# IMPACT OF HYDROELECTRIC DEVELOPMENT OF THE UPPER REACHES OF IRRAWADDY RIVER ON THE LOWER REACHES

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# China Institute of Water Resources and Hydropower Research



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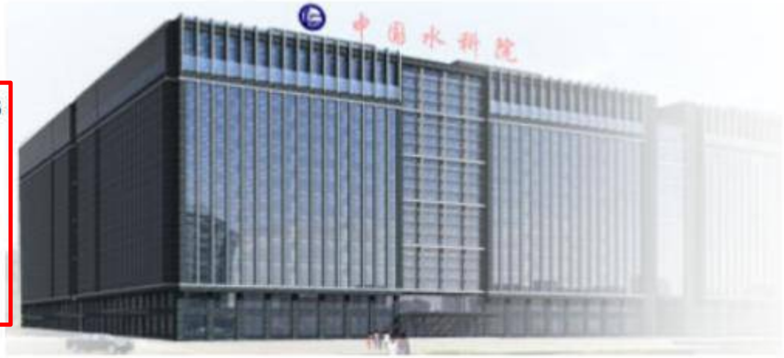
China Institute of Water Resources and Hydropower Research (IWHR) is situated in the western part of Beijing, consisting of south campus and north campus. IWHR has its Daxing Experimental Base located in the south suburb of Beijing Municipality and another two departments located outside Beijing, namely the Department of water Resources for Pastoral Areas in Huhhot and the Department of Mechanical and Electrical Research in Tianjin.



The history of IWHR can be traced back to the establishment of the first Hydraulic Laboratory in Tianjin in 1933. Over 60 years of evolution since its establishment in 1958, IWHR has now become the largest comprehensive research institute at the top level in the field of water resources and hydroelectric power in China. At present, IWHR has over 1,300 staff members, 12 research departments and 32 laboratories. The total land area of the institute covers 480,000 $m^2$.

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# BACKGROUND

## D&Q

- The MOEP(1) recommended to carry out the impact of upstream hydroelectric development on the lower reaches in 2010
- A serious lack of basic information on the drainage basin of Irrawaddy River
- The conventional approach for modeling analysis is very difficult.

## O&M

- Focusing on the use of the satellite remote sensing techniques
- To obtain the land utilization, precipitation, river channel morphology, information on the natural change of estuarine ecological systems
- To analyzing the nature evolution process of the drainage basin
- Using remote sensing to drive hydrological simulation

# MAIN WORKS:

1. Analysis of the current runoff of Irrawaddy River Basin
2. Remote Sensing Survey on Land Utilization
3. Change of the natural circumstances of Irrawaddy river basin
4. Impact of Hydroelectric Development of the Upper Reaches of Irrawaddy River on the Lower Reaches
5. Flood control benefits of Hydroelectric Development of the Upper Reaches of Irrawaddy River

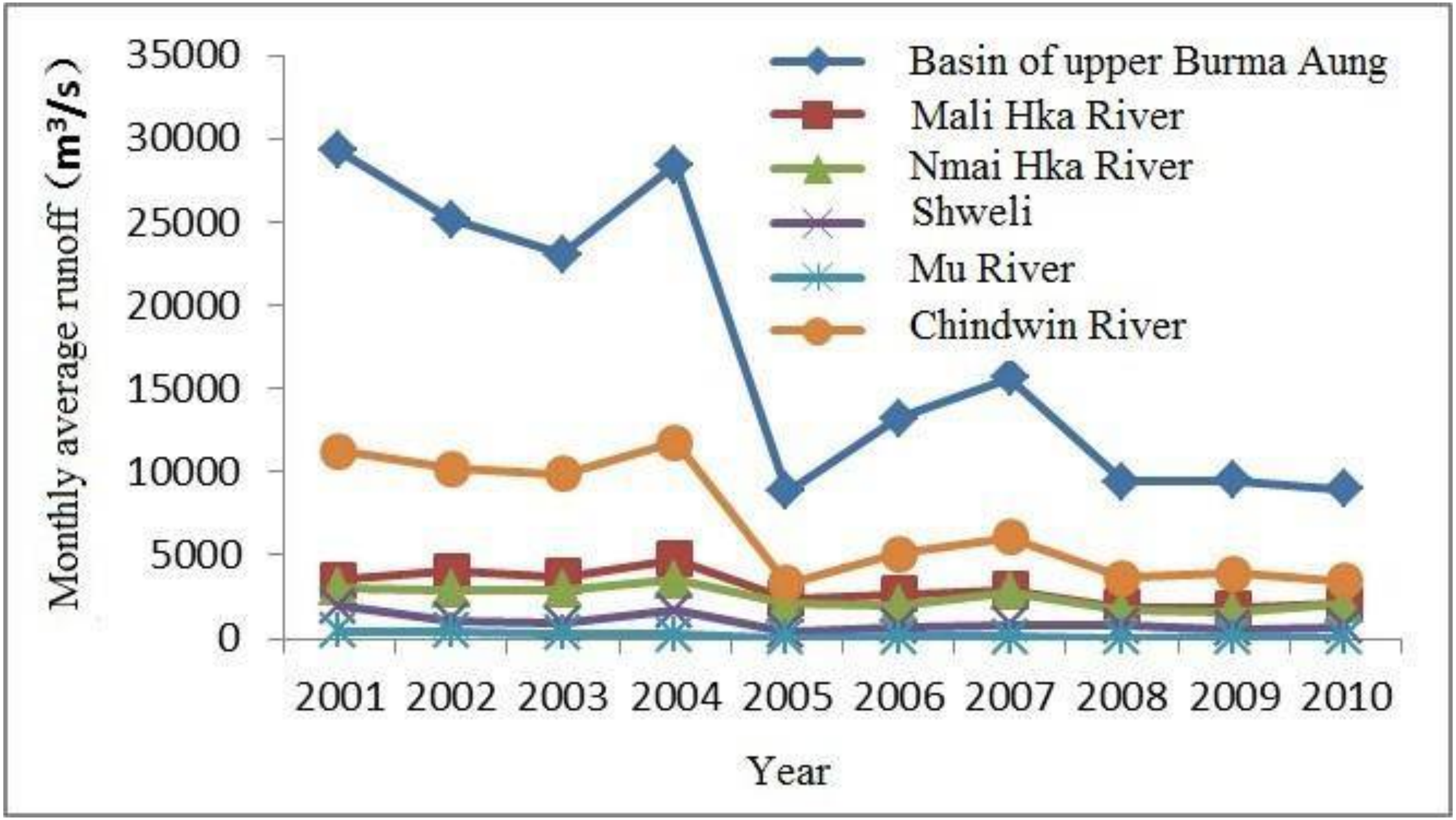
# 1 Analysis of the current runoff of Irrawaddy River Basin

**Method:** This study selected the current international widely used distributed hydrological model SWAT to simulate the precipitation runoff process.

**Data:** daily precipitation TRMM satellites from 2001 to 2011

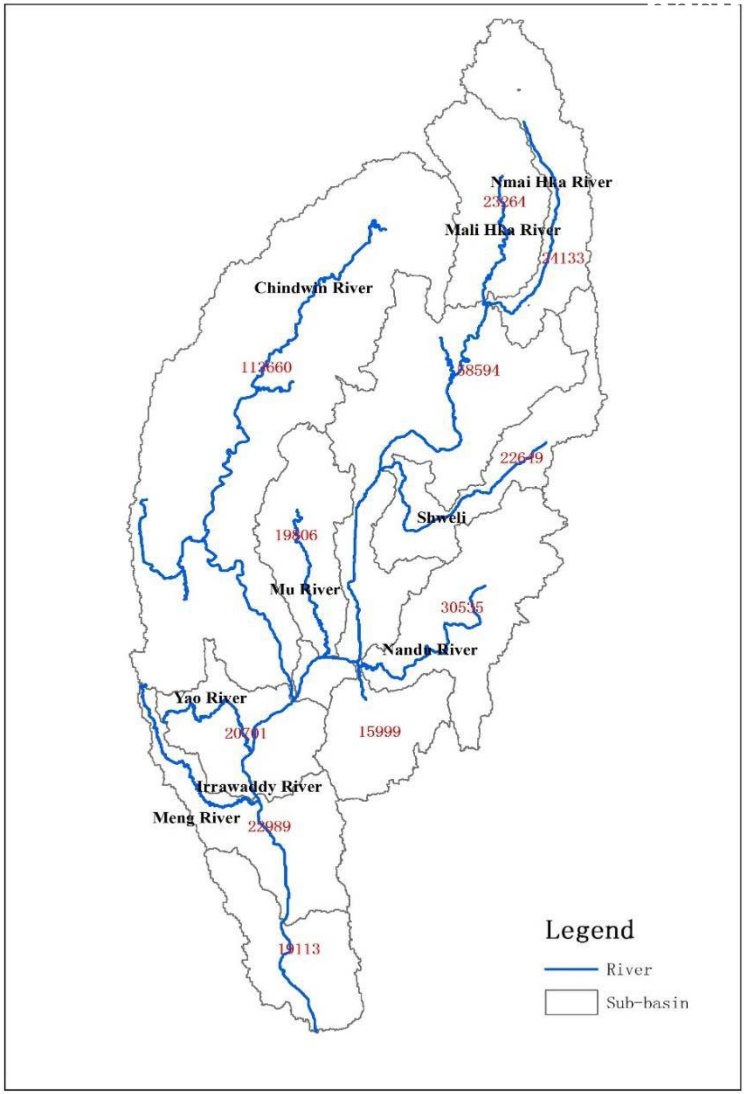
- **Annual runoff from 2001 to 2010**
- **Runoff of the main tributary**
- **Runoff of each main river section**

