Assessing Climate Change Vulnerability and Adaptation Strategies for Maharashtra State

Government of Maharashtra Project on Climate Change for the Preparation of the Maharashtra State Adaptation Action Plan

Presentation - October 7, 2013, Mumbai
Structure of the presentation

- Summary of activities carried out so far
- Approach
- Key Observations
  - Climate Model output
  - MMR - A coastal case study
  - Health
  - Ecosystems
  - Agriculture, Livelihoods and Risk Management
  - Water
- Key Recommendations
  - Adaptation strategy
  - Action Plan
- Way Forward
  - Institutional and financial implications
Post July 12th, 2013...

Summary of activities

- Revisited methods being used and results projected for all components of the study
- Analysed the data procured from different departments
- Cross validated the results of model output with data wherever possible
- Approached various departments including Water Resources (CAD) and Disaster Management cells of ULBs (specific for MMR).
- Consultations with Departments - Health, UD (I), Environment and BMC
  - Flood map for Mumbai/ MMR
- Shared basic data and data gaps with Dept. of Environment
- Shared the district proposals with DCs and revisited the recommendations.
- Circulated the sector-wise background information, literature review, key observations and recommendations.
Approach

• There are two sets of information
  – Sector wise background information, literature review and key observations
  – Action plan and recommendations
• The presentation focusses on the Action plan and way forward
Key Observations

• Climate Model Output
  – Rainfall and temperature changes have been projected for three time slices - 2030, 2050 and 2070.
  – There is an increase in rainfall and temperature in the range of 10-40% for the rainfall and 1-3°C for temperature.
  – Northern Maharashtra, Marathwada and Vidarbha region may experience increase in rainfall and temperature in the next 20-60 years.
  – Sea level rise projection indicates 2 cm rise by 2050.

• Flood Mapping for MMR
  – Scenarios of inundation studied for events of different magnitude indicate certain vulnerable areas prone to water logging.
Approach to assess rainfall variations

Example- Thane, 100 years (0 line- long term average of observed data: 1980 mm)
Approach to assess rainfall variations
Example- Solapur, 100 years (0 line- long term average of observed data: 550 mm)
## Frequency of rainfall variations - Thane

<table>
<thead>
<tr>
<th></th>
<th>Rainfall in mm</th>
<th>Classification</th>
<th>Number of events</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline</strong></td>
<td></td>
<td></td>
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<tr>
<td><strong>Above normal</strong></td>
<td></td>
<td>Class I- (250-500)</td>
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<tr>
<td></td>
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<td>Class II- (500-1000)</td>
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<td>Class III- (1000 &amp; above)</td>
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<tr>
<td><strong>Below normal</strong></td>
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<td>Class I- (250-500)</td>
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<tr>
<td></td>
<td></td>
<td>Class II- (500-1000)</td>
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</table>

## Solapur

<table>
<thead>
<tr>
<th></th>
<th>Rainfall in mm</th>
<th>Classification</th>
<th>Number of events</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Above normal</strong></td>
<td></td>
<td>Class I- (150-300)</td>
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<tr>
<td></td>
<td></td>
<td>Class II- (300-500)</td>
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<tr>
<td><strong>Below normal</strong></td>
<td></td>
<td>Class I- (100-200)</td>
<td>14</td>
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<tr>
<td></td>
<td></td>
<td>Class II- (200-300)</td>
<td>6</td>
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</tbody>
</table>
Coastal impacts assessment
Compounded Impacts on MMR - A case study

• Sea level rise
• High tide levels
• Intensity of Precipitation
Out of 15 models, 9 models were selected which had over 30 years of data available.

