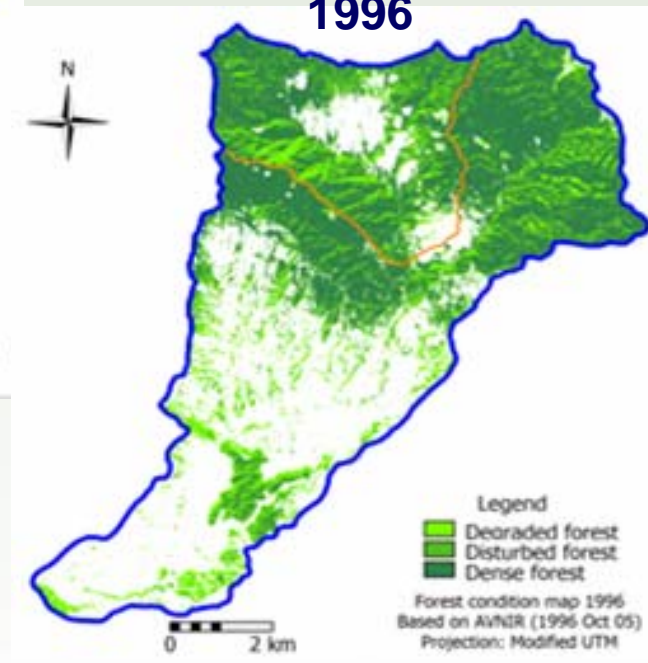


Forest status (NDVI)

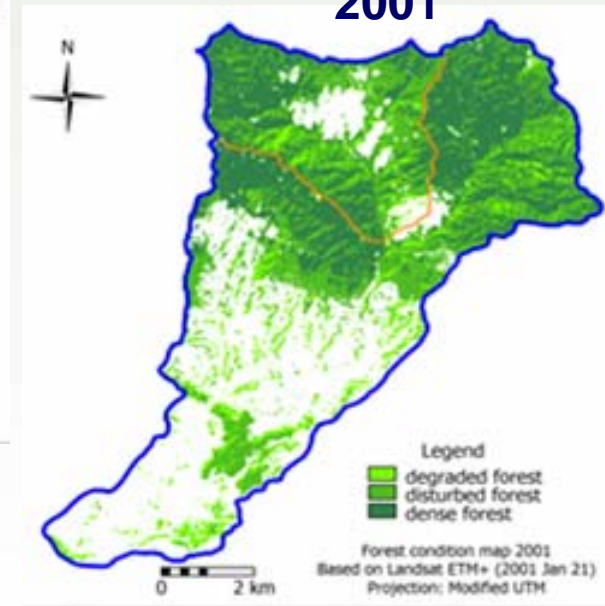
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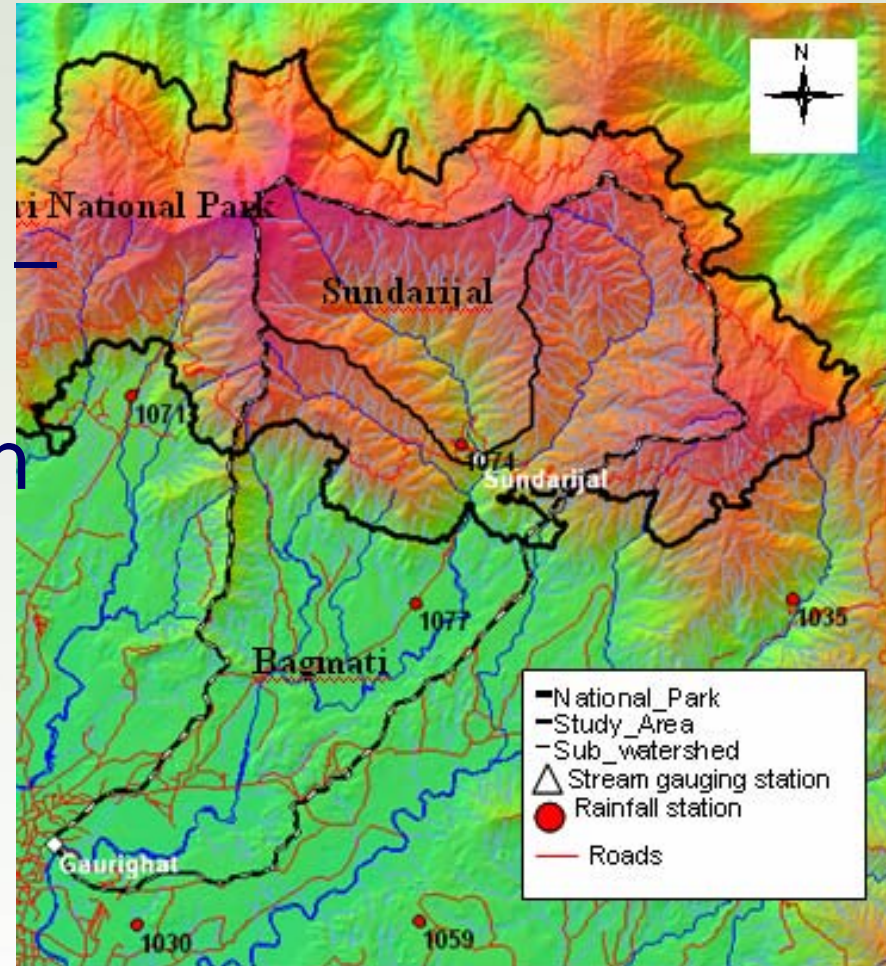