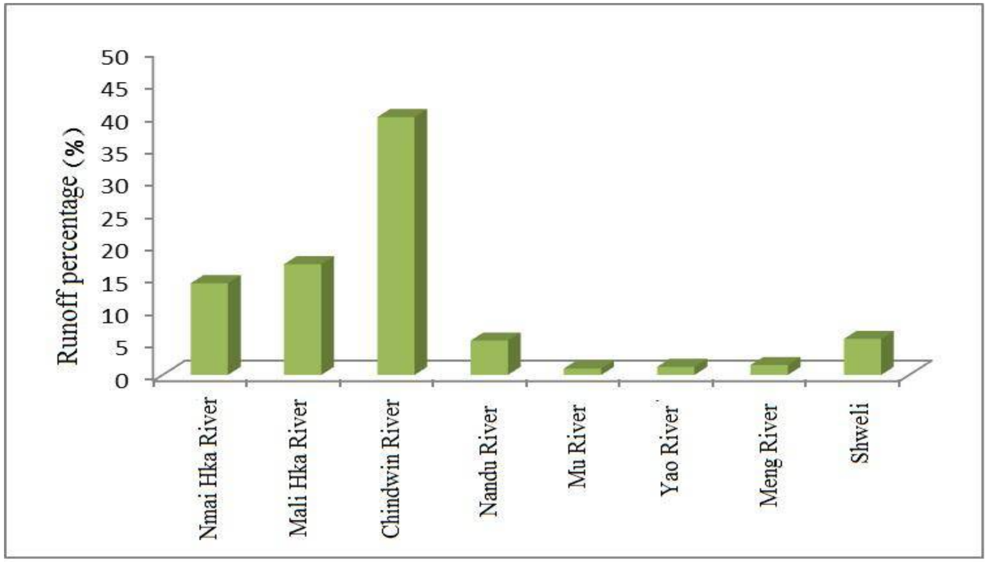
# 1.1 Annual runoff from 2001 to 2010



# 1.2 Runoff of the main tributary

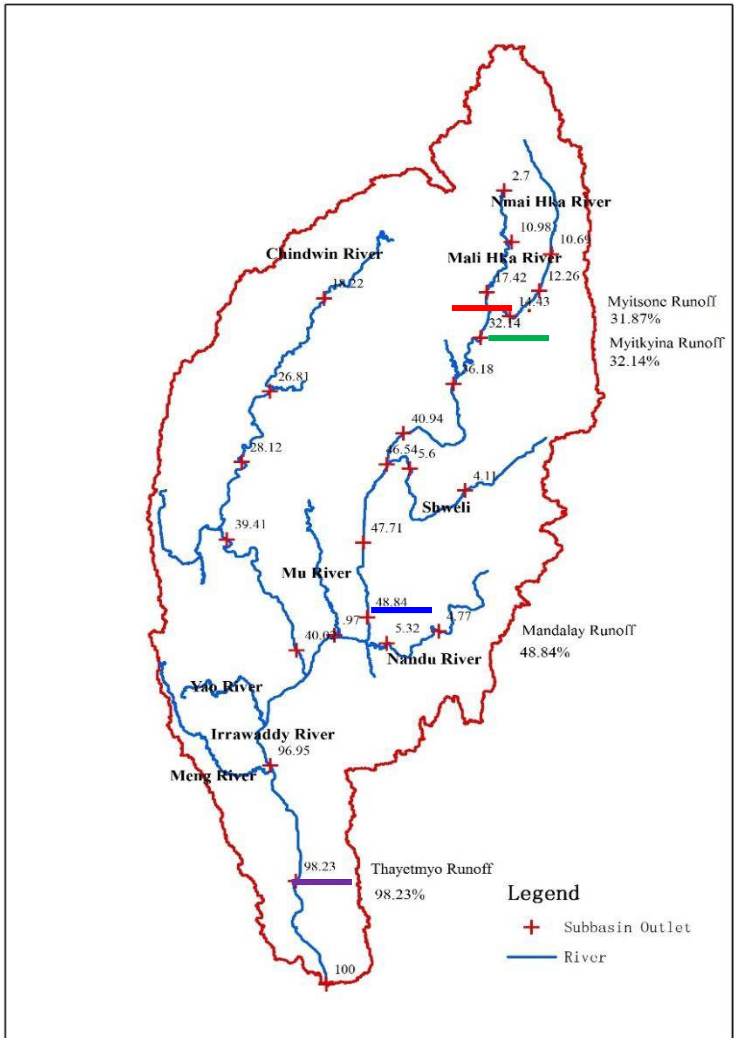
**Annual runoff proportion of tributaries in Irrawaddy River**




| Name | Area （km²） | Sub-basins contained | Area percentage |
|---|---|---|---|
| Nmai Hka River | **24132.9** | **3、4、8** | **14.15** |
| Mali Hka River | **23263.93** | **1、2、6** | **17.09** |
| Chindwin River | **113659.9** | **5、13、14、15、16、21、22、24、25、26、27、37** | **39.78** |
| Nandu River | 30535.15 | 28、35 | 5.3 |
| Mu River | 19806.38 | 29 | 0.99 |
| Yao River | 20700.87 | 40 | 1.26 |
| Meng River | 22988.79 | 41 | 1.52 |
| Shweli | 22648.66 | 19、20 | 5.56 |

# 1.3 Runoff of each main river section




- Runoff proportion of each cross sections
  - Myitsone 31.87%
  - Myitkyina 32.14%
  - Mandalay 48.84%
  - Thayetmyo 98.23%

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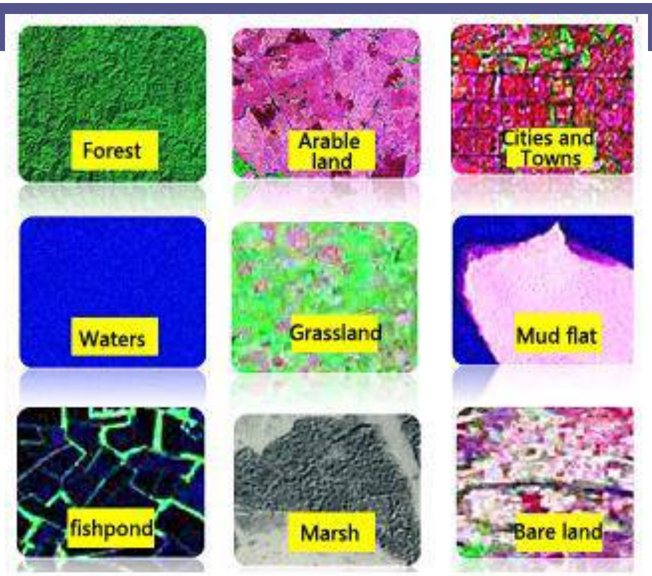
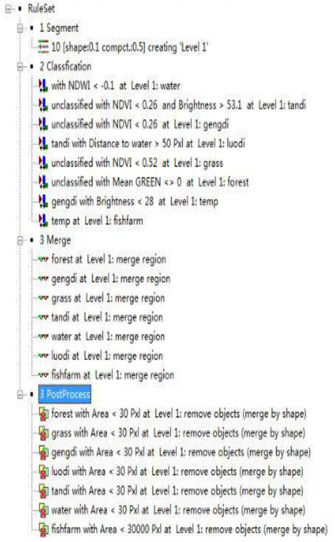
# 2 Remote Sensing Survey on Land Utilization

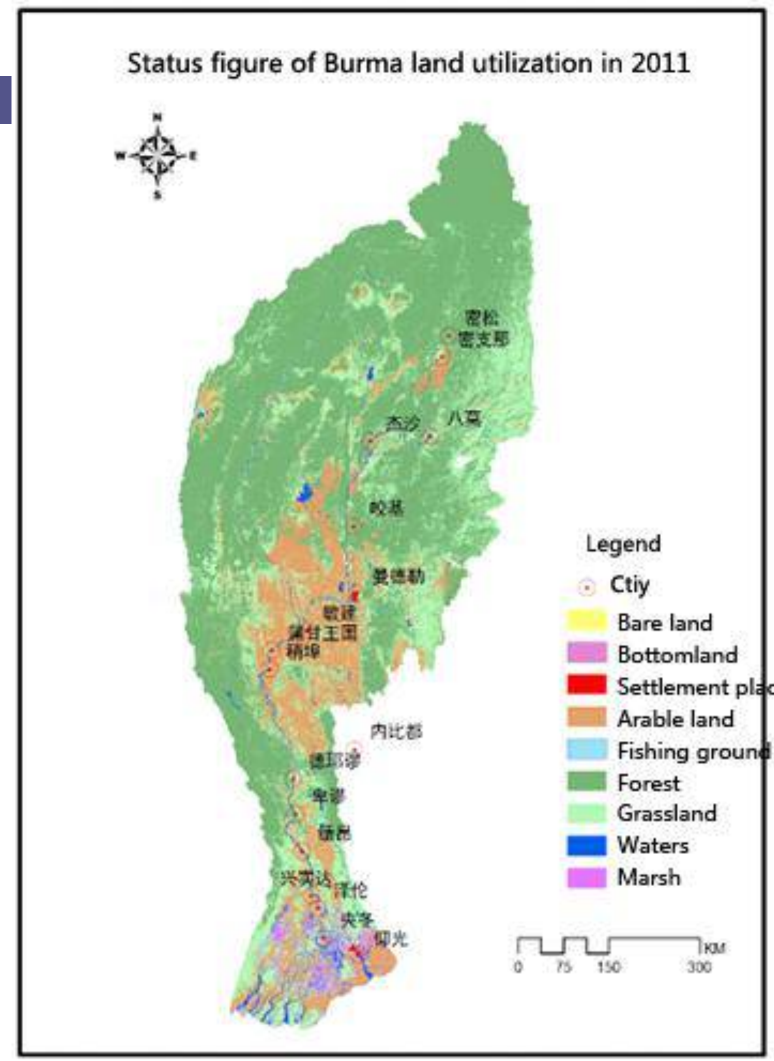
- Survey methods
  - Image integration
  - NDVI Vegetation Index
  - NDWI Water Index
  - Quantitative Threshold Segmentation
  - Supervised Classification
  - Visual Interpretation with GE
  - Field Survey



# Analysis of image interpretation and results verification

| Category | Code | Area ($km^2$) | Proportion to the drainage basin area (%) |
|---|---|---|---|
| Arable land | 1 | 92977.22 | 21.32 |
| Forest | 2 | 23178.00 | 53.15 |
| Grassland | 3 | 87169.01 | 19.99 |
| Waters | 4 | 6087.35 | 1.44 |
| Bottomland | 5 | 6291.88 | 1.40 |
| Settlement place | 6 | 3207.52 | 0.74 |
| Fishing ground | 7 | 855.43 | 0.20 |
| Marsh | 8 | 4614.14 | 1.06 |
| Bare land | 9 | 3078.86 | 0.71 |
| **Total** | | **436064.40** | **100.00** |

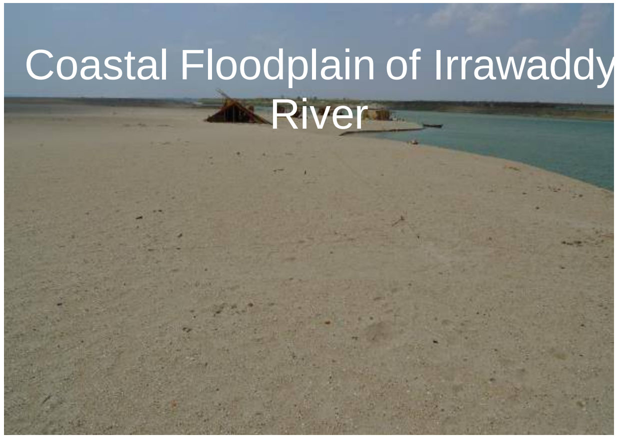


# Analysis of image interpretation and results verification

- Investigation method： The investigation combines the line transect method with the private visits
- Investigation tragets： River channel, Land use/Land cover, Bio-circumstances, farming methods on farmland, irrigation method, key ecological protection objectives, social economy and cultural customs
- The Joint investigation lasted seven days, covered a total of nearly 3,000 km

# Analysis of image interpretation and results verification





# Analysis of image interpretation and results verification

The land utilization/coverage characteristics:

- The main land types within the drainage basin are woodland, cultivated land and grassland, the three types account for 94.46% of the total area of the drainage basin.
- Within the drainage basin of Irrawaddy River has lush vegetation, and the vegetation here has vertical zonality and horizontal zonality.
- Paddy field and dry land mainly lacated in low-lying flat plains
- Grassland mainly distributed in the area between the cultivated land and the woodland, more sporadic and scattered in the spatial form
- Eshoals and sandbanks distributed in both sides of the river channel of Irrawaddy River and the estuarine delta
- The places for settlement are mainly distributed in the lower reaches of Irrawaddy River, fewer in the gorge area in the upper reaches of Myitsone