Due to the coarse global model resolution ~300km, Krigging methodology applied to interpolate the data onto 1degree or 100km resolution, bringing closer to the coast.
## 2. High Tide Level (HTL) – MMR

<table>
<thead>
<tr>
<th>Year</th>
<th>Highest rainfall in mm</th>
<th>Date of highest rainfall</th>
<th>Station</th>
<th>High tide level in mtrs</th>
<th>Time of high tide</th>
<th>Post Event Headlines in Media</th>
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</thead>
<tbody>
<tr>
<td>2005</td>
<td>944.2</td>
<td>7/27/2005</td>
<td>Santacruz, Mumbai</td>
<td>3.7</td>
<td>4:13 AM</td>
<td>Rains wreak havoc in Mumbai; 150 killed in Konkan</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.1</td>
<td>4:16 PM</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.1</td>
<td>4:16 PM</td>
<td></td>
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<tr>
<td>2006</td>
<td>231</td>
<td>7/5/2006</td>
<td>Santacruz, Mumbai</td>
<td>3.1</td>
<td>7:05 AM</td>
<td>Heavy rains lash Mumbai, schools remain close</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.4</td>
<td>6:15 PM</td>
<td>Rain causes havoc in Mumbai, 24 killed</td>
</tr>
<tr>
<td>2008</td>
<td>249.7</td>
<td>7/28/2008</td>
<td>Colaba, Mumbai</td>
<td>3.7</td>
<td>8:17 AM</td>
<td>Wet weekend spells good news for lake levels</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.4</td>
<td>7:24 PM</td>
<td>Waterlogging, during the high tide in the afternoon, was reported.</td>
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<tr>
<td>2009</td>
<td>439.1</td>
<td>7/16/2009</td>
<td>Dahanu, Thane</td>
<td>3.4</td>
<td>5:51 AM</td>
<td>Heavy rains lashed the city</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.6</td>
<td>5:20 PM</td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td>236</td>
<td>6/24/2010</td>
<td>Dahanu, Thane</td>
<td>4.2</td>
<td>10:56 AM</td>
<td>The city also witnessed waterlogging and wall collapses in several areas following the downpour</td>
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<tr>
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<td></td>
<td></td>
<td></td>
<td>3.5</td>
<td>10:22 PM</td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>232.6 (New Moon)</td>
<td>8/29/2011</td>
<td>Santacruz, Mumbai</td>
<td>4.7</td>
<td>11:58 AM</td>
<td>Mumbai weather: Incessant rainfall leaves city in deep water</td>
</tr>
</tbody>
</table>
Flood Map for 900 mm and above rainfall

- Maximum intensity was 190.3 mm/hr
- Total Rainfall 944.42 mm over 24 Hrs period
Flood Map 2007

T-R-F Relation

Point near Mahim Creak
(X axis- Time is hours)
Specific Recommendations for MMR

- Strict compliance with CRZ norms.
- Preservation of mangroves, salt pans, coastal wetlands and lakes.
- Protection of native species in these zones.
- Re-naturalization of Mithi River.
- Removal of plastic and unnatural debris from the wetland areas.
- Retain and conserve the Riparian buffer zone around wetlands for improved surface runoff.
## Integrated Flood Management Plan for Mumbai

### Key components of the action
- **Establish flood rescue center** at flood hot spots
- **Networking** flood rescue centers with other service providers in the city
- **Use porous asphalt** surfaces to increase GW recharge
- **Map** identified **flood hot spots** and share maps with communities to include their inputs
- **Train the community** on actions in case of a flood event
- **Maintenance of storm water drains and drainage systems**

### Timeframe
- **Short Term: 1-2 years**
  - Mapping of identified flood hot spots and sharing maps with the community so as to include their inputs on possible spots of flooding in their area.
  - Training the community on actions to be taken in case of a flood event
- **Medium Term: 3-5 years**
  - Establishing a flood rescue center at each of the flood hot spots
  - Networking the flood rescue centers with other service providers in the city
  - Using porous asphalt to increase groundwater recharge
Integrated Flood Management Plan for Sub-urban and Peri-urban areas

