OVERVIEW OF THE IMPACTS, VULNERABILITY AND ADAPTATION OF CLIMATE CHANGE FOR AGRICULTURE IN DIFFERENT REGIONS BASED ON IPCC FOURTH ASSESSMENT REPORT

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(WORKSHOP ON CC, ORLANDO, 18-21 NOV. 08)
1. INTRODUCTION

- GLOBAL CLIMATE IS A DYNAMIC REGIME SUBJECT TO NATURAL VARIATIONS ON ALL TIME SCALES AND TO POSSIBLE ALTERATION BY HUMAN ACTIVITIES

- INCREASE IN ATMOSPHERIC CO$_2$ CONC.
  - DUE TO BURNING OF FOSSIL FUELS
  - RAPID INDUSTRIALIZATION AND
  - DEFORESTATION

- THE CONSEQUENCES OF INCREASE OF CO$_2$ AND OTHER GREEN HOUSE GASES VIZ. METHANE (CH$_4$), NITROUS OXIDE (N$_2$O) AND CHLOROFLUOROCARBONS (CFC) ARE:
  - WARMING OF MEAN TEMPERATURE
  - ALTERATION IN PRECIPITATION PATTERNS AND
  - MODIFICATION IN PHOTOSYNTHESIS
FIGURE 1. WARMING WILL LEAD TO MAJOR CHANGES IN WATER AVAILABILITY ACROSS THE GLOBE, WITH CONSEQUENCES FOR DROUGHTS AND FLOODS

Change in the 2050s, based on IPCC Scenario A1

Source: Arnell (2004)
THE ROLE OF THE GASES IN CLIMATE CHANGE (CC), IMPACTS VULNERABILITY STUDY AND ADAPTATION REQUIRE AUTHENTIC SCIENTIFIC KNOWLEDGE

IN 1988, THE UNEP (UNITED NATIONS ENVIRONMENT PROGRAMME) AND THE WMO JOINTLY ESTABLISHED IPCC (INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE) TO ASSESS:

- AVAILABLE SCIENTIFIC INFORMATION ON CC,
- SOCIO – ENVIRONMENTAL IMPACTS OF CC AND
- TO FORMULATE ADAPTATION STRATEGIES

IPCC HAS PRODUCED FOUR MAJOR ASSESSMENTS, SO FAR, IN:

- 1990
- 1995
- 2001
- 2007
CLIMATE CHANGE 2007: IMPACTS, ADAPTATION AND VULNERABILITY’, DRAWING ON OVER 29000 DATA SERIES PROVIDES A MUCH BROADER SET OF EVIDENCE OF OBSERVED IMPACTS COMING FROM LARGE NUMBER OF FIELD STUDIES

CC IS DEFINED AS A MOVEMENT IN CLIMATE SYSTEM (CS) AS A RESULT OF INTERNAL CHANGES WITHIN CLIMATE SYSTEM OR IN INTERACTION OF ITS COMPONENTS OR BECAUSE OF CHANGES IN EXTERNAL FORCING BY NATURAL FACTORS OR ANTHROPOGENIC ACTIVITIES (IPCC, 2001)

CLIMATIC CHANGE REFERS TO ANY CHANGE IN CLIMATE OVER TIME, WHETHER DUE TO NATURAL VARIABILITY OR AS A RESULT OF HUMAN ACTIVITY
FIGURE 2. DIAGRAM SHOWING THE COMPONENTS OF THE CLIMATE SYSTEM (IPCC, 1996)
THREE MAIN WORKING GROUPS (WG) WORKS UNDER IPCC WITH RESPONSIBILITIES OF:

✓ A) SCIENCE OF CLIMATE CHANGE (WG I),
✓ B) IMPACTS OF CLIMATE CHANGE, VULNERABILITY AND OPTIONS FOR ADAPTATION TO SUCH CHANGES (WG II) AND
✓ C) MITIGATING AND SLOWING THE CC WITH POSSIBLE POLICY OPTIONS (WG III, FIGURE 3)

FIGURE 3. THE IPCC THIRD ASSESSMENT REPORT PROCESS
ASSESSMENT OF OBSERVED CHANGES

ASSESSMENT OF FUTURE IMPACTS & ADAPTATION – SYSTEMS AND SECTORS

SECTIONS OF WGII FOR IPCC 4TH ASSESSMENT REPORT

ASSESSMENT OF RESPONSES TO IMPACTS

ASSESSMENT OF FUTURE IMPACTS & ADAPTATION FOR DIFF. REGIONS
COUNTRIES BY REGION FOR WGII 4TH ASSESSMENT

AFRICA (49)
ASIA (44)
AUSTRALIA & NEW ZEALAND (2)
EUROPE (45)
POLAR REGIONS (3)
LATIN AMERICA (21)
NORTH AMERICA (2)
SMALL ISLANDS (33)
CLIMATE VARIABILITY AND CHANGE

FUTURE IMPACTS FREQUENTLY REFLECT:

- INCREASE IN CO₂
- INCREASE IN TEMP.
- CHANGE IN PRECIPITATION
- SEA LEVEL RISE
- VARIABILITY AND EXTREME EVENTS SUCH AS FLOODS AND DROUGHT
### TABLE 1. AGRICULTURAL IMPACTS IN AFRICA, ASIA AND LATIN AMERICA OF (PRIMARILY) DOUBLED CARBON DIOXIDE SCENARIOS

<table>
<thead>
<tr>
<th>REGION</th>
<th>CHANGE IN TOTAL AGRICULTURAL PRODUCTION (PER CENT)</th>
<th>CHANGE IN PER CAPITA GDP (PER CENT)</th>
<th>CHANGE IN AGRICULTURAL PRICES (PER CENT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFRICA</td>
<td>-13 TO -9</td>
<td>-10 TO -7</td>
<td>-9 TO +56</td>
</tr>
<tr>
<td>ASIA</td>
<td>-6 TO 0</td>
<td>-3 TO 0</td>
<td>-17 TO +48</td>
</tr>
<tr>
<td>LATIN AMERICA</td>
<td>-15 TO -6</td>
<td>-6 TO -2</td>
<td>-8 TO +46</td>
</tr>
<tr>
<td>REGION</td>
<td>CROP</td>
<td>YIELD IMPACT (%)</td>
<td>COUNTRIES STUDIED/COMMENTS</td>
</tr>
<tr>
<td>--------------</td>
<td>----------</td>
<td>------------------</td>
<td>-------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>LATIN AMERICA</td>
<td>MAIZE</td>
<td>-61 TO INCREASE</td>
<td>ARGENTINA, BRAZIL CHILE, MEXICO WITH AND WITHOUT THE CO₂ EFFECT.</td>
</tr>
<tr>
<td></td>
<td>WHEAT</td>
<td>-50 TO -5</td>
<td>ARGENTINA, BRAZIL, URUGUAY, WITH AND WITHOUT THE CO₂ EFFECT.</td>
</tr>
<tr>
<td>EUROPE</td>
<td>MAIZE</td>
<td>-30 TO INCREASE</td>
<td>FRANCE, SPAIN, NORTHERN EUROPE. WITH ADAPTATION, CO₂ EFFECT.</td>
</tr>
<tr>
<td></td>
<td>WHEAT</td>
<td>INCREASE OR DECREASE</td>
<td>FRANCE, UK, NORTHERN EUROPE. WITH ADAPTATION, CO₂ EFFECT.</td>
</tr>
<tr>
<td>NORTH AMERICA</td>
<td>MAIZE</td>
<td>-55 TO +62</td>
<td>WITH OR WITHOUT CO₂ EFFECT.</td>
</tr>
<tr>
<td></td>
<td>WHEAT</td>
<td>-100 TO +234</td>
<td>LESS SEVERE OR INCREASE IN YIELD WHEN CO₂ EFFECT AND ADAPTATION CONSIDERED.</td>
</tr>
<tr>
<td></td>
<td>SOYBEAN</td>
<td>-96 TO +58</td>
<td></td>
</tr>
<tr>
<td>AFRICA</td>
<td>MAIZE</td>
<td>-65 TO +6</td>
<td>EGYPT, KENYA, SOUTH AFRICA, ZIMBABWE. WITH CO₂ EFFECT</td>
</tr>
<tr>
<td></td>
<td>MILLET</td>
<td>-79 TO -63</td>
<td>SENEGAL. CARRYING CAPACITY FELL 11-38 %.</td>
</tr>
<tr>
<td>SOUTH ASIA</td>
<td>RICE</td>
<td>-22 TO +28</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MAIZE</td>
<td>-65 TO -10</td>
<td>BANGLADESH, INDIA, PHILIPPINES, THAILAND, INDONESIA, MALAYSIA, BURMA WITH THE CO₂ EFFECT S</td>
</tr>
<tr>
<td></td>
<td>WHEAT</td>
<td>-61 TO +67</td>
<td></td>
</tr>
<tr>
<td>MAINLAND CHINA</td>
<td>RICE</td>
<td>-78 TO +28</td>
<td>INCLUDES RAINFED AND IRRIGATED RICE. POSITIVE EFFECTS IN NE AND NW CHINA, NEGATIVE IN MOST OF THE COUNTRY.</td>
</tr>
</tbody>
</table>
CLIMATE CHANGE HAS THE POTENTIAL TO CHANGE SIGNIFICANTLY THE PRODUCTIVITY OF AGRICULTURE, FORESTRY AND FISHERIES IN MOST LOCATIONS