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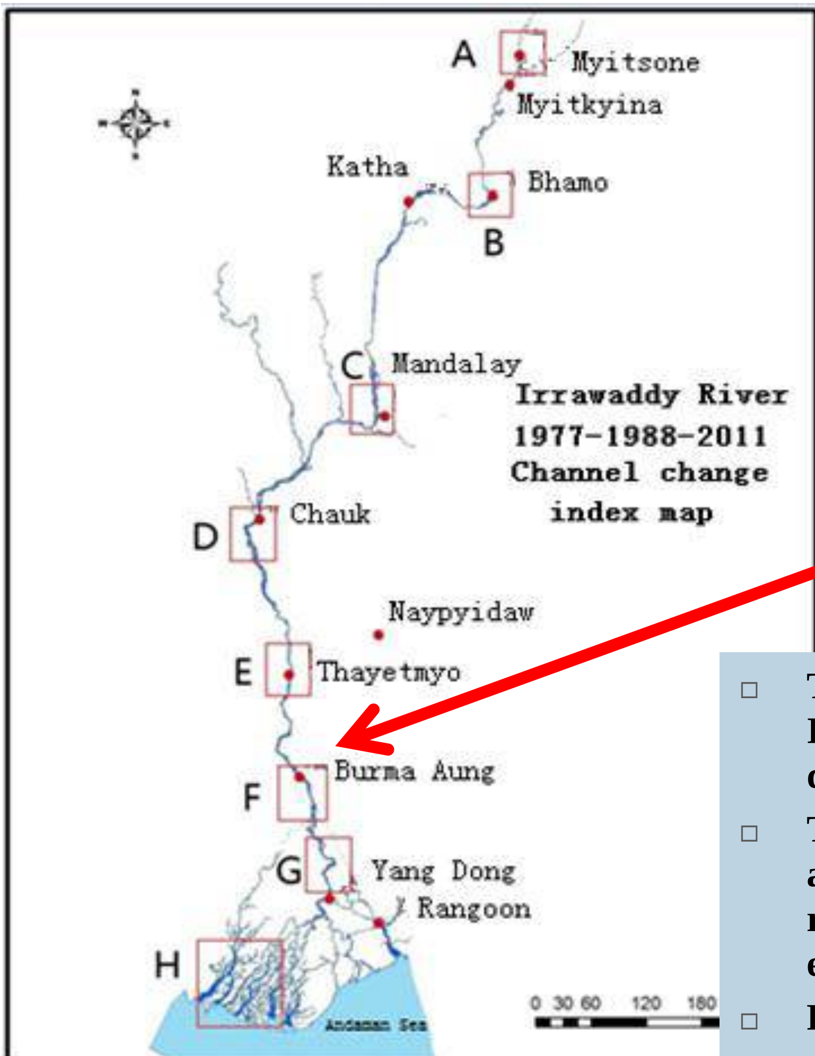
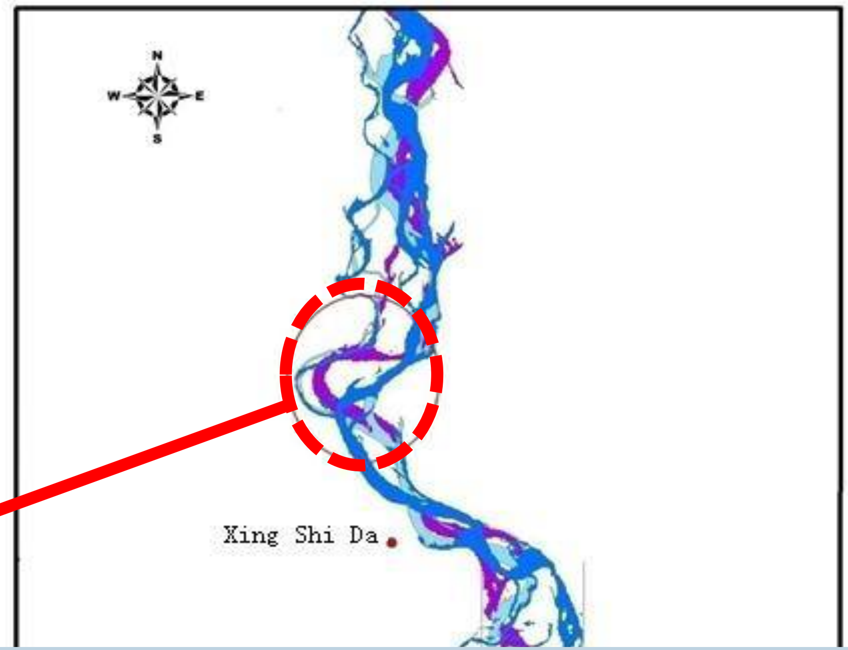
# 3.1 Evolution of the river channel under natural circumstances




- The natural swing of the middle and lower reach channel of Irrawaddy River basin is relatively obvious, the largest swing distance of the main stream is about 7km
- The Irrawaddy River system down Burma Aung is characterized as braided distribution and there are no large changes of main river channel but small effluents have obvious redirection and erosion and deposition changes
- River channel can be trained / regulated through reservoir operation.

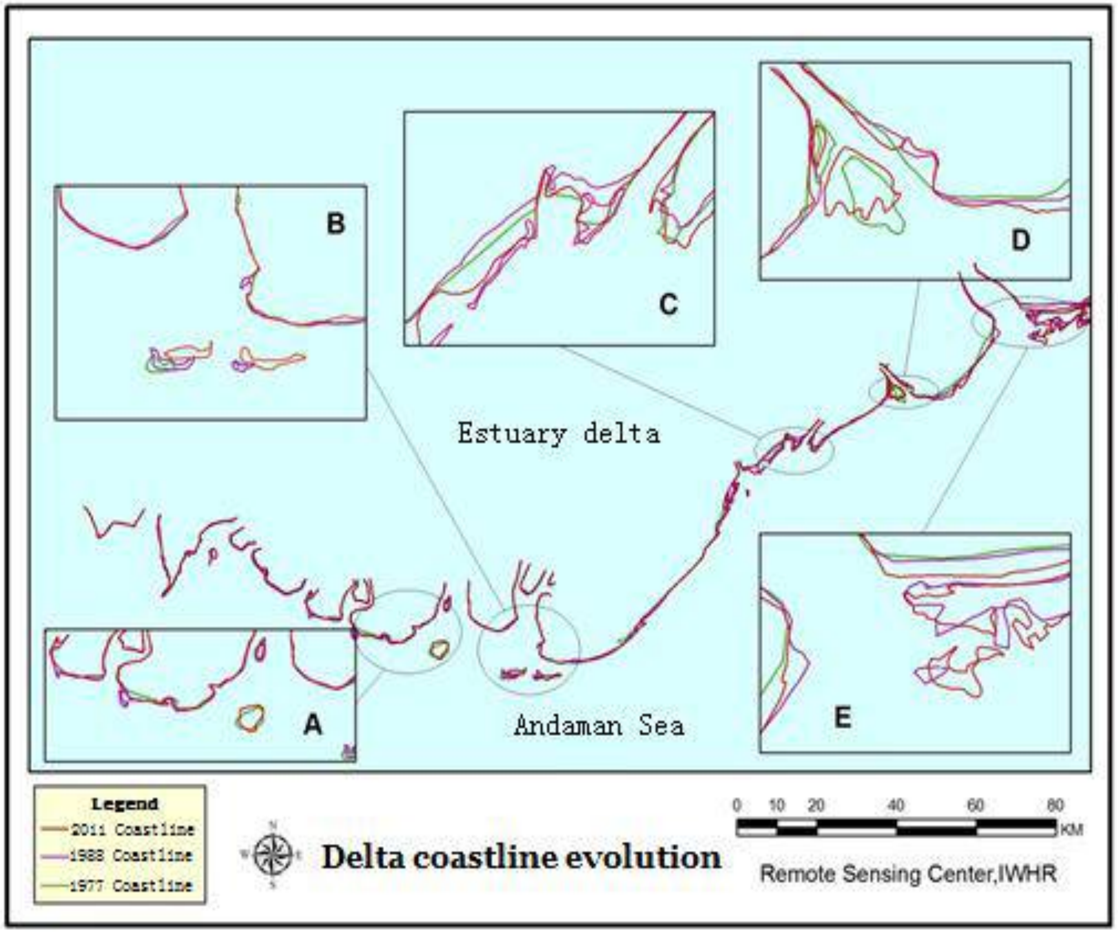
# 3.2 Erosion and deposition of the natural river basin

| | River channel erosion and deposition area from end of 1970s to 2001 ($km^2$) | | Erosion and deposition area differentials ($km^2$) | Annual average ($km^2$) |
|---|---|---|---|---|
| | Erosion | Deposition | | |
| **Myitsone-Katha** | **96.71** | 115.78 | **+19.07** | **0.79** |
| **Katha-Mandalay** | **151.80** | 149.95 | **-1.85** | **-0.08** |
| **Mandalay-Chauk** | **131.44** | 154.88 | **+23.44** | **0.98** |
| **Chauk-Thayetmyo** | **153.23** | 103.24 | **-49.99** | **-2.08** |
| **Thayetmyo-Burma Aung** | **93.14** | 47.52 | **-45.62** | **-1.90** |
| **Burma Aung-estuary** | **359.00** | 780.46 | **+421.46** | **17.56** |
| **Total** | **985.32** | **1351.83** | **+366.51** | **15.27** |

# 3.3 Evolution of estuary delta in natural state

- In the recent 40 years, the configuration and the position of the delta coastline and the estuary shoal all change slowly

- Coastline change at the estuary of various braided rivers is relatively obvious. the beach near the coastline is extending towards the sea to 2 km in the maximum( C and E)

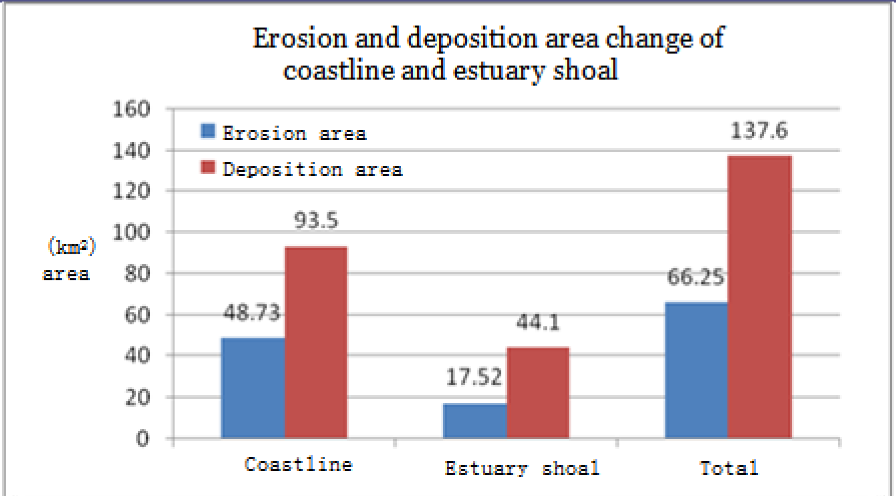



Configuration evolution of the delta coastline

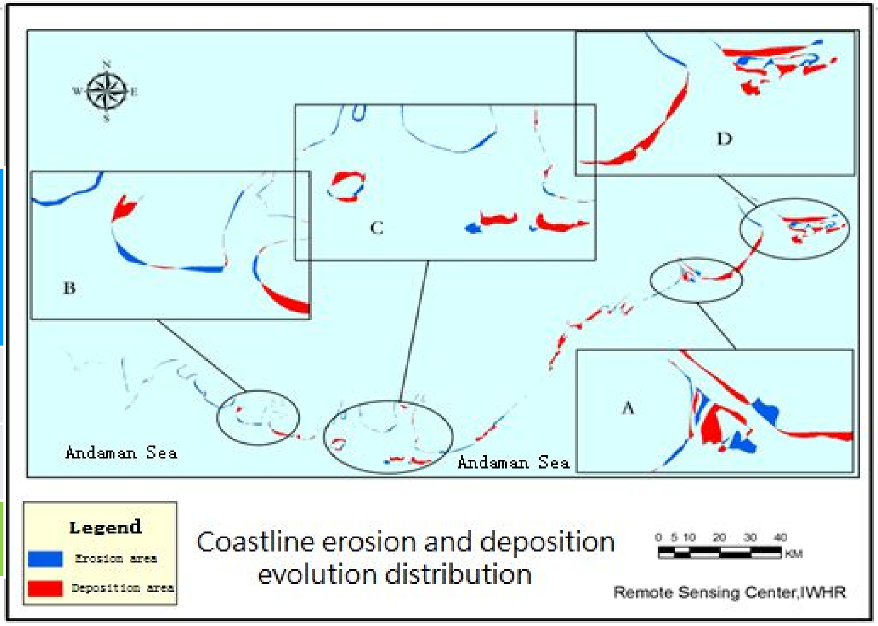
# 3.3 Evolution of estuary delta in natural state

- In recent 40 years, the erosion area of the delta coastline and the estuary shoal is 66.25km², the deposition area is 137.6km².