Key components of the action

- **Establish flood management department** in suburban and peri-urban municipal corporations/ councils of MMR.
- **storm water drainage**: develop storm water drainage network, clean-up drainage network, maintenance and other related tasks.
- **rain water harvesting**: mandate rainwater harvesting structures, regulate and implement permeable surfaces/ roads to increase groundwater percolation
- **weather forecasts**: disseminate real time weather forecast information in monsoons

**Publish annual flood management reports** to keep a check on the status of the infrastructure.

**Regulate conversion of agriculture** and forest land into non-agricultural land

Timeframe

- **Short-term (1 to 2 years)**: Establishing flood management department in the municipal corporations/ councils of MMR; Publishing annual flood management reports; Regulating conversion of agriculture and forest land
- **Medium-term (3 to 5 years)**: Increasing tree cover in the region
Health
Difference in average number of Conducive Days for spread of Malaria (a) between 2030s and Baseline (b) between 2050s and Baseline

- When compared to the Baseline, some regions (mostly in coastal and eastern tip of Maharashtra) are seen to be showing an increase in average number of conducive days (positive difference) while other regions (mostly Northern, central and south-eastern Maharashtra) show varying degrees of reduction (negative difference) in both 2030s and 2050s.

- The negative difference (reduction in number of conducive days) is seen to be larger in 2050s than 2030s, since the projected rise in mean temperature in 2050s is high enough to exceed the specified temperature criteria for parasite development.
Recommendations - Health

• Address data gaps for improved assessments on health. eg., cases reported daily, mortality and morbidity information

• Continue with monitoring & surveillance of climate-sensitive diseases. May cover diseases like dengue and leptospirosis

• Develop systems to adapt to conditions of extreme heat for instance fix certain work hours preventing direct exposure to heat, construct shelters near farm areas

• Invest in health research - Promote research on mutations and its impacts due to changes in temperatures and humidity patterns for emergence of new diseases
Fragmentation captured by land use land cover model for parts of the Western Ghats.
Vulnerable Terrestrial biodiversity in Maharashtra

- **Biodiversity Hotspots:** Total 32 identified sites. Examples include.
  - Kalasubai- Harishchandragad WS (Wild life Sanctuary).
  - Bhimashankar WS
  - Amboli – Sawantwadi.
  - Ambavane-Khandala Valley.
  - Koyana WS
  - Mahabaleshwar plateau and Hill Complex.
  - Marleshwar

![Map of Maharashtra with Vehetation Type]

- **Great Indian Bustard** (*Ardeotis nigriceps*)
- **Indian Black buck** (*Antilope cervicapra*)
- **Bengal Florican** (*Houbaropsis bengalensis*)
Recommendation 1 – Ecosystems

• Revival of existing forest monitoring plots at places such as Bhimashankar, Mahabaleshwar, several protected areas, etc. (SFD could undertake this activity collaboratively).

• Need to have genetic prospecting of coastal biota for various purposes e.g. salinity tolerant alleles, etc.

• Diversification of fisheries-based livelihoods
Recommendation 2 – Ecosystems

- Data compilation for detailed analysis of climate impacts
  - Season-wise sea surface temperatures to correlate with season-wise landings
  - Time series data on net primary productivity
  - Data on coastal upwelling and chlorophyll
  - Reasonably long time series data on climatic and oceanographic parameters to detect displacement of stocks and changes in productivity
  - Non-climatic variables that might be responsible for changing composition of fish catch and distributions (e.g. changing tastes and markets, price paid for various fish species, change in type of gear and effort, level of mechanization, location of the actual catch, etc.)
Recommendation 3 – Ecosystems

• Model development for climate change impacts on fish species
  – Need to develop simulation models
  – Regional models are required to assess the implications of climate change on tropical marine fish to understand dispersal patterns, spatial and temporal patterns of various fish species, and ability of fish to cope with a changing climate (thresholds).
  – To run various models like Ecopath, Ecosim and Ecospace, detailed data like biomass, production rates, consumption rates, physiological efficiencies and diet consumption needed
Agriculture, Livelihoods, and Risk Management
Approach 1: Trend analysis
Observation

• Observed that in the year 2007-08, majority of the crops have given good yields.