SOME CURRENTLY HIGH PRODUCTIVE AREAS MAY BECOME MUCH LESS PRODUCTIVE

POLEWARD REGIONS WHERE AGRICULTURE IS LIMITED BY SHORT GROWING SEASONS ARE MORE LIKELY TO GAIN, WHILE SUB – TROPICAL, TROPICAL REGIONS MAY BE MORE LIKELY TO SUFFER DROUGHT AND LOSSES IN PRODUCTIVITY
VULNERABILITY

- DEGREE TO WHICH A SYSTEM IS SUSCEPTIBLE TO AND UNABLE TO COPE WITH ADVERSE EFFECTS OF CLIMATE CHANGE
- FUNCTION OF THE CHARACTER, MAGNITUDE AND RATE OF CLIMATE CHANGE AND VARIATION TO WHICH A SYSTEM IS EXPOSED
- THE SENSITIVITY AND ADAPTIVE CAPACITY OF THAT SYSTEM (IPCC, 2007)

ADAPTATION

- ADJUSTMENT IN NATURAL OR HUMAN SYSTEMS IN RESPONSE TO ACTUAL OR EXPECTED CLIMATIC STIMULI OR THEIR EFFECTS
- POSSIBLE ADAPTATIONS ARE BASED ON EXPERIENCE, OBSERVATION, SPECULATION ABOUT ALTERNATIVES
- THE DEGREE TO WHICH A FUTURE CLIMATE CHANGE RISK IS DANGEROUS DEPENDS GREATLY ON LIKELIHOOD AND EFFECTIVENESS OF ADAPTATIONS IN THAT SYSTEM
IMPORTANCE OF AGRICULTURE, FORESTRY AND FISHERIES

40% OF EARTH’S LAND SURFACE IS MANAGED FOR CROPLAND & PASTURE
(FOLEY et al., 2005)

FORESTLAND COVERS ANOTHER 30% OF LAND SURFACE PROVIDING 35% OF GLOBAL ROUNDWOOD
(FAO, 2000)

FISH PROVIDES AT LEAST 20% OF MEAN PER CAPITA ANIMAL PROTEIN INTAKE OF MORE THAN 2.6 BILLION PEOPLE
(FAO, 2004)

≥ 70% PEOPLE IN RURAL AREAS OF DEVELOPING COUNTRIES SURVIVE THROUGH AGRIL.

LIVELIHOOD OF ROUGHLY 450 MILLION OF THE WORLD’S POOREST PEOPLE ARE ENTIRELY DEPENDENT ON MANAGED ECOSYSTEM SERVICES

AGRICULTURAL INCOME IN DEVELOPING COUNTRIES COMPENSATE DEMAND FOR NON-BASIC GOODS AND SERVICES
AGRICULTURE, FORESTRY & FISHERIES ARE INHERENTLY SENSITIVE TO CLIMATIC CONDITIONS

MOST VULNERABLE TO WEATHER AND CLIMATE RISKS

CROP LOSSES IN AGRICULTURE, MAINLY DUE TO DIRECT WEATHER AND CLIMATE EFFECTS VIZ. FLOODS, DROUGHTS, UNTIMELY RAINS, FROST, HAIL, HEAT / COLD WAVES, SEVERE STORMS (HAY, 2007)

RISK FACTORS IN AGRICULTURE, RELATIONSHIP BETWEEN WEATHER, CLIMATE AND PRODUCTION RISK IS WELL KNOWN (GEORGE et al., 2005)
## TABLE 3. ANTHROPOGENIC METHANE AND NITROUS OXIDE EMISSIONS BY AGRICULTURE

<table>
<thead>
<tr>
<th>Nations</th>
<th>(A) 1996</th>
<th>(B) 1998</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total (Gg)</td>
<td>Methane Agriculture (Gg)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Agriculture</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Nitrous oxide</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Australia</td>
<td>5 308</td>
<td>3 096</td>
</tr>
<tr>
<td>Austria</td>
<td>574</td>
<td>207</td>
</tr>
<tr>
<td>Belgium</td>
<td>591</td>
<td>354</td>
</tr>
<tr>
<td>Canada</td>
<td>4 000</td>
<td>1 100</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>573</td>
<td>134</td>
</tr>
<tr>
<td>France</td>
<td>2 712</td>
<td>1 565</td>
</tr>
<tr>
<td>Germany</td>
<td>4 724</td>
<td>1 547</td>
</tr>
<tr>
<td>Ireland</td>
<td>800</td>
<td>655</td>
</tr>
<tr>
<td>Netherlands</td>
<td>1 179</td>
<td>476</td>
</tr>
<tr>
<td>New Zealand</td>
<td>1 593</td>
<td>1 431</td>
</tr>
<tr>
<td>U.K.</td>
<td>3 712</td>
<td>1 064</td>
</tr>
<tr>
<td>United States</td>
<td>31 138</td>
<td>9 300</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>1 739</td>
<td>1363</td>
</tr>
<tr>
<td>China</td>
<td>25 389-32 889</td>
<td>12 599-20 090</td>
</tr>
<tr>
<td>India</td>
<td>18 477</td>
<td>12 654</td>
</tr>
<tr>
<td>Indonesia</td>
<td>4 413.04</td>
<td>3 387.52</td>
</tr>
<tr>
<td>Pakistan</td>
<td>2 689.0</td>
<td>2 146.0</td>
</tr>
<tr>
<td>Thailand</td>
<td>2 746.37</td>
<td>2454.22</td>
</tr>
<tr>
<td>AGRICULTURAL METRIC</td>
<td>OBSERVED CHANGE</td>
<td>LOCATION (PERIOD)</td>
</tr>
<tr>
<td>---------------------</td>
<td>--------------------------------------------------------------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>PHENOLOGY</td>
<td>ADVANCE OF STEM ELONGATION FOR WINTER RYE (10 DAYS) AND EMERGENCE FOR MAIZE (12DAYS)</td>
<td>GERMANY (1961-2000)</td>
</tr>
<tr>
<td></td>
<td>ADVANCE IN CHERRY TREE FLOWERING (0.9DAYS/10YEARS), APPLE TREE FLOWERING (1.1DAYS/10YEARS) IN RESPONSE (-5DAYS/°C) TO MARCH/APRIL TEMPERATURE INCREASE</td>
<td>GERMANY (1951-2000)</td>
</tr>
<tr>
<td></td>
<td>ADVANCE IN BEGINNING OF GROWING SEASON OF FRUIT TREES (2.3DAYS/10YEARS), CHERRY TREE BLOSSOM (2.0DAYS/10YEARS), APPLE TREE BLOSSOM (2.2DAYS/10YEARS) IN AGREEMENT WITH 1.4°C ANNUAL AIR TEMPERATURE INCREASE</td>
<td>GERMANY (1961-1990)</td>
</tr>
<tr>
<td></td>
<td>ADVANCE OF FRUIT TREE FLOWERING OF 1-3 WEEKS FOR APRICOT AND PEACH TREES, INCREASE IN SPRING FROST RISKS AND MORE FREQUENT OCCURRENCE OF BUD FALL OR NECROSIS FOR SENSITIVE APRICOT VARIETIES</td>
<td>SOUTH FRANCE (1970-2001)</td>
</tr>
<tr>
<td>YIELDS</td>
<td>LOWER HAY YIELDS, IN RELATION TO WARMER SUMMERS</td>
<td>ROTHAMSTED UK (1965-1998)</td>
</tr>
<tr>
<td></td>
<td>PART OF OVERALL YIELD INCREASE ATTRIBUTED TO RECENT COOLING DURING GROWING SEASON: 25% MAIZE, 33% SOYBEAN</td>
<td>USA COUNTY LEVEL (1982-1998)</td>
</tr>
<tr>
<td></td>
<td>DECREASE OF RICE YIELD ASSOCIATED WITH INCREASE IN TEMP. (0.35°C AND 1.13°C FOR T&lt;sub&gt;MAX&lt;/sub&gt; AND T&lt;sub&gt;MIN&lt;/sub&gt;, RESP.) DURING 1979 TO 2003</td>
<td>PHILIPPINES (1992-2003)</td>
</tr>
</tbody>
</table>
AIM OF THE STUDY

- The aim of this study is to provide an overview with a focus on agriculture (mainly), forestry and fisheries of different regions.
- To review and summarize key impacts and future impacts of climate change.
- To identify climate sensitivities, vulnerabilities to examine deficiencies in agricultural sector (mainly), in different regions.
- To appraise and report on current capabilities in analysis of climate change and variabilities.
- To assess effectiveness of adaptation in offsetting damages.
- To identify adaptation options.
- To explore implications of responding to CC towards sustainable development.
2. IMPACTS, VULNERABILITY AND ADAPTATION OF CLIMATE CHANGE

- IMPACT, VULNERABILITY AND ADAPTATION STUDY REQUIRE
  - MOST COMPREHENSIVE AND UP-TO-DATE KNOWLEDGE
  - SCIENTIFIC ASSESSMENT
  - IPCC’s PERIODIC ASSESSMENTS AS WELL AS ‘CLIMATE CHANGE 2007 – IMPACTS, ADAPTATION AND VULNERABILITY’ OF THE CAUSES, IMPACTS AND POSSIBLE RESPONSE STRATEGIES TO CLIMATE CHANGE ARE THE MOST AUTHENTIC REPORTS
THE MAGNITUDE OF IMPACT IS A FUNCTION OF EXTENT OF CHANGE IN A CLIMATIC PARAMETER VIZ.