- The main process is deposition, the erosion and deposition difference value is 71.35km².

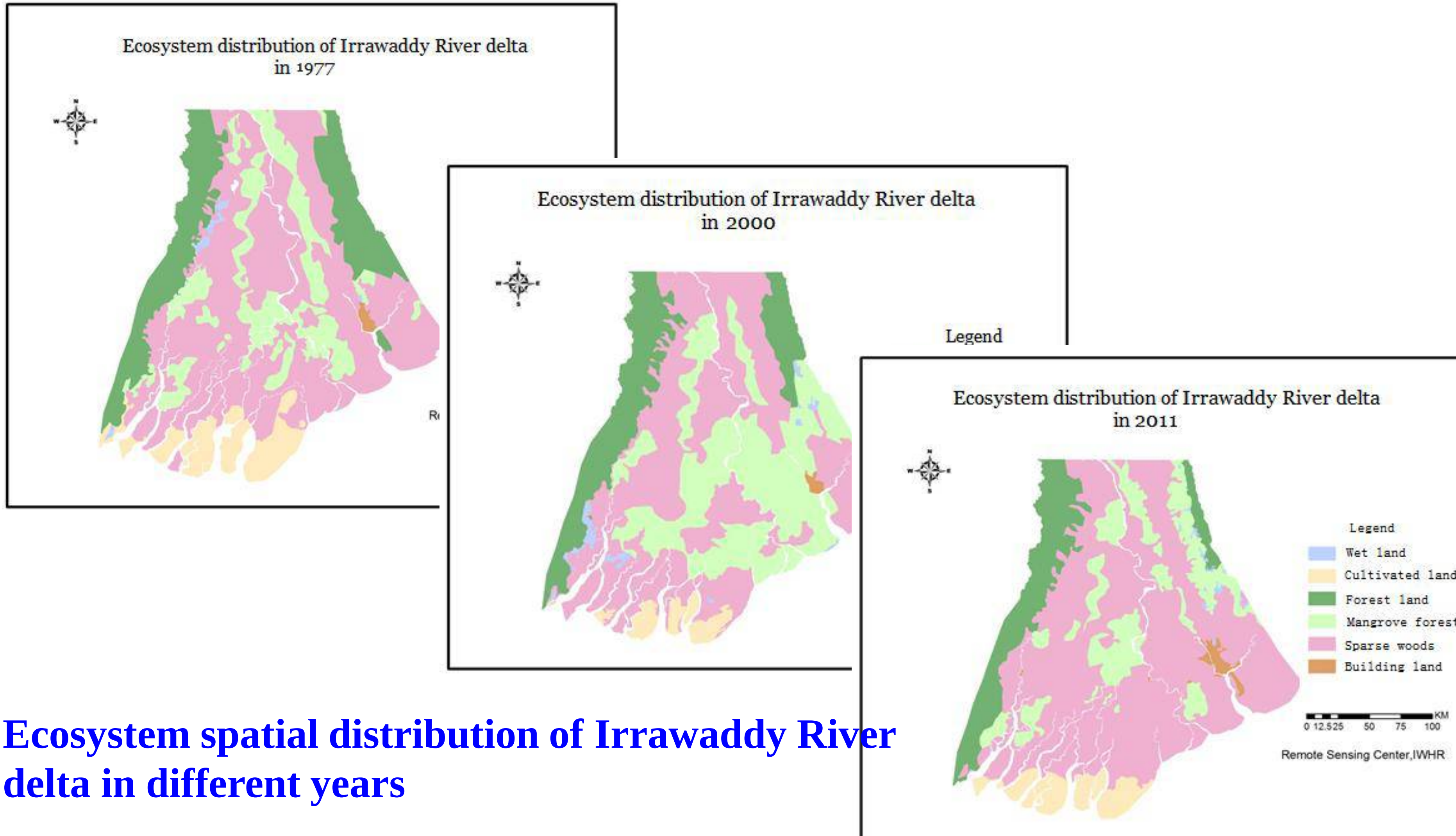



| Erosion and deposition evolution | Erosion (km²) | Deposition (km²) | Difference value (km²) |
|---|---|---|---|
| Coastline | 48.73 | 93.5 | +44.77 |
| Estuary shoal | 17.52 | 44.1 | +26.58 |
| Total | 66.25 | 137.6 | +71.35 |




Coastline erosion and deposition evolution distribution

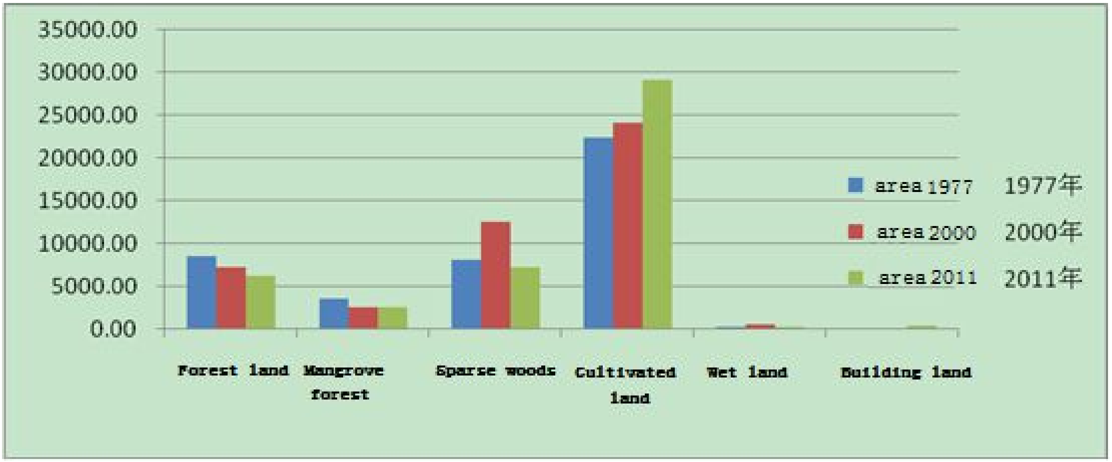
# 3.3 Evolution of estuary delta in natural state




**Ecosystem spatial distribution of Irrawaddy River delta in different years**

# 3.3 Evolution of estuary delta in natural state

- In the recent 40 years, the crop land and residential area of the delta district are continuously increased.
- The area of wet land, forest land and grass land are gradually reduced.




Evolution of the estuary delta 'Ecosystem

| Land category name | Land category code | Area (km²) | | | Increased or reduced area of 2000 compared to 1977 (km²) | Increased or reduced area of 2011 compared to 2000 (km²) | Increased or reduced area of 2011 compared to 1977 (km²) |
|---|---|---|---|---|---|---|---|
| | | In 1977 | In 2000 | In 2011 | | | |
| Forest land | 1 | 8584.96 | 7309.82 | 6191.20 | -1275.14 | -1118.62 | -2393.76 |
| Sparse woods | 2 | 8095.01 | 12515.41 | 7187.62 | 4420.40 | -5327.79 | -907.39 |
| Mangrove forest | 3 | 3601.10 | 2601.97 | 2541.73 | -999.13 | -60.24 | -1059.37 |
| Cultivated land | 4 | 22347.90 | 24000.11 | 29043.52 | 1652.21 | 5043.41 | 6695.62 |
| Wet land | 5 | 337.69 | 467.78 | 221.19 | 130.09 | -246.59 | -116.50 |
| Urban land | 6 | 180.02 | 251.60 | 461.42 | 71.58 | 209.82 | 281.40 |
| Total | | 45646.68 | 45646.68 | 45646.68 | 0.00 | 0.00 | 0.00 |

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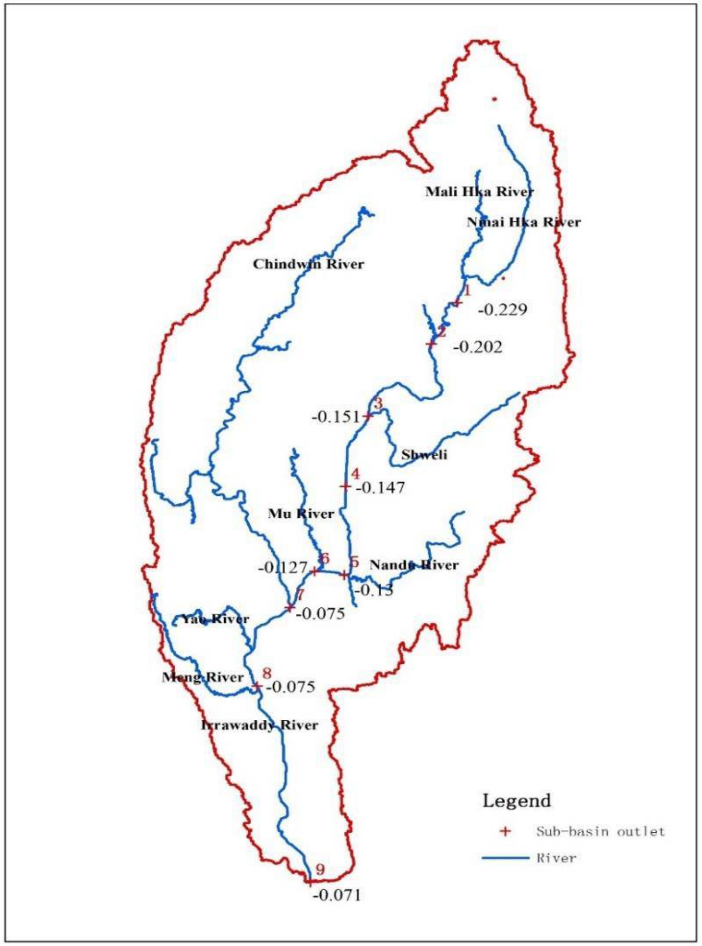
# 4.1 Impacts of on the runoff of Lower Reaches