• We observed strong correlation with rainfall pattern.

• There is a possibility that consecutive good rainfall years has an influence on overall productivity.
Productivity trend shows increase till the year 2007-08 and then there is a decline. Area under cultivation varies across the years.
Similar Observations for the production trend have been noticed for the year 2007-08
Soybean: Area Vs. Production across years (2001-10)

Total area vs. production of Soybean in Maharashtra (2001-10)

Area (in 00 hect.) / Production (in 00 tonnes)

Year

Area (In Hundred Hectare)  Production (In Hundred Tonne)  Productivity (In Kg./Hect.)
Cotton: Area Vs. Production across years (2001-10)

Total area vs. production of cotton in Maharashtra (2001-10)

Area (in Hundred Hectare) / Production (In Hundred Tonnes) / Productivity (In Kg./Hect.)

Note:
Production of Cotton in "00" Bales of 170 kg each.
Observation: Between three consecutive years 2005-07 the rainfall has been consistently matching the average.

The consistent rainfall may have resulted in higher production of most of the major kharif crops in the financial year 2007-08.
Approach 2: Assessment of vulnerable areas

• Set I: 6 Case Studies. Vulnerability analysis (Socioeconomic and Biophysical factors) of the state indicates that Nandurbar is the most vulnerable district.

• Set II: Six areas which might be impacted due to climatic variations (2030, 50, 70) as indicated by the climate model have been analysed.
  – Nashik, Dhule, Aurangabad, Ahmednagar, Wardha and Gadchiroli.
  – Important Kharif crops of the region include
    • Cotton, Soybean, Maize and Rice
  – Important Rabi crops of the region include
    • Wheat and Jowar
  – Important Summer crops of the region include
    • Maize and ground nut
Sugarcane- Perennial, most productive

Sugarcane production status in Maharashtra (2009-10)

Concerns: water intensive crop. Thus if there is rise in temperature, water requirement for irrigation would increase

Recommendation: Technologies like drip fertigation/ irrigation, sprinkler have enhanced productivity by 133% while saving 49% of water. Thus huge potential exists to scale up area using such technologies.

Major sugarcane producing regions: Pune and Kolhapur
Sugarcane: Highest production in Pune

• Ideal climatic conditions:
  – Rainfall between 1100 - 1500 mm
  – Optimum temperature is 32°C to 38°C.

• Mean /Projected Increase:
  • Min Temperature = 0.9 - 1.9°C = 17.76/ 19.66
  • Max Temp = 0.5 – 1.3 ℃ = 31.59/ 32.89
  • Rainfall = ~30 % = 741/ 963

• Possible Impact:
The water requirement for the crop are higher than the rainfall of the region which will result in demand for irrigation.
Rice: Highest Production in Konkan

• Ideal climatic conditions:
  – Rainfall between 1200-1400 mm
  – Optimum temperature is 20° to 38°C.

• Mean /Projected Increase:
  • Min Temperature = 1.01 - 1.6°C = 21.6/ 23.2
  • Max Temp = 0.6 – 1.8 °C = 32.8/ 33.6
  • Rainfall (mm)= ~12 % = 3164/ 3543

• Possible Impact:
  Temperature rise in the konkan region lies in the range of the conditions optimum for rice cultivation, however flash floods may impact the yield of rice.
Rice: Highest Summer Rice Production in Bhandara

• Ideal climatic conditions:
  – Rainfall between 1200-1400 mm
  – Optimum temperature is 20° to 38°C.