- CLIMATE VARIABILITY
- FREQUENCY AND MAGNITUDE OF EXTREMES
- CLIMATIC CHARACTERISTICS ETC. AND
- THE SENSITIVITY OF THE SYSTEM TO THAT CLIMATE RELATED STIMULI
KEY FUTURE IMPACTS AND VULNERABILITIES

- VULNERABILITY CAN BE USEFUL IN DECISION MAKING
- DEPENDS ON OBSERVATIONAL UNIT AND GEOGRAPHICAL SCALE
- YIELDS ARE RELATIVELY MORE VULNERABLE IF SMALL CHANGE IN CLIMATE RESULTS IN LARGE CHANGE IN YIELD
- OVER 40 MILLION HECTARE OF LAND AREA IN INDIA IS VULNERABLE TO FLOODS, OUT OF WHICH ABOUT 8 MILLION HECTARE IS SEVERELY AFFECTED BY FLOODS EACH YEAR
- RAINFED WHEAT GROWN AT 450 PPM CO₂ DEMONSTRATED YIELD INCREASES WITH TEMPERATURE INCREASE OF UPTO 0.8°C, BUT DECLINES WITH TEMPERATURE INCREASE BEYOND 1.5°C
INCREASE IN FREQUENCY OF CLIMATE EXTREMES MAY LOWER CROP YIELDS BEYOND IMPACTS OF MEAN CC

DESER BIODIVERSITY LIKELY TO BE VULNERABLE TO CC (REID et al., 2005)

STABILISATION OF CO₂ CONCENTRATION REDUCES DAMAGE TO CROP PRODUCTION

IMPACTS OF CC ON IRRIGATION WATER REQUIREMENT

SPECIFIC NEW KNOWLEDGE W.R.T. CC
ADAPTATION

- Adaptation is concerned with responses to both adverse and positive effects of climate change.
- Any adjustment - whether passive, reactive or anticipatory, which can respond to anticipated or actual consequences associated with climate change is referred as adaptation.
- Adaptation options have two purposes:
  - To reduce damage from CC
  - To increase resilience of ecosystems to aspects of CC
ADAPTATION MEASURES ARE INTER-LINKED WITH MITIGATION MEASURES.

PROTECTION, RETREAT AND ACCOMMODATION ARE THREE TYPES OF ADAPTATION MEASURES

ADAPTATIONS ARE OF TWO CATEGORIES:

A) AUTONOMOUS ADAPTATION i.e. ONGOING IMPLEMENTATION OF EXISTING KNOWLEDGE AND TECHNOLOGY IN RESPONSE TO CHANGES IN CLIMATE AND

B) PLANNED ADAPTATION, WHICH IS INCREASE IN ADAPTIVE CAPACITY BY MOBILISING INSTITUTIONS AND POLICIES TO ESTABLISH CONDITIONS FAVOURABLE FOR EFFECTIVE ADAPTATION

TAR NOTED THAT AGRICULTURE HAS HISTORICALLY SHOWN HIGH LEVELS OF ADAPTABILITY TO CLIMATE VARIATION

ADAPTATION ASSESSED ARE MOST EFFECTIVE IN MID – LATITUDES & LEAST EFFECTIVE IN LOW– LATITUDE DEVELOPING REGIONS WITH POOR RESOURCE ENDOWMENTS OF FARMERS TO RESPOND & ADAPT

ADAPTATION IN VARIOUS DEGREES AND IN SOME FORM OR OTHER MAY BE NECESSARY TO COPE WITH ECOSYSTEM CHANGES
FIGURE 4. SYSTEM OF LINKED MODELS EXAMINED IN THE ADAPTIVE STRATEGY
TABLE 5. SUMMARY OF SELECTED ADAPTATION FOR FOOD CROPS

<table>
<thead>
<tr>
<th>TEMP. CHANGE</th>
<th>SUB-SECTOR</th>
<th>REGION</th>
<th>ADAPTATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>+1 TO +2°C</td>
<td>FOOD CROPS</td>
<td>MID TO HIGH LATITUDES</td>
<td>ADAPTATION OF MAIZE AND WHEAT INCREASES YIELD 10-15%; RICE YIELD NO CHANGE; REGIONAL VARIATION IS HIGH</td>
</tr>
<tr>
<td></td>
<td>FOOD CROPS</td>
<td>LOW LATITUDES</td>
<td>ADAPTATION OF MAIZE, WHEAT, RICE MAINTAINS YIELDS AT CURRENT LEVELS</td>
</tr>
<tr>
<td>+2 TO +3°C</td>
<td>FOOD CROPS</td>
<td>MID TO HIGH LATITUDES</td>
<td>ADAPTATION INCREASES ALL CROPS ABOVE BASELINE YIELD</td>
</tr>
<tr>
<td></td>
<td>FOOD CROPS</td>
<td>LOW LATITUDES</td>
<td>ADAPTATION MAINTAINS YIELDS OF ALL CROPS ABOVE BASELINE; YIELDS DROPS BELOW BASELINE FOR ALL CROPS WITHOUT ADAPTATION</td>
</tr>
<tr>
<td>+3 TO +5°C</td>
<td>FOOD CROPS</td>
<td>LOW LATITUDES</td>
<td>ADAPTATION MAINTAINS YIELDS OF ALL CROPS ABOVE BASELINE; YIELD DROPS BELOW BASELINE FOR ALL CROPS WITHOUT ADAPTATION</td>
</tr>
<tr>
<td></td>
<td>FOOD CROPS</td>
<td>LOW LATITUDES</td>
<td>MAIZE AND WHEAT YIELDS REDUCED BELOW BASELINE REGARDLESS OF ADAPTATION, BUT ADAPTATION MAINTAINS RICE YIELDS AT BASELINE LEVELS</td>
</tr>
</tbody>
</table>
ADAPTATION OPTIONS

- CAPACITY BUILDING ABOUT RESPONSES TO EFFECTS OF NATURAL CLIMATIC VARIABILITY & POTENTIAL FUTURE CC
- CHANGES IN LAND USE ALLOCATION INCLUDING DEVELOPING POTENTIAL OF TROPICAL PLANT SPECIES
- IMPROVEMENTS IN FOOD SECURITY POLICIES
- REDUCTION OF POST HARVEST LOSSES
- INTENSIFYING AGRICULTURAL DEVELOPMENT
- LARGE SCALE INTRODUCTION OF INTEGRATED ‘CONTROLLED ENVIRONMENT AGRICULTURE’
ADAPTATION OPTIONS OCCUR PRIMARILY AT THREE SPATIAL SCALES

FIELD SCALE, BY CHANGING MACHINERY, TIMING OF OPERATIONS, USE OF DIFFERENT CROPS, INTRODUCING IRRIGATION

THE FARM SCALE THROUGH SOCIO–ECONOMIC CHANGES AFFECTING FARM SIZES OR DIVERSIFICATION TO NON–AGRICULTURAL LAND USES

REGIONAL AND/OR NATIONAL SCALE, THROUGH POLICY RESPONSES AIMED AT MARKET SUPPORT OR ENVIRONMENTAL REGULATION
IMPACTS OF CLIMATE CHANGE – SOME EXAMPLES

- Himalayan glaciers, could disappear by 2035
- A rise in climate extremes in Western Siberia, the Baikal region and eastern parts of boreal Asia
- Extremes of Southern Oscillation responsible for large climate variability at inter-annual scales in Latin America
- West coast of North America, which gets water from glaciers in mountain ranges are likely to be affected
- Deficient rainy seasons observed during ENSO years in northern Amazonia and North-East Brazil
FOREST FIRES AS A RESULT OF DROUGHT OBSERVED DURING VERY STRONG ENSO EVENTS OF 1911/12, 1925/26, 1982/83 AND RECENTLY IN 1997/98 AND NORTH EAST BRAZIL EXPERIENCED DROUGHT DURING THOSE YEARS.


DURING LA NIÑA YEARS, MORE HURRICANES ARE AFFECTING CENTRAL AMERICA. AFRICAN CONTINENT IS MORE PRONE TO IMPACTS OF CLIMATE CHANGE DUE TO RECURRENT DROUGHTS, INEQUITABLE LAND DISTRIBUTION AND RAINFED AGRICULTURE.