2001



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)



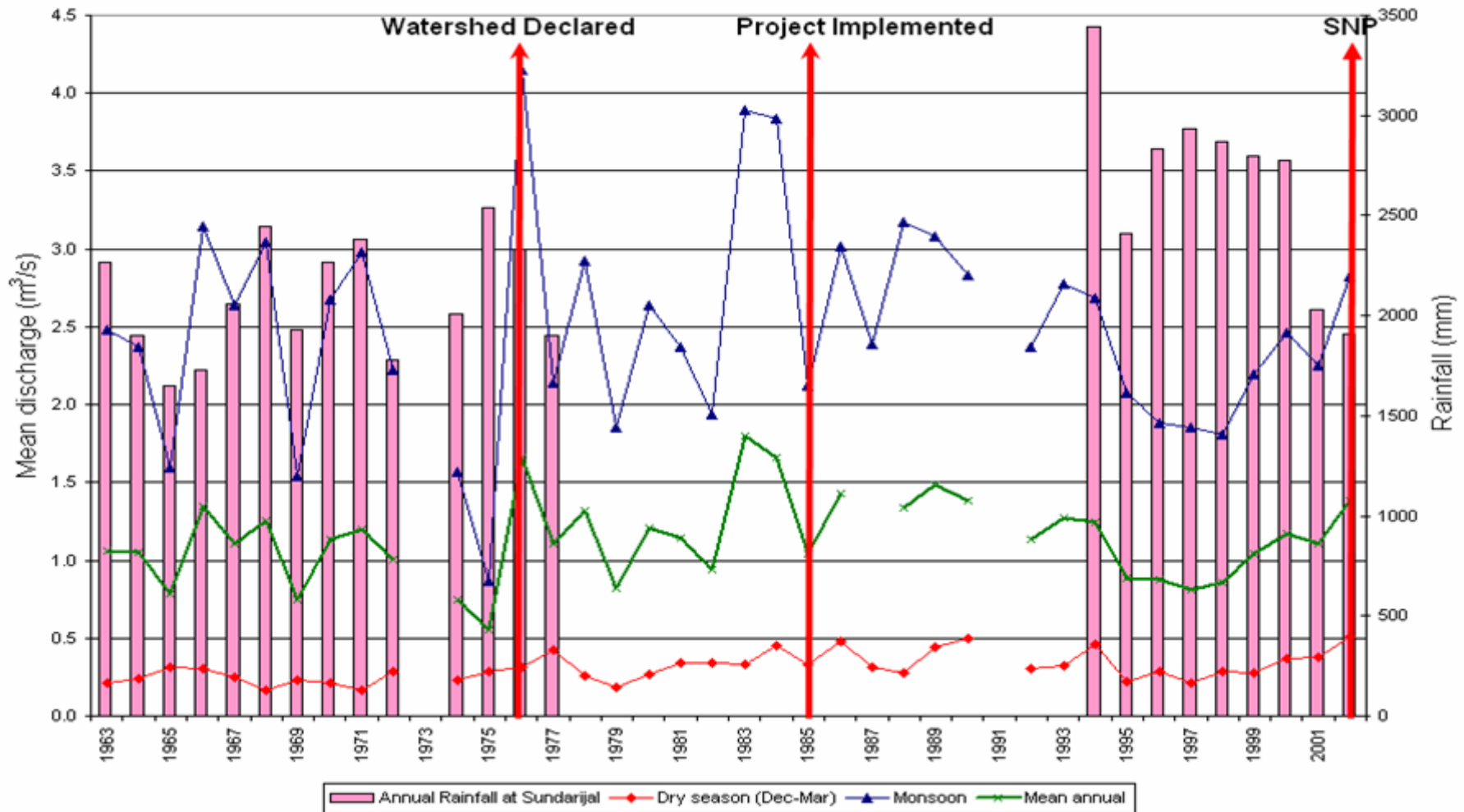
General Water Accounts (values are in million m³)