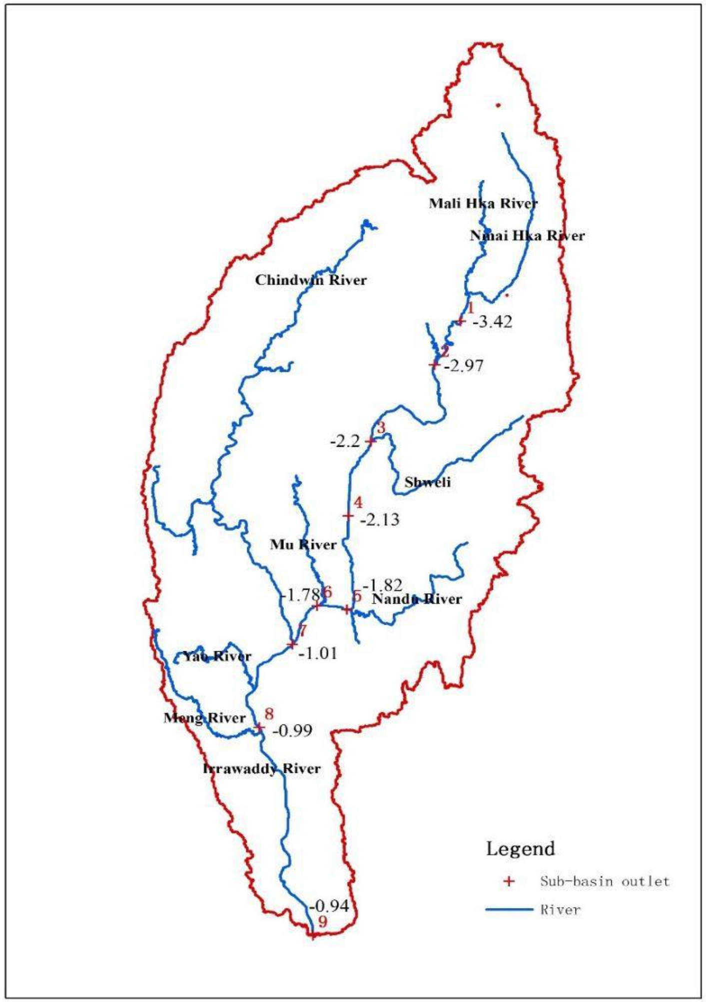
## Annual runoff change after dam establishment




- The annual runoff change after dam establishment is very small.
- Myitkyina station is only -0.229% and in Mandalay only -0.130%. After the afflux of the largest tributary Chindwin River, the impact decreases to -0.075%.
- It is very little to Irrawaddy River having an annual runoff of 486 billion $m^3$ or so.

# 4.1 Impacts of on the runoff of Lower Reaches

## Runoff change in High Flow Period after dam establishment



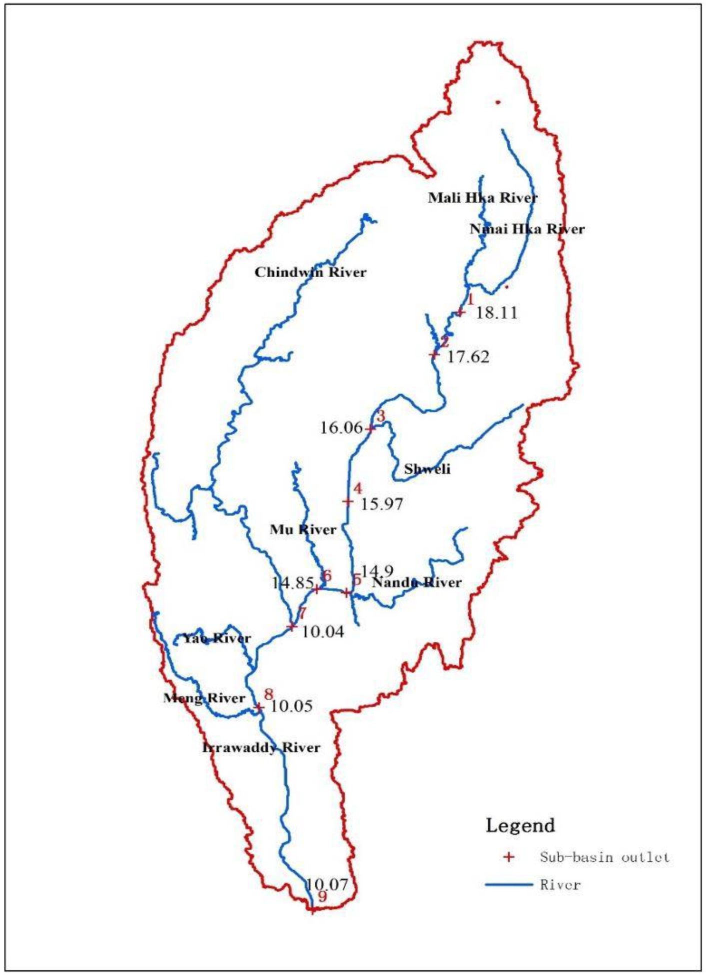

- Effect of the dam is to reduce flood peak and adjust flood.

- Myitkyina monthly average runoff will decrease 3.42%, Besides, reservoir reserves 0.85 billion $m^3$ flood control storage capacity for Myitkyina city, which has a significant influence on the flood control.

- Mandalay only decreases 1.82%, and the effect decreases to about 1% after Chindwin River joining in.

# 4.1 Impacts of on the runoff of Lower Reaches

## Runoff change in Low Flow Period after dam establishment




- The average runoff in Myitkyina can increase by 18.1%, in Mandalay 14.9%, and it can increased by 10% when met the afflux of Chindwin River.

- Impact on runoff in low flow period is greater than that in high flow period. increasing the runoff of Irrawaddy River in low flow period and mitigating problems of midstream and downstream, such as irrigation, shipping and tourism

## 4.1 Impacts of on the runoff of Lower Reaches

- Chindwin River is the main water source for the middle and lower reaches, together with the Shweli and Nandu River, and so on, flowing into the Irrawaddy River , The impacts of the hydroelectric development of the Upper Reaches of Irrawaddy River on the Lower Reaches is very small.

- Specially, the impact in High Flow Period is very little, Myitkyina monthly average runoff will decrease 3.42%, decrease about 1% after Chindwin River joining in ； In Low Flow Period, The average runoff in Myitkyina can increase by 18.1%, in Mandalay 14.9%, and increase by 10% when meet the afflux of Chindwin River；
- After the completion of the Myitsone reservoir, although the downstream runoff, flow rate will change compared with the natural state, but the runoff tends to be uniform during the year, and will have a positive effect on irrigation, shipping, tourism of the middle and lower reaches and prevent seawater backflow.

# 4.2 Analysis on history flooding in agricultural region based on remote sensing

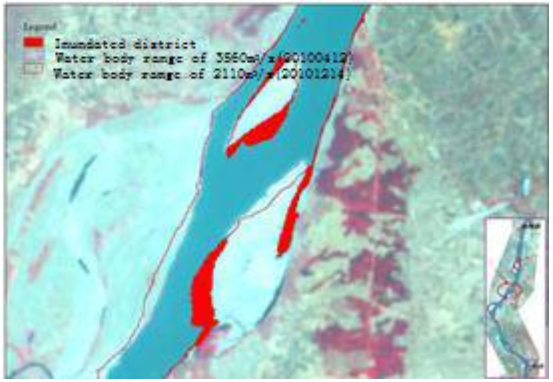
## Analysis of hydrological inundation in agricultural area

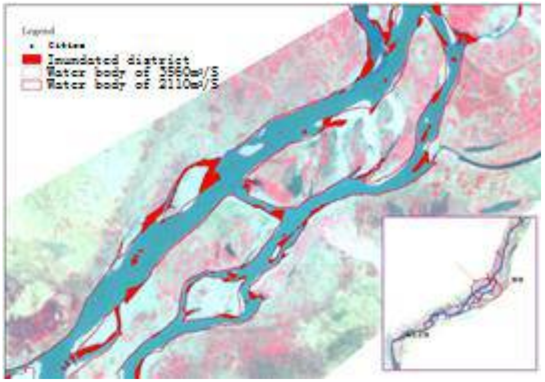
- Based on the simulation results and designed report of the reservoir operation in the dry season, determined the flow in dry season and twice of it.
- By comparing the measured daily runoff of the Myitkyina station in 2010 and 2011, sifted and determined specific dates when the measured rate of flow was similar with different reservoir regulation water levels.
- Directed by the above dates, valid remote sensing images (HJ data,2 images) are sifted and downloaded to establish simulation analysis data sequence used for inundated range under different reservoir regulation water levels.
- Based on the derived inundated range under different reservoir regulation water levels , impacts of discharge water volume of the dam in dry season on middle and lower agricultural planting regions were evaluated.

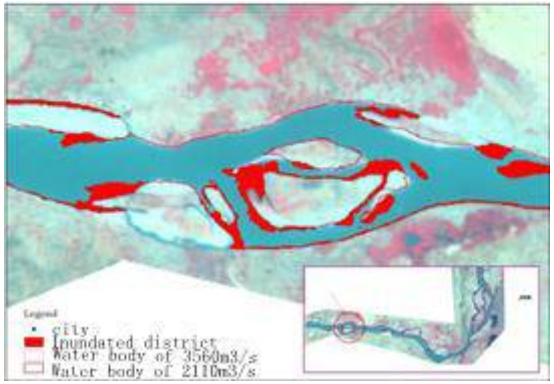
# 4.2 Analysis on history flooding in agricultural region based on remote sensing

## Analysis of hydrological inundation in agricultural area

| Category | Day flow | Water area | Inundated area | Inundated type |
|---|---|---|---|---|
| **HJ20101214** | $2110m^3/s$ | $4235.63km^2$ | -- | -- |
| **HJ20100412** | $3560m^3/s$ | $4527.55km^2$ | $346\ km^2$ | bottomland |



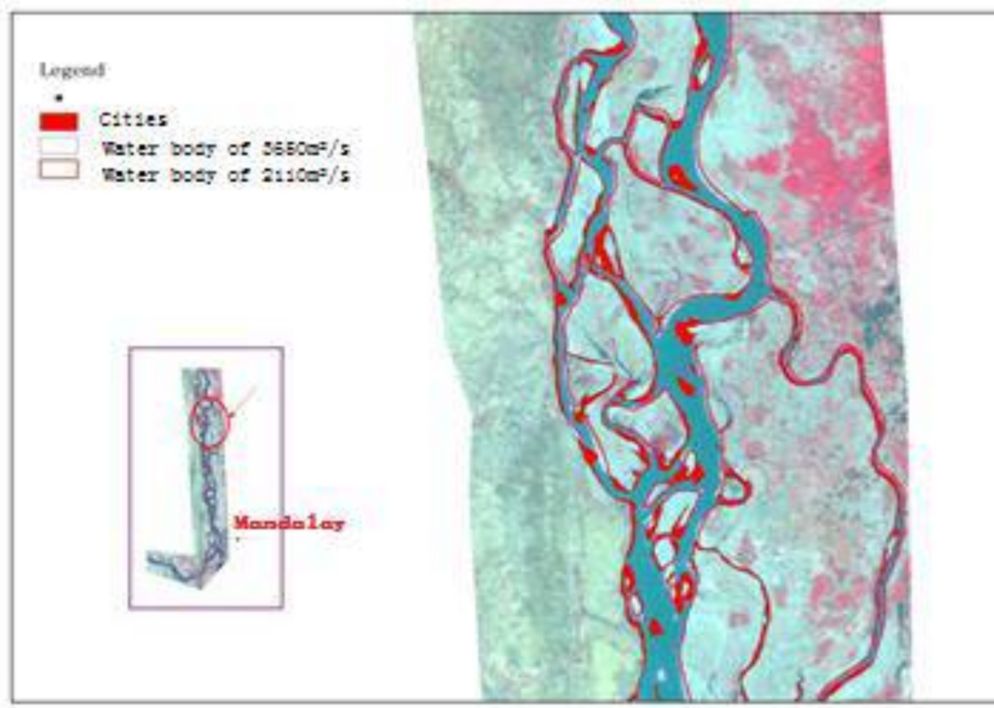



# 4.2 Analysis on history flooding in agricultural region based on remote sensing

## Analysis of hydrological inundation in agricultural area

- Under the condition that the average daily flow is two times of the discharge flow of the reservoir in dry season, the inundated land area of the middle and the lower basin is about 346 km$^2$, basically include bottomland within the channel and along the two sides, accounts for 3% of the bottomland in the basin.