LIKELY EXTINCTION OF 20 TO 30% OF SPECIES ASSESSED, SO FAR, AS GLOBAL MEAN TEMPERATURES MAY EXCEED 2 TO 3\(^0\) C.
### TABLE 6. EXAMPLES OF SIMULATED CLIMATE CHANGE IMPACTS ON FORESTRY

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>PRODUCTION IMPACT</th>
<th>ECONOMIC IMPACT</th>
</tr>
</thead>
</table>
| GLOBAL  | I) 2045: PRODUCTION UP BY 29-38%; REDUCTION IN N.AMERICA, RUSSIA; INCREASES IN S. AMERICA AND OCEANIA.  
II) 2145: PRODUCTION UP BY 30%, INCREASES IN N. AMERICA, S. AMERICA AND RUSSIA. | I) 2045: PRICES REDUCED, HIGH LATITUDE LOSS, LOW LATITUDE GAIN.  
II) 2145: PRICES INCREASES UP TO 80% (NO CLIMATE CHANGE), 50%(WITH CLIMATE CHANGE), HIGH LATITUDE GAIN, LOW LATITUDE LOSS. BENEFITS GO TO CONSUMERS. |
| EUROPE  | INCREASED PRODUCTION IN W.EUROPE, DECREASED PRODUCTION IN E. EUROPE. | PRICE DROP WITH AN INCREASE IN WELFARE TO PRODUCERS AND CONSUMERS. INCREASED PROFITS OF FOREST INDUSTRY AND FOREST OWNERS. |
| GLOBAL  | HARVEST INCREASE IN US WEST (+2 TO +11%), NEW ZEALAND (+10 TO +12%) AND S.AMERICA (+10 TO +13%). HARVEST DECREASE IN CANADA. | DEMAND SATISFIED: PRICES DROP WITH AN INCREASE IN WELFARE TO PRODUCERS AND CONSUMERS. |
| EUROPE  | I) INCREASED FOREST GROWTH (ESPECIALLY IN N. EUROPE)  
II) 60-80% OF STOCK CHANGE IS DUE TO MANAGEMENT, CLIMATE EXPLAINS 10-30% AND THE REST IS DUE TO LAND USE CHANGE. | WOOD DEMAND EXCEEDS POTENTIAL FELLING, PARTICULARLY IN THE SECOND HALF OF THE 21ST CENTURY. |
SOME OF THE PROJECTED IMPACTS FOR DIFFERENT REGIONS (IPCC 2007)

IMPACTS IN ASIA

- 1M RISE IN SEA LEVEL
- LOSS OF ALMOST HALF OF MANGROVE AREA IN THE MEKONG RIVER DELTA
- 100,000 HECTARE OF CULTIVATED LAND AND AQUACULTURE AREA WOULD BECOME SALT MARSH
- FLOODING IN COASTAL AREAS
- TIBETAN PLATEAU GLACIERS MAY DISAPPEAR WITH A TEMPERATURE INCREASE OF 3°C
- HIMALAYAN GLACIERS COULD DECAY AT VERY RAPID RATES
- 120 MILLION TO 1.2 BILLION AND 185 TO 981 MILLION PEOPLE WILL EXPERIENCE INCREASED WATER STRESS BY THE 2020S AND THE 2050S, RESPECTIVELY
- PER CAPITA AVAILABILITY OF FRESH WATER IN INDIA IS EXPECTED TO DROP FROM AROUND 1,900M³ CURRENTLY TO 1,000M³ BY 2025
- More intense rain and frequent flash floods during monsoon resulting in runoff
- Crop yields could increase up to 20% in East and South-East Asia, while they could decrease up to 30% in Central and South Asia by mid-21st century.
- Agricultural irrigation demand in arid and semi-arid regions of East Asia will increase by 10% for an increase in temperature of 1°C
- Frequency and extent of forest fires in Northern Asia may increase in future
### TABLE 7. CLIMATE CHANGE IMPACT FOR INDIA IN DIFFERENT CROP SEASONS

<table>
<thead>
<tr>
<th>Year</th>
<th>Season</th>
<th>Increase in Temperature, °C</th>
<th>Change in Rainfall, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Lowest</td>
<td>Highest</td>
</tr>
<tr>
<td>2020s</td>
<td>Rabi</td>
<td>1.08</td>
<td>1.54</td>
</tr>
<tr>
<td></td>
<td>Kharif</td>
<td>0.87</td>
<td>1.12</td>
</tr>
<tr>
<td>2050s</td>
<td>Rabi</td>
<td>2.54</td>
<td>3.18</td>
</tr>
<tr>
<td></td>
<td>Kharif</td>
<td>1.81</td>
<td>2.37</td>
</tr>
<tr>
<td>2080s</td>
<td>Rabi</td>
<td>4.14</td>
<td>6.31</td>
</tr>
<tr>
<td></td>
<td>Kharif</td>
<td>2.91</td>
<td>4.62</td>
</tr>
</tbody>
</table>

Source: Aggarwal, IARI
2.2 IMPACTS IN EUROPE

- Probability of extreme winter precipitation exceeding two above normal is expected to increase by up to a factor of five in parts of UK and Northern Europe by 2080s with a doubling of CO₂.

- By 2070s, annual runoff will increase in Northern Europe and decrease by up to 36% in Southern Europe, with summer low flows reduced by up to 80%.

- Percentage of river-basin area in severe water stress category is expected to increase from 19% today to 34 to 36% by 2070s.

- European flora become vulnerable, endangered, critically endangered or extinct by end of 21st century.
BY 2050, CROPS ARE EXPECTED TO SHOW A NORTHWARD EXPANSION IN AREA. GREATEST INCREASES IN CLIMATE-RELATED CROP YIELDS ARE EXPECTED IN NORTHERN EUROPE e.g.,

✓ WHEAT: +2 TO +9 % BY 2020,
✓ +8 TO 25 % BY 2050,
✓ +10 TO +30% BY 2080

WHILE LARGEST REDUCTIONS ARE EXPECTED IN THE SOUTH e.g.,

✓ WHEAT: +3 TO +4 % BY 2020,
✓ -8 TO 22% BY 2050,
✓ -15 TO +32% BY 2080
2.3 IMPACTS IN NORTH AMERICA

- **Severe Heat Waves, Warm Air Masses and Nights with High Minimum Temp.** Likely to increase in number, magnitude and duration in cities.

- **Daily Average O$_3$ Levels.** Projected to increase by 3.7 ppb across Eastern USA.

- **Warming in Western Mountains.** By mid-21$^{st}$ century to cause large decreases in snowpack, earlier snow melt, more winter rain events, increased peak winter flows, flooding and reduced summer flows.

- **CC in Early 21$^{st}$ Century.** Is likely to increase forest production, but with high sensitivity to drought, storms, insects and other disturbances.

- **Moderate CC in Early Decades.** Of century to increase aggregate yields of rainfed agriculture by 5 to 20%.

- **Warmer Summer Temp.** Projected to extend high fire risk by 10 to 30%, and increase area burned by 74 to 118% in Canada by 2100.
2.4 IMPACTS IN LATIN AMERICA

- INTER-TROPICAL GLACIERS ARE VERY LIKELY TO DISAPPEAR
- FUTURE REDUCTIONS IN RAINFALL IN ARID AND SEMI-ARID REGIONS OF ARGENTINA, CHILE AND BRAZIL
- SEA-LEVEL RISE VERY LIKELY TO HAVE IMPACTS ON LOW LYING AREAS, MANGROVES (E.G., IN BRAZIL, ECUADOR, COLOMBIA, VENEZUELA)
- RICE YIELDS ARE EXPECTED TO DECLINE AFTER YEAR 2020
- INCREASE IN TEMP. AND PRECIPITATION IN SOUTH-EASTERN, SOUTH AMERICA ARE LIKELY TO INCREASE SOYABEAN YIELDS IF CO2 EFFECTS ARE CONSIDERED
- SEA SURFACE TEMP. INCREASES HAVE ADVERSE EFFECTS ON LOCATION OF FISH STOCKS IN SOUTH-EAST PACIFIC
- INCREASE OF 2°C AND DECREASES IN SOIL WATER WOULD LEAD TO REPLACEMENT OF TROPICAL FOREST BY SAVANNAS IN EASTERN AMAZONIAN AND IN TROPICAL FORESTS OF CENTRAL AND SOUTHERN MEXICO, ALONG WITH REPLACEMENT OF SEMI-ARID BY ARID VEGETATION IN PARTS OF NORTH-EAST BRAZIL AND MOST OF CENTRAL AND NORTHERN MEXICO
2.5 IMPACTS IN AUSTRALIA AND NEW ZEALAND

- Most vulnerable are natural ecosystems, water security and coastal communities.
- Increased fire danger likely with CC in South-East Australia; frequency of very high and extreme fire danger days likely to rise to 25% by 2020 and 15 to 70% by 2050.
- Production from agriculture and forestry by 2030 projected to decline over much of southern and eastern Australia, and over parts of eastern New Zealand, due to increased drought and fire. In New Zealand initial benefits in western and southern areas due to longer growing season, less frost and increased rainfall.
- In South and West of New Zealand, growth rates of economically important plantation crops likely to increase with CO₂-fertilisation.
2.6 IMPACTS IN AFRICA

- INCREASE OF 5 TO 8% (60 TO 90 MILLION HECTARE) OF ARID AND SEMI-ARID LAND IN AFRICA IS PROJECTED BY 2080S
- DECLINING AGRICULTURAL YIELDS LIKELY DUE TO DROUGHT AND LAND DEGRADATION
- CHANGES IN LENGTH OF GROWING PERIOD
- CURRENT STRESS ON WATER IN MANY AREAS OF AFRICA LIKELY TO BE ENHANCED
- INCREASE IN RUNOFF IN EAST AFRICA AND DECREASES IN RUNOFF AND LIKELY INCREASED DROUGHT RISK IN OTHER AREAS BY 2050S
- LIKELY TO REDUCE PRIMARY PRODUCTION AND POSSIBLE FISH YIELDS BY 30%
- ECOSYSTEMS IN AFRICA ARE LIKELY TO EXPERIENCE MAJOR SHIFTS AND POSSIBLE EXTINCTIONS
- MANGROVES TO BE FURTHER DEGRADED, PROJECTED SEA-LEVEL RISE WILL AFFECT LOW-LYING COASTAL AREAS
2.7 IMPACTS IN SMALL ISLANDS

- Sea-level rise and increased sea-water temp. accelerate beach erosion
- Degradation of natural coastal defences such as mangroves
- Coastal erosion on Arctic islands has additional climate sensitivity through impact of warming
- 10% reduction in average rainfall by 2050 likely to correspond to a 20% reduction in size of fresh water lens
- Agricultural economic costs likely to reach between 2-3% and 17-18% of 2002 GDP by 2050
2.8 IMPACTS IN POLAR REGIONS

- In Siberia and North America, there may be an increase in agriculture and forestry as northern limit for these activities shifts by several hundred kilometres by 2050.
- Large-scale forest fires and outbreaks of tree-killing insects, triggered by warm weather, likely to increase.
- 10 to 50% of Arctic tundra will be replaced by forest, and around 15 to 25% of polar desert will be replaced by tundra.
- Reductions in lake and river ice cover.
- Warming of fresh waters likely to lead to reductions in fish stock.
- Increase in frequency and severity of Arctic flooding, erosion, drought and destruction of permafrost.
MEANWHILE

IT'S BECOMING WARMER AROUND HERE!