• Mean /Projected Increase:
  • Min Temperature = 0.9-2.1°C = 20.9/ 22.1
  • Max (Summer) Temp = 1.12 – 1.6 °C = 32-38/ 33.31-39.6
  • Rainfall = ~20 % = 1388/ 1665

• Possible Impact:
  As summer temperature of Bhandara lies between 32-38 °C, projected increase in temperature of 1.6 °C summer rice may get affected as more than 37°C temperature affects the flowering and hence reduces the yield.
Summer crops are productive and significant for the state

Significance: Highly productive and may provide as an excellent source for food and fodder

Concern: The area under cultivation is very low and hence its potential is not fully exploited

Recommendation:
- The area under cultivation to be increased using water efficient technologies like drip.
- Water storage could be looked at as an option to harness increase in rainfall being projected.
- Provide food and fodder during peak summer months through these highly productive summer crops.
Approach 3: Crop Modelling – rice as an example

Potential yields for rice simulated by DSSAT model for Karjat

- Average potential yield for model baseline (1976-1996): 2.75 tonnes/hectare
- Average actual yield for Raigad district (1998-2010) (Min of Agr data): 2.44 tonnes/hectare
- Average potential yield for 2030s under climate change: 3.67 tonnes/hectare
- Average potential yield for 2050s under climate change: 3.39 tonnes/hectare
- Average potential yield for 2070s under climate change: 3.27 tonnes/hectare
Critical gaps

• Field experiments to allow for simulations
• Data on crops grown, cultivars, genetic coefficients, crop management practices, soil conditions needed
• Region specific observed data on actual and potential yields of crops
• Our understanding about other factors and its influence for instance changes in disease dynamics and pest infestation of crops
Research: Scope for further improvement

Management Information System

- Maintain localized data regarding climatic factors, socioeconomic and biochemical factors governing crop productivity.
- Practices followed across the world could be analysed and suitably adopted.
- Research stations should be equipped to demonstrate these practices at field levels for uptake and maintenance of records by communities.
Approach 4: Community consultations - Six case study sites

Key Highlights

- Perceptions about changes in climate and sensitivity of crops reported
- While % access to irrigation is reported to be high in case study areas, poor water supply are noted to affect rabi and summer yields
- Large percentage of households report weather forecasts to be reliable and useful. Varied sources reported from where information is picked up.
Recommendations 1 - for Agriculture, Livelihoods, Risk Management

• Potential for scaling up water efficient technologies – may enhance area under irrigation and assure water supplies for irrigation in peak months

• Water storage could be enhanced to capitalise on increase in rainfall

• Considerable scope for agricultural processing and value addition of various crops
Recommendations 2 - for Agriculture, Livelihoods, Risk Management

• Introduce modes that can help non-loanee farmers also to draw on risk covering mechanisms (small-marginal, medium categories)

• Farmers’ access to farm management information and technologies needs to be strengthened

• Participatory exercises could be used to develop village specific information that may help for planning and better utilisation of in-situ resources (align with RKVY and Eco-villages)
Water Resources
Basins in Study Area

Legend

Maharashtra Basins
- Godavari
- Krishna
- Narmada
- Tapi
- West flowing

% area under each river basin
# Summary of regional rainfall patterns and key climate vulnerabilities

<table>
<thead>
<tr>
<th>Region</th>
<th>Divisions</th>
<th>Districts</th>
<th>Normal annual rainfall (mm)</th>
<th>Key vulnerabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vidarbha</td>
<td>Amravati</td>
<td>Amravati, Akola, Buldhana, Washim, Yavatmal</td>
<td>1104.6</td>
<td>Long dry spells, Recent increase in rainfall variability and decrease in amount, Salinity problem in Amravati, Akola, and Buldhana districts</td>
</tr>
<tr>
<td></td>
<td>Nagpur</td>
<td>Nagpur, Bhandara, Chandrapur, Gadchiroli, Gondia, Wardha</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marathwada</td>
<td>Aurangabad</td>
<td>Aurangabad, Beed, Hingoli, Jalna, Latur, Nanded, Parbhani, Usmanabad</td>
<td>840.4</td>
<td>Drought-prone, Low forest cover, Low irrigation availability</td>
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<tr>
<td>Western</td>
<td>Nashik</td>
<td>Nashik, Ahmedanagar, Dhule, Jagaon, Nandurbar</td>
<td>850.5</td>
<td>Drought-prone, Water-intensive cultivation, Soil erosion,</td>
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<tr>
<td>Maharashtra</td>
<td>Pune</td>
<td>Pune, Kolhapur, Sangli, Satara, Solapur</td>
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<td></td>
</tr>
<tr>
<td>Konkan</td>
<td>Konkan</td>
<td>Mumbai City, Mumbai Suburban, Raigadh, Ratnagiri, Sindhudurg, Thane</td>
<td>2978.6</td>
<td>High intensity rainfall, Coastal salinity, Severe soil erosion</td>
</tr>
</tbody>
</table>