- It will provide sufficient water source to irrigation of downstream agricultural region in dry season, thereby realizing stable yield and income increase of crop cultivation.



# 4.3 Impacts on the agriculture and irrigation

- **According to the results of remote sensing survey of land use / land cover in Irrawaddy River Basin, farmland is mainly distributed in the middle and lower reaches;**
- **The upper reaches of Myitsone to Mandalay basically have no irrigation facilities, and the upstream hydropower development has no impact on the irrigation water.**
- **Based on the hydrology simulation, there are Shweli and Nandu River, and so on flowing into the Irrawaddy River below the Myistone , providing enough water for the middle and lower reaches' farmland irrigation.**
- **Although the flow will increase under the reservoir operation in the dry , basically there will not have impact on the farmland.**
- **The changing of farmland in the Irrawaddy River delta in recent 40 years shows that, human activities should always be the main factor for the evolution of the delta. the upstream hydropower development will have very little impact on the farmland.**

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# 5. Flood prevention benefits of hydroelectric projects in upper stream of Irrawaddy Basin

## Floods occurred frequently in Irrawaddy river have caused large damages

| Floods location | Safety level (cm) | Flood water level (cm) | Flood Duration | year |
|---|---|---|---|---|
| Ayeyarwady | | | | |
| Hintheda | 1342 | 1582 | 23 Days 12Hrs | 1966 |
| Chauk | 1450 | 1532 | 12 Days 12Hrs | 1974 |
| Minhu | 1700 | 1982 | 17Days 12Hrs | 1974 |
| Aunglan | 2550 | 2737 | 15Days | 1974 |
| Pyay | 2900 | 3025 | 13Days | 1974 |
| **Myitkyina** | **1200** | **1411** | **4 Days 12Hrs** | **1979** |
| Katha | 1040 | 1154 | 7Days 6Hrs | 1979 |
| Bhamo | 1150 | 1338 | 8Days 2Hrs | 2004 |
| Mandalay | 1260 | 1382 | 16 Days | 2004 |
| Chindwin | | | | |
| Homalin | 2900 | 3107 | 18Days 6Hrs | 1968 |
| Mawlaik | 1230 | 1608 | 15Days 12Hrs | 1976 |
| Hkamti | 1360 | 1771 | 16Days 6Hrs | 1991 |
| Kalewa | 1550 | 1920 | 10Days 12Hrs | 2002 |
| Monywa | 1000 | 1099 | 9Days 6Hrs | 2002 |



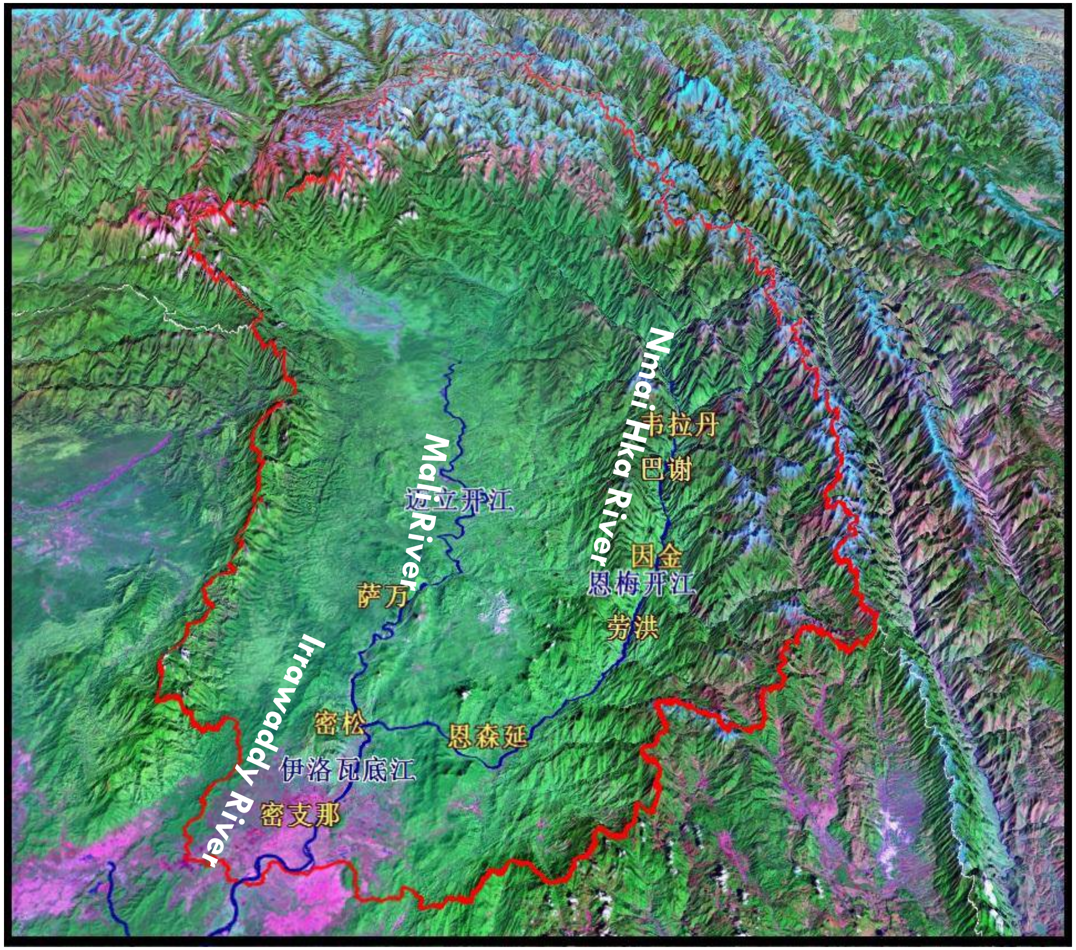
How to protect the Myanmar people from flood disasters?


# 5. Flood prevention benefits of hydroelectric projects in upper stream of Irrawaddy Basin

## Current Status of Irrawaddy River Basin Flood Control System

| SN | Item | Current Status |
|---|---|---|
| 1 | Reservoir | No control reservoirs at the main stream<br>reservoirs built at tributaries, with no flood control storage |
| 2 | Embankment | Most are embankment, low elevation, as well as low flood control capacity |
| 3 | Spillway | Many tributaries in the downstream<br>Insufficient discharge capacity |
| 4 | Hydrological monitoring | since 1950s and 1960s<br>rainfall, flow and water level |
| 5 | Institution of basin management | Not established yet, nor river basin flood forecasting system |
| | | |

# 5. Flood prevention benefits of hydroelectric projects in upper stream of Irrawaddy Basin




3D map of upper stream of Irrawaddy River

**Hydropower:**

**Mainly concentrated in upper reaches of Myitkyina**

**Nmai Hka and Mali Hka:**

**High drop, large water yield, abundant water resources**

**Suitable for constructing cascade hydropower station.**

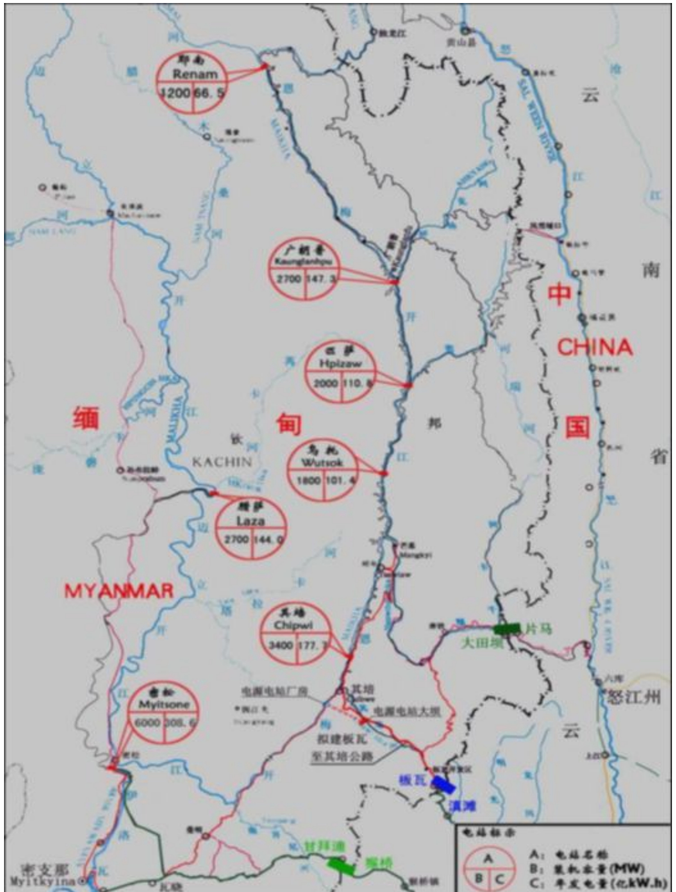
**Total energy : 188.3 billion kW•h**

# 5. Flood prevention benefits of hydroelectric projects in upper stream of Irrawaddy Basin

## Project overview

**Hydroelectric project : 7 cascade hydropower projects in Nmai Hka, Mali Hka and the main stream :**

- **Renam（1010m, the 3rd batch of projects)**
- **Kaunglanhpu（875m, the 2nd batch of projects）**
- **Hpizaw（665m , the 2nd batch of projects）**
- **Wutsok（525m , the 2nd batch of projects）**
- **Chipwi（400m , the 1st batch of projects ）**
- **Myitsone（245m, the 1st batch of projects）**
- **Laza（370m, the 2nd batch of projects）**