YES, IT'S HARD TO SURVIVE!!

SEE!!! THE CORALS ARE LOSING THEIR COLOURS!!!

YES—AND I'VE LOST WEIGHT!!!!

I'M SUFFOCATING! THERE'S LESS AND LESS OXYGEN!
FUTURE IMPACTS AND VULNERABILITY OF CLIMATE CHANGE ON AGRICULTURE, FORESTRY AND FISHERIES

- Future climate change in Asia expected to affect agriculture through declining production, reductions in arable land area and food supply for fishes affecting fish breeding.

- **Figure 5. Potential impact of climate change on wheat production in India**

Source: Aggarwal et al. (2002)
IN CHINA YIELDS OF MAJOR CROPS EXPECTED TO DECLINE, WHILE IN INDIA RICE PRODUCTION WILL BE ADVERSELY AFFECTED BY HEAT STRESS

CROP DISEASES FOR RICE, WHEAT COULD BECOME MORE WIDESPREAD DUE TO WARMER AND WETTER ASIAN CLIMATE

CROP SUITABILITY LIKELY TO CHANGE THROUGHOUT EUROPE

CROP PRODUCTIVITY LIKELY TO INCREASE IN NORTHERN EUROPE AND DECREASE ALONG MEDITERRANEAN AND SOUTH-WEST EUROPE

FORESTS ARE PROJECTED TO EXPAND IN NORTH AND RETREAT IN SOUTH

AGRICULTURE WILL HAVE TO COPE WITH INCREASING WATER DEMAND FOR IRRIGATION IN SOUTHERN EUROPE DUE TO CC
IN LATIN AMERICA, BY 2020S GENERALISED REDUCTION IN RICE YIELD, WHILE INCREASE IN SOYBEAN YIELD IS PROJECTED

POTENTIAL FOR LIKELY INCREASE IN DROUGHT IS EXPECTED IN AREAS OF CANADA

DECREASING TRENDS DURING RECENT DECADES ARE FOUND IN SPARSE RECORDS OF PAN EVAPORATION OVER USA

ACTUAL EVAPOTRANSPERSION INCREASED DURING SECOND HALF OF 20TH CENTURY OVER MOST DRY REGIONS OF USA AND RUSSIA AS A RESULT OF GREATER AVAILABILITY OF SOIL SURFACE MOISTURE

IN AMERICAS, TEMPERATE DESERTS PROJECTED TO EXPAND SUBSTANTIALLY UNDER DOUBLED CO₂ CLIMATE SCENARIOS

IN AUSTRALIA AND NEW ZEALAND, HEATWAVES AND FOREST FIRES ARE CERTAIN TO INCREASE IN INTENSITY AND FREQUENCY

IN AFRICA, AGRICULTURAL LOSSES WILL POSSIBLY BE SEVERE FOR SEVERAL AREAS (VIZ. SAHEL, EAST AFRICA AND SOUTHERN AFRICA)

WATER STRESS AND LAND DEGRADATION WILL AFFECT INLAND FISHERIES. IN SMALL ISLANDS, MANY FISH BREEDING GROUNDS AND HABITATS WILL FACE INCREASED DISRUPTION DUE TO SEA LEVEL RISE
MAJOR CLASSES OF ADAPTATIONS CONSIDERED

- Seasonal changes & sowing dates of crops
- Use of different crop varieties/species
- Adequate water supply & irrigation systems
- New varieties, tillage & improved short term climate prediction. Changing cropping calendars & patterns (Stigter et al., 2007)

SOME IMPORTANT ADAPTATIONS
- Irrigation is established adaptation to soil moisture deficits. Similarly, farmers will adapt to CC by changing other land management practices
- Adaptation means to produce some crop at no additional cost
Forestry adaptation is especially necessary in areas with low land availability or low growth potential.

All adaptation activities, specifically designed to reduce impact of CC.
FIGURE 6. ADAPTATION AS A PROCESS (WARRICK 2006)
3. STUDY OF CLIMATE CHANGE FOR AGRICULTURE, FORESTRY AND FISHERIES IN DIFFERENT REGIONS – IMPACTS, VULNERABILITIES AND ADAPTATIONS

3.1 ASIA

- OBSERVED INCREASES IN SOME PARTS OF ASIA DURING RECENT DECADES RANGED BETWEEN LESS THAN 10°C TO 30°C PER CENTURY
- INCREASES IN SURFACE TEMPERATURE ARE MOST PRONOUNCED IN NORTH ASIA (IZRAEL ET AL., 2002; GRUZA AND RANKOVA, 2004)
- INCREASING FREQUENCY AND INTENSITY OF DROUGHTS IN MANY PARTS OF ASIA ARE DUE TO RISE IN TEMPERATURE DURING SUMMER AND ENSO EVENTS (LAL, 2002, 2003).
- ABOUT 2.5 TO 10 % DECREASE IN CROP YIELD FOR PARTS OF ASIA IN 2020S & 5 TO 30 % DECREASE IN 2050S COMPARED WITH 1990 LEVELS WITHOUT CO₂ EFFECTS
Increasing climate variability lead to floods, cyclones, earthquakes, tropical storms, heat and cold waves, landslides, forest fires, droughts, frost, dust and sand storms.

In India 28% of land is vulnerable to droughts, 12% to floods and 8% to cyclones.

Ecological stability of mangroves will be at risk.

Damage caused by intense cyclones has risen significantly, particularly in India, China, Philippines, Japan, Cambodia, Iran etc.
<table>
<thead>
<tr>
<th>REGION</th>
<th>COUNTRY</th>
<th>CHANGE IN TEMPERATURE</th>
<th>CHANGE IN PRECIPITATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>CENTRAL ASIA</td>
<td>NORTH-WEST CHINA</td>
<td>0.7°C INCREASE IN MEAN ANNUAL TEMPERATURE FROM 1961 TO 2000</td>
<td>BETWEEN 22% AND 33% INCREASE IN RAINFALL</td>
</tr>
<tr>
<td>EAST ASIA</td>
<td>CHINA</td>
<td>WARMING DURING LAST 50 YEARS, PRONOUNCED DURING WINTER, RATE OF INCREASE PRONOUNCED IN MIN. THAN IN MAX. TEMPERATURE</td>
<td>ANNUAL RAIN DECLINED IN NORTH – EAST AND NORTH CHINA, INCREASED IN WESTERN CHINA, CHANGJIANG RIVER AND ALONG SOUTH AND EAST COAST</td>
</tr>
<tr>
<td></td>
<td>JAPAN</td>
<td>ABOUT 1.0 °C RISE IN 20TH CENTURY, 2 TO 3 °C RISE IN LARGE CITIES</td>
<td>NO SIGNIFICANT TREND IN THE 20TH CENTURY ALTHOUGH FLUCTUATIONS INCREASED</td>
</tr>
<tr>
<td>SOUTH ASIA</td>
<td>INDIA</td>
<td>0.68 °C INCREASE PER CENTURY, INCREASING TRENDS IN ANNUAL MEAN TEMP., WARMING PRONOUNCED DURING POST MONSOON AND WINTER</td>
<td>INCREASED RAINS IN NORTH- WEST DURING SUMMER MONSOON IN RECENT DECADES, LOWER NUMBER OF RAINY DAYS ALONG EAST COAST</td>
</tr>
<tr>
<td>S-E ASIA</td>
<td>PHILIPPINES</td>
<td>INCREASE IN MEAN ANNUAL, MAX. AND MIN. TEMP. BY 0.14°C BETWEEN 1971 TO 2000</td>
<td>INCREASE IN ANNUAL MEAN RAINFALL SINCE 1980S AND NUMBER OF RAINY DAYS SINCE 1990S, INCREASE IN INTER – ANNUAL VARIABILITY OF ONSET OF RAINFALL</td>
</tr>
</tbody>
</table>
PRODUCTION OF RICE, MAIZE AND WHEAT IN PAST FEW DECADES HAS DECLINED IN MANY PARTS OF ASIA DUE TO INCREASING WATER STRESS ARISING DUE TO RISE IN TEMPERATURE, INCREASING FREQUENCY OF EL NIÑO AND DECLINE IN NUMBER OF RAINY DAYS (TAO et al., 2004)