| S.N. | Component | Sundarijal (upstream of the reservoir) | Bagmati (including Sundarijal) |
|----------|---|--|-----------------------------------|
| 1 | Inflow (Rainfall) | 43.8 | 162.4 |
| 2 | Depletion | 9.8 | 48.3 |
| 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 |
| 3 | Transfer to Kathmandu | -- | 7.0 |
| 4 | Out flow (stream discharge) | 33.1 | 100.9 |
| 5 | Estimation Error | 0.9 | 6.3 |

Land use and Hydrologic Response

Hydro-meteorological observations at Sundaridal

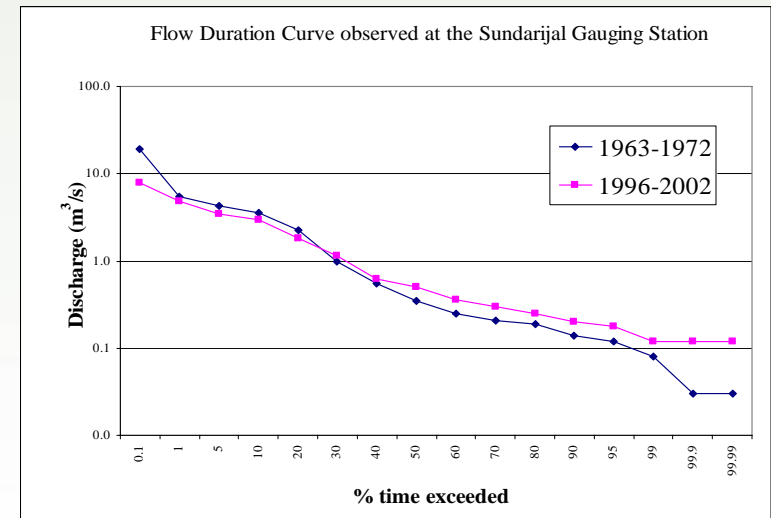
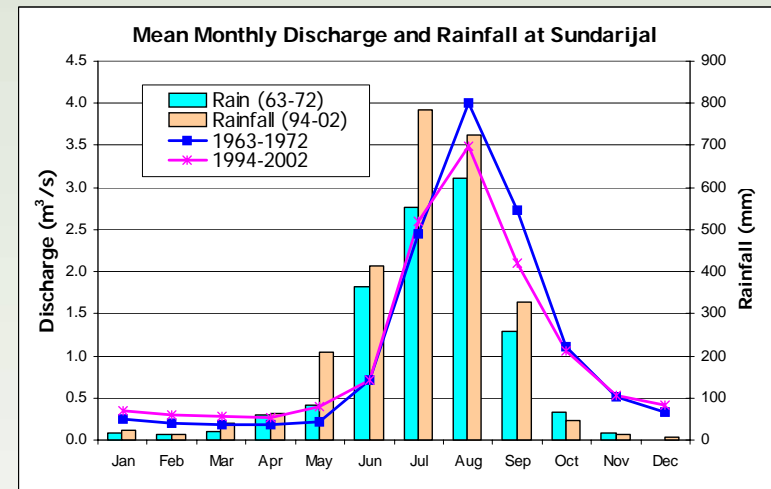
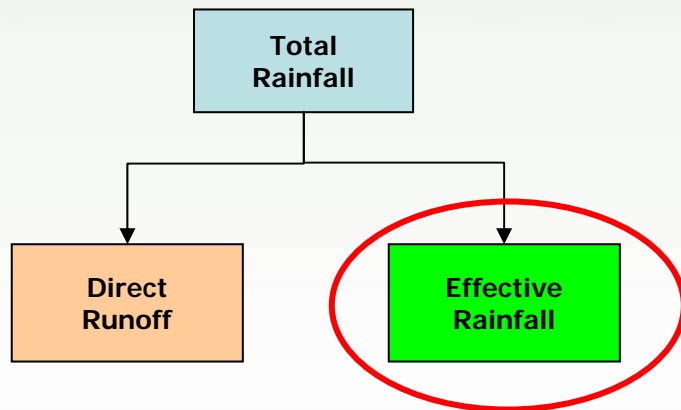
Mean seasonal flows and annual rainfall observed at Sundaridal