# 5. Flood prevention benefits of hydroelectric projects in upper stream of Irrawaddy Basin

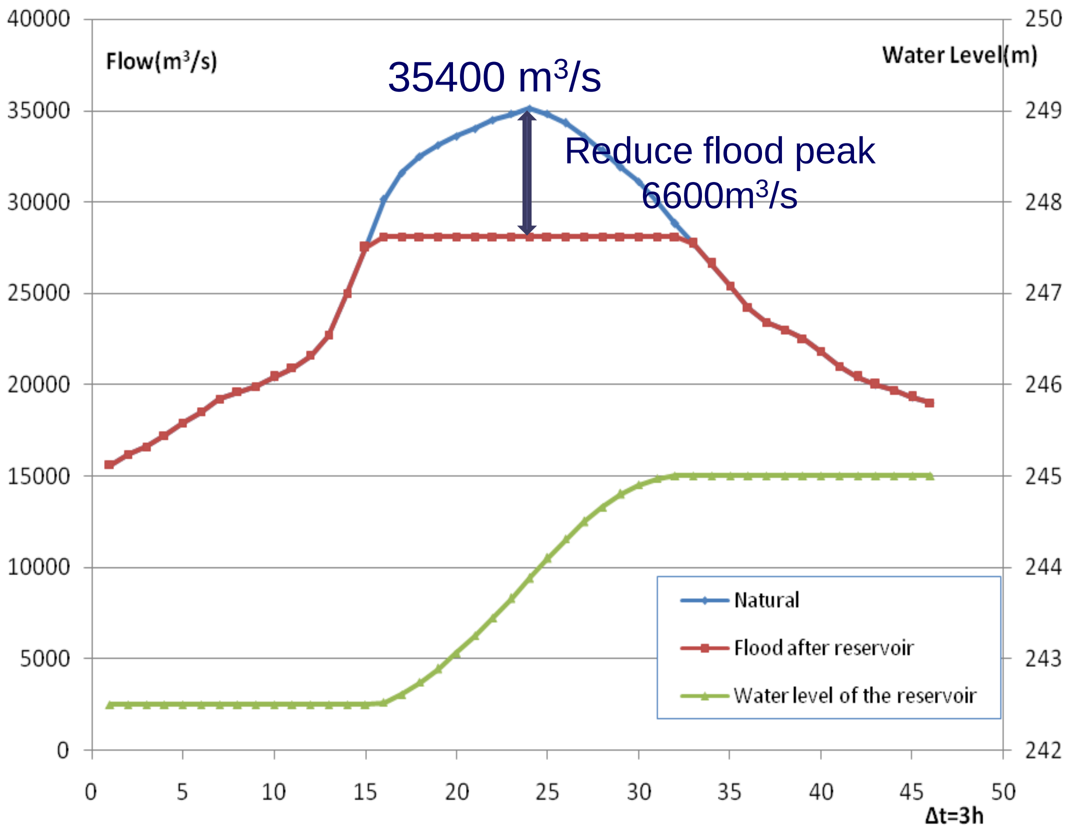
## Design parameters of Myitsone hydropower station

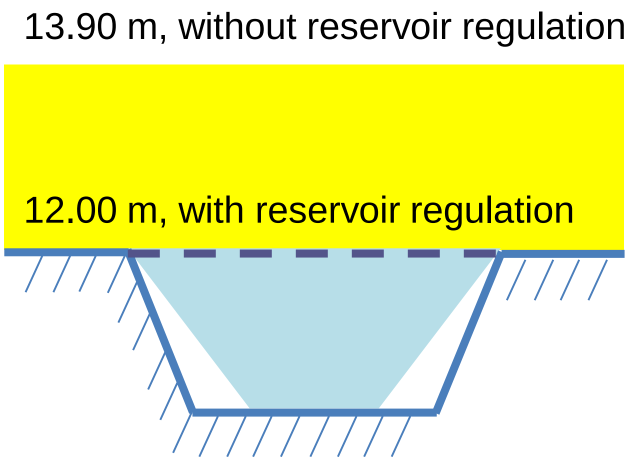
| Description | | Unit | Parameter |
|---|---|---|---|
| Normal water level | | m | 245 |
| Flood control level | | m | 242.5 |
| Dead water level | | m | 230 |
| Storage capacity below normal water level | | Billion $m^3$ | 12.072 |
| Dead storage capacity | | Billion $m^3$ | 7.569 |
| Regulated storage capacity | | Billion $m^3$ | 4.503 |
| Storage coefficient | | % | 2.8 |
| Installed capacity | | MW | 6000 |
| Comnibed operation of Myitsone and Chipwi hydropower stations | Guaranteed output（P=90%） | MW | 1244 |
| | Average annual energy output | Billion kW ħ | 29.4 |
| Combined operation of all cascade hydropower stations | Guaranteed output（P=90%） | MW | 1722 |
| | Average annual energy output | Billion kW ħ | 30.86 |

# 5. Flood prevention benefits of hydroelectric projects in upper stream of Irrawaddy Basin

Flood storage 0.85 billion $m^3$

Improve flood safety level at Myitkyina from <5 year to 20 years flood

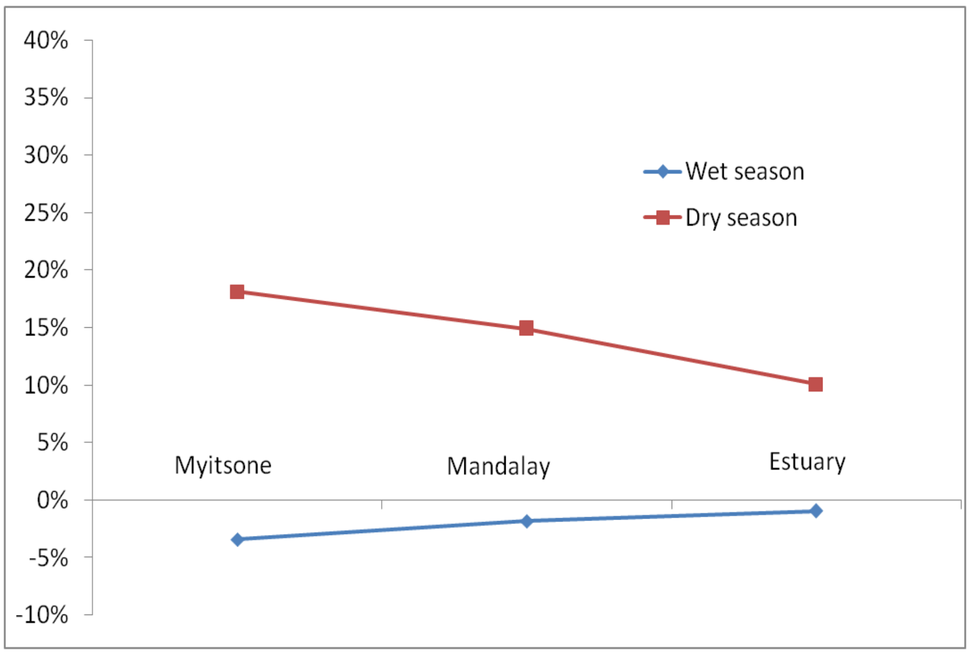


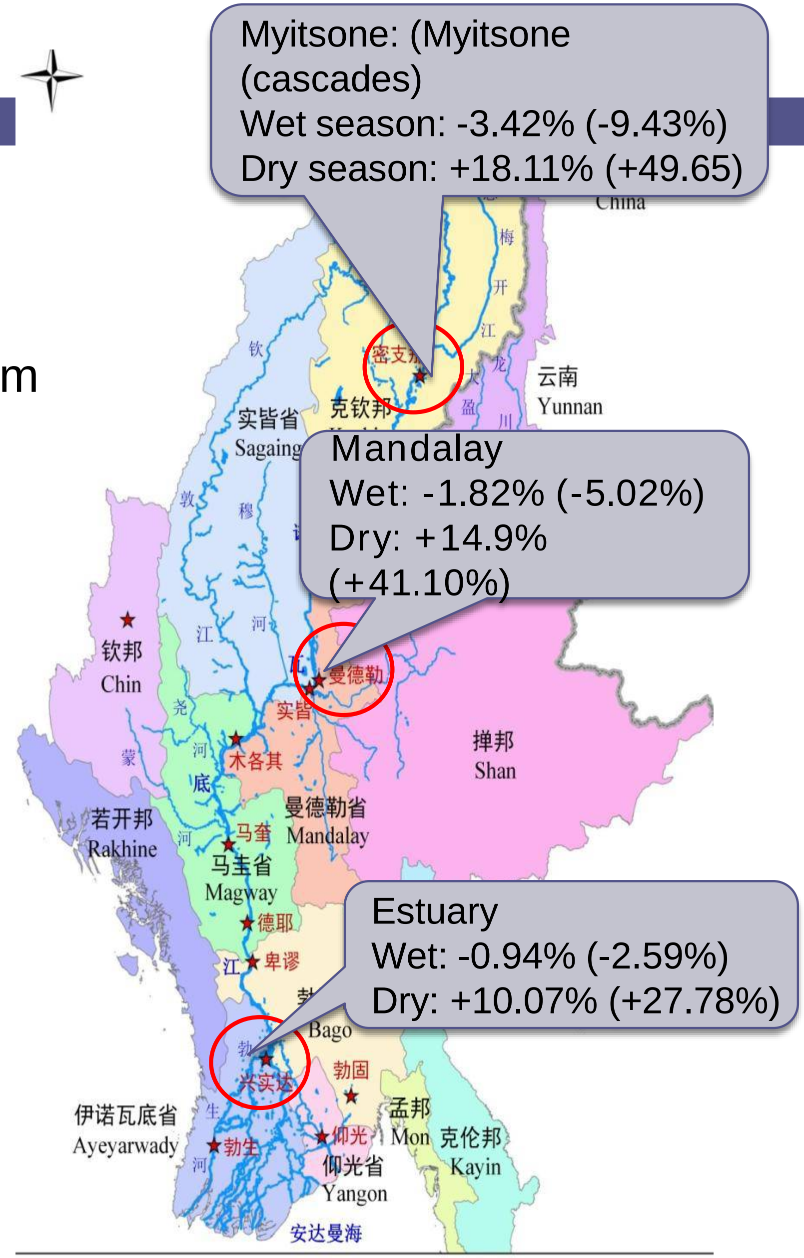

Reduce 1.90 m for 20 years flood at Myitkyina City

# 5. Flood prevention benefits of hydroelectric projects in upper stream of Irrawaddy Basin

- ❑ No effect to total water volume
- ❑ Store water in wet season, discharge in dry season
- ❑ Impacts decrease from upstream to downstream




Impacts to the runoff reduces downstream-wards



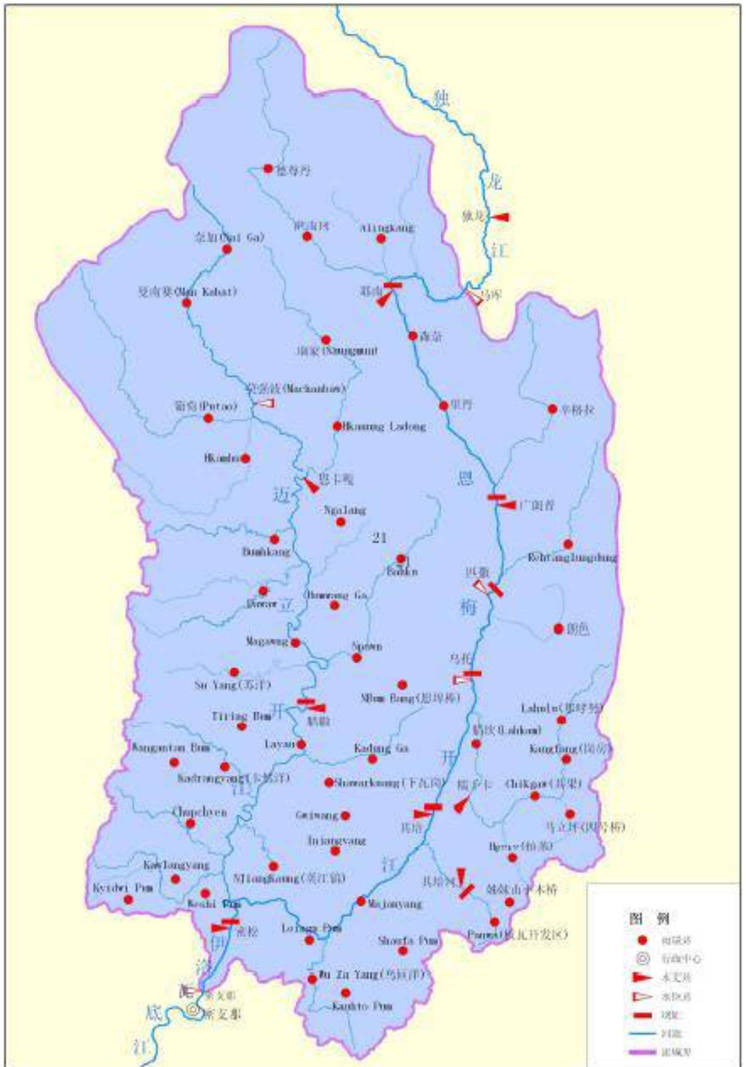
# 5. Flood prevention benefits of hydroelectric projects in upper stream of Irrawaddy Basin