SUBSTANTIAL DECREASES IN CEREAL PRODUCTION POTENTIAL IN ASIA IS LIKELY BY END OF THIS CENTURY

RICE PRODUCTION IN ASIA COULD REDUCE BY 3.8 % BY END OF 21ST CENTURY (MURDIYARSO, 2000)
### TABLE 9. SUMMARY OF OBSERVED CHANGES IN EXTREME EVENTS AND SEVERE CLIMATE ANOMALIES IN ASIA

<table>
<thead>
<tr>
<th>COUNTRY/REGION</th>
<th>KEY TREND</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A) HEATWAVES</strong></td>
<td></td>
</tr>
<tr>
<td>CHINA</td>
<td>INCREASE IN SHORT DURATION HEATWAVES IN RECENT DECADE, INCREASING WARMER DAYS AND NIGHTS</td>
</tr>
<tr>
<td>JAPAN</td>
<td>INCREASING DAILY MAXIMUM TEMPERATURE &gt;35°C, DECREASE IN EXTREMELY LOW TEMPERATURE</td>
</tr>
<tr>
<td>INDIA</td>
<td>HOT DAYS AND MULTIPLE-DAY HEATWAVE HAS INCREASED IN PAST CENTURY</td>
</tr>
<tr>
<td><strong>B) INTENSE RAINS AND FLOODS</strong></td>
<td></td>
</tr>
<tr>
<td>JAPAN</td>
<td>INCREASING EXTREME RAINS IN PAST 100 YEARS; SERIOUS FLOOD IN 2004; INCREASE IN MAXIMUM RAINFALL DURING 1961 TO 2000</td>
</tr>
<tr>
<td><strong>C) DROUGHTS</strong></td>
<td></td>
</tr>
<tr>
<td><strong>D) CYCLONES AND TYPHOONS</strong></td>
<td></td>
</tr>
<tr>
<td>SOUTH ASIA</td>
<td>FREQUENCY OF MONSOON DEPRESSIONS AND CYCLONES FORMATION IN BAY OF BENGAŁ AND ARABIAN SEA ON DECLINE SINCE 1970 BUT INTENSITY INCREASED CAUSING SEVERE FLOODS.</td>
</tr>
</tbody>
</table>
INDIA AND HER AGRICULTURAL SCENARIO

- **POPULATION**: 1 BILLION +
- **GDP FROM AGRICULTURE**: 34% (1994), 42% (1980)
- **AREA UNDER AGRICULTURE**: 50% (160 MHA)
- **POPULATION DEPENDENT ON AGRICULTURE**: 70%
- **AVERAGE FARM SIZE**: 1 TO 5 HA

<table>
<thead>
<tr>
<th></th>
<th>T.AREA (MHA)</th>
<th>IRRIGATED (MHA)</th>
<th>PRODN. (MT)</th>
<th>EARNINGS (RS)</th>
<th>% OF GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>RICE</td>
<td>42</td>
<td>20</td>
<td>73</td>
<td>365</td>
<td>22</td>
</tr>
<tr>
<td>WHEAT</td>
<td>24</td>
<td>21</td>
<td>57</td>
<td>208</td>
<td>12.6</td>
</tr>
</tbody>
</table>
AN INCREASE OF 2°C IN TEMP. COULD DECREASE RICE YIELD OF ABOUT 0.75 TON/HA IN HIGH YIELD AREAS (SINHA AND SWAMINATHAN, 1991)

WHEAT YIELDS COULD DECREASE BETWEEN 28 TO 68% WITHOUT CONSIDERING CO₂ FERTILIZATION EFFECTS; AND WOULD RANGE BETWEEN +4 TO –34% AFTER CONSIDERING CO₂ FERTILIZATION EFFECTS (RAO AND SINHA, 1994)

WTGROWS MODEL SHOWED THAT A 2°C RISE WOULD DECREASE WHEAT YIELDS IN MOST PLACES (AGGARWAL AND SINHA, 1993)

SHOWED THAT FOR EVERY 1°C RISE IN TEMP. DECLINE IN RICE YIELD WOULD BE ABOUT 6% (SASEENDHRAN et al. 2000)

ESTIMATED IMPACTS ON WHEAT AND OTHER CEREAL CROPS USING WTGROWS AND RECENT CC SCENARIOS (AGGARWAL et al.)

A 0.5°C RISE IN WINTER TEMP. WOULD REDUCE WHEAT YIELD BY 0.45 TONNES PER HECTARE IN INDIA (KALRA et al., 2003). A 2 TO 5% DECREASE IN YIELD POTENTIAL OF WHEAT AND MAIZE FOR A TEMPERATURE RISE OF 0.5 TO 1.5°C IN INDIA WAS SUGGESTED (AGGARWAL, 2003)
IN SOUTH ASIA, DROP IN YIELDS OF NON-IRRIGATED WHEAT AND RICE WILL BE SIGNIFICANT FOR A TEMP. INCREASE OF BEYOND 2.5\degree C RESULTING A LOSS IN FARM – LEVEL NET REVENUE BETWEEN 9 AND 25 % (LAL, 2007)

NET CEREAL PRODUCTION IN SOUTH ASIAN COUNTRIES IS PROJECTED TO DECLINE AT LEAST BY 4 TO 10 % BY END OF THIS CENTURY (LAL, 2007)

AGRICULTURAL IRRIGATION DEMAND IN ARID AND SEMI – ARID REGIONS OF ASIA IS ESTIMATED TO INCREASE BY AT LEAST 10 % FOR AN INCREASE IN 1\degree C (FISCHER et al., 2002)

FAO (2004) REVEALED THAT HIGHER TEMP. AND LONGER GROWING SEASONS CAN RESULT IN INCREASED PEST POPULATIONS IN TEMPERATE REGIONS OF ASIA

GENERALLY, ADAPTIVE MEASURES ARE INTENDED TO INCREASE ADAPTIVE CAPACITY BY MODIFYING FARMING PRACTICES, IMPROVING CROPS THROUGH NEW TECHNOLOGIES
### SECTORS            ADAPTATION MEASURES

<table>
<thead>
<tr>
<th>1°C TEMP. INCREASE IN JUNE TO AUGUST</th>
<th>A) CHOICE OF CROP AND CULTIVAR:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I) MORE HEAT/DROUGHT-TOLERANT CROP VARIETIES IN AREAS UNDER WATER STRESS</td>
</tr>
<tr>
<td></td>
<td>II) MORE DISEASE AND PEST TOLERANT CROP VARIETIES</td>
</tr>
<tr>
<td></td>
<td>III) SALT-TOLERANT CROP VARIETIES</td>
</tr>
<tr>
<td></td>
<td>IV) INTRODUCE HIGH YIELDING, EARLY MATURING CROP VARIETIES IN COLD REGIONS</td>
</tr>
<tr>
<td></td>
<td>B) FARM MANAGEMENT:</td>
</tr>
<tr>
<td></td>
<td>I) ALTER APPLICATION OF NUTRIENTS/FERTILISERS</td>
</tr>
<tr>
<td></td>
<td>II) ALTER APPLICATION OF INSECTICIDES/PESTICIDES</td>
</tr>
<tr>
<td></td>
<td>III) CHANGE PLANTING DATE TO EFFECTIVELY USE PROLONGED GROWING SEASON AND IRRIGATION</td>
</tr>
<tr>
<td></td>
<td>IV) DEVELOP ADAPTIVE MANAGEMENT STRATEGY AT FARM LEVEL</td>
</tr>
<tr>
<td>IMPROVEMENT OF AGRICULTURAL INFRASTRUCTURE</td>
<td>I) IMPROVE IRRIGATION SYSTEMS AND THEIR EFFICIENCY</td>
</tr>
<tr>
<td></td>
<td>II) IMPROVE USE/STORE OF RAIN AND SNOW WATER</td>
</tr>
<tr>
<td></td>
<td>III) IMPROVE INFORMATION EXCHANGE SYSTEM ON NEW TECHNOLOGIES AT NATIONAL AS WELL AS REGIONAL AND INTERNATIONAL LEVEL</td>
</tr>
<tr>
<td></td>
<td>IV) IMPROVE ACCESS OF HERDERS, FISHERIES AND FARMERS TO TIMELY WEATHER FORECASTS</td>
</tr>
</tbody>
</table>

### TABLE 10. ADAPTATION MEASURES IN AGRICULTURE
IN CHINA, ADAPTIVE MEASURES VIZ. ASSURING SOWN ACREAGE TO ATTAIN PRODUCTION TARGET, STRENGTHENING IRRIGATION CAPACITY, TRANSFORMING MEDIUM/LOW YIELD FARMLAND, USING SUPERIOR CROP SPECIES, USING DRYLAND FARMING, ADAPTING CULTURAL TECHNIQUES ARE SUGGESTED.

IN BANGLADESH AGRICULTURAL ADAPTATION STRATEGIES INCLUDED RICE GENOTYPE DEVELOPMENT TO SUSTAIN ITS YIELD.

IN INDIA INTEGRATED AGROMETEOROLOGICAL ADVISORY SERVICES BULLETIN STARTED SINCE 01.06.2008, INTEGRATING SERVICES OF ALL THE SERVICE PROVIDERS. DISTRICT LEVEL CROP SPECIFIC ADVISORIES ARE ISSUED, TWICE IN A WEEK DEPENDING UPON FORECAST AND ONGOING AGRICULTURAL OPERATIONS FOR THE BENEFIT OF FARMERS.