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 - Sundarijal

- ▶ 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:

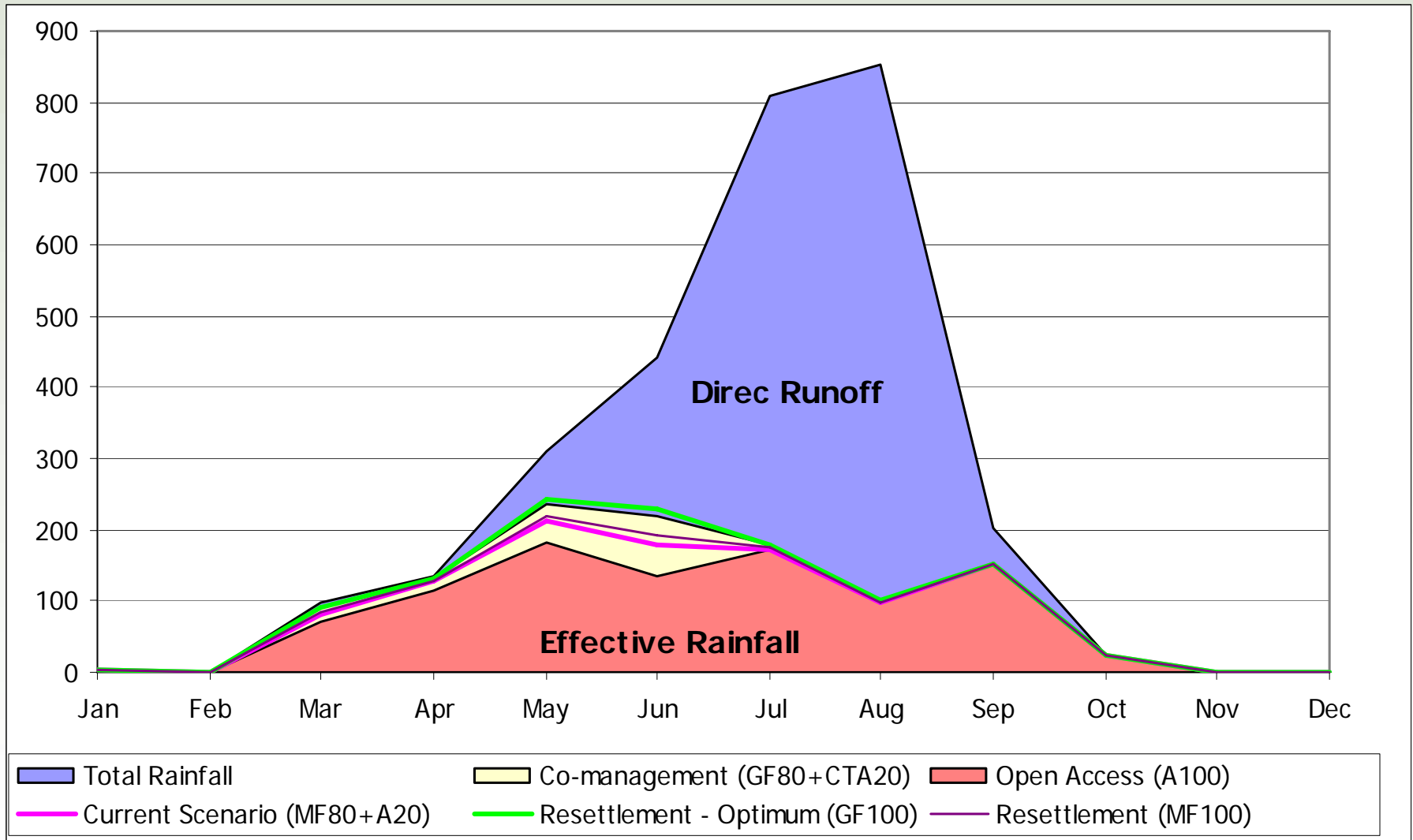
- **Status quo** – 80% moderate forest and 20% agricultural without conservation treatment
- **Co-management** – 80% good forest and 20% agriculture with **conservation treatment**
- **Resettlement** – 100% moderate forest
- **Resettlement optimum** – 100% good forest
- **Open access** - 100% Agricultural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

Scenario results - Sundarikal

Catchment area: 15.76 km²

| 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 |
| Total | 2867 | 1817 | 1050 | 1734 | 1134 | 1712 | 1155 | 1793 | 1074 | 1921 | 946 |
| 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 ³) | % 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/m³ (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/m³).
- 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!