## Flood prevention benefits for the upper stream of Irrawaddy River

**Meteorological hydrology survey and automatic measuring**

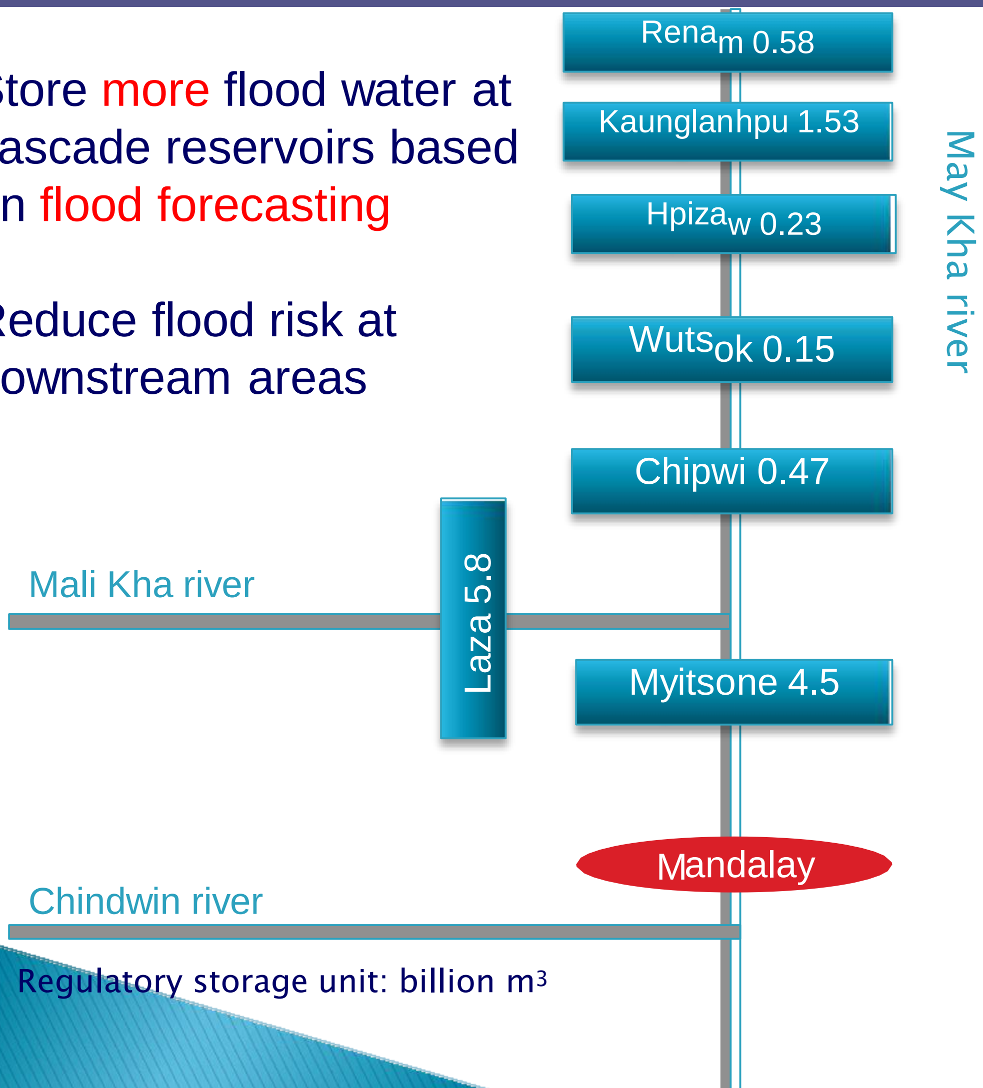
**1 center station**
**7 sub-center stations,**
**24 automatic meteorological stations**
**84 precipitation stations.**

**Flood forecasting and warning system**
**will greatly improve the flood control capacity.**

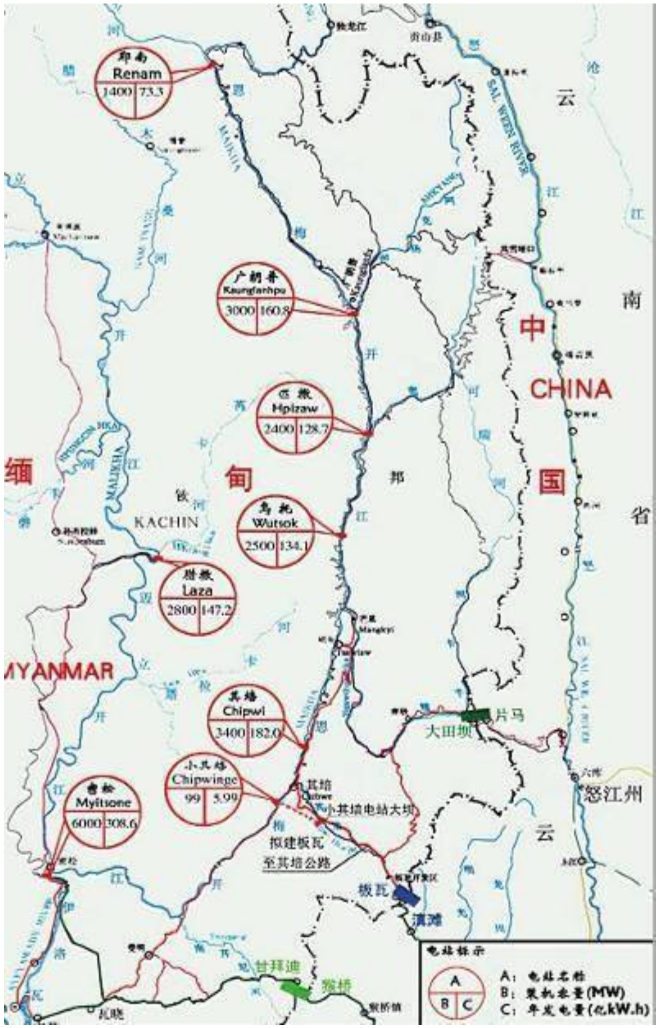


# 5. Flood prevention benefits of hydroelectric projects in upper stream of Irrawaddy Basin

- Store more flood water at cascade reservoirs based on flood forecasting
- Reduce flood risk at downstream areas



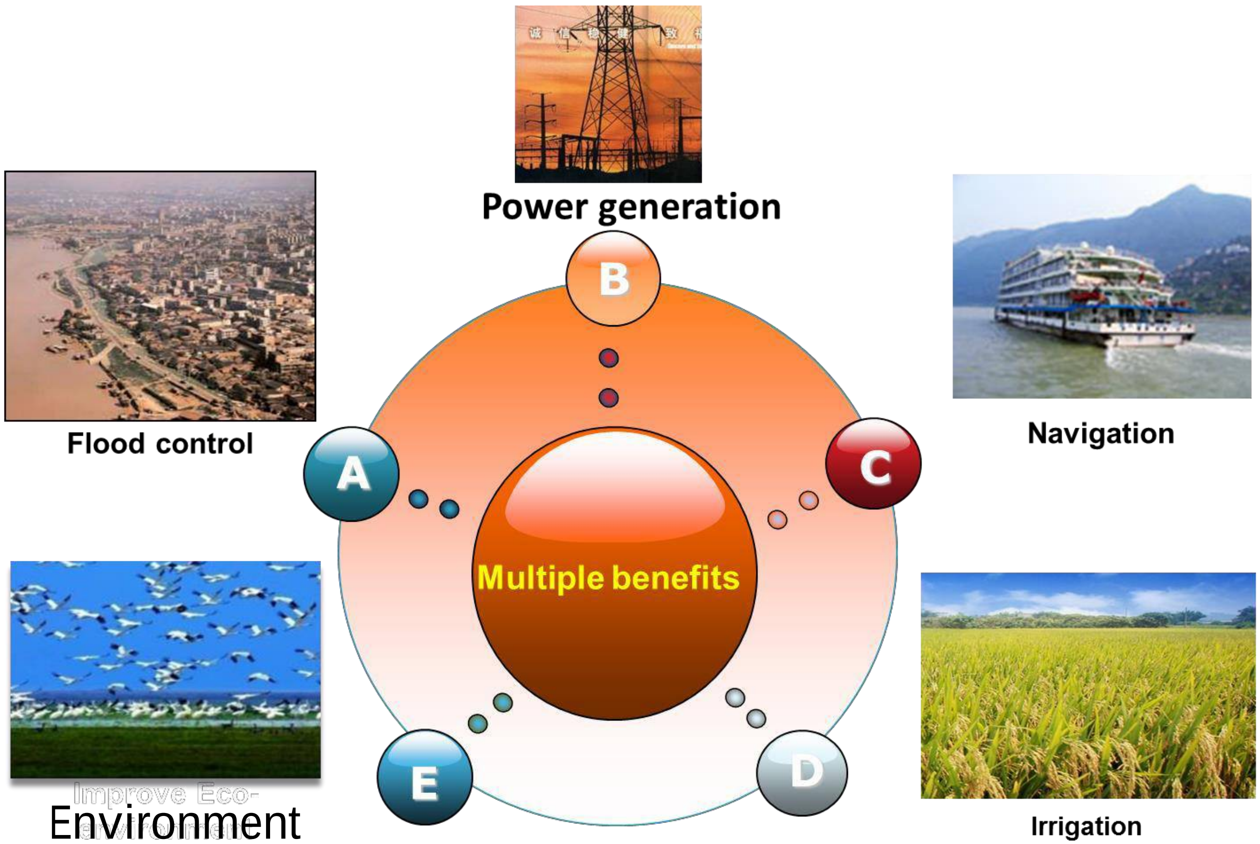

Regulatory storage unit: billion m3



# 5. Flood prevention benefits of hydroelectric projects in upper stream of Irrawaddy Basin

- Improve the national **power** supply situation & enhance energy structure with clean energy.
- Meet the requirement of No. 4 of the **12 economic strategies**: *development priority goes to construction of infrastructures such as electricity supply, transportation, harbors etc….*

# 5. Flood prevention benefits of hydroelectric projects in upper stream of Irrawaddy Basin



# THANK YOU ！