AN EFFECTIVE STRATEGY FOR ADVANCING UNDERSTANDING OF ADVERSE IMPACTS OF CLIMATE CHANGE IN ASIA WILL REQUIRE STRENGTHENING OF RESEARCH RELATED TO MORE FEASIBLE, & ADAPTIVE MEASURES.

IDENTIFICATION OF CRITICAL VULNERABILITIES

CLIMATE THRESHOLDS
3.2 EUROPE

- An increase in annual temp. in Europe of 0.1 to 0.4°C/decade over 21st century. Likely increase in intensity and frequency of summer heat waves throughout Europe.

- EU25 (25 countries of European Union) in 2002 had average gas emission of 11 tonnes CO₂ per capita (EEA 2004) and is likely to increase to 12 tonnes CO₂ per capita in 2030 (EEA 2006).

- The TAR identified other climate change impacts viz.
  - Increasing CO₂ concentrations may increase agricultural yields in southern and south–eastern Europe,
  - Warmer temp. & higher CO₂ levels may increase potential timber harvest in northern Europe and may increase forest fire risk in southern Europe.
  - The effects of climate change and increased atmospheric CO₂ are expected to lead to overall small increases in European crop productivity.
  - Forested areas of Europe are increasing and are sink of atmospheric CO₂.
  - Over-fishing has put many fish stocks in European water outside sustainable limit.
Climate related increases in crop yields are expected mainly in Northern Europe,

- e.g. Wheat: +2 to +9% by 2020, +8 to +25% by 2050 and +10 to +30% by 2080 (Ewert et al., 2005; Olesen et al., 2007);
- Sugar Beet: +14 to +20% until 2050s in England and Wales (Richter and Semenov, 2005)

In Southern Europe, general decreases in yield e.g.

- Legumes: -30 to +5%;
- Sunflower: -12 to +3% and
- Tuber crops: -14 to 7% by 2050

Increases in water demand

- e.g. For maize: +2 to +4% and
- Potato: +6 to 10% by 2050

Yield is expected to strongly decrease in most Southern areas and increase in Northern or cooler areas.
- SHORT TERM ADAPTATION OF AGRICULTURE IN SOUTHERN EUROPE MAY INCLUDE CHANGES IN CROP SPECIES
  - e.g. REPLACING WINTER WITH SPRING WHEAT (MINGUEZ et al., 2007),
  - HIGHER DROUGHT RESISTANCE AND LONGER GRAIN FILLING (RICHTER AND SEMENOV, 2005)

- LONG TERM ADAPTATION MEASURE IS TO CHANGE ALLOCATION OF AGRICULTURAL LAND ACCORDING TO CHANGING SUITABILITY

- TEMP. INCREASE HAS A MAJOR EFFECT ON FISHERIES PRODUCTION IN NORTH ATLANTIC

- IN NORTHERN EUROPE CLIMATE CHANGE WILL ALTER PHENOLOGY AND SUBSTANTIALLY INCREASE NET PRIMARY PRODUCTIVITY AND BIOMASS OF FORESTS (FREEMAN et al., 2005)

- IN EASTERN EUOROPE, SOME OF ADAPTIVE MEASURES INCLUDE IMPLEMENTING SNOW RESERVING, INCREASING FALLOW AREAS AND SWITCHING TO MORE SUITABLE WHEAT VARIETIES
3.3 NORTH AMERICA

- NORTH AMERICAN REGION HAS EXPERIENCED RECENT WEATHER RELATED EXTREME EVENTS INCLUDING FLOODS, DROUGHTS, HEAT WAVES, WILD FIRE, SEVERE STORMS AND HURRICANES

- U.S. AND CANADA WILL EXPERIENCE CLIMATE CHANGES THROUGH DIRECT EFFECTS OF LOCAL CHANGES VIZ.
  - TEMPERATURE,
  - RAINFALL AND
  - WEATHER EXTREMES

- INDIRECT EFFECTS TRANSMITTED AMONG REGIONS

- TAR OPINED BENEFITS FROM WARMING FOR FOOD PRODUCTION IN NORTH AMERICA, BUT WITH STRONG REGIONAL DIFFERENCES;

- ANNUAL MEAN AIR TEMP., AS A WHOLE, INCREASED DURING THE PERIOD FROM 1955 TO 2005

- LENGTH OF VEGETATION GROWING HAS INCREASED BY 2 DAYS/DECADE SINCE 1950 IN CANADA
ANNUAL RAINFALL HAS INCREASED FOR MOST OF NORTH AMERICA WITH LARGE INCREASES IN NORTHERN CANADA, BUT WITH DECREASES IN SOUTH – WEST U.S.

IN AGRICULTURE, YIELDS OF MAJOR CROPS HAVE INCREASED CONSISTENTLY @ 1 TO 2 % PER YEAR (TROYER, 2004)

HEAVY RAINFALL REDUCED VALUE OF CORN CROP IN U.S.A. BY AN AVERAGE OF 3 BILLION $ PER YEAR BETWEEN 1951 AND 1998 (ROSENZWEIG et al., 2002)

YIELDS OF CORN AND SOYBEAN WERE NEGATIVELY IMPACTED BY WARM TEMP. FROM 1982 TO 1998, DECREASING 17 % FOR EACH 1°C OF WARM TEMP. ANOMALY (LOBELL AND ASNER, 2003)

MORE VARIABLE WEATHER, OUT – MIGRATION FROM RURAL AREAS AND ECONOMIC STRESS HAS INCREASED VULNERABILITY OF AGRICULTURAL SECTOR (WHEATON et al., 2005)

NORTH AMERICAN AGRICULTURE IS DYNAMIC, HENCE ADAPTIVE TO MULTIPLE STRESSES

RECENT ADAPTATIONS INCLUDE IMPROVED WATER CONSERVATION AND CONSERVATION TILLAGE

ADAPTIVE MEASURES IN U.S.A. AND CANADA SUGGEST TO INCLUDE EARLIER PLANTING AND SWITCHING TO MORE DIVERSE CROPS
TAR OPINED THAT MODERATE CLIMATE CHANGE LIKELY TO INCREASE YIELDS OF NORTH AMERICAN RAINFED AGRICULTURE.

CROPS THAT ARE CURRENTLY NEAR CLIMATE THRESHOLDS LIKELY TO SUFFER DECREASES IN YIELDS, QUALITY EVEN WITH MODERATE WARMING

COLD–WATER FISHERIES ARE NEGATIVELY AFFECTED BY CLIMATE CHANGE, WHILE WARM – WATER FISHERIES WILL GENERALLY GAIN.

NORTH AMERICAN ADAPTATION MEASURES TO CLIMATE RELATED RISKS ARE IMPLEMENTED AT COMMUNITY LEVEL, WHICH INCLUDE EFFORTS TO MINIMISE DAMAGE FROM HEAT WAVES, DROUGHTS, FLOODS, WILD FIRE OR TORNADOES

WITH HIGHLY DETAILED WEATHER INFORMATION FARMERS ARE ADJUSTING CROP AND VARIETY SELECTION, IRRIGATION STRATEGIES AND PESTICIDE APPLICATION

FORESTRY SECTOR IS INVESTIGATING IN:
- IMPROVED VARIETIES,
- FOREST PROTECTION,
- FOREST REGENERATION,
- SILVICULTURAL MANAGEMENT &
- FOREST OPERATIONS
3.4 LATIN AMERICA

HIGHLY UNUSUAL EXTREME EVENTS RECORDED WERE

VENEZUELAN RAINFALL (1999, 2005)

FLOODING IN ARGENTINEAN PAMPAS (2000 – 2002)

HAIL STORM IN BUENOS AIRES AREA (2006)

AMAZONIAN DROUGHT (2005)

HAIL STORM IN BOLIVIA (2002)
TAR DOCUMENTED ENSO RELATED CLIMATE VARIABILITY VIZ.

- HIGH/LOW WHEAT YIELD DURING EL NIÑO/LA NIÑA IN SONORA, MEXICO

- SHORTENING OF COTTON AND MANGO GROWING CYCLES ON NORTHERN COAST OF PERU DURING EL NIÑO DUE TO RISE IN TEMP. (TORRES et al., 2001)

- INCREASES IN INCIDENCE OF PLANT DISEASES DUE TO HIGH RAINFALL & HUMIDITY WAS OBSERVED

- IN LATIN AMERICA, SOME ADAPTIVE MEASURES INCLUDED CHANGING CROP VARIETIES, CROPPING PATTERN TO SUIT CHANGING CLIMATE CONDITIONS AND IMPLEMENTING AGROFORESTRY SYSTEMS

- IN MEXICO SMALL FARMERS ARE ADAPTING TO CURRENT AND FUTURE CLIMATE THROUGH
  
  - DRIP IRRIGATION SYSTEM,
  
  - GREEN HOUSES &
  
  - USING COMPOST (CONDE et al., 2006)
STEPS TO REDUCE CLIMATE CHANGE IMPACTS IN ECUADOR

- AGRO – ECOLOGICAL ZONING
- APPROPRIATE SOWING & HARVESTING SEASONS
- INTRODUCING HIGH YIELDING VARIETIES
- INSTALLING IRRIGATION SYSTEMS
- ADEQUATE USE OF FERTILIZERS
- CONTROLLING PESTS & DISEASES
IN GUYANA, SEVERAL ADJUSTMENTS WERE IDENTIFIED VIZ.  
✓ CROP VARIETY  
✓ SOIL MANAGEMENT  
✓ LAND ALLOCATION  
✓ NEW SOURCES OF WATER  
✓ HARVESTING EFFICIENCY.  