Source of rainfall data: India Meteorological Department
Consultations with Water Resources Department

• Meeting with Irrigation department on 18 September 2013 requesting to share data on surface runoff

• Meeting with Chief Engineer, Water Resources Department, Nashik on 5 October 2013.
  – Agreed to share processed runoff data with TERI. But need to follow the procedures and require time to process the data.
Validation of model results with the observed data from Water Resources department

<table>
<thead>
<tr>
<th>Date</th>
<th>Runoff depth (in mm)</th>
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<td>7/23/2011</td>
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<td>Total Runoff</td>
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Partial catchment area of Godavari River

Total 253 stations in Maharashtra located in each sub-basin for each of the rivers
Constraint: High data cost (INR 600 per station per year)
(Data for 30 years, 253 stations= ~40 lakhs)
Action Plan

• MMR
  – Adaptation Strategy
    • Preservation of mangroves, salt pans, and other wetlands
    • Introduce integrated flood management system for the city and suburbs
  – Action Plan
    • Strict compliance of CRZ norms in the coastal parts of Shivadi, Navi Mumbai and Thane.
    • Protection of mangroves along the coast- Shivadi, Airoli, Borivali and Western suburbs, preservation of salt pans in the entire MMR region.
    • Wetlands protection plan for urban areas. Holding ponds at Navi Mumbai need to be specially protected.
    • Compounded impacts of developmental and environmental pressures on the urban ecosystems need to be assessed and subsequent changes in the policy need to be brought out

• Agriculture
  – Adaptation Strategy
    • Safeguard farmers against climate risks
    • Enhance resilience of farming systems
    • Secure food supply chains
  – Action Plan
    • Agri universities and research stations to help disseminate climate services to communities.
    • To assess best management practices for significant crops like Sugarcane, Maize and Ground nut.
    • To compare potential of new varieties developed at other states/ research institutions and to assess potential for introduction into the state.
    • Water efficient technologies to be promoted in general, but specifically for water intensive crops.
Action Plan

• **Ecosystems**
  – **Adaptation Strategy**
    • Promote Biodiversity conservation.
    • Research including simulation/ modeling exercise for selected locations and species.
  – **Action Plan**
    • Launch a Green Maharashtra Mission that aims to promote conservation of species, address data gaps and improve research in related areas.
    • Revival of existing forest monitoring plots at places such as Bhimashankar, Mahabaleshwar, several protected areas, etc. (SFD could undertake this activity collaboratively).
    • To diversify fisheries related livelihood especially in districts like Sindhudurg.

• **Health**
  – **Adaptation Strategy**
    • Improvement in health infrastructure.
    • Invest in health research.
    • Develop systems to adapt to conditions of extreme heat
  – **Action Plan**
    • Enhanced monitoring & surveillance for different climate-sensitive diseases
    • Promote research on mutations and its impacts due to changes in temperatures and humidity patterns for emergence of new diseases
    • To fix certain work hours preventing direct exposure to heat, construct shelters near farm areas especially in the districts where temperature increase is projected to be high. For Examples- Wardha, Nagpur, Gondia and Solapur.
Way forward

• Template to be developed for detailing key recommendations drawn from the adaptation strategies
• Institutional framework for implementation
• Financial needs on key recommendations to be taken forward
Thank you