AS ADAPTIVE MEASURE ARGENTINA, BRAZIL, COSTA RICA AND PERU HAVE ADAPTED NEW FORESTRY LAWS AND POLICIES  
RESEARCH PRIORITIES MAY BE GIVEN  
TO REDUCE UNCERTAINTIES IN FUTURE PROJECTIONS  
TO ASSESS THE IMPACTS OF DIFFERENT POLICY OPTIONS ON REDUCING VULNERABILITY AND/OR INCREASING ADAPTIVE MEASURES
3.5 AUSTRALIA AND NEW ZEALAND

- Since 1950, 0.4 to 0.7°C warming with more heat waves, more rain and fewer frost was noticed in north-west Australia and south-west New Zealand.

- Less rain in southern & eastern Australia and north-eastern New Zealand with an increase in intensity of Australian droughts.

- In Australia, potential impacts of CC on wheat vary regionally.

- South-west Australian regions to have significant yield reduction by 2070, while north-eastern Australia are likely to have moderate increase in yield.

- CC likely modify landuse in southern Australia, with cropping becoming non-viable. Even though yield increases from elevated CO₂ partly offset this effect.

- In north of Australia, CC & CO₂ increases likely to enable cropping to persist.

- Australian temp. fruits and nuts likely to be negatively affected by warmer conditions.
KEY VARIABLES EXPECTED TO DRIVE IMPACTS ON MARINE FISHERIES ARE:

- Changes in ocean temperature
- Currents
- Winds
- Acidification,
- Nutrient supply &
- Rainfall

CLIMATE CHANGE IMPACTS LIKELY TO BE GREATER FOR THE TEMPERATE ENDEMICS THAN FOR TROPICAL SPECIES.

PLANNED ADAPTATION REDUCES VULNERABILITY DUE TO CC.
Hurdles identified as barriers to adaptation:

- Lack of methods for integrated assessment of impacts & adaptation
- Lack of well-developed evaluation tools for assessing planned adaptation options
- Weak linkages between various strata of govt.
- Ongoing scepticism about climate change science
- Uncertainty in regional CC

More works need to be done to assess vulnerability within risk management frame work.
3.6 AFRICA

- Most vulnerable continent to CC and climate variability
- Agricultural production and food security in many African countries and regions likely to be severely compromised by CC and climate variability
- Half of sub-humid and semi-arid parts of Southern African region are at moderate to high risk of desertification
- In Egypt CC may pose serious threat by:
  - Inundation of delta-land area due to sea level rise
  - Temp. rises will be likely to reduce productivity of major crops and increase their water requirements
  - General increase in irrigation demand and high uncertainty about flow of River Nile
➢ By 2100 parts of Sahara will be most vulnerable, showing likely agricultural losses of 2 to 7% of GDP.

➢ Western and Central Africa are also vulnerable with impacts ranging from 2 to 4%.

➢ By 2080s a significant decrease in suitable rainfed land extent and production potential for cereals is estimated.

➢ Southern Africa is likely to experience reduction in maize production under possible increased ENSO conditions (Stige et al., 2006).

➢ Fisheries are affected by various biophysical impacts of CC.

➢ With a rise in annual global temp. Fisheries in North West Africa and East African lakes are affected.
ADAPTIVE CAPABILITY IS MODIFIED BY VARIOUS FACTORS VIZ.

TECHNOLOGY  EDUCATION
INFORMATION  SKILL
INFRASTRUCTURE  ACCESS TO RESOURCES ETC.

PERIOD OF DROUGHT AND FLOOD AS WELL AS LONG TERM CHANGE MAY DIRECTLY OR INDIRECTLY AFFECT FOOD SECURITY

LOCAL COMMUNITIES AND FARMERS IN AFRICA HAVE DEVELOPED INTRICATE SYSTEMS OF

GATHERING PREDICTING
INTERPRETING & DECISION MAKING IN RELATION TO WEATHER

IN NIGERIA INDIGENOUS METHODS OF WEATHER FORECASTING ARE KNOWN TO HELP FARMERS IN THEIR DAY TO DAY FIELD OPERATIONS

MUCH OF CC RESEARCH IN AFRICA IS FOCUSED ON IMPACTS. MORE REGIONAL AND LOCAL RESEARCH IS STILL REQUIRED TO STUDY RELATIONSHIP OF CO₂ - ENRICHMENT, FUTURE PRODUCTION OF AGRICULTURAL CROPS UNDER CC SCENARIO
3.7 SMALL ISLANDS

- AGRICULTURE OF SMALL ISLANDS ARE DRASTICALLY AFFECTED BY CC
- PROJECTED IMPACTS INCLUDE:
  - EXTENDED PERIODS OF DROUGHT
  - INCREASED TEMP. IN HIGH LATITUDE ISLANDS LIKELY TO BE MORE SUITABLE FOR AGRICULTURE
  - IF INTENSITY OF TROPICAL CYCLONES INCREASES, IT IS LIKELY TO HAVE SIGNIFICANT DAMAGE TO FOOD CROPS.
  - IN FISHERIES SECTOR, TWO MAIN EFFECTS OF CC ON TUNA FISHING ARE LIKELY TO DECLINE IN TOTAL STOCK AND A MIGRATION OF STOCK EASTWARDS

- TAR IDENTIFIED 4 FUNCTIONS FOR VULNERABILITY OF SMALL ISLANDS, VIZ.
  - (I) DEGREE OF EXPOSURE TO CC
  - (II) LIMITED CAPACITY TO ADAPT TO PROJECTED IMPACTS,
  - (III) ADAPTATION TO CLIMATE IS NOT A HIGH PRIORITY &
  - (IV) UNCERTAINTY ASSOCIATED WITH GLOBAL CC PROJECTIONS AND THEIR LOCAL VALIDITY

- ADAPTIVE MEASURES TAKEN IN MALDIVES ARE:
  - (A) EXPLORING ALTERNATE METHODS OF GROWING FRUITS, VEGETABLES AND FOODS,
  - (B) CROP PRODUCTION USING HYDROPONIC SYSTEM
  - LACK OF ADEQUATE DATA IS THE MAIN HINDERANCE IN OPERATIONAL RESEARCH WORK TOWARDS ADAPTIVE MEASURES
3.8 POLAR REGIONS (ARCTIC AND ANTARCTICA)

- Strong evidence of impacts of CC on terrestrial and fresh water species are available.
- The adaptive capability of Arctic ecosystems is small as their extent is likely to be reduced by:
  - Compression between general northwards expansion of forest
  - The current coastline and
  - Longer term flooding of northern coastal wetlands as sea level rises
- Sea surface warming in North-East Atlantic is accompanied by increasing abundance of phytoplankton in cooler regions and decreasing abundance in warmer regions
- Extension of ice free season may lead to decline in fish habitat availability
- Studies of polar regions reveals that new data improved models, increasing use of indigenous local knowledge and validation may help in better understanding for adaptive measures
ONE WINTER...

Hey, brother! what is the date?

Oh! I don't understand, it's still early in the season! But let's go—there's a meeting...
DEAR FELLOW BEARS: I REGRET TO INFORM YOU THAT, DUE TO HIGHER TEMPERATURES THIS YEAR, OUR HABITAT IS MELTING AWAY!
4. CONCLUSIONS

The study revealed the following conclusions:

- Observational evidence shows that many systems are being affected by regional climate changes viz. temperature rise, which has discernible influence on agriculture, forestry and fisheries.

- More specific information is now available concerning nature of future impacts.

- Magnitude of impact, can now be estimated more systematically.

- Some large scale events have potential to cause large impacts.

- Vulnerability to climate change can be exacerbated by presence of other stresses.
A wide array of adaptation options are available, but more extensive adaptations are required to reduce vulnerability of future climate change.

Many impacts can be avoided, reduced or delayed by suitable adaptive measures.

Location and crop specific agrometeorological advisory services bulletin, meant for end users, can minimize impacts.

Sometimes indigenous knowledge can also help at local level to reduce impact.

An effective global as well as regional strategy for understanding of adverse impacts of climate change and feasible, operational research for adaptive measures are essentially required to achieve fruitful goal.
ACKNOWLEDGEMENTS

DGM, IMD, NEW DELHI

P. R. OF INDIA TO W.M.O. FOR NOMINATING FOR THE ASSIGNMENT

WORLD METEOROLOGICAL ORGANIZATION FOR PROVIDING THIS OPPERTUNITY AND FINANCIAL ASSISTANCE

ORGANISATION SECTION (INTERNATIONAL), IMD, NEW DELHI

DDGM(AG), IMD, PUNE

MRS. ARCHANA P.HAGE, MRS. DEEPA A.KULKARNI,
MRS. ANITA S.BAHOT, IMD, PUNE
HELLO FATTY, HAVE YOU NOTICED—THE GRASS IS NO LONGER TASTY?

THE AIR IS HEAVY, SOME PART OF THE FOREST IS ALWAYS ON FIRE!

NO, MORE'S THE PITY—AND THE FARMER IS HOLDING THE WATER BACK!!

I CAN'T PRODUCE MILK BECAUSE OF THE STRESS. MEUUUUUHH I'M SWEATING!!

DO YOU KNOW WE ARE BLAMED FOR EMITTING A GAS CALLED METHANE, WHICH IS WARMING THE CLIMATE UP?

SNIFF!! SNIFF!!
THANK